H

PIONEER JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION
HIGHER 2

CANDIDATE NAME	

CT GROUP	1	7	S			INDEX NUMBER					

CHEMISTRY 9729/01

Paper 1 Multiple Choice **21 September 2018**

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, Centre number and index number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

This document consists of **14** printed pages

For each question, there are four possible answers labelled **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.

1 In an experiment, 25.0 cm^3 of 0.02 mol dm^{-3} of vanadium(II) ions was found to react with 15.00 cm^3 of 0.02 mol dm^{-3} of acidified $KMnO_4$. The half equation for the reduction of MnO_4^- is:

$$MnO_4^- + 8H^+ + 5e \rightleftharpoons Mn^{2+} + 4H_2O$$

What is the final oxidation state of vanadium?

A +3

B +4

C +5

D +6

2 Sulfur dichloride dioxide, SO_2Cl_2, reacts with water to give a mixture of sulfuric acid and hydrochloric acid.

How many moles of calcium hydroxide, $Ca(OH)_2$, would be needed to neutralise the solution formed by adding one mole of SO_2Cl_2 to an excess of water?

A 1

B 2

C 3

D 4

3 *The use of Data Booklet is relevant to this question.*

An ion $\mathbf{E^{2+}}$ contains 24 protons.

Which of the following statements about $\mathbf{E^{2+}}$ is **incorrect**?

A The enthalpy change for the reaction $\mathbf{E}(g) \rightarrow \mathbf{E^{2+}}(g) + 2e$ is +2243 kJ mol^{-1}.

B The removal of the two electrons from **E** to form $\mathbf{E^{2+}}$ is from the 4s subshell.

C The angle of deflection of $\mathbf{E^{2+}}$ in an electric field is smaller than that of $\mathbf{E^{3+}}$.

D $\mathbf{E^{2+}}$ is isoelectronic with Mn^{3+}.

4 Which of the following statements explain why aluminium chloride, Al_2Cl_6, sublime at a relatively low temperature?

1 Intermolecular forces between the Al_2Cl_6 molecules are weak.

2 The dative bonds between Al and Cl atoms are weak.

3 The covalent bonds between Al and Cl atoms are weak.

A 1 only

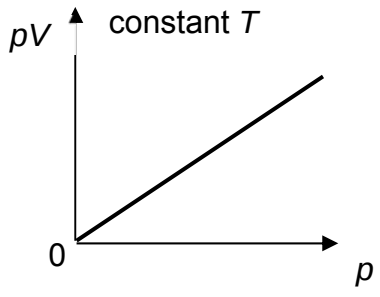
B 1 and 2 only

C 2 and 3 only

D 3 only

5 Which of the following diagrams correctly describes the behavior of a fixed mass of an ideal gas? (T is measured in K)

A



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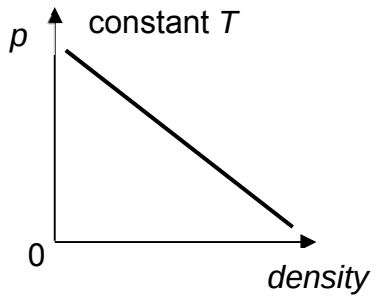

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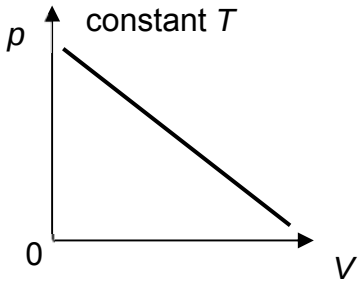
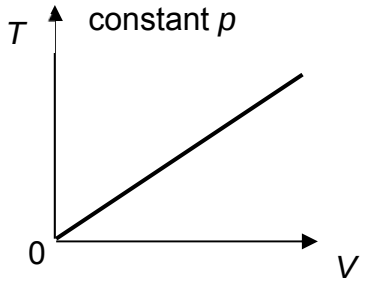


D



6 The enthalpy change of reaction between hydrogen sulfide and oxygen is ΔH_1.

$$H_2S(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(g) + S(s) \qquad \Delta H_1$$

What information is **not** needed to calculate ΔH_1?

A enthalpy change of vaporisation of $H_2O(l)$

B enthalpy change of formation of $H_2S(g)$

C enthalpy change of formation of $H_2O(l)$

D enthalpy change of combustion of S(s)

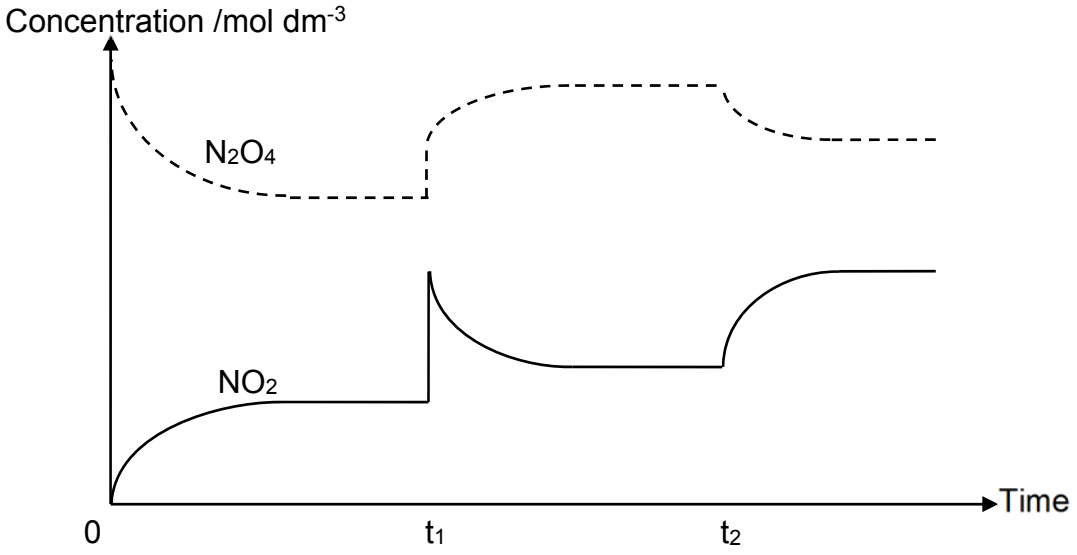
7 Which suggested mechanism is consistent with the experimentally determined rate equations?

	Rate equation	Suggested mechanism	
A	Rate = $k[NO]^2[O_2]$	$2NO(g) \rightarrow N_2O_2(g)$	(fast)
		$N_2O_2(g) + O_2(g) \rightarrow 2NO_2(g)$	(slow)
B	Rate = $k[H_2][I_2]$	$H_2(g) \rightarrow 2H(g)$	(slow)
		$2H(g) + I_2(g) \rightarrow 2HI(g)$	(fast)
C	Rate = $k[HBr][O_2]$	$2HBr(g) + O_2(g) \rightarrow 2HBrO(g)$	(slow)
		$HBrO(g) + HBr(g) \rightarrow H_2O(g) + Br_2(g)$	(fast)
D	Rate = $k[H_2O_2][I^-]$	$2H^+(aq) + 2I^-(aq) \rightarrow 2HI(aq)$	(fast)
		$2HI(aq) + H_2O_2(aq) \rightarrow I_2(aq) + 2H_2O(l)$	(slow)

8 An amount of N_2O_4 was placed in a closed vessel and allowed to reach equilibrium as shown below.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = +57 \text{ kJ mol}^{-1}$$

Two changes were made to the equilibrium system at t_1 and t_2.



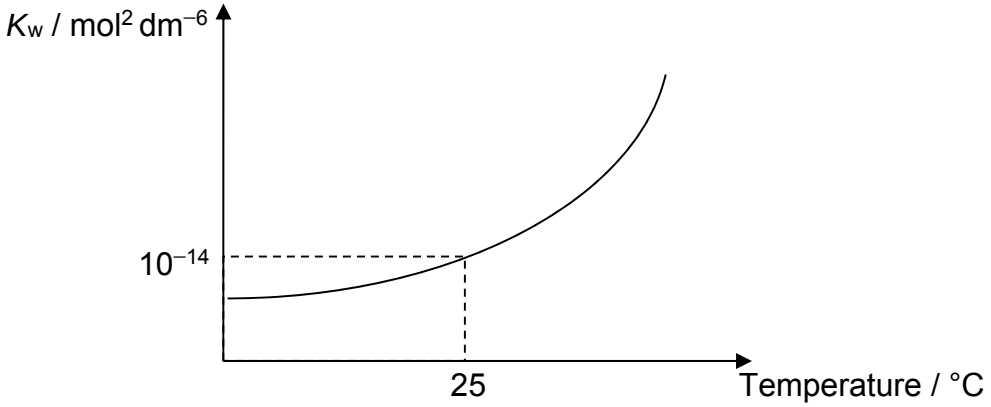
Which are the changes made at t_1 and t_2?

	t_1	t_2
A	More NO_2 was added	Temperature was increased
B	An inert gas was added at constant volume	Temperature was decreased
C	Volume of the system was decreased	Temperature was increased
D	Volume of the system was increased	Temperature was decreased

9 Water dissociates as shown:

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The ionic product of water, K_w, varies with temperature as shown in the graph below.



Which statements about the above equilibrium system are correct?

1 The pH of water decreases as temperature increases.

2 The concentrations of H^+ and OH^- are equal at all temperatures.

3 The dissociation of water is exothermic.

A 2 only

B 3 only

C 1 and 2 only

D 2 and 3 only

10 The pH range and colour changes for two acid-base indicators are given below:

Indicator	Colour in acidic solution	pH range	Colour in basic solution
P	Violet	3.0-5.0	red
Q	Yellow	5.7-7.6	blue

Which solution will appear red in **P** and yellow in **Q**?

A 0.1 mol dm^{-3} of HC*l*

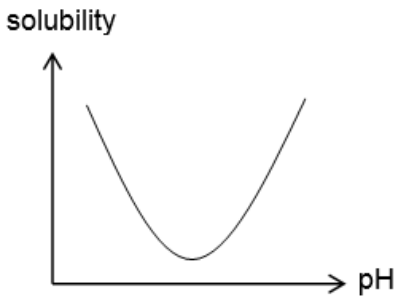
B 0.1 mol dm^{-3} of NaOH

C 0.1 mol dm^{-3} of CH_3CO_2H (K_a = 1.8 x 10^{-5} mol dm^{-3})

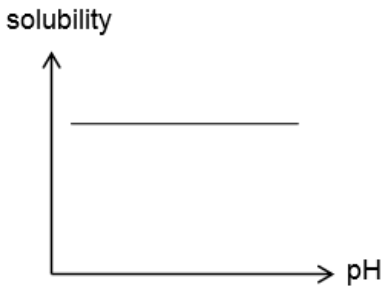
D 0.1 mol dm^{-3} of HX (K_a= 2.5 x 10^{-10} mol dm^{-3})

11 The solubility product of calcium carbonate, $CaCO_3$, is 4.81 x 10^{-9} mol^2 dm^{-6}. Which of the following graphs shows how the solubility of $CaCO_3$ will vary with pH at constant temperature?

A



B



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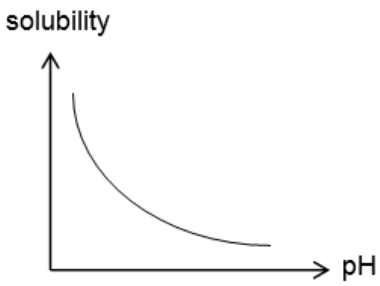
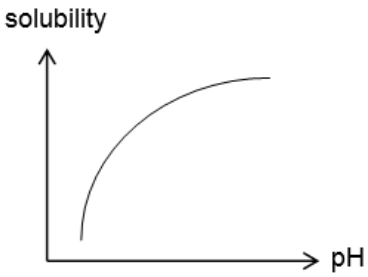


D



12 The equilibrium between Ag_2CO_3, a sparingly soluble salt, and its saturated solution is as shown below.

$$Ag_2CO_3(s) + aq \rightleftharpoons 2Ag^+(aq) + CO_3^{2-}(aq)$$

K_{sp} of Ag_2CO_3 = 8.2 × 10^{-12} mol^3 dm^{-9}

Which one of the following is correct?

1 Adding NaC*l*(aq) will cause more Ag_2CO_3 solid to dissolve.

2 Upon the addition of sodium carbonate, solubility of Ag_2CO_3 increases.

3 K_{sp} of Ag_2CO_3 decreases as $AgNO_3$ solution is added to it.

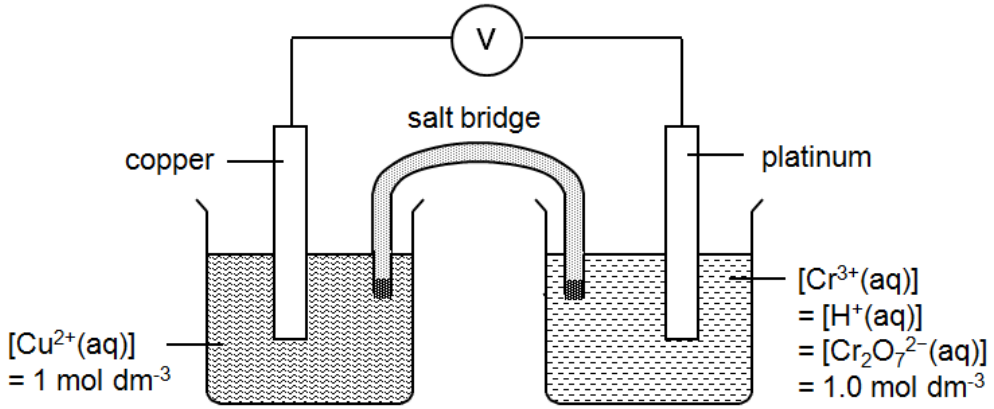
A 1 only

B 1 and 2 only

C 2 and 3 only

D 1, 2 and 3

13 *Use of the Data Booklet is relevant to this question.*
A cell is set up by connecting a Cu^{2+}/Cu half-cell and an acidified $Cr_2O_7^{2-}/Cr^{3+}$ half-cell under standard conditions.

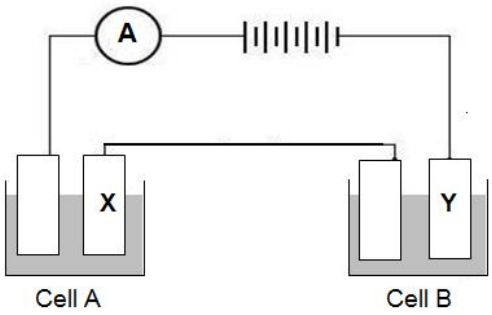


Which of the following correctly describes the effect on the e.m.f of the cell when the respective change is made?

	change	effect on e.m.f of cell
A	using a larger copper electrode	increases
B	addition of concentrated H_2SO_4 into reduction half-cell	decreases
C	addition of dilute NaOH into oxidation half-cell	decreases
D	addition of water into oxidation half-cell	increases

14 *Use of the Data Booklet is relevant to this question.*

A student carried out an experiment involving the electrolysis of aqueous copper(II) sulfate in cell **A** and aqueous chromium(III) sulfate in cell **B**.



Given that 6.35 g of copper was deposited at electrode **X** at the end of the experiment, what is the mass of chromium deposited at electrode **Y**?

A 0.87 g
B 1.74 g
C 3.47 g
D 10.4 g

15 ***P*, *Q*** and ***R*** are elements of the third period of the Periodic Table. The oxide of ***P*** is amphoteric, the oxide of ***Q*** is basic and oxide of ***R*** is acidic.

What is the order of increasing ionic radius?

A ***RQP***

B ***QPR***

C ***PRQ***

D ***PQR***

16 Which of the following statements about Group 2 elements and their compounds is correct?

1 Magnesium hydroxide decomposes on heating to give magnesium oxide and steam.

2 1 mole of strontium carbonate, on heating over a short period of time, decomposes to give more carbon dioxide gas than 1 mole of magnesium carbonate

3 Magnesium has a higher melting point than strontium.

A 1 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3

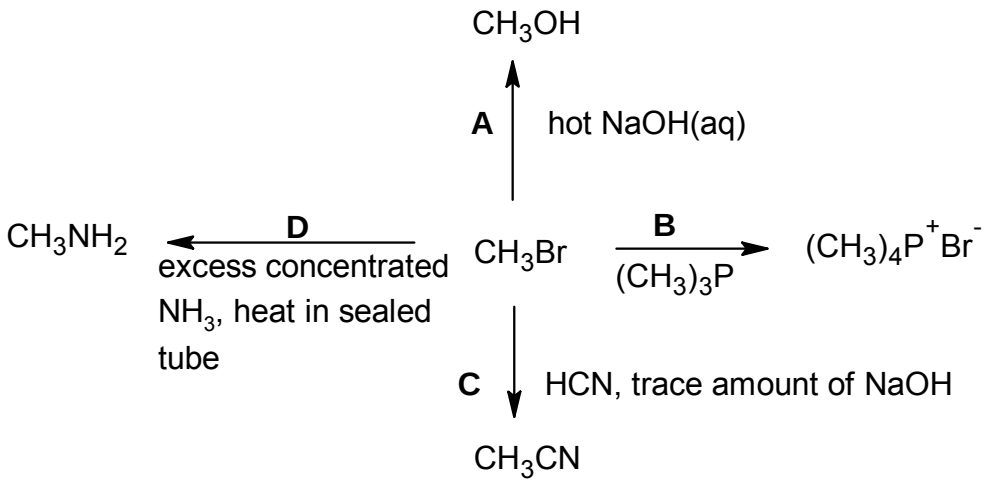
17 Adding KSCN (aq) to $FeNO_3$(aq) causes the colour of the solution to change from yellow to blood red.

Which of the following row correctly shows the number of d-electrons and the energy gap between the d-orbitals, before and after the reaction?

	number of d-electrons	energy gap between the d-orbitals
A	changes	changes
B	changes	remains the same
C	remains the same	changes
D	remains the same	remains the same

18 A reaction scheme involving bromomethane is given below.

Which of the reactions does **not** take place?



19 3-ethylpentane can react with bromine in the presence of sunlight to give two monosubstituted halogenoalkanes:

1-bromo-3-ethylpentane and 3-bromo-3-ethylpentane.

Given the relative rates of abstracting H atoms are:

Type of H atom	primary	secondary	Tertiary
Relative rate of abstraction	1	4	6

What is the expected ratio of 1-bromo-3-ethylpentane to 3-bromo-3-ethylpentane formed?

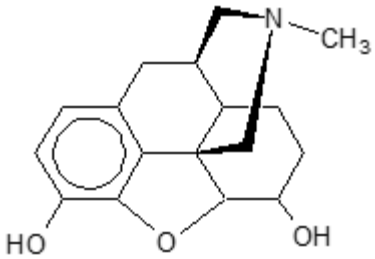
A 9 : 1

B 6 : 1

C 3 : 2

D 1 : 6

20 Morphine is an effective pain killer.



morphine

Which of the following statements about morphine is correct?

A It contains 10 chiral centers.

B It does not decolourise Br_2(aq).

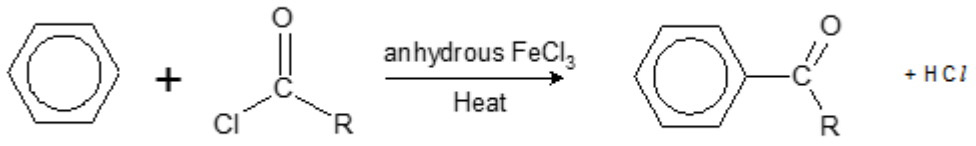
C It turns cold alkaline $KMnO_4$ from purple to colourless.

D One mole of morphine reacts with excess sodium to give 1 mole of H_2 gas.

21 Under suitable conditions, ethene may undergo a reaction with an interhalogen compound, IC*l*. Which of the following shows the structure of the intermediate formed?

A $[CH_3CH_2]^+$ **B** $[CH_3CHI]^+$ **C** $[CH_2CH_2I]^+$ **D** $[CH_2CH_2Cl]^+$

22 Anhydrous iron(III) chloride is made by passing chlorine gas over heated iron. It can be used as a catalyst in the acylation of benzene, a process called Friedel-Crafts acylation, to produce carbonyl compounds.



The mechanism of the above reaction is similar to that of chlorination of benzene. Which of the following statements is **not** correct about the mechanism?

A The organic intermediate has a ring with one sp^3 hybridised carbon.

B The overall order of reaction is 1.

C The mechanism involves RCO^+ as an electrophile.

D $FeCl_3$ is a homogeneous catalyst.

23 Some chlorobutanes were separately treated with hot ethanolic sodium hydroxide. Two of these gave the same hydrocarbon, C_4H_6.

From which pair of chlorobutanes was this hydrocarbon obtained?

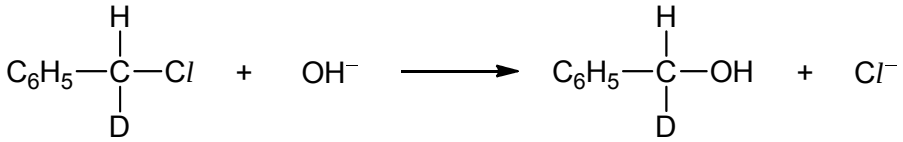
A $CH_3CH_2CH_2CH_2Cl$ and $CH_3CH_2CH_2CHCl_2$

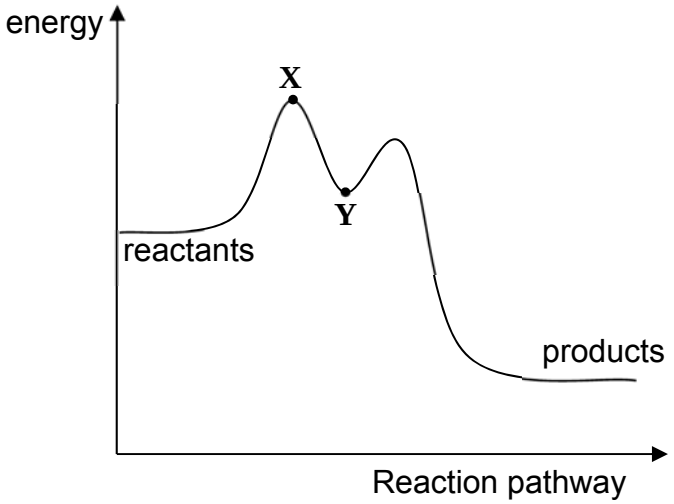
B $CH_3CHClCHClCH_3$ and $ClCH_2CH_2CH_2CH_2Cl$

C $CH_3CH_2CH_2CH_2Cl$ and $ClCH_2CH_2CH_2CH_2Cl$

D $CH_3CH_2CH_2CH_2Cl$ and $CH_3CH_2CHClCH_3$

24 The energy profile for the following reaction is shown below. [D = ^2H]



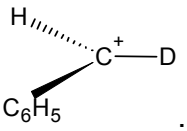


Which of the following conclusions can be drawn?

A The product has no effect on the rotation of plane polarised light.

B The rate of reaction can be increased by increasing concentration of OH^-.

C The structure of the species at point **X** is



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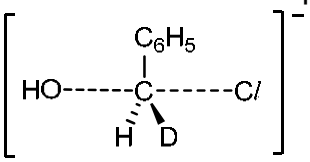
D The structure of the species at point **Y** is



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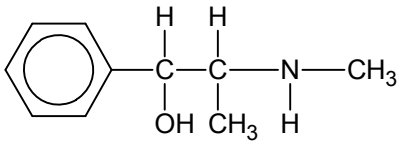
25 Ephedrine is a drug that is widely used in cold and allergy medications.



Ephedrine

Which of the following pairs of reagents consists of one which reacts with ephedrine and one which does **not** react with ephedrine?

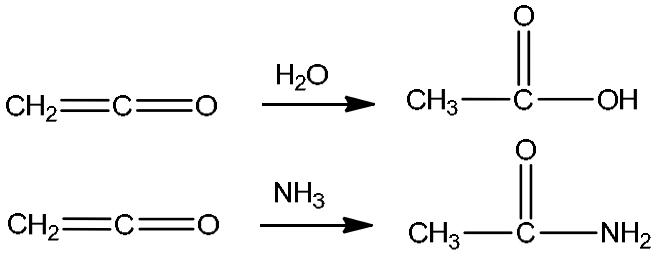
A CH_3CO_2H CH_3COCl

B $HCl(aq)$ $SOCl_2$

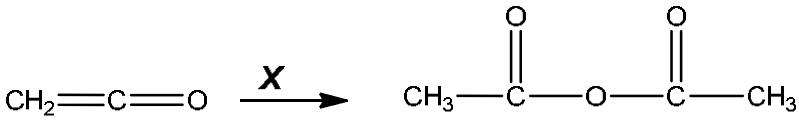
C CH_3Br NaOH(aq)

D $[Ag(NH_3)_2]^+$ 2,4-dinitrophenylhydrazine

26 Ketene ($CH_2{=}C{=}O$) can combine with nucleophiles such as H_2O or NH_3 to make ethanoic acid and ethanamide respectively, as shown below.



Which of the following is the correct nucleophile ***X*** for the reaction below?



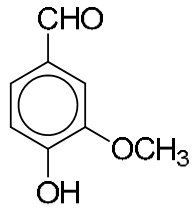
A HCO_2CH_3

B CH_3CHO

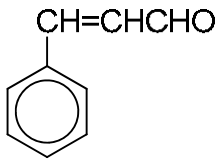
C CH_3COCH_3

D CH_3CO_2H

27 Vanillin and cinnamaldehyde are found in natural products and have very pleasant fragrances.



vanillin



cinnamaldehyde

Which of the following reagents could be used to distinguish between the two compounds? You may assume that the $–OCH_3$ group in vanillin is inert.

1 Fehling's solution

2 hot acidified aqueous $KMnO_4$

3 2, 4-dinitrophenylhydrazine

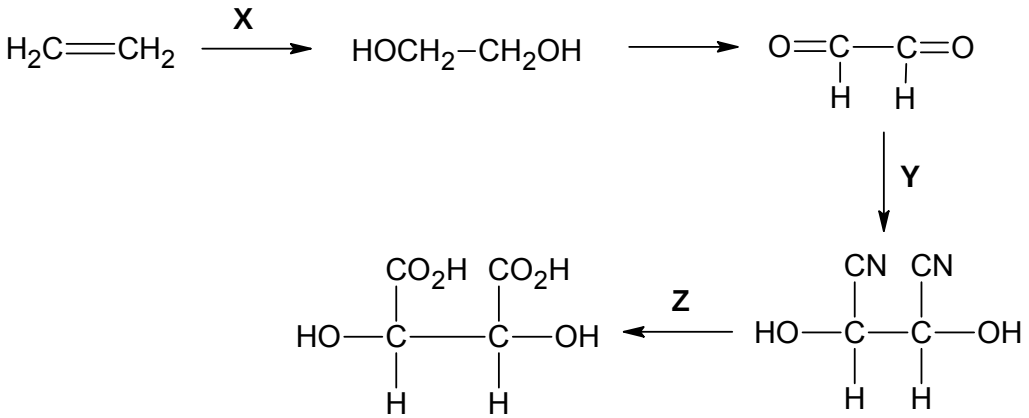
A 1 only

B 2 only

C 1 and 2 only

D 1, 2 and 3

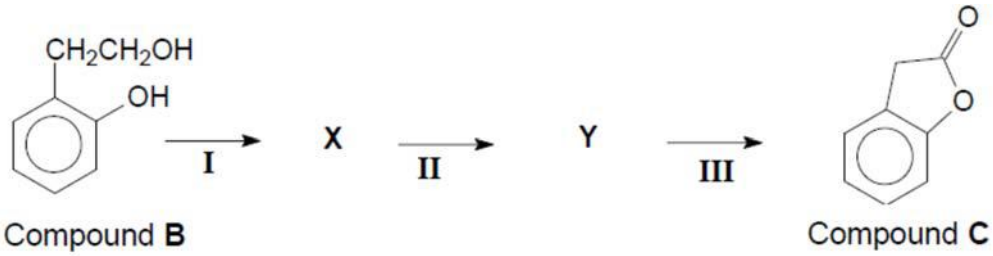
28 The following is a method of synthesising tartaric acid, a compound found in wine.



Which set of reagents and conditions can be used for the synthesis?

	stage **X**	stage **Y**	stage **Z**
A	cold $KMnO_4$, NaOH(aq)	cold HCN, trace KCN(aq)	hot $K_2Cr_2O_7$, H_2SO_4(aq)
B	cold $KMnO_4$, NaOH(aq)	ethanolic KCN, heat	HC*l*(aq), heat
C	cold $KMnO_4$, H_2SO_4(aq)	ethanolic KCN, heat	hot $K_2Cr_2O_7$, H_2SO_4(aq)
D	cold $KMnO_4$, H_2SO_4(aq)	cold HCN, trace KCN(aq)	HC*l*(aq), heat

29 Compound **B** can be converted to compound **C** as shown below.



Which of the following statements regarding the reaction scheme is correct?

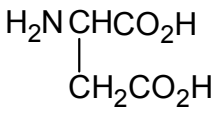
A Step **I** may involve the use of PCl_5.

B Step **I** may involve the use of hot acidified $KMnO_4$.

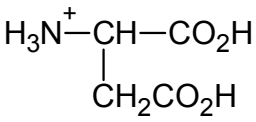
C Step **III** may involve the use of aqueous NaOH.

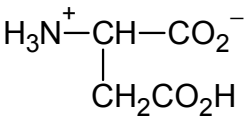
D Step **III** may involve the use of hot concentrated H_2SO_4.

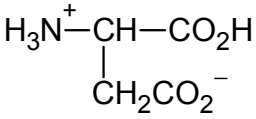
30 Which structure will be present when the amino acid aspartic acid,

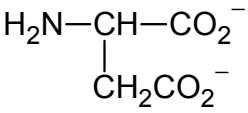


is in aqueous solution at pH 10?

A 

B 

C 

D 

End of paper

2018 P1 Prelim answers

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
C	B	B	A	D	D	A	C	C	D	C	A	D	C	D
16	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
B	C	C	C	D	**C**	B	B	A	C	D	C	**D**	C	D

H

PIONEER JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION
HIGHER 2

CANDIDATE NAME									
CT GROUP	1	7	S			INDEX NUMBER			

CHEMISTRY **9729/02**

Paper 2 Structured **11 September 2018**

2 hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your class, index number and name on all work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough workings.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINER'S USE			
Paper 1			**/ 30**
Paper 2			
1	/ 9	4	/12
2	/ 8	5	/ 10
3	/ 18	6	/ 18
Penalty		sf	unit
Paper 2			**/ 75**
Paper 3			**/ 80**
Paper 4			**/ 55**
Total			

This document consists of **21** printed pages.

Answer **all** questions in the spaces provided.

1 **(a)** Water hardness is determined by the concentration of multivalent cations in the water. Common cations found in hard water include Ca^{2+} and Mg^{2+}. Lime softening is a type of water treatment where aqueous Na_2CO_3 is added to remove Ca^{2+} ion as $CaCO_3$ is precipitated. These precipitates are then removed by sedimentation and filtration, where X^{2+} can be Ca^{2+} and Mg^{2+}.

$$X^{2+}(aq) + Na_2CO_3(aq) \rightarrow XCO_3(s) + 2Na^+(aq)$$

In the laboratory, 1 cm^3 of 0.50 mol dm^{-3} Na_2CO_3 is added to 10 cm^3 of a raw water sample. What is the minimum concentration of Ca^{2+} in the original raw water sample, which would cause a white precipitate to be observed?

The value of K_{sp} for $CaCO_3$ is 4.81 x 10^{-9} mol^2 dm^{-6}.

[2]

(b) A saturated solution of raw water containing both CaF_2 and $Ca(OH)_2$ has a pH of 12 at 25°C.

calcium compound	numerical value of K_{sp}
CaF_2	3.2 x 10^{-11}
$Ca(OH)_2$	6.4 x 10^{-6}

(i) Calculate the concentration of hydroxide ions in the solution.

[1]

(ii) Hence, calculate the solubility of CaF_2 in the raw water sample. Show your working clearly.

[2]

(c) Using the following data, construct an energy cycle to calculate the enthalpy change for the thermal decomposition of calcium carbonate.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

	ΔH / kJ mol^{-1}
$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$	−57.1
$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$	−63.7
$H_2SO_4(aq) + CaCO_3(s) \rightarrow CaSO_4(aq) + H_2O(l) + CO_2(g)$	−151.5

[4]
[Total: 9]

2 The reaction of ethanal with iodine occurs in the presence of acid catalyst, HC*l*. . The reaction is given below.

$$I_2 + CH_3CHO \xrightarrow{HCl} CH_2ICHO + HI \qquad \text{Reaction 1}$$

The table shows the results obtained when the concentrations of I_2, CH_3CHO and HC*l* were varied.

Experiment	Initial [HC*l*] / mol dm^{-3}	Initial [I_2] / mol dm^{-3}	Initial [CH_3CHO] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.10	0.20	0.20	1.6×10^{-6}
2	0.10	0.40	0.30	2.4×10^{-6}
3	0.40	0.40	0.20	6.4×10^{-6}
4	0.10	0.20	2.00	1.6×10^{-5}

(a) **(i)** Deduce the orders of reaction with respect to I_2, CH_3CHO and HC*l*. Hence, determine the rate equation.

[3]

(ii) The half-life of ethanal in experiment 1 was 60 seconds. Predict the half-life of ethanal in experiments 2 and 3. Explain your answer.

……

……

……

…… .[2]

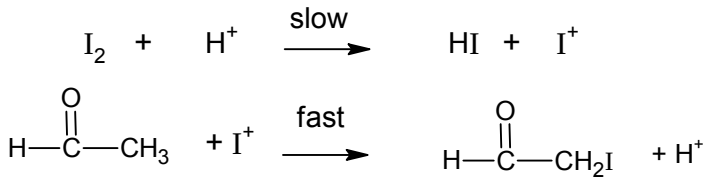
(iii) Sketch the graph of concentration of iodine against time for experiment 4.

Experiment	Initial [HC*l*] / mol dm^{-3}	Initial [I_2] / mol dm^{-3}	Initial [CH_3CHO] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
4	0.10	0.20	2.00	1.6 x 10^{-5}

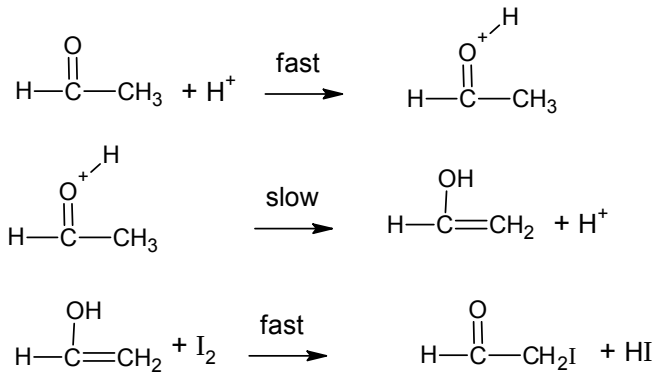
[1]

(b) The following mechanisms **A** and **B** are proposed for the reaction of ethanal, iodine and acid catalyst in Reaction 1.

Mechanism A



Mechanism B



Which of the above mechanisms best agrees with the experimentally determined rate equation in **(a)(i)**? Explain your answer.

.....

.....

.....

..... [2]

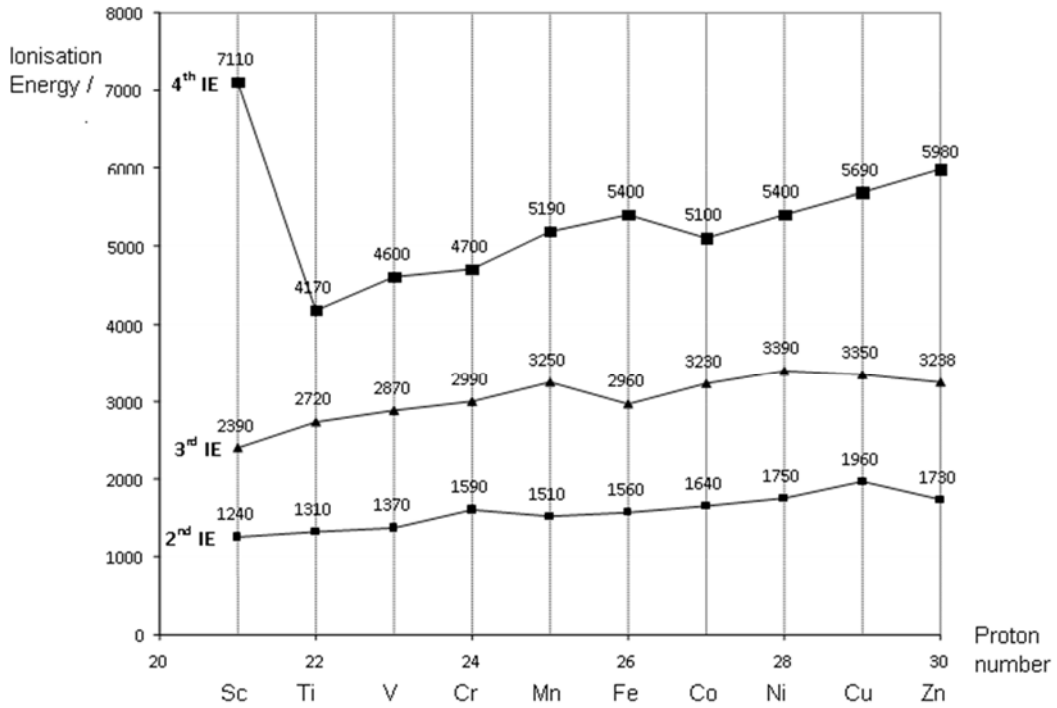
[Total: 8]

3 Transition metal is "an element whose atom has a partially filled d sub-shell, or which can give rise to cations with an incompletely filled d sub-shell". Chromium and vanadium, both transition metals, have found a number of industrial uses due to their toughness and resistance to heat and corrosion.

The table below shows some information of a Group 2 metal calcium, vanadium and chromium.

	Vanadium	**Chromium**	**Calcium**
Melting point/ ^{o}C	1910	1875	843
Atomic radius/ nm	0.135	0.129	0.197
Common Oxidation Number	+2, +3, +4, +5	+2, +3, +6	+2

The graph below shows the second to fourth ionisation energies for the first row d block elements scandium to zinc.



(a) **(i)** Although the vanadium atom has more electrons than the calcium atom, the atomic radius of vanadium is smaller than that of calcium. Suggest an explanation for this.

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.....

.....[2]

(ii) Explain why the second ionisation energies of transition elements from Ti to Cu are relatively invariant.

.....

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.....

..... [2]

(iii) Explain why the second ionisation energy of chromium is higher than that of manganese.

.....

.....

.....

..... [2]

(b) **(i)** State the **full** electronic configuration of Cr^{3+} ion.

..... [1]

(ii) The complex ion $[Cr(H_2O)_6]^{3+}$ is green, and it is an octahedral complex. On the Cartesian axes shown in Fig. 2.1, draw **fully-labelled** diagrams of the following:

- One of the d orbitals at the lower energy level in an octahedral complex- Label this diagram 'lower'.
- One of the d orbitals at the upper energy level in an octahedral complex. Label this diagram 'upper'.

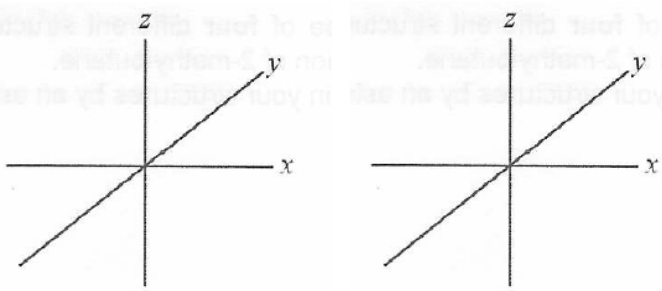


Fig. 3.1

[2]

(iii) Suggest which of the two compounds chromium(III) oxide, Cr_2O_3, and chromium(III) carbonate, $Cr_2(CO_3)_3$, would have a more exothermic lattice energy. Explain your answer.

…….....

…….....

…….....

……..... [2]

(iv) The compound K_3CrO_4 is a green solid. When mixed with dilute H_2SO_4, it undergoes disproportionation to yield Cr^{3+}(aq) and $Cr_2O_7^{2-}$(aq) ions.

By writing appropriate half-equations, write an overall balanced equation for the disproportionation of CrO_4^{3-} in acid.

…….....

…….....

…….....

……..... [2]

(v) Purification of chromium can be achieved by electro-refining chromium from an impure chromium anode onto a pure chromium cathode in an electrolytic cell. How many hours will it take to plate 130 g of chromium onto the cathode if the current passed through the cell is held constant at 34.0 A?

Assume the chromium in the electrolytic solution is present as Cr^{3+}.

[2]

(c) The reaction between $S_2O_8^{2-}$ ions and I^- ions is very slow:

$$S_2O_8^{2-}(aq) + 2I^-(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq)$$

If a small amount of aqueous manganese(II) ions, Mn^{2+}, is added to the mixture, the rate of reaction increases rapidly.

State the property, typical of transition metals, which allow manganese (II) ions to behave as a homogeneous catalyst in this reaction.

By considering the data given below, write relevant chemical equations to support your answer.

$$Mn^{3+} + e^- \rightleftharpoons Mn^{2+}$$

……

……

……

……

…… [3]

[Total:18]

4 **(a)** Citric acid is commonly found in citrus fruits such as lemons. Mixtures of citric acid and its salt, sodium citrate, are often used as "acidity regulators". These are food additives that have a buffering action on the pH of foodstuffs.

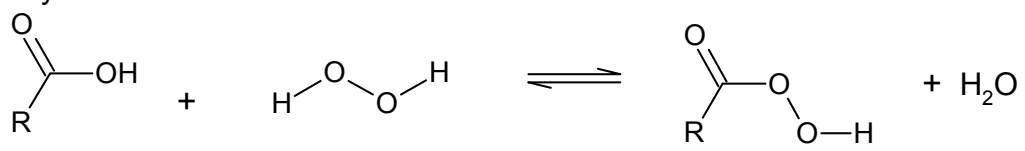
$$\underset{\text{citric acid}}{C_5H_7O_4CO_2H} \rightleftharpoons \underset{\text{citrate}}{C_5H_7O_4CO_2^-} + H^+$$

K_a of citric acid = 7.4×10^{-4} mol dm^{-3}

A typical citric acid / sodium citrate buffer mixture is prepared by mixing 0.100 mol dm^{-3} citric acid and 0.200 mol dm^{-3} sodium citrate in a volume ratio 2:3 respectively. Calculate the pH of the buffer solution.

[2]

(b) The reaction between carboxylic acids and hydrogen peroxides produce peroxyacids.



The p*K*a values of four compounds are listed in the table below.

name	**formula**	***pK*a**
Water	H_2O	14.0
Hydrogen peroxide	H_2O_2	11.7
Methanoic acid	HCO_2H	3.7
Peroxymethanoic acid	HCO_3H	7.1

Suggest an explanation for why

(i) The p*K*a of H_2O_2 is less than that for water

…….....

……..... [1]

(ii) the p*K*a of HCO_3H is more than that for HCO_2H

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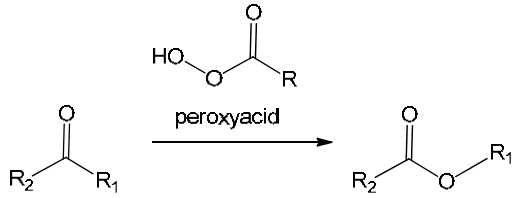
..... [2]

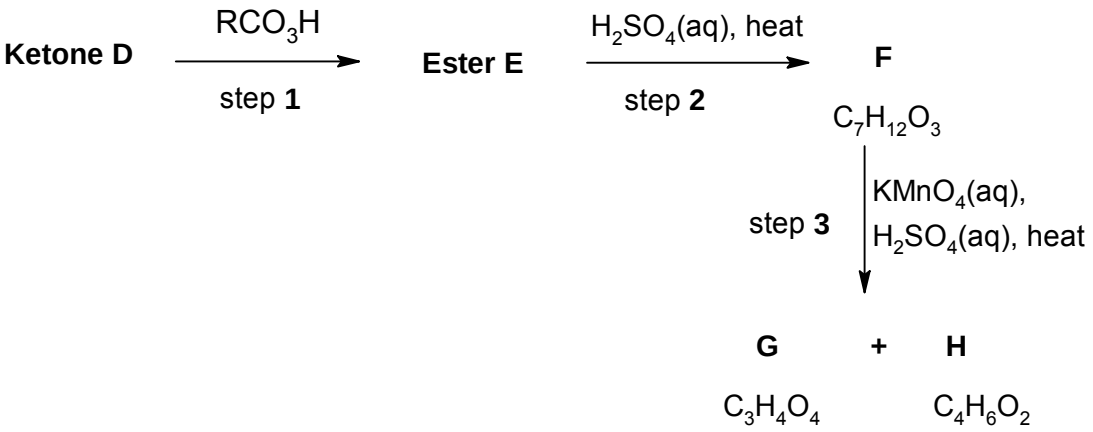
(c) The Baeyer-Villiger oxidation is an organic reaction in which peroxyacids react with ketones to give esters, as shown in the equation below.



In the following scheme, ketone **D** ($C_7H_{10}O$) undergoes Baeyer-Villiger oxidation in step **1** to form ester **E**. Ketone **D** also decolourises orange aqueous Br_2.

F is the **only** product formed, from treating ester **E** with hot H_2SO_4(aq).

Hot acidified $KMnO_4$ oxidises several classes of organic compounds to ketones, carboxylic acids and carbon dioxide. By this means, the structures of compounds can be determined. The scheme below shows the oxidation products of **F**.



(i) State the type of reaction Ester **E** undergoes with hot H_2SO_4(aq) in step 2.

Type of reaction: ..... [1]

(ii) 1 mole **H** reacted with alkaline aqueous iodine to form 2 moles of CHI_3 yellow ppt. Suggest the structure of **H**.
Give the product of the reaction of **H** with alkaline aqueous iodine.
Structure of **H:**

Product**:**

[2]

(iii) **G** ($C_3H_4O_4$) was found to react with Na_2CO_3(aq). Suggest the structure of **G**.

[1]

(iv) From your answer in **(ii)** and **(iii)**, deduce and suggest the structure of **F**.

[1]

(v) Hence, suggest the structures of ketone **D** and ester **E**.

[2]
[Total: 12]

5 (a) (i) Oleic acid, $CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$ is a fatty acid found in oils and fats, which has C=C double bond in the cis configuration.

The trans isomer of oleic acid is known as *elaidic acid*, which is found in partially hydrogenated vegetable oils.

Draw the skeletal formula for the ***trans*** isomer of oleic acid, $CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$, which is also known as *elaidic acid*.

[1]

(ii) Suggest a brief explanation for the differences in melting points between oleic acid and its *trans* isomer, elaidic acid.

Compound	***Mr***	**Melting point / °C**
oleic acid (cis-isomer)	282	4.0
elaidic acid (trans-isomer)	282	45.0

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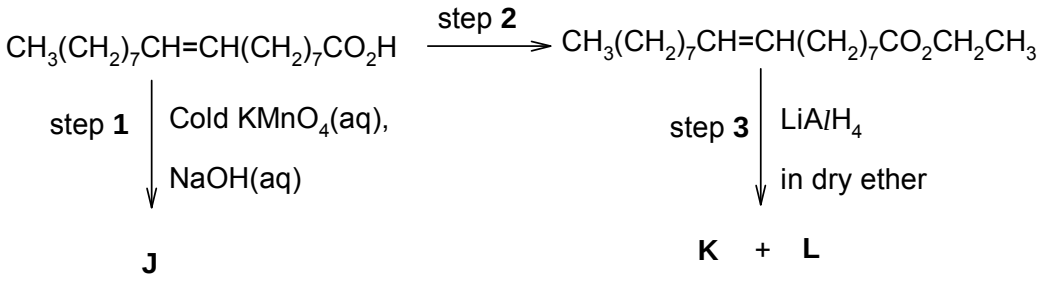
..... [1]

(iii) Below outlines a reaction scheme involving oleic acid.



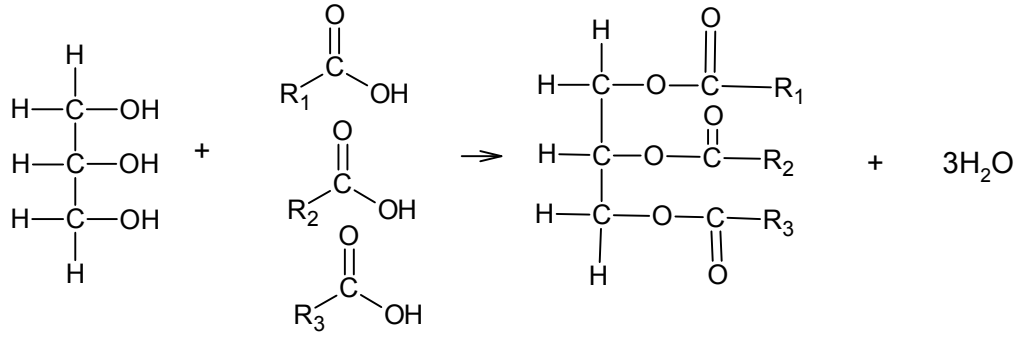
Give the reagents and conditions for step 2, and draw the structures of compounds **J**, **K** and **L** in the boxes provided below.

Step **2:** ……

J	**K**	**L**

[4]

(b) Avocado oil consists mainly of triesters formed from glycerol (propane-1,2,3-triol) and long-chain carboxylic acids (fatty acids) as shown by the general equation.

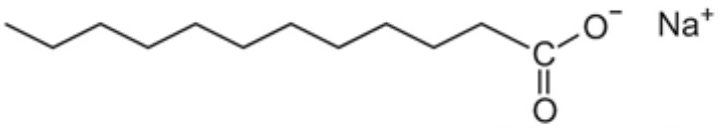


glycerol fatty acids triester

The major component of avocado oil is triolein, the triester formed from glycerol and three units of oleic acid (fatty acid).

(i) A student tried to flush his cup with water to wash away the avocado oil, but was not successful. The student then tried using soap to wash away the avocado oil in the cup, and was successful.

The following compound, sodium stearate is a typical soap for washing.



By reference to the type of intermolecular forces formed between the soap, avocado oil and water, explain why sodium stearate is able to wash away the avocado oil in the cup.

…….....

…….....

…….....

…….....[2]

(ii) Below shows the nutrition content of fats, carbohydrates and protein present in one serving of avocado milkshake.

	Mass present in 1 serving of milkshake	Fuel value/ kJ g^{-1}
Total Fat	30 g	
Saturated fat (tristearin)	6 g	42.4
Unsaturated fat (triolein)	24 g	x
Trans fat	0 g	-
Carbohydrates	18g	17
Protein	2g	17
Dietary Fiber	16g	8
Potassium	850 mg	-

Fats constitute the bulk of the milkshake, and are metabolised into carbon dioxide and water when subjected to combustion in a bomb calorimeter. There are two types of fats in the milkshake, saturated versus unsaturated fat.

You may assume that the unsaturated fat and saturated fat in the milkshake are triolein and tristearin respectively.

The combustion of triolein, $C_{57}H_{104}O_6$, the unsaturated fat is as follows:

$$C_{57}H_{104}O_6 + 80O_2 \rightarrow 57\ CO_2 + 52\ H_2O \quad \Delta H_c^{\ominus} = -35100\ \text{kJ mol}^{-1}$$

The **fuel value** of a substance is defined as the heat energy released, when **one gram** of the substance undergoes combustion.

Calculate x, the fuel value of triolein, the unsaturated fat, and hence deduce if triolein or tristearin is a better source of energy (M_r of triolein = 884).

[2]
[Total: 10]

6 Aluminium oxide is frequently used in organic reactions and is also a common component in cosmetics. It is primarily used in the production of aluminium.

(a) Aluminium oxide reacts with aqueous sodium hydroxide to give a homogeneous solution. Similarly, aluminium reacts with aqueous sodium hydroxide to give the same homogeneous solution and a gas that pops with a lighted splint.

(i) Write a balanced equation for the reaction of a piece of aluminium foil when it is placed into aqueous sodium hydroxide.

……..……..... [1]

(ii) In reaction **(a)(i)**, a white solid layer was first seen on the aluminium foil before the homogeneous solution was formed. Identify the solid and write an equation to explain how the homogeneous solution was formed from the solid.

Solid: ……

……..……..

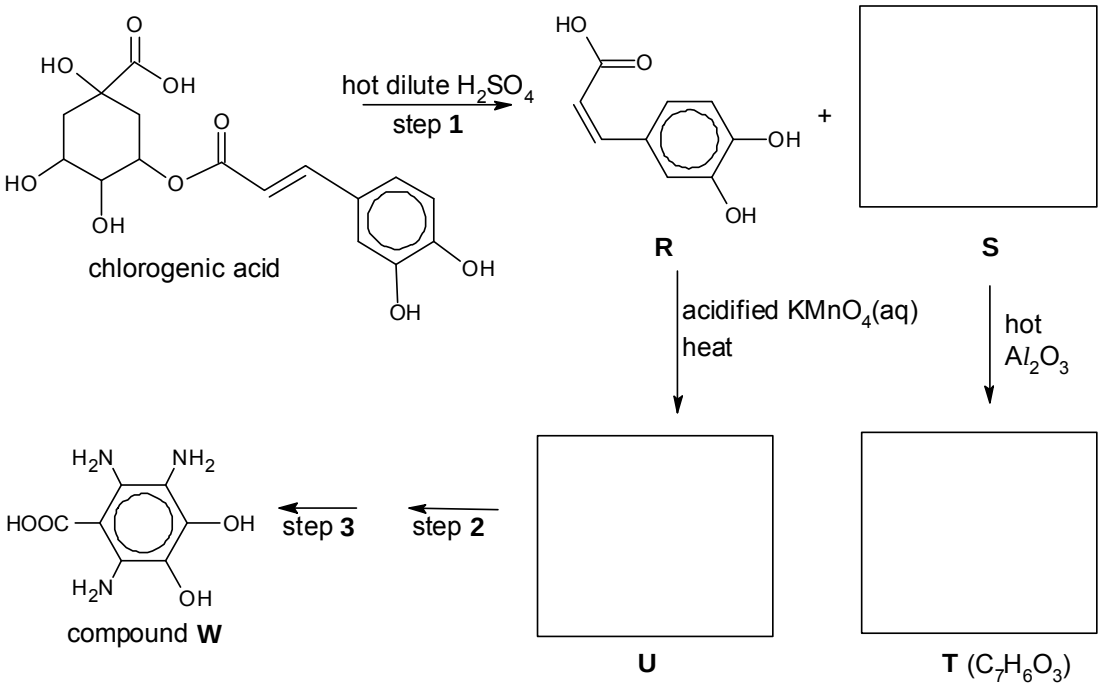
……..……..

……..…… [2]

(b) Polyphenols are often reducing agents known as antioxidants.

An example of a polyphenol is chlorogenic acid.

The structure of chlorogenic acid and its reaction scheme is shown below. In the reaction scheme, compound **T**, $C_7H_6O_3$, is formed from compound **S** and heated Al_2O_3. Compound **T** reacts with neutral aqueous iron(III) chloride to form a violet solution.



(i) Draw the structures of organic compounds **S**, **T** and **U** in the boxes provided in the scheme above. [3]

(ii) Compound **U** can be converted to compound **W** in two steps.

Suggest reagents and conditions for steps **2** and **3**.

Step 2: ……..... [1]

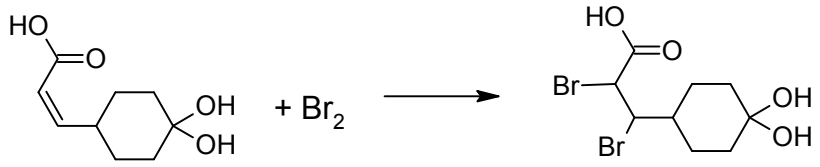
Step 3: ……..... [1]

(iii) If hot dilute sodium hydroxide was used to react with chlorogenic acid, state the number of moles of NaOH that would be required to react with one mole of chlorogenic acid.

Number of mol of NaOH: ……..... [1]

(iv) Compound **X** shown below is an analog of compound **R** in the scheme. When compound **X** is added to bromine in CCl_4 in the dark, there is a rapid reaction 2, that decolourises the bromine.

reaction 2:



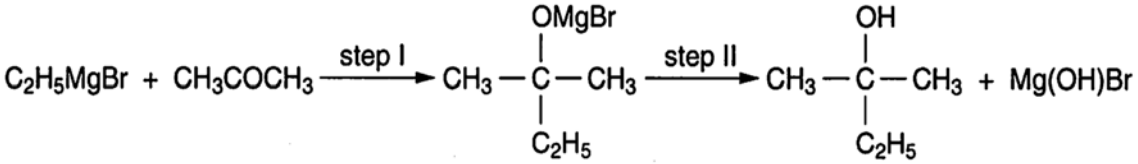
X

The product of this reaction 2, exists as a mixture of four stereoisomers. State the type of isomerism exhibited and draw all the stereoisomers.

[3]

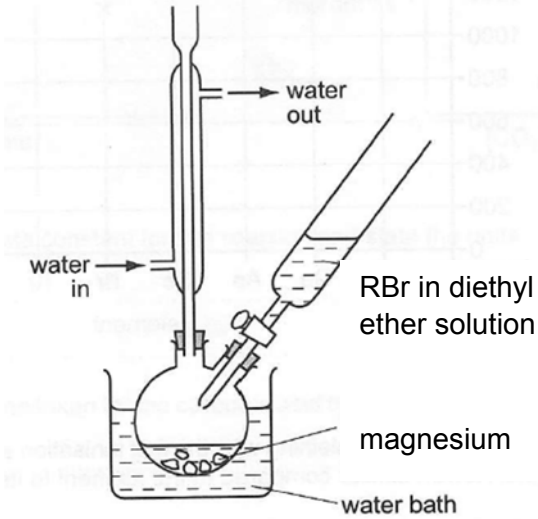
(c) In a Grignard reaction, the Grignard reagent, RMgBr (alkyl or aryl magnesium halide), may be added to a carbonyl compound for the formation of an alcohol.

A typical example of the use of a Grignard reagent is the two-step reaction of C_2H_5MgBr with propanone, CH_3COCH_3, to form 2-methylbutan-2-ol.



(i) Draw the structural formula of the Grignard reagent that will react with propanone to form 2–methylhexan–2–ol in a similar two–step reaction. [1]

(ii) To prepare 2–methylhexan–2–ol, the following set-up and procedure was used.



<u>Preparation of the Grignard reagent:</u>

1. Several small pieces of Mg was placed in a round-bottomed flask.
2. 9.6 g of an appropriate bromoalkane, RBr, was dissolved in anhydrous diethyl ether. It is important to exclude water as Grignard reagent undergoes acid-base reaction with water rapidly to form an alkane, destroying the Grignard reagent.
3. To initiate the reaction, add just enough RBr/ ether solution from the dropping funnel to cover the magnesium. Start stirring with a magnetic stir bar and use a water bath to heat the reaction flask as the RBr/ ether solution is slowly added dropwise into the metal.
4. The mixture was heated under reflux for about 15 minutes and cooled in an ice-bath.

Reaction of Grignard reagent with propanone:

5. Add 1.2 g of anhydrous propanone in the dropping funnel and add propanone dropwise to the Grignard reagent.
6. Allow the reaction mixture to stand at room temperature for 30 minutes.
7. The mixture was then slowly poured with vigorous stirring into an ice-cold substance **Z** in a beaker. Almost immediately, a solid precipitate is seen.
8. Filter the mixture and collect the ethereal solution in a clean and dry conical flask.
9. Add anhydrous magnesium sulfate to the ethereal solution, cork the flask tightly and leave the mixture to stand for a while.
10. Filter and collect the filtrate in a round-bottom flask which is then placed on a rotary dryer to evaporate all the solvent diethyl ether away.

I. Assuming that 1.9 g of 2–methylhexan–2–ol was prepared using the procedure, calculate the percentage yield for this synthesis. [2]

II. During the preparation of the Grignard reagent, anhydrous diethyl ether was used as the solvent in step 2, as the Grignard reagent can be destroyed in the presence of water.

Write an equation to show the reaction of the Grignard reagent with water.

……..... [1]

III. Identify substance **Z** in step 7, in the beaker.

……..... [1]

IV. Suggest what is removed when anhydrous magnesium sulfate is added to the ethereal solution in step 9.

……..... [1]

[Total: 18]

End of paper

PIONEER JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION
HIGHER 2

CANDIDATE NAME									
CT GROUP	1	7	S			INDEX NUMBER			

CHEMISTRY 9729/02

Paper 2 Structured **11 September 2018**

2 hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your class, index number and name on all work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough workings.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINER'S USE			
Paper 1			**/ 30**
Paper 2			
1	/ 9	4	/12
2	/ 8	5	/ 10
3	/ 18	6	/ 18
Penalty		sf	unit
Paper 2			**/ 75**
Paper 3			**/ 80**
Paper 4			**/ 55**
Total			

This document consists of **21** printed pages.

Answer **all** questions in the spaces provided.

1 **(a)** Water hardness is determined by the concentration of multivalent cations in the water. Common cations found in hard water include Ca^{2+} and Mg^{2+}. Lime softening is a type of water treatment where aqueous Na_2CO_3 is added to remove Ca^{2+} ion as $CaCO_3$ is precipitated. These precipitates are then removed by sedimentation and filtration, where X^{2+} can be Ca^{2+} and Mg^{2+}.

$$X^{2+}(aq) + Na_2CO_3(aq) \rightarrow XCO_3(s) + 2Na^+(aq)$$

In the laboratory, 1 cm^3 of 0.50 mol dm^{-3} Na_2CO_3 is added to 10 cm^3 of a raw water sample. What is the minimum concentration of Ca^{2+} in the original raw water sample, which would cause a white precipitate to be observed?

The value of K_{sp} for $CaCO_3$ is 4.81 x 10^{-9} mol^2 dm^{-6}.

[2]

$Ca^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow CaCO_3(s)$

Let original concentration of Ca^{2+} be y mol dm^{-3}

Upon mixing

$[Ca^{2+}] = \frac{10\times10^{-3}\times y}{11\times10^{-3}}$ = 0.9091y mol dm^{-3}

$[CO_3^{2-}] = \frac{1\times10^{-3}\times0.5}{11\times10^{-3}}$ = 0.04545 mol dm^{-3}

Both $[Ca^{2+}]$ and $[CO_3^{2-}]$ correct

$IP = [Ca^{2+}][CO_3^{2-}] \geq K_{sp}$

$(0.9091y)(0.04545) = 4.81 \times 10^{-9}$

$y = 1.16 \times 10^{-7}$ mol dm^{-3}

(b) A saturated solution of raw water containing both CaF_2 and $Ca(OH)_2$ has a pH of 12 at 25°C.

calcium compound	numerical value of K_{sp}
CaF_2	3.2×10^{-11}
$Ca(OH)_2$	6.4×10^{-6}

(i) Calculate the concentration of hydroxide ions in the solution. [1]

pH = 12

pOH = 2

$[OH^-] = 10^{-2} = 1.00 \times 10^{-2}$ mol dm^{-3}

(ii) Hence, calculate the solubility of CaF_2 in the raw water sample. Show your working clearly. [2]

K_{sp} of $Ca(OH)_2$ = $[Ca^{2+}]_{total}[OH^-]^2$

$6.4 \times 10^{-6} = [Ca^{2+}]_{total}(1.00 \times 10^{-2})^2$

$[Ca^{2+}]_{total} = 0.0640$ mol dm^{-3}

$[Ca^{2+}]_{total}[F^-]^2 = 3.2 \times 10^{-11}$

$(0.0640)[F^-]^2 = 3.2 \times 10^{-11}$

$[F^-] = 2.24 \times 10^{-5}$ mol dm^{-3}

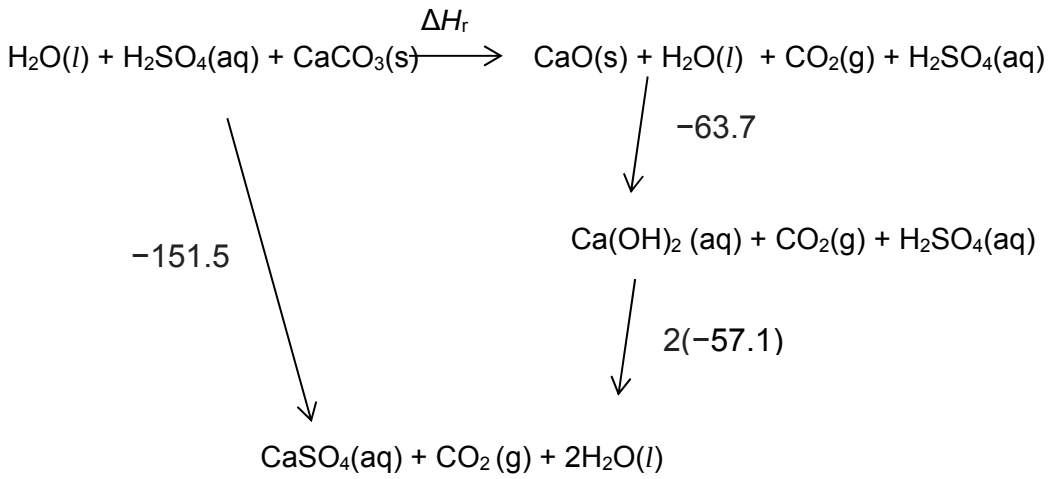
Solubility of CaF_2 = $(2.24 \times 10^{-5})/2 = 1.12 \times 10^{-5}$ mol dm^{-3}

[2]

(c) Using the following data, construct an energy cycle to calculate the enthalpy change for the thermal decomposition of calcium carbonate.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

	ΔH / kJ mol^{-1}
$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$	−57.1
$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$	−63.7
$H_2SO_4(aq) + CaCO_3(s) \rightarrow CaSO_4(aq) + H_2O(l) + CO_2(g)$	−151.5



By Hess' Law,

$\Delta H_r = -151.5 - (2)(-57.1) - (-63.7)$

$\Delta H_r = +26.4$ kJ mol^{-1}

[Total: 9]

2 The reaction of ethanal with iodine occurs in the presence of acid catalyst, HC*l*. . The reaction is given below.

$$I_2 + CH_3CHO \xrightarrow{HCl} CH_2ICHO + HI \qquad \text{Reaction 1}$$

The table shows the results obtained when the concentrations of I_2, CH_3CHO and HC*l* were varied.

Experiment	Initial [HC*l*] / mol dm^{-3}	Initial [I_2] / mol dm^{-3}	Initial [CH_3CHO] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}

1	0.10	0.20	0.20	1.6×10^{-6}
2	0.10	0.40	0.30	2.4×10^{-6}
3	0.40	0.40	0.20	6.4×10^{-6}
4	0.10	0.20	2.00	1.6×10^{-5}

(a) **(i)** Deduce the orders of reaction with respect to I_2, CH_3CHO and HC*l*. Hence, determine the rate equation.

[3]

Comparing expt 1 and 4

[HC*l*] and [I_2] are kept constant, when [CH_3CHO] is 10 times, initial rate is 10 times.

Hence reaction is first order wrt CH_3CHO.

Let rate = k [HC*l*]^m [I_2]^n [CH_3CHO]

Comparing expt 1 and 2

When $\frac{(2)}{(1)}$, $\frac{(\text{rate})_2}{(\text{rate})_1} = \frac{2.4 \times 10^{-6}}{1.6 \times 10^{-6}} = \frac{k\,(0.10)^m\,(0.40)^n\,(0.3)}{k\,(0.10)^m\,(0.20)^n\,(0.2)}$

n = 0

Hence reaction is zero order wrt I_2.

Comparing expt 2 and 3

When $\frac{(2)}{(3)}$, $\frac{(\text{rate})_2}{(\text{rate})_3} = \frac{2.4 \times 10^{-6}}{6.4 \times 10^{-6}} = \frac{k\,(0.10)^m\,(0.3)}{k\,(0.40)^m\,(0.2)}$

m = 1

Hence reaction is first order wrt HC*l*.

Hence rate = k [HC*l*] [CH_3CHO]

(ii) The half-life of ethanal in experiment 1 was 60 seconds. Predict the half-life of ethanal in experiments 2 and 3. Explain your answer.

HC*l* functions as a catalyst. Hence, [HC*l*] remains constant in each expt. Therefore, for each experiment, the reaction becomes a pseudo-first order reaction.

Rate = k [ethanal] [HC*l*]

= k^* [ethanal] where $k^* = k$ [HC*l*]

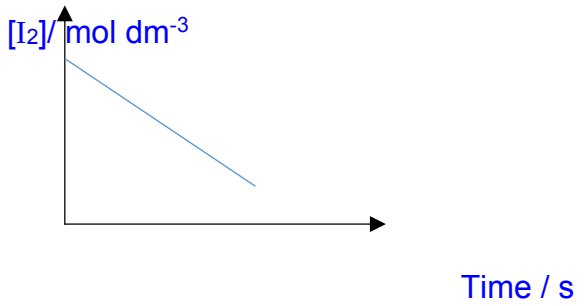
For a first order reaction, $t_{1/2} = \ln 2 / k^* = \ln 2 / k$ [HC*l*]

In expt 2, when [HC*l*] is the same as in expt 1, $t_{1/2}$ = 60 s

In expt 3, when [HC*l*] is four times compared to expt 1**, $t_{1/2}$ = 60/4 = 15 s**

(iii) Sketch the graph of concentration of iodine against time for experiment 4.

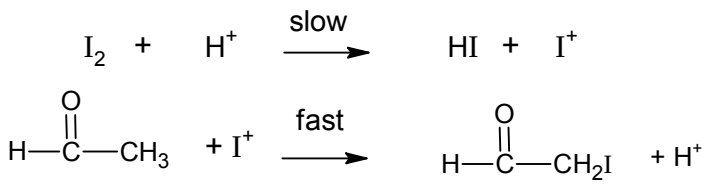
Experiment	Initial [HC*l*] / mol dm^{-3}	Initial [I_2] / mol dm^{-3}	Initial [CH_3CHO] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
4	0.10	0.20	2.00	1.6 x 10^{-5}



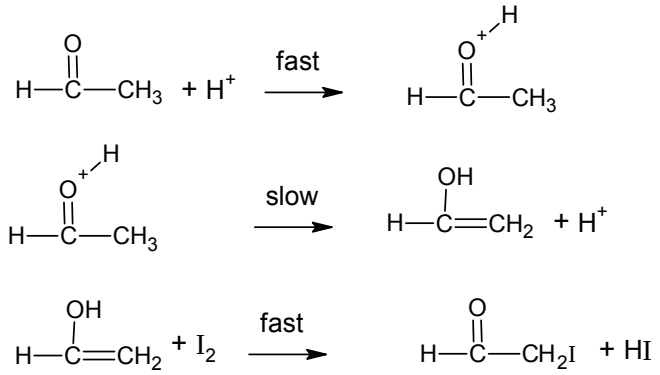
[1]

(b) The following mechanisms **A** and **B** are proposed for the reaction of ethanal, iodine and acid catalyst in Reaction 1.

Mechanism A



Mechanism B



Which of the above mechanisms best agrees with the experimentally determined rate equation in **(a)(i)**? Explain your answer.

Mechanism B

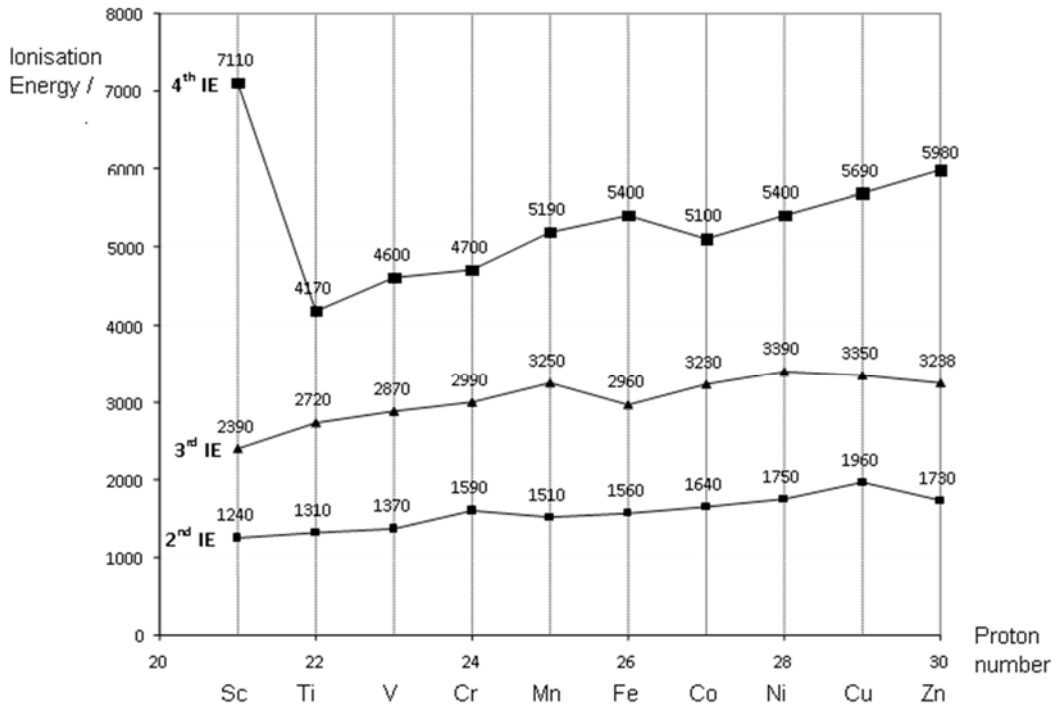
The slow (rate-determining) step involves one molecule of ethanal and colliding with one molecule of hydrochloric acid.

3 Transition metal is "an element whose atom has a partially filled d sub-shell, or which can give rise to cations with an incompletely filled d sub-shell". Chromium and vanadium, both transition metals, have found a number of industrial uses due to their toughness and resistance to heat and corrosion.

The table below shows some information of a Group 2 metal calcium, vanadium and chromium.

	Vanadium	**Chromium**	**Calcium**
Melting point/ °C	1910	1875	843
Atomic radius/ nm	0.135	0.129	0.197
Common Oxidation Number	+2, +3, +4, +5	+2, +3, +6	+2

The graph below shows the second to fourth ionisation energies for the first row d block elements scandium to zinc.



(a) **(i)** Although the vanadium atom has more electrons than the calcium atom, the atomic radius of vanadium is smaller than that of calcium. Suggest an explanation for this.

Atomic radius of vanadium is smaller than that of calcium because vanadium has higher nuclear charge and the 3d electrons shield the 4s electrons poorly.

These result in a greater effective nuclear charge attraction in Vanadium, for the valence electrons, than calcium.

(ii) Explain why the second ionisation energies of transition elements from Ti to Cu are relatively invariant.

Effective nuclear charge increase very slightly or almost constant invariant. There is increase in nuclear charge but shielding effect increases due to electrons added to the 3d penultimate (inner) shell.

(iii) Explain why the second ionisation energy of chromium is higher than that of manganese.
Cr^+ = [Ar]$3d^5$, Mn^+ = [Ar]$3d^5 4s^1$

The second electron removed from manganese is a 4s−electron while the second electron removed from chromium is a 3d−electron.

Since a 3d−electron is (is in inner shell) closer to the nucleus and has lower energy, more energy is required to remove it, causing second ionisation energy of Cr to be higher than that of Mn.

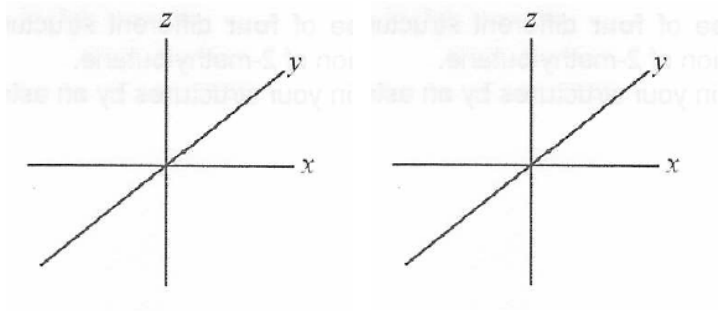
(b) **(i)** State the **full** electronic configuration of Cr^{3+} ion.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$

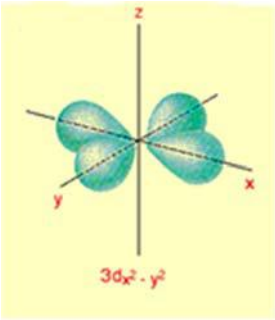
(ii) The complex ion $[Cr(H_2O)_6]^{3+}$ is green, and it is an octahedral complex. On the Cartesian axes shown in Fig. 2.1, draw **fully-labelled** diagrams of the following:

- One of the d orbitals at the lower energy level in an octahedral complex- Label this diagram 'lower'.
- One of the d orbitals at the upper energy level in an octahedral complex. Label this diagram 'upper'. [2]

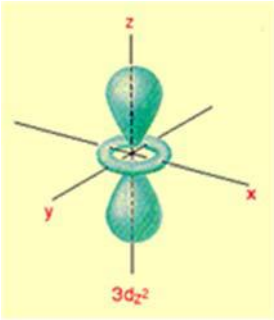
Fig. 3.1



Upper

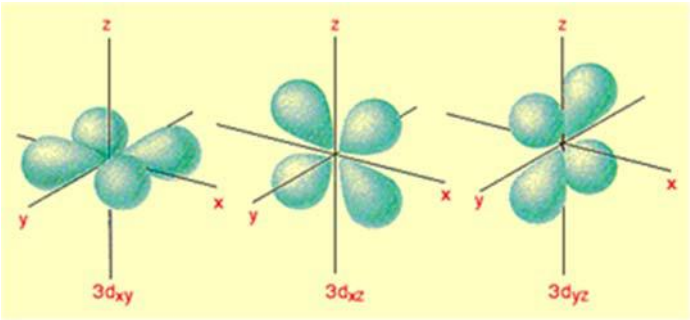


or



Lower

Any of the 3 orbitals (labelled) below



(iii) Suggest which of the two compounds chromium(III) oxide, Cr_2O_3, and chromium(III) carbonate, $Cr_2(CO_3)_3$, would have a more exothermic lattice energy. Explain your answer.

All ions have same charges. O^{2-} has smaller ionic radius than CO_3^{2-}, thus magnitude of lattice energy is bigger, Cr_2O_3 so more exothermic .

(iv) The compound K_3CrO_4 is a green solid. When mixed with dilute H_2SO_4, it undergoes disproportionation to yield Cr^{3+}(aq) and $Cr_2O_7^{2-}$(aq) ions.

By writing appropriate half-equations, write an overall balanced equation for the disproportionation of CrO_4^{3-} in acid.

(+5) (+3)

$CrO_4^{3-} + 8H^+ + 2e^- \rightarrow Cr^{3+} + 4H_2O$

2(+5) 2(+6)

$2CrO_4^{3-} + 2H^+ \rightarrow Cr_2O_7^{2-} + 2e^- + H_2O$

Overall equation: $3CrO_4^{3-} + 10H^+ \rightarrow Cr^{3+} + Cr_2O_7^{2-} + 5H_2O$

(v) Purification of chromium can be achieved by electro-refining chromium from an impure chromium anode onto a pure chromium cathode in an electrolytic cell. How many hours will it take to plate 130 g of chromium onto the cathode if the current passed through the cell is held constant at 34.0 A?

Assume the chromium in the electrolytic solution is present as Cr^{3+}.

n(Cr) = 130/ 52.0 = 2.50 mol

n(e) = 2.50 x 3 = 7.50 mol

96500 C for 1 mol of e.

No of charges = 96500 x 7.50 = 7.238 x 10^5C

(96500 x 7.50) = 34 x t

t = 5.91 h

[2]

(c) The reaction between $S_2O_8^{2-}$ ions and I^- ions is very slow:

$$S_2O_8^{2-}(aq) + 2I^-(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq)$$

If a small amount of aqueous manganese(II) ions, Mn^{2+}, is added to the mixture, the rate of reaction increases rapidly.

State the property, typical of transition metals, which allow manganese (II) ions to behave as a homogeneous catalyst in this reaction.

By considering the data given below, write relevant chemical equations to support your answer.

$$Mn^{3+} + e^- \rightleftharpoons Mn^{2+}$$

Property: Mn^{2+}, a transition metal ion, can exist as variable oxidation states.

Step 1: Formation of intermediate (Mn^{2+} reacting with $S_2O_8^{2-}$)

$Mn^{2+} \rightleftharpoons Mn^{3+} + e^-$ $E^{\ominus}_{oxd}$ = -1.54V

$S_2O_8^{2-} + 2e^- \rightleftharpoons SO_4^{2-}$ $E^{\ominus}_{red}$ = +2.01 V

$2Mn^{2+} + S_2O_8^{2-} \longrightarrow 2Mn^{3+} + SO_4^{2-}$

$E^{\ominus}_{cell} = E^{\ominus}_{oxd} + E^{\ominus}_{red}$ = +2.01 +-1.54 =+ 0.47V> 0, thus reaction is energetically feasible.

Step 2: Regeneration of catalyst

$Mn^{3+} + e^- \rightleftharpoons Mn^{2+}$ $E^{\ominus}_{red}$ = +1.54

$2I^- \rightleftharpoons I_2 + 2e^-$ $E^{\ominus}_{oxd}$ = –0.54 V

$2I^- + 2Mn^{3+} \longrightarrow I_2 + 2Mn^{2+}$

$E^{\ominus}_{cell} = E^{\ominus}_{oxd} + E^{\ominus}_{red}$ = + 1.00V >0, thus reaction is energetically feasible

[Total:18]

4 **(a)** Citric acid is commonly found in citrus fruits such as lemons.

Mixtures of citric acid and its salt, sodium citrate, are often used as "acidity regulators". These are food additives that have a buffering action on the pH of foodstuffs.

$$\underset{\text{citric acid}}{C_5H_7O_4CO_2H} \rightleftharpoons \underset{\text{citrate}}{C_5H_7O_4CO_2^-} + H^+$$

K_a of citric acid = 7.4×10^{-4} mol dm^{-3}

A typical citric acid / sodium citrate buffer mixture is prepared by mixing 0.100 mol dm^{-3} citric acid and 0.200 mol dm^{-3} sodium citrate in a volume ratio 2:3 respectively.

Calculate the pH of the buffer solution. [2]

$[C_5H_7O_4CO_2H] = \frac{2}{5} \times 0.100$

$= 0.040$ mol dm^{-3}

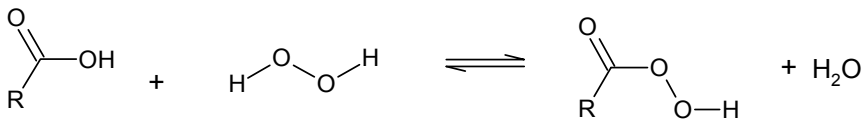
$[C_5H_7O_4CO_2Na] = \frac{3}{5} \times 0.200$

$= 0.120$ mol dm^{-3}

pH of the buffer = $-\lg(7.46 \times 10^{-4}) + \lg\left(\frac{0.120}{0.040}\right)$

$= 3.60$

(b) The reaction between carboxylic acids and hydrogen peroxides produce peroxyacids.



The p*K*a values of four compounds are listed in the table below.

Name	**formula**	***pK*a**
Water	H_2O	14.0
Hydrogen peroxide	H_2O_2	11.7
Methanoic acid	HCO_2H	3.7

Peroxymethanoic acid	HCO_3H	7.1

Suggest an explanation for why

(i) The p*K*a of H_2O_2 is less than that for water [1]

Lower pK_a of H_2O_2 means H_2O_2 is stronger acid than H_2O.

Stability of anion: H-O-O$^-$ > HO$^-$

H-O-O$^-$ has additional O atom bonded to negatively charged O$^-$, this additional electronegative O helps to disperse the negative charge more (via inductive effect), stabilising H-O-O$^-$ relative to HO$^-$

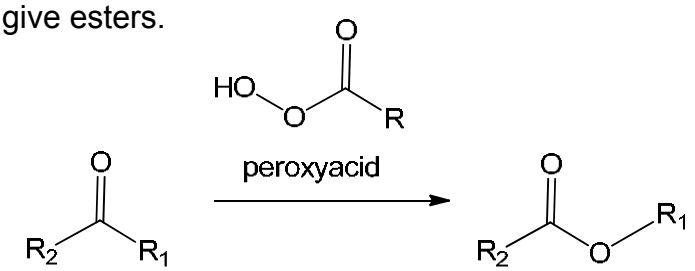
A **(ii)** The p*K*a of HCO_3H is more than that for HCO_2H [2]

Lower pK_a of HCO_2H means HCO_2H is stronger acid than HCO_3H

In HCO_2^-, the p orbitals of the 3 atoms of $–CO_2^-$ are all adjacent to each other, overlap sideways, allowing the delocalisation of the negative charge across the 3 atoms of $–COO^-$, thus HCO_2^- is much more stable than HCO_3^-.

In HCO_3^-, the negative charge cannot be delocalised thus HCO_3^- is less stable.

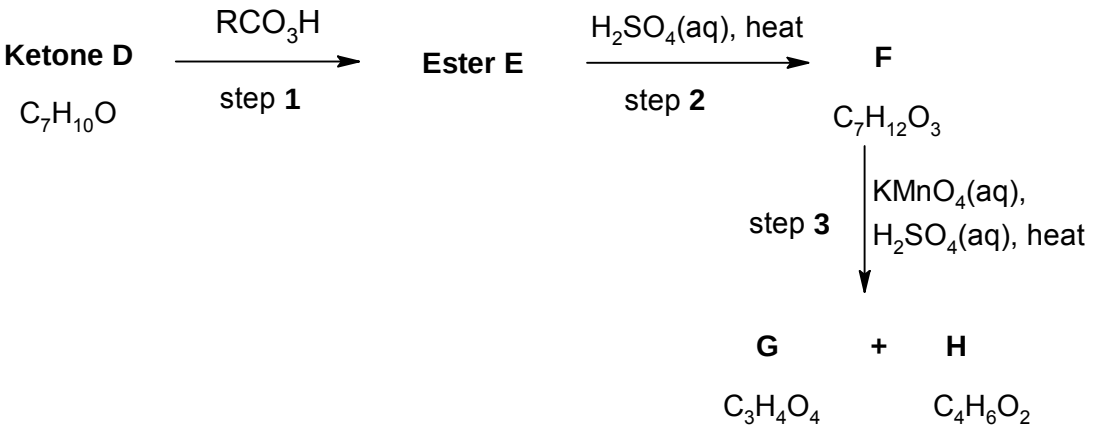
(c) The Baeyer-Villiger oxidation is an organic reaction in which peroxyacids react with ketones to give esters.



In the following scheme, ketone **D** ($C_7H_{10}O$) undergoes Baeyer-Villiger oxidation in step **1** to form ester **E**. Ketone **D** also decolourises orange aqueous Br_2.

F is the **only** product formed, from treating ester **E** with hot H_2SO_4(aq).

Hot acidified $KMnO_4$ oxidises several classes of organic compounds to ketones, carboxylic acids and carbon dioxide. By this means, the structures of compounds can be determined. The scheme below shows the oxidation products of **F**.

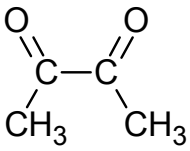


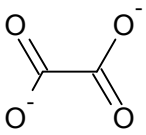
(i) State the type of reaction Ester **E** undergoes with hot H_2SO_4(aq) in step 2.

Hydrolysis

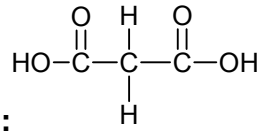
(ii) 1 mole **H** reacted with alkaline aqueous iodine to form 2 moles of CHI_3 yellow ppt. Draw the structure of **H**.

Give the product of the reaction of **H** with alkaline aqueous iodine. [2]

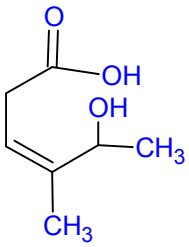
H: 

Product:  or $C_2O_4^{2-}$

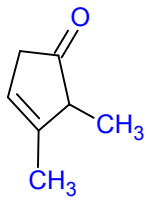
K **(iii)** **G** ($C_3H_4O_4$) was found to react with Na_2CO_3(aq). Suggest the structure of **G**.

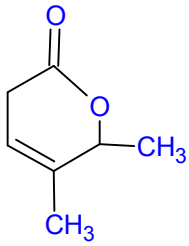
G: 

(iv) From your answer in **(ii)** and **(iii)**, deduce and suggest the structure of **F**. [1]

F: 

(v) Hence, suggest the structures of ketone **D** and ester **E**.





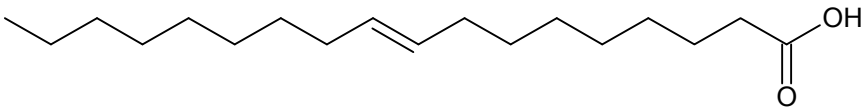
D:$C_7H_{10}O$ E: $C_7H_{10}O_2$

[Total: 12]

5 (a) (i) Oleic acid, $CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$ is a fatty acid found in oils and fats, which has C=C double bond in the cis configuration.

The trans isomer of oleic acid is known as *elaidic acid*, which is found in partially hydrogenated vegetable oils.

Draw the skeletal formula for the ***trans*** isomer of oleic acid, $CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$, which is also known as *elaidic acid*.



[1]

(ii) Suggest a brief explanation for the differences in melting points between oleic acid and its *trans* isomer, elaidic acid.

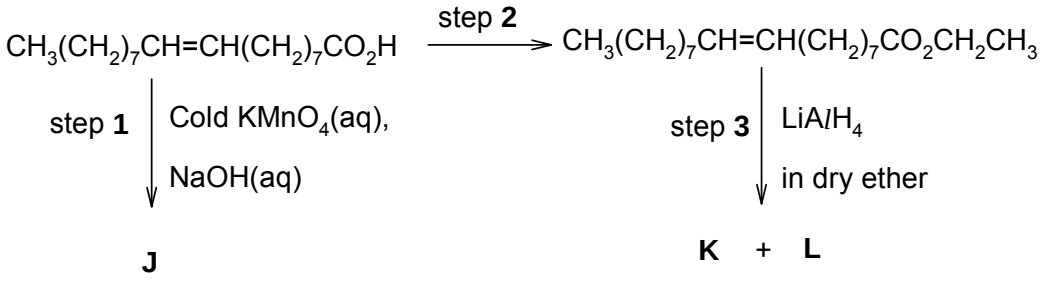
Compound	***Mr***	**Melting point / °C**
oleic acid (cis-isomer)	282	4.0
elaidic acid (trans-isomer)	282	45.0

[1]

The trans-double bond isomer of oleic acid, elaidic acid, has a more symmetrical shape and is thus able to pack more closely together, thus

more energy to overcome the stronger instantaneous dipole-induced dipole forces of attraction which cause it to have a higher melting point.

(iii) Below outlines a reaction scheme involving oleic acid.

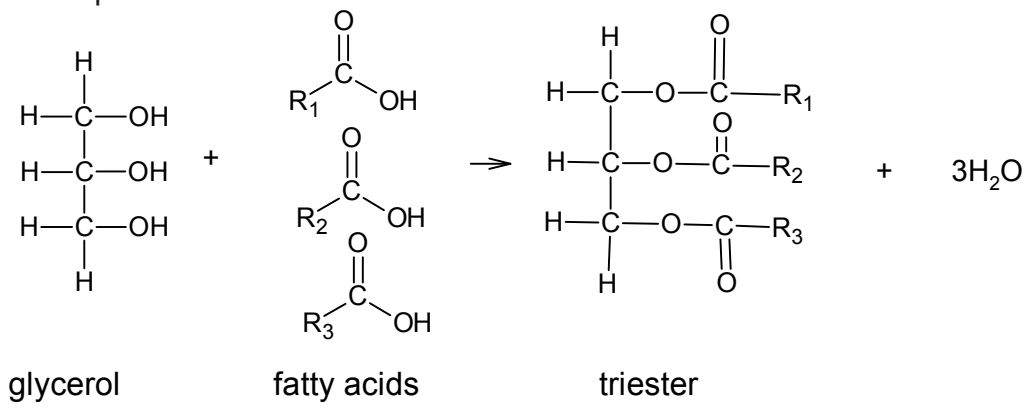


Give the reagents and conditions for step 2, and draw the structures of compounds **J**, **K** and **L** in the boxes provided below.

step **2**:	CH_3CH_2OH, concentrated H_2SO_4, heat
J:	$CH_3(CH_2)_7CH(OH)CH(OH)(CH_2)_7CO_2^-$ Na^+ If student wrote $CH_3(CH_2)_7CH(OH)CH(OH)(CH_2)_7COO^-$
K:	$CH_3(CH_2)_7CH{=}CH(CH_2)_7CH_2OH$
L:	CH_3CH_2OH(K and L are inter-changeable)

[4]

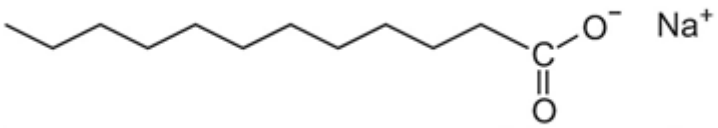
(b) Avocado oil consists mainly of triesters formed from glycerol (propane-1,2,3-triol) and long-chain carboxylic acids (fatty acids) as shown by the general equation.



The major component of avocado oil is triolein, the triester formed from glycerol and three units of oleic acid (fatty acid).

(i) A student tried to flush his cup with water to wash away the avocado oil, but was not successful. The student then tried using soap to wash away the avocado oil in the cup, and was successful.

The following compound, sodium stearate is a typical soap for washing.



By reference to the type of intermolecular forces formed between the soap, avocado oil and water, explain why sodium stearate is able to wash away the avocado oil in the cup.

The alkyl group of the soap is non-polar and able to form instantaneous dipole – induced dipole attraction with the non-polar avocado oil, while the $-COO^-$ part of the soap is able to form ion-dipole interaction with water molecules, these allow the avocado oil to be washed away by the water, in the presence of the soap.

(ii) Below shows the nutrition content of fats, carbohydrates and protein present in one serving of avocado milkshake.

	Mass present in 1 serving of milkshake	Fuel value/ kJ g^{-1}
Total Fat	30 g	
Saturated fat (tristearin)	6 g	42.4
Unsaturated fat (triolein)	24 g	x
Trans fat	0 g	-
Carbohydrates	18g	17
Protein	2g	17
Dietary Fiber	16g	8
Potassium	850 mg	-

Fats constitute the bulk of the milkshake, and are metabolised into carbon dioxide and water when subjected to combustion in a bomb calorimeter. There are two types of fats in the milkshake, saturated versus unsaturated fat.

You may assume that the unsaturated fat and saturated fat in the milkshake are triolein and tristearin respectively.

The combustion of triolein, $C_{57}H_{104}O_6$, the unsaturated fat is as follows:

$$C_{57}H_{104}O_6 + 80O_2 \rightarrow 57\ CO_2 + 52\ H_2O \quad \Delta H_c^{\ominus} = -35100\ \text{kJ mol}^{-1}$$

The **fuel value** of a substance is defined as the heat energy released, when **one gram** of the substance undergoes combustion.

Calculate x, the fuel value of triolein, the unsaturated fat, and hence deduce if triolein or tristearin is a better source of energy (M_r of triolein = 884).

No. of moles of triolein in 1 g = 1/884 = 1.131×10^{-3} mol

Fuel value of triolein = $1.131 \times 10^{-3} \times 35100 = 39.7$ kJ g^{-1}

• Since less energy is produced per gram,triolein is a poorer source of energy than tristearin (42.4 kJ g^{-1}).

[2]
[Total: 10]

6 Aluminium oxide is frequently used in organic reactions and is also a common component in cosmetics. It is primarily used in the production of aluminium.

(a) Aluminium oxide reacts with aqueous sodium hydroxide to give a homogeneous solution. Similarly, aluminium reacts with aqueous sodium hydroxide to give the same homogeneous solution and a gas that pops with a lighted splint.

(i) Write a balanced equation for the reaction of a piece of aluminium foil when it is placed into aqueous sodium hydroxide.

$2Al(s) + 2NaOH(aq) + 6H_2O(l) \rightarrow 2Na[Al(OH)_4](aq) + 3H_2(g)$

(ii) In reaction **(a)(i)**, a white solid layer was first seen on the aluminium foil before the homogeneous solution was formed. Identify the solid and write an equation to explain how the homogeneous solution was formed from the solid. [2]

Solid: Aluminium hydroxide

$Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$

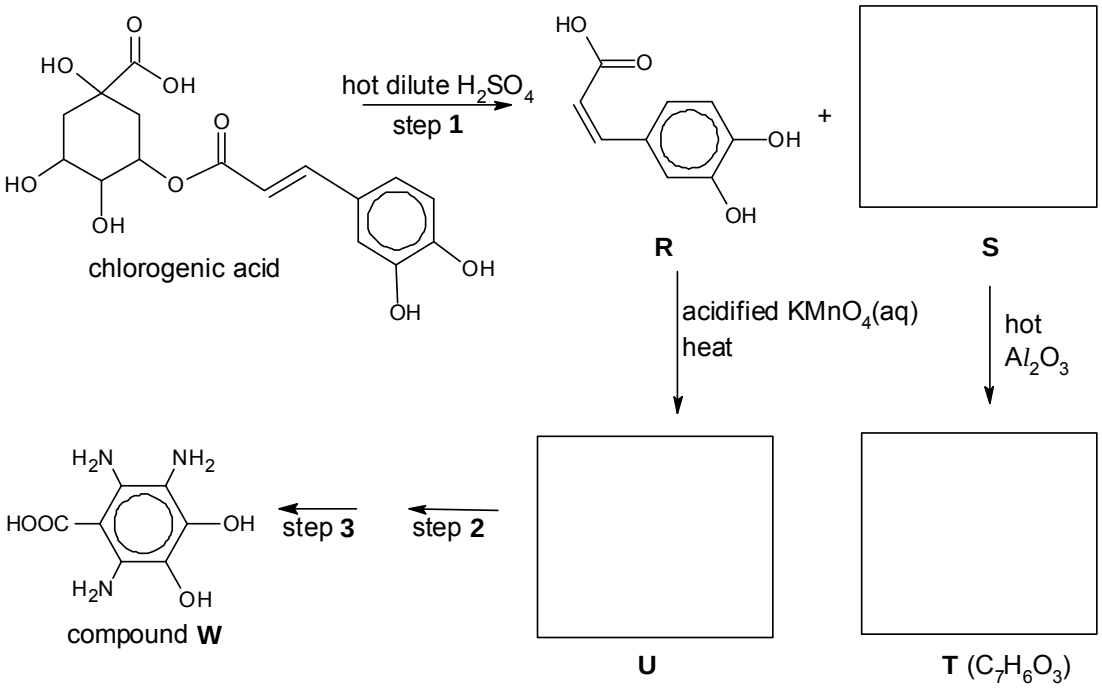
or

$Al(OH)_3(s) + NaOH(aq) \rightarrow Na[Al(OH)_4](aq)$

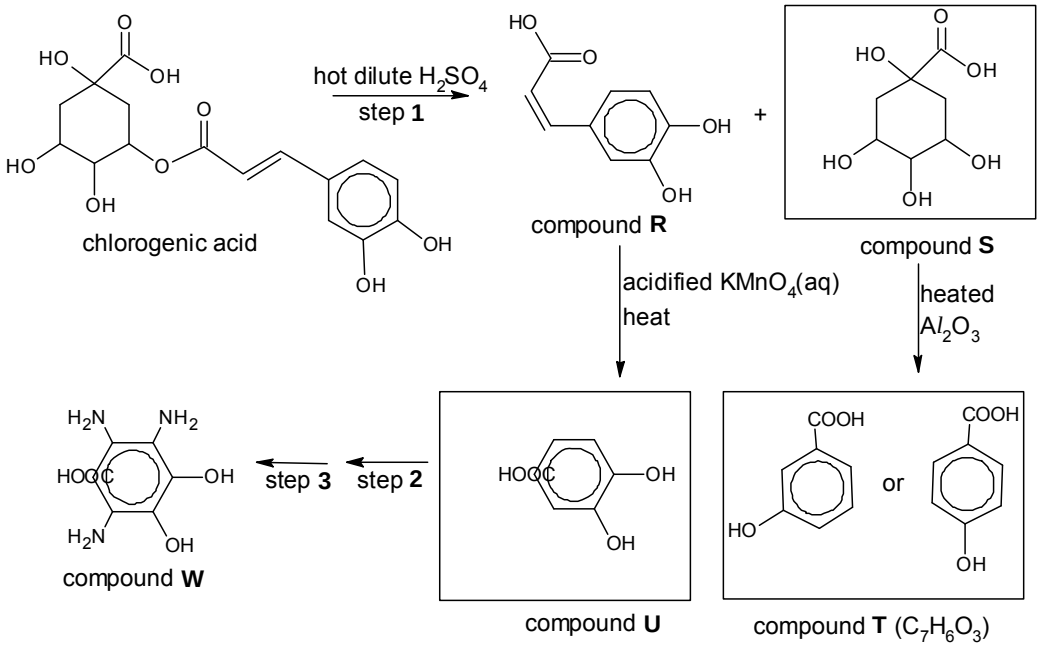
(b) Polyphenols are often reducing agents known as antioxidants.

An example of a polyphenol is chlorogenic acid.

The structure of chlorogenic acid and its reaction scheme is shown below. In the reaction scheme, compound **T**, $C_7H_6O_3$, is formed from compound **S** and heated Al_2O_3. Compound **T** reacts with neutral aqueous iron(III) chloride to form a violet solution.



(i) Draw the structures of organic compounds **S**, **T** and **U** in the boxes provided in the scheme above. [3]



(ii) Compound **U** can be converted to compound **W** in two steps.

Suggest reagents and conditions for steps **2** and **3**.

Step 2: ..... [1]

Step 3: ..... [1]

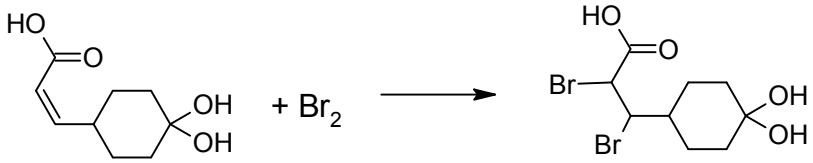
Step **2**:	dilute HNO_3 / HNO_3(aq) / HNO_3(*l*) / concentrated HNO_3
Step **3**:	Sn, concentrated HC*l*, heat, followed by <u>controlled</u> addition of NaOH(aq)

(iii) If hot dilute sodium hydroxide was used to react with chlorogenic acid, state the number of moles of NaOH that would be required to react with one mole of chlorogenic acid. [1]

Number of mol of NaOH: 4

(iv) Compound **X** shown below is an analog of compound **R** in the scheme. When compound **X** is added to bromine in CCl_4 in the dark, there is a rapid reaction 2, that decolourises the bromine.

reaction 2:



X

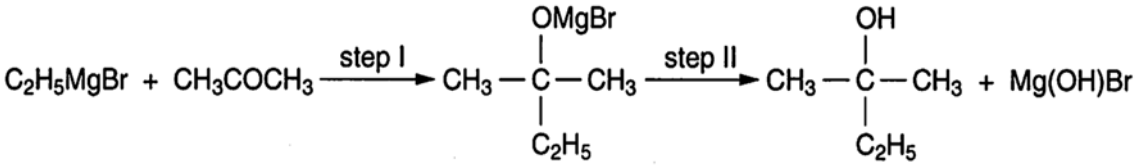
The product of this reaction 2, exists as a mixture of four stereoisomers. State the type of isomerism exhibited and draw all the stereoisomers.

Enantiomerism

[3]

(c) In a Grignard reaction, the Grignard reagent, RMgBr (alkyl or aryl magnesium halide), may be added to a carbonyl compound for the formation of an alcohol.

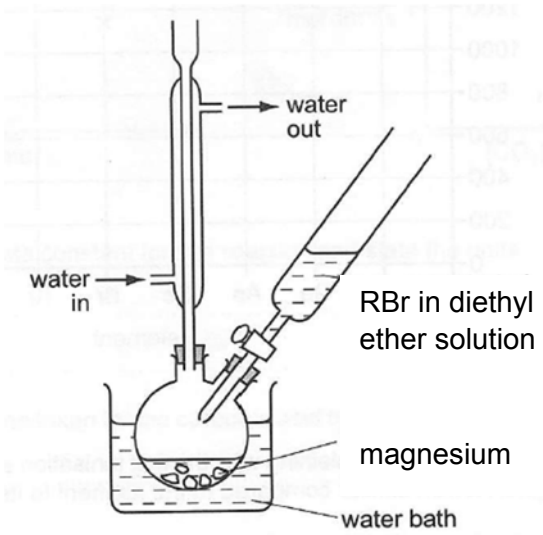
A typical example of the use of a Grignard reagent is the two-step reaction of C_2H_5MgBr with propanone, CH_3COCH_3, to form 2-methylbutan-2-ol.



(i) Draw the structural formula of the Grignard reagent that will react with propanone to form 2–methylhexan–2–ol in a similar two–step reaction. [1]

$CH_3CH_2CH_2CH_2MgBr$

(ii) To prepare 2–methylhexan–2–ol, the following set-up and procedure was used.



Preparation of the Grignard reagent:

1. Several small pieces of Mg was placed in a round-bottomed flask.
2. 9.6 g of an appropriate bromoalkane, RBr, was dissolved in anhydrous diethyl ether. It is important to exclude water as Grignard reagent undergoes acid-base reaction with water rapidly to form an alkane, destroying the Grignard reagent.
3. To initiate the reaction, add just enough RBr/ ether solution from the dropping funnel to cover the magnesium. Start stirring with a magnetic stir bar and use a water bath to heat the reaction flask as the RBr/ ether solution is slowly added dropwise into the metal.
4. The mixture was heated under reflux for about 15 minutes and cooled in an ice-bath.

Reaction of Grignard reagent with propanone:

5. Add 1.2 g of anhydrous propanone in the dropping funnel and add propanone dropwise to the Grignard reagent.
6. Allow the reaction mixture to stand at room temperature for 30 minutes.
7. The mixture was then slowly poured with vigorous stirring into an ice-cold substance **Z** in a beaker. Almost immediately, a solid precipitate is seen.
8. Filter the mixture and collect the ethereal solution in a clean and dry conical flask.
9. Add anhydrous magnesium sulfate to the ethereal solution, cork the flask tightly and leave the mixture to stand for a while.
10. Filter and collect the filtrate in a round-bottom flask which is then placed on a rotary dryer to evaporate all the solvent diethyl ether away.

I. Assuming that 1.9 g of 2–methylhexan–2–ol was prepared using the procedure, calculate the percentage yield for this synthesis. [2]

n(RBr) = 9.6 / 136.9 = 0.07012 mol (4 s.f)
n(propanone) = 1.2 / 58 = 0.02069 mol (4 s.f) (limiting reagent)
Recognising propanone is limiting reagent = no. of mol of 2–methylhexan–2–ol
n(2–methylhexan–2–ol = 0.02069 x 116 = 2.400g
% yield = 1.9/2.400 x 100 = 79.2%

II. During the preparation of the Grignard reagent, anhydrous diethyl ether was used as the solvent in step 2, as the Grignard reagent can be destroyed in the presence of water.

Write an equation to show the reaction of the Grignard reagent with water.
RMgBr + HO → RH + MgBr(OH)

III. Identify substance **Z** in step 7, in the beaker.

Water

IV. Suggest what is removed when **anhydrous** magnesium sulfate added to the ethereal solution in step 9.

To remove water from the ethereal solution.

[Total: 18]

End of paper

H

PIONEER JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION
HIGHER 2

CANDIDATE NAME

CT GROUP | 1 | 7 | | | |

INDEX NUMBER | | | | |

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CHEMISTRY **9729/03**

Paper 3 Free Response **19 September 2018**

2 hours

Candidates answer on separate paper.

Additional Materials: Answer Paper
Data Booklet
Cover Page

READ THESE INSTRUCTIONS FIRST

Write your name, index number and CT group on all work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough workings.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **15** printed pages.

r

Section A

Answer all questions in this section.

1 **(a)** Steam reforming is an important industrial method for producing hydrogen and carbon monoxide, from hydrocarbon fuels. This is achieved in a processing device called a reformer which reacts steam at high temperature with the fuel, such as methane gas.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H = +210 \text{ kJ mol}^{-1}$$

(i) Write an expression of K_p for the reaction, indicating its units. [2]

(ii) At temperature ***T***, a mixture of gaseous methane, steam and carbon monoxide were introduced into an evacuated reactor.

The table below shows the initial pressures of the gases before they were added to the reactor.

Gas	Initial pressure / atm
methane, CH_4	1.50
steam, H_2O	2.50
carbon monoxide, CO	0.70

Given that the percentage dissociation of methane is 20% at equilibrium, find the K_p for the reaction. [2]

(iii) A chemist decided to raise the temperature of the reactor. He suggested that this would result in a lower yield of the product.

Do you agree with the chemist? Explain your answer. [2]

In order to produce more hydrogen gas, the carbon monoxide gas that is produced from the steam reforming reaction can further react with steam. This is known as the "water-gas shift" reaction.

$$CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g) \qquad \Delta H_1$$

(iv) Given that the reaction conditions were set at 500°C and 1.5 atm, determine the maximum volume of hydrogen gas that can be produced from 5kg of carbon monoxide gas.

State the assumption made in your calculation. [3]

(v) Given the following,

enthalpy change of formation of CO(g) / kJ mol^{-1}	-99
enthalpy change of formation of H_2O(g) / kJ mol^{-1}	-245
enthalpy change of formation of CO_2(g) / kJ mol^{-1}	-394

With reference to the above data, calculate the enthalpy change of reaction of the "water-gas shift" reaction, ΔH_1.

[1]

(b) The hydrogen gas obtained from the steam reforming process in part **(a)** can be reacted with nitrogen gas to produce ammonia gas.

This reaction is known as the Haber-Bosch Process, using iron as a catalyst.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(i) Predict and explain the sign of ΔS for the Haber-Bosch reaction. [1]

(ii) Using your answer in **(b)(i)**, calculate the maximum temperature for the Haber-Bosch reaction to be spontaneous.

It is known that the numerical value of ΔS is 198 J K^{-1} mol^{-1}, and that ΔH = -92.0 kJ mol^{-1}. [2]

(c) The hydrogen gas obtained from steam reforming, and the ammonia gas obtained from the Haber-Bosch reaction, are the key reagents required for the reductive amination reaction. Many amines in the pharmaceutical drugs are synthesised through this reaction.

The diagram, **Fig. 1.1**, shows the 3 stages involved in reductive amination.

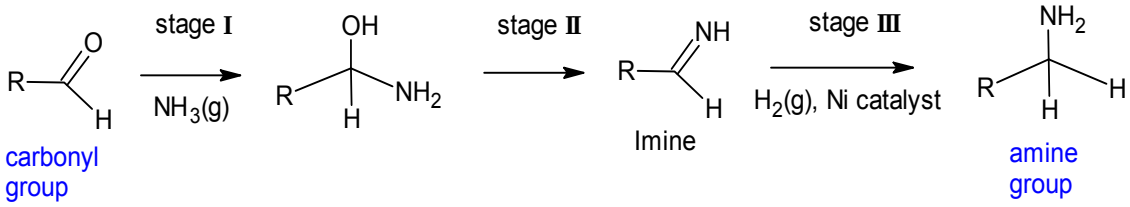


Fig. 1.1

During the reaction, a carbonyl group is converted into an amine group via an intermediate imine.

(i) State the types of reaction occurring in stage **I** and stage **II**. [2]

The reaction scheme below, **Fig.1.2**, shows the production of α-methylphenethylamine, which involves reductive amination in step **4**.

Step **4** in **Fig. 1.2** comprises of the 3 stages of reductive amination in Fig. 1.1.

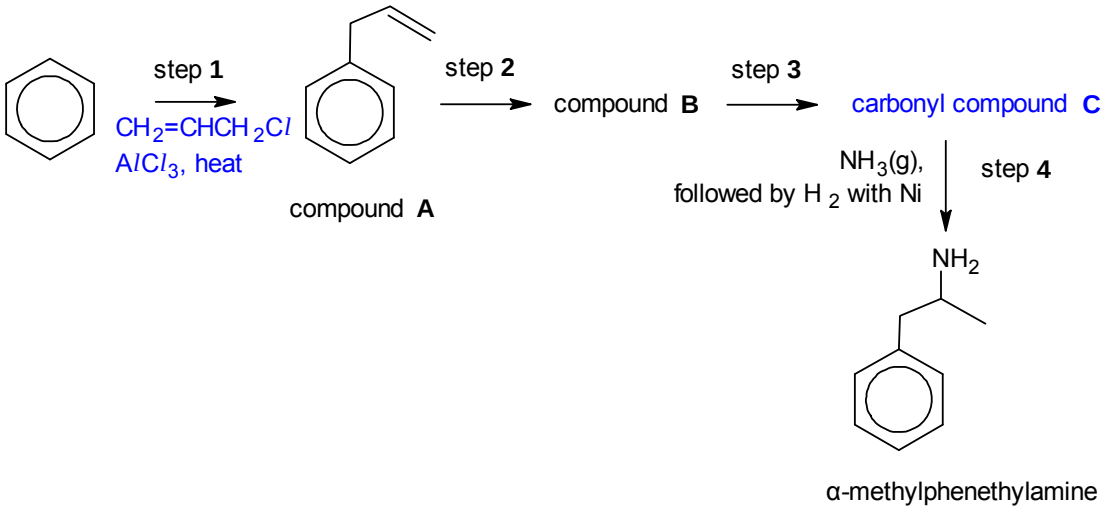


Fig.1.2

(ii) In step **1**, benzene undergoes a reaction with 3-chloroprop-1-ene with the aid of anhydrous aluminium chloride catalyst. Name and describe the mechanism for step **1**, showing clearly any relevant charges, dipoles or lone pairs of electrons that are important.

[4]

(iii) Deduce and draw the structure for carbonyl compound **C**, and suggest the structure of compound **B**. [2]

[Total: 21]

2 This question is on halogen-containing compounds.

(a) The following experiments are carried out starting from solid aluminium chloride.

$$AlCl_3(s) \xrightarrow{\text{water}} \text{acidic solution} \xrightarrow{Na_2CO_3(aq)} \text{white precipitate } \mathbf{D} + \text{effervescence}$$

(i) Explain with the aid of balanced equations, why $AlCl_3(s)$ dissolves to form an acidic solution. Suggest the pH of the acidic solution. [3]

(ii) Identify precipitate **D**. [1]

(b) When aqueous $AgNO_3$ is added to separate test-tubes containing aqueous KCl and KI, the various AgX ($X = Cl, I$) precipitates were observed.

With the aid of relevant equations, explain why a precipitate of $AgCl$ is soluble in excess aqueous NH_3 but a precipitate of AgI is insoluble in excess aqueous NH_3. [3]

(c) The standard redox potential of chlorate (V) ions is given below.

$$ClO_3^- + 6H^+ + 6e^- \rightleftharpoons Cl^- + 3H_2O \quad E^\ominus = 1.45\ V$$

Predict what you expect to observe, when acidified potassium chlorate (V) is added separately to each of the following reagents.

State clearly if no reaction occurs. Write a balanced equation for any reaction that occurs. Explain your answer using $E^\ominus$ values from the *Data Booklet.*

(i) $FeSO_4$ (aq)

(ii) Acidified $KMnO_4$ (aq)

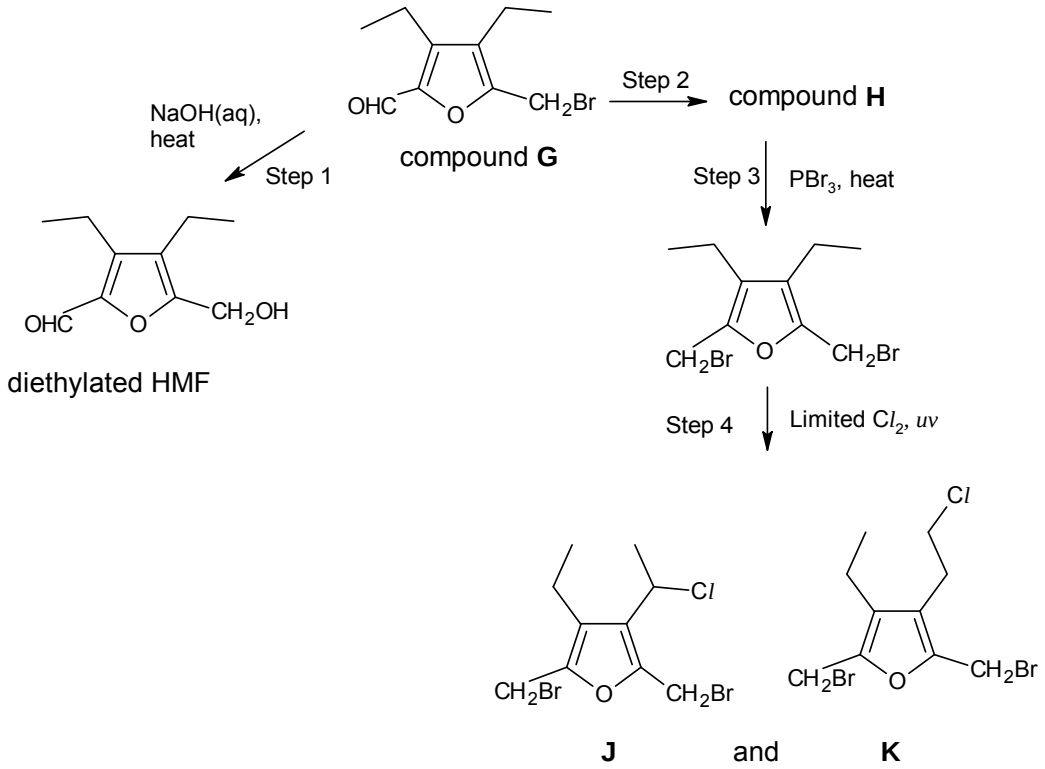
[3]

(d) PCl_5 reacts with hydrazine, N_2H_4, to give compound **E**, which has the following composition by mass: P, 20.5%; N, 9.2%; Cl, 70.3%. The molecule of **E** contains an N-N single bond.

Calculate the empirical formula of **E**, and suggest its molecular formula and the structure of its molecule, assuming its constituent atoms show their usual valencies.

[2]

(e) Diethylated HMF is used to synthesize a variety of pharmaceuticals. The flow-scheme below shows the reactions involving diethylated HMF and compound **G**, its precursor. Assume the C-O-C ether group is inert.



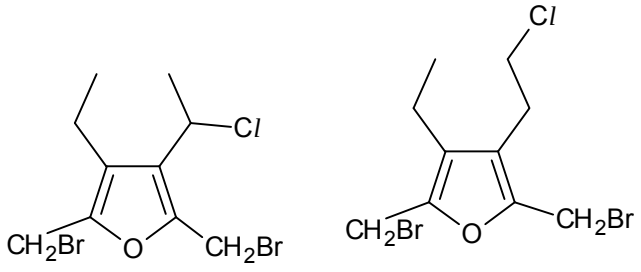
(i) When the reaction in step **1** was investigated kinetically, it was found that its rate was independent of [OH^-], but was first order with respect to [compound **G**].

Name and describe a mechanism for this reaction, showing curly arrows in your answer. [3]

You may represent compound **G** as R-CH_2Br.

(ii) Draw the structure of compound **H**. [1]

(iii) When the mono-chlorination is carried out in step **4**, two possible monochloroalkanes **J** and **K** can be formed.



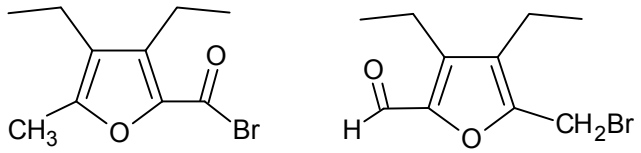
J and **K**

Predict the relative proportions of **J** and **K** formed. [1]

(iv) When the monochlorinated products of step **4** were analysed, it is found that the mole ratio of **J: K** formed was about 97: 3.

Suggest a reason for the difference between this ratio and the one you gave in (**iii**). [1]

(v) Compounds **M** and **G** are both bromine-containing compounds that are isomers of each other.



Compound **M** Compound **G**

Compare the reactivities of **M** and **G** with water. Explain your answer. [2]

[Total:20]

3 **(a)** **(i)** Use the following data to construct an energy level diagram and hence calculate the enthalpy change for the hydrogenation of ethene gas to ethane gas.

	ΔH / kJ mol^{-1}
Enthalpy change of combustion of $CH_3CH_3(l)$	-1545
Enthalpy change of condensation of $CH_3CH_3(g)$	-15
Enthalpy change of combustion of $H_2(g)$	−286
Enthalpy change of combustion of $CH_2{=}CH_2(g)$	−1411

[4]

(ii) Define the term bond energy. [1]

(iii) Using appropriate bond energy values from the *Data Booklet* alone, calculate another value for the enthalpy change of the reaction in **(a)(i)**.

[2]

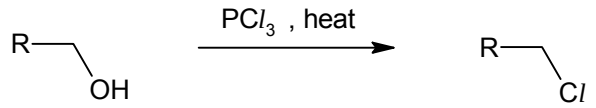
(iv) Suggest a reason for the discrepancy between the enthalpy change for the hydrogenation of ethene gas to ethane gas calculated in **(a)(i)** and **(a)(iii)**. [1]

(b) Hot sulfuric acid, H_2SO_4 is added to ethanol, an alcohol, to produce ethene.

Draw a 'dot-and-cross' diagram showing the electrons (outer shell only) in a H_2SO_4 molecule.

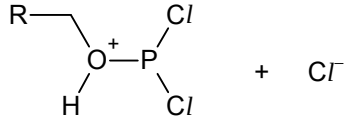
Use the VSEPR (valence shell electron pair repulsion) theory to predict the bond angle around sulfur in H_2SO_4. [3]

(c) Phosphorous halides such as PX_3 can act as both Lewis acids or Lewis bases. PCl_3 is used to convert an alcohol to an alkyl chloride.



The mechanism above involves 2 steps:

- Step **1**: The nucleophilic alcohol attacks PCl_3 to form the following intermediate, along with a Cl^- ion:



- Step **2**: (slow) Cl^- ion attacks the electrophilic carbon on the intermediate, simultaneously the C–O bond breaks heterolytically.

State and explain if PCl_3 acts as a Lewis acid or Lewis base in step **1** of the mechanism. [1]

(d) For the following pair of compounds, describe **one** chemical test which would enable you to distinguish clearly between them.

State the observations for **each** compound.

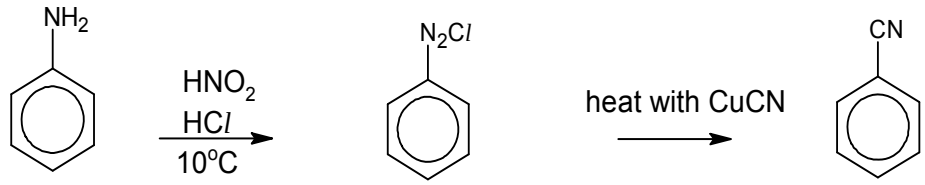
State the type of reaction undergone for the compound that shows a positive test.

compound **N** compound **O**

[3]

(e) Phenylamine reacts with nitrous acid, HNO_2, and hydrochloric acid at 10°C to form benzenediazonium chloride, $C_6H_5N_2Cl$.

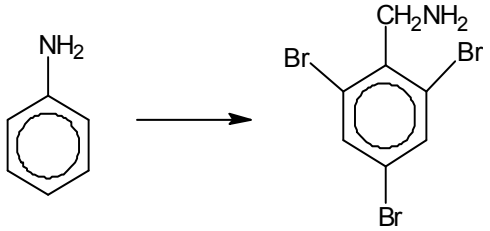
This is an important intermediate in the synthesis of aromatic compounds. It undergoes the Sandmeyer reaction, shown below, in the presence of a copper(I) catalyst to form aryl nitriles.



benzenediazonium chloride

aryl nitrile

Suggest a four-step reaction sequence for the following conversion. You are to make use of the Sandmeyer reaction in one of the steps.



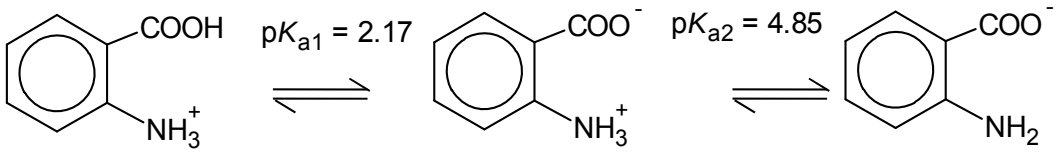
[4]

[Total:19]

Section **B**
Answer **one** question from this section.

4 **(a)** Vitamin L1, also known as 2-aminobenzoic acid, can be obtained from bovine liver, and its deficiency has been associated with lactation issues in females.

The diagram below shows how the protonated form of Vitamin L1 acts as a dibasic acid, which dissociates in two stages:



Protonated form
of Vitamin L1

(i) Calculate the pH of 10 cm^3 of 0.100 mol dm^{-3} of the protonated form of Vitamin L1. Ignore the effect of pK_{a2} on the pH of the sample. [1]

(ii) A sample containing 10 cm^3 of 0.100 mol dm^{-3} of the protonated form of Vitamin L1 was titrated with 30 cm^3 of 0.100 mol dm^{-3} of NaOH.

Sketch clearly the titration curve obtained, which should include the following key points:

- initial pH;
- points where pK_{a1} and pK_{a2} occur;
- isoelectric point of Vitamin L1 and its estimated value, given that: isoelectric point = $(pK_{a1} + pK_{a2}) / 2$

[4]

(iii) Define what is meant by a buffer. [1]

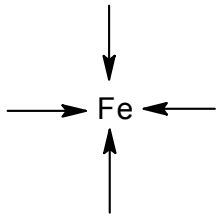
(iv) Draw the structures of the two chemical species present in a solution of Vitamin L1 at pH 5.00.

Hence, show by means of balanced equations, how this solution regulates the acidity on addition of H^+ ions and OH^- ions. [3]

(b) Iron ions can form transition metal complexes with the basic form of the amino acid, alanine. The formula of the complex formed is $Fe(CH_3CH(NH_2)COO)_2$.

(i) State the oxidation state of Fe in the transition complex. [1]

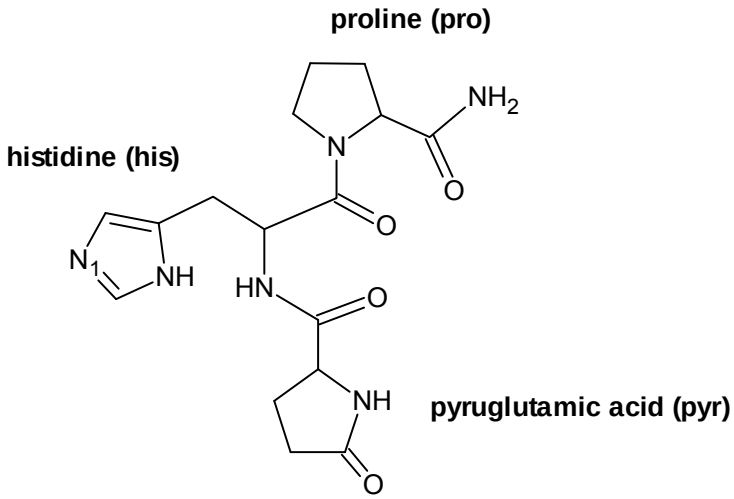
(ii) The diagram below shows the incomplete structure of the complex. Copy the diagram and draw the complete structure of this complex.



[1]

(c) Thyrotropin-releasing hormone (TRH) is a hormone that is produced by the hypothalamus in the brain. TRH has been used clinically for the treatment of the disturbance of consciousness in humans.

TRH is a tripeptide that is made of three amino acids proline, histidine and pyruglutamic acid, as shown in the diagram below.



TRH tripeptide

In the questions below, assume that the side chain for histidine (his) is inert.

(i) State the reagents and conditions for TRH to undergo hydrolysis. [1]

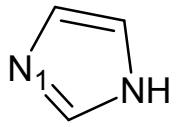
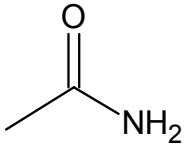
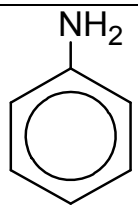
(ii) Draw the structures of the amino acids formed when TRH undergoes hydrolysis using the reagents and conditions stated in **(c)(i)**. [3]

(iii) Explain why amino acids exist as solids with high melting points. [1]

(iv) State the hybridisation state of nitrogen atom labeled N_1 in the histidine side chain of TRH. [1]

(v) The amino acid histidine has a cyclic imidazole side-chain.

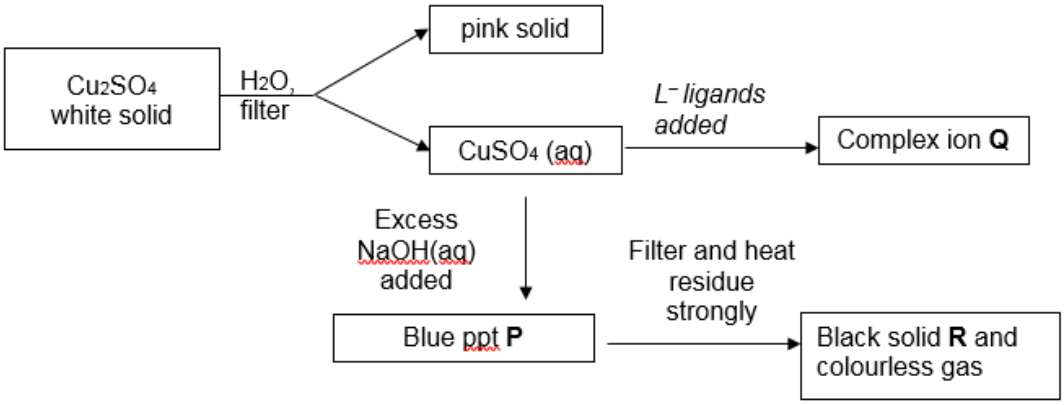
The table below compares the pK_b value of N_1 nitrogen atom of imidazole ring, with the pK_b values of ethanamide and phenylamine.

Compound name	**Structure**	**pK_b**
imidazole		8.8 (pK_b of N_1)
ethanamide		14.5
phenylamine		9.4

Using the data provided, list the 3 compounds in increasing basicity, and suggest explanations for their relative basicities. [3]

[Total: 20]

5 **(a)** The scheme below shows the reactions of different compounds of copper.



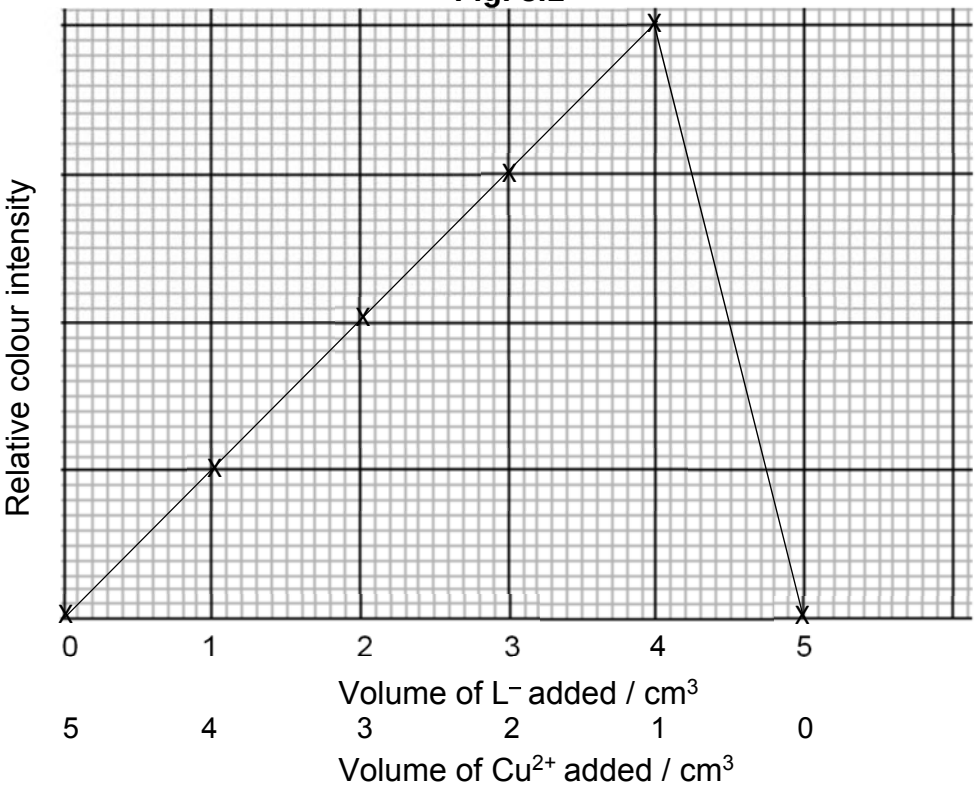
(a) **(i)** Suggest the formulae of blue ppt **P** and black solid **R**. [2]

(ii) Write an equation to show how the pink solid and $CuSO_4$ are obtained when Cu_2SO_4 is added to water. [1]

To determine the stoichiometry of the green complex ion **Q** formed between aqueous copper (II) sulfate and L^- ligands, the colour intensities of solutions containing different proportions of the ligand, L^-, and Cu^{2+} ion were measured.

The intensity of the green colour is directly proportional to the concentration of the complex ion. The higher the concentration of the complex, the higher is the colour intensity. In one such experiment, the results obtained for different volume mixtures of 1.0×10^{-3} mol dm^{-3} Cu^{2+}(aq) and 1.0×10^{-3} mol dm^{-3} L^-(aq) were plotted below.

Fig. 5.1



(iii) State the type of reaction that occurs when complex ion **Q** is formed from aqueous $CuSO_4$. [1]

(iv) Based on the plotted graph in **Fig. 5.1**, determine the mole ratio of Cu^{2+}(aq) to L^- (aq) in the complex **Q**.

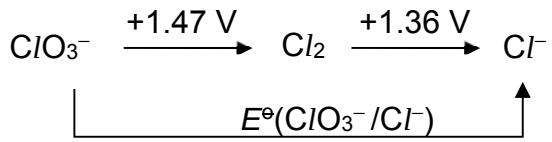
Given that complex **Q** has an octahedral shape and it retains some water molecules as ligands, suggest a formula for the complex **Q**, including its overall charge. [2]

(b) Explain why complexes of Cu(II) are coloured whereas complexes of Cu(I) are colourless. [4]

(c) Chlorine can exist in different oxidation states.

Half-equation	$E^{\ominus}$ **/ V**
$2ClO_3^- + 12H^+ + 10e^- \rightleftharpoons Cl_2 + 6H_2O$	+1.47
$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$	+1.36

A Latimer diagram shown below, summarises the standard electrode potential, $E^{\ominus}$ of different chlorine-containing species in acidic medium. The most highly oxidised form of the element is on the left, with successively lower oxidation states to the right. The electrode potentials are shown on the arrows.



The standard electrode potential of converting ClO_3^- to Cl^-, $E^{\ominus}(ClO_3^-/Cl^-)$ is **NOT** the summation of +1.47 V and +1.36 V.

Determine the number of electrons involved in the conversion of 1 mole of ClO_3^- to 1 mole of Cl^-.

Hence, given that $\Delta G^{\ominus}$ for the conversion of ClO_3^- to Cl^- is -150 kJ mol^{-1}, calculate $E^{\ominus}(ClO_3^-/Cl^-)$. [2]

(d) *Use of the Data Booklet is relevant to this question.*

X, $C_5H_6O_3$, is soluble in dilute NaOH. **X** gives an orange precipitate with 2,4-dinitrophenylhydrazine reagent, and a yellow precipitate with warm alkaline aqueous iodine. **X** decolourises aqueous bromine.

When it is reacted with a methanolic solution of $NaBH_4$ it gives **Y**, $C_5H_8O_3$. Catalytic hydrogenation of **X** gives **Z**, $C_5H_{10}O_3$. When **Z** is reacted with alkaline aqueous iodine, it gives $^{-}O_2C(CH_2)_2CO_2^{-}$.

Oxidation of 1 mole of **X** with hot acidified potassium manganate(VII) gives 1 mole of CH_3COCO_2H and 2 moles of CO_2 gas.

*Additional optional information: **X**, **Y** and **Z** have a proton (^1H) chemical shift value of 13.0 ppm. (Refer to Data Booklet Section 6: Typical proton (^1H) chemical shift values (δ))*

Suggest structures for **X**, **Y** and **Z**. Explain your reasoning clearly. [8]

[Total: 20]

End of paper

H

PIONEER JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION
HIGHER 2

CANDIDATE NAME	

CT GROUP	1	7				INDEX NUMBER					

CHEMISTRY **9729/03**

Paper 3 Free Response **19 September 2018**

2 hours

Candidates answer on separate paper.

Additional Materials: Answer Paper
Data Booklet
Cover Page

READ THESE INSTRUCTIONS FIRST

Write your name, index number and CT group on all work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough workings.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **15** printed pages.

r

Section A

Answer all questions in this section.

1 **(a)** Steam reforming is an important industrial method for producing hydrogen and carbon monoxide, from hydrocarbon fuels. This is achieved in a processing device called a reformer which reacts steam at high temperature with the fuel, such as methane gas.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H = +210 \text{ kJ mol}^{-1}$$

(i) Write an expression of K_p for the reaction, indicating its units. [2]

$K_p = \dfrac{(P_{CO})(P_{H_2})^3}{(P_{CH_4})(P_{H_2O})}$ atm^2

(ii) At temperature ***T***, a mixture of gaseous methane, steam and carbon monoxide were introduced into an evacuated reactor.

The table below shows the initial pressures of the gases before they were added to the reactor.

Gas	Initial pressure / atm
methane, CH_4	1.50
steam, H_2O	2.50
carbon monoxide, CO	0.70

Given that the percentage dissociation of methane is 20% at equilibrium, find the K_p for the reaction. [2]

	$CH_4(g)$	$+ H_2O(g) \rightleftharpoons$	$CO(g)$	$+ 3H_2(g)$
Initial P /atm	1.50	2.50	0.70	0
Change P /atm	-0.2(1.5) = -0.3	-0.3	+0.3	+0.9
Eqm P /atm	1.20	2.20	1.00	0.90

$$K_p = \frac{(P_{CO})(P_{H_2})^3}{(P_{CH_4})(P_{H_2O})}$$

$$K_p = \frac{(1.00)(0.90)^3}{(1.20)(2.20)} = 0.276 \text{ atm}^2$$

(iii) A chemist decided to raise the temperature of the reactor. He suggested that this would result in a lower yield of the product.

Do you agree with the chemist? Explain your answer. [2]

No. When the temperature is raised, the endothermic reaction is favoured since it absorbs energy. The position of equilibrium shifts to the right in favour of the forward reaction, yield of H_2 should increase.

In order to produce more hydrogen gas, the carbon monoxide gas that is produced from the steam reforming reaction can further react with steam. This is known as the "water-gas shift" reaction.

$$CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$$

(iv) Given that the reaction conditions were set at 500°C and 1.5 atm, determine the maximum volume of hydrogen gas that can be produced from 5kg of carbon monoxide gas.

State the assumption made in your calculation. [3]

Amount of CO in 5kg = (5 x 1000)/28 = 178.6 mol = Amount of H_2 gas

Amount of H_2 produced = 178.6 mol

pV=nRT

$$V = \frac{nRT}{p}$$

$$V = \frac{178.6 \times 8.31 \times (500 + 273)}{1.5 \times 1.01 \times 10^{-5}}$$

$= 7.55\ m^3$

Assumption: Hydrogen gas is behaving like an ideal gas

(v) Given the following,

enthalpy change of formation of CO(g) / kJ mol^{-1}	-99
enthalpy change of formation of $H_2O(g)$ / kJ mol^{-1}	-245
enthalpy change of formation of $CO_2(g)$ / kJ mol^{-1}	-394

With reference to the above data, calculate the enthalpy change of reaction of the "water-gas shift" reaction, ΔH_1. [1]

$$CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$$

$\Delta H_1 = \Delta H_f(CO_2(g)) - [\Delta H_f(CO(g)) + \Delta H_f H_2O(g))$

$= (-394) - (-99 + -245) = -50$ kJ mol^{-1}

(b) The hydrogen gas obtained from the steam reforming process in part **(a)** can be reacted with nitrogen gas to produce ammonia gas.

This reaction is known as the Haber-Bosch Process, using iron as a catalyst.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(i) Predict and explain the sign of ΔS for the Haber-Bosch reaction. [1]

ΔS is negative as the there is a decrease in number of moles of gaseous particles (from 4 mol to 2 mol), hence less disorderliness.

(ii) Using your answer in **(b)(i)**, calculate the maximum temperature for the Haber-Bosch reaction to be spontaneous.

It is known that the numerical value of ΔS is 198 J K^{-1} mol^{-1}, and that ΔH = -92.0 kJ mol^{-1}. [2]

$\Delta G = \Delta H - T\Delta S$
$0 = (-92.0) - T\,(-198/1000)$
$T = 465K$

(c) The hydrogen gas obtained from steam reforming, and the ammonia gas obtained from the Haber-Bosch reaction, are the key reagents required for the reductive amination reaction.

Many amines in the pharmaceutical drugs are synthesised through this reaction.

The diagram, **Fig. 1.1**, shows the 3 stages involved in reductive amination.

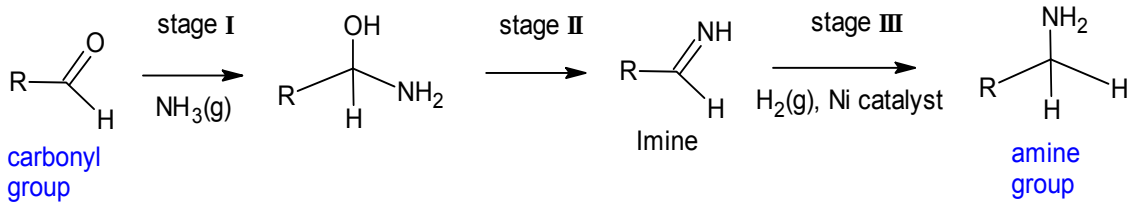


Fig. 1.1

During the reaction, a carbonyl group is converted into an amine group via an intermediate imine.

(i) State the types of reaction occurring in stage **I** and stage **II**. [2]

stage **I**: Nucleophilic addition.
stage **II**: elimination

The reaction scheme below, **Fig.1.2**, shows the production of α-methylphenethylamine, which involves reductive amination in step **4**.

Step **4** in **Fig. 1.2** comprises of the 3 stages of reductive amination in Fig. **1.1**.

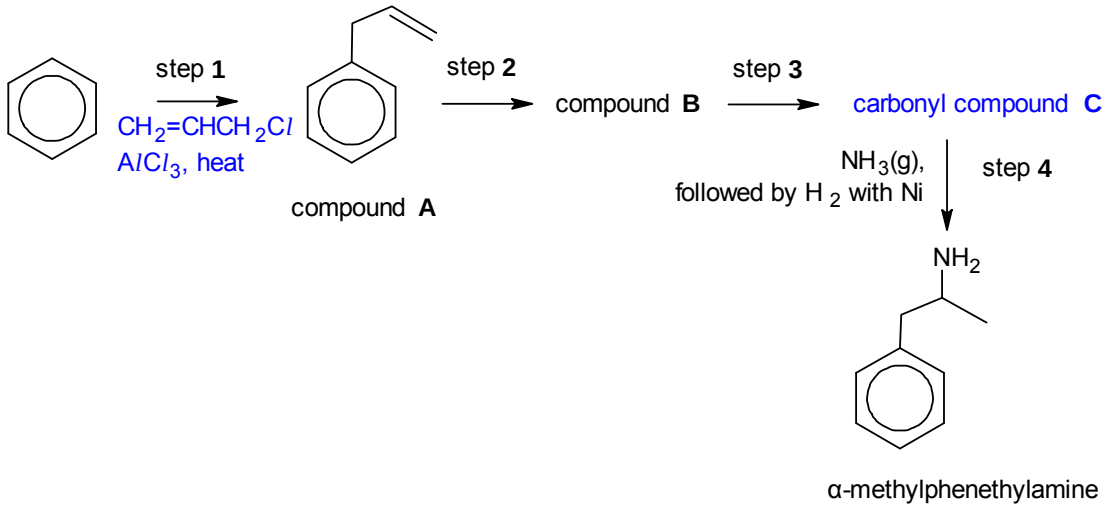


Fig.1.2

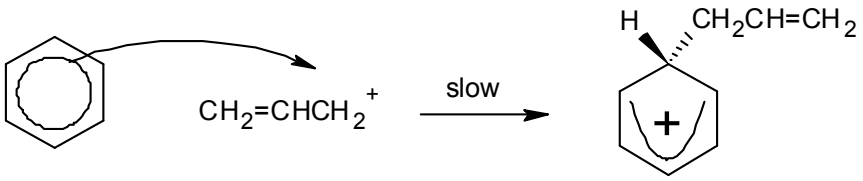
(ii) In step **1**, benzene undergoes a reaction with 3-chloroprop-1-ene with the aid of anhydrous aluminium chloride catalyst.

Name and describe the mechanism for step **1**, showing clearly any relevant charges, dipoles or lone pairs of electrons that are important. [4]

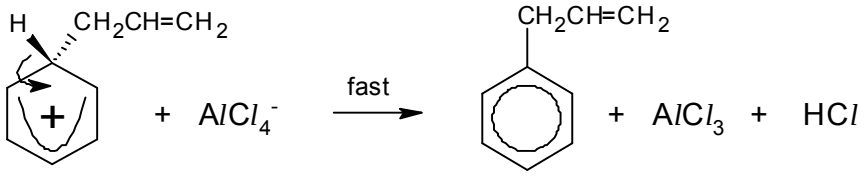
Electrophilic Substitution

Step 1: $CH_2{=}CHCH_2Cl + AlCl_3 \rightleftharpoons AlCl_4^- + CH_2{=}CHCH_2^+$

Step 2:

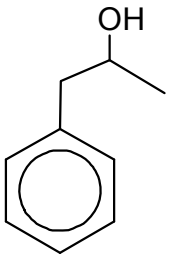


Step 3:

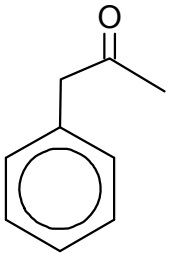


(iii) Deduce and draw the structure for carbonyl compound **C**, and suggest the structure of compound **B**. [2]

compounds **B**:



compounds **C**:



[Total: 21]

2 This question is on halogen-containing compounds.

(a) The following experiments are carried out starting from solid aluminium chloride.

$$AlCl_3(s) \xrightarrow{\text{water}} \text{acidic solution} \xrightarrow{Na_2CO_3(aq)} \text{white precipitate } \mathbf{D} + \text{effervescence}$$

(i) Explain with the aid of balanced equations, why $AlCl_3(s)$ dissolves to form an acidic solution. Suggest the pH of the acidic solution. [3]

$AlCl_3(s)$ dissolves in water to form $[Al(H_2O)_6]^{3+}(aq)$

- $AlCl_3(s) + 6H_2O(l) \rightarrow [Al(H_2O)_6]^{3+}(aq) + 3Cl^-(aq)$

A hydrolysis reaction occurs, making the solution acidic.

- $[Al(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H_3O^+(aq)$
- Since Al^{3+} has high charge density, it polarises and weakens the O-H bond of the water attached to it, causing the O-H bond to break to release H^+ (hydrolysis)
- pH=3

(ii) Identify precipitate **D**.
[1]

$Al(OH)_3$

(b) When aqueous $AgNO_3$ is added to separate test-tubes containing aqueous KCl and KI, the various AgX (X = Cl, I) precipitates were observed.

With the aid of relevant equations, explain why a precipitate of $AgCl$ is soluble in excess aqueous NH_3 but a precipitate of AgI is insoluble in excess aqueous NH_3. [3]

$Ag^+(aq) + X^-(aq) \rightleftharpoons AgX(s)$ ....(1)
$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons [Ag(NH_3)_2]^+(aq)$ ....(2)

When excess NH_3 is added (high $[NH_3]$), the position of equilibrium for (2) shifts to the right **to form complex $[Ag(NH_3)_2]^+$** and **$[Ag^+]$ decreases**, resulting in **eqm (1) to shift left** & a **decrease** in ionic product of AgX .
For $AgCl$, IP decreases, **ionic product becomes smaller than $K_{sp}(AgCl)$** and the position of equilibrium (1) to shift to the left and $AgCl$ dissolves completely.
For AgI, although IP decreases, ionic product is **still higher** than $K_{sp}(AgI)$ (as $K_{sp}(AgI)$ is very small) and thus there is no dissolution of AgI in excess aqueous ammonia.

(c) The standard redox potential of chlorate (V) ions is given below.

$$ClO_3^- + 6H^+ + 6e^- \rightleftharpoons Cl^- + 3H_2O \quad E^\ominus = 1.45\ V$$

Predict what you expect to observe, when acidified potassium chlorate (V) is added separately to each of the following reagents.

State clearly if no reaction occurs. Write a balanced equation for any reaction that occurs. Explain your answer using $E^\ominus$ values from the *Data Booklet.*

(i) $FeSO_4$ (aq)

From the eqn given and highly positive $E^{\ominus}$ = 1.45 V, ClO_3^- is easily reduced.
For redox to occur, Fe^{2+} must be oxidised.
$Fe^{2+} \rightleftharpoons Fe^{3+} + e$ $\quad E^{\ominus}_{ox}$ = -0.77 V
$E^{\ominus}_{cell}$ =+1.45 +-0.77 =+0.68V>0 (3 s.f) reaction is energetically feasible
Solution turns yellow (from green).

(ii) Acidified $KMnO_4$ (aq)
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ $\quad E^{\ominus}_{red}$ = + 1.52V
MnO_4^- and ClO_3^- both can only be reduced – thus no redox possible and solution remains purple

[3]

(d) PCl_5 reacts with hydrazine, N_2H_4, to give compound **E**, which has the following composition by mass: P, 20.5%; N, 9.2%; C*l*, 70.3%. The molecule of **E** contains an N-N single bond.

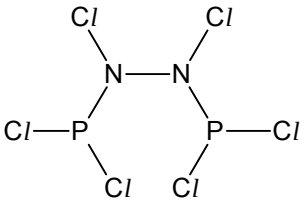
Calculate the empirical formula of **E**, and suggest its molecular formula and the structure of its molecule, assuming its constituent atoms show their usual valencies.

[2]

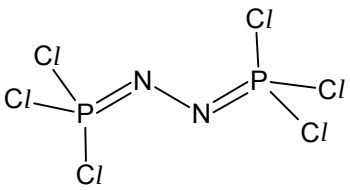
	P	N	Cl
Mass / g	20.5	9.2	70.3
Amt / mol	0.661	0.657	1.98
Mole ratio	1	1	3

Empirical formula = $PNCl_3$

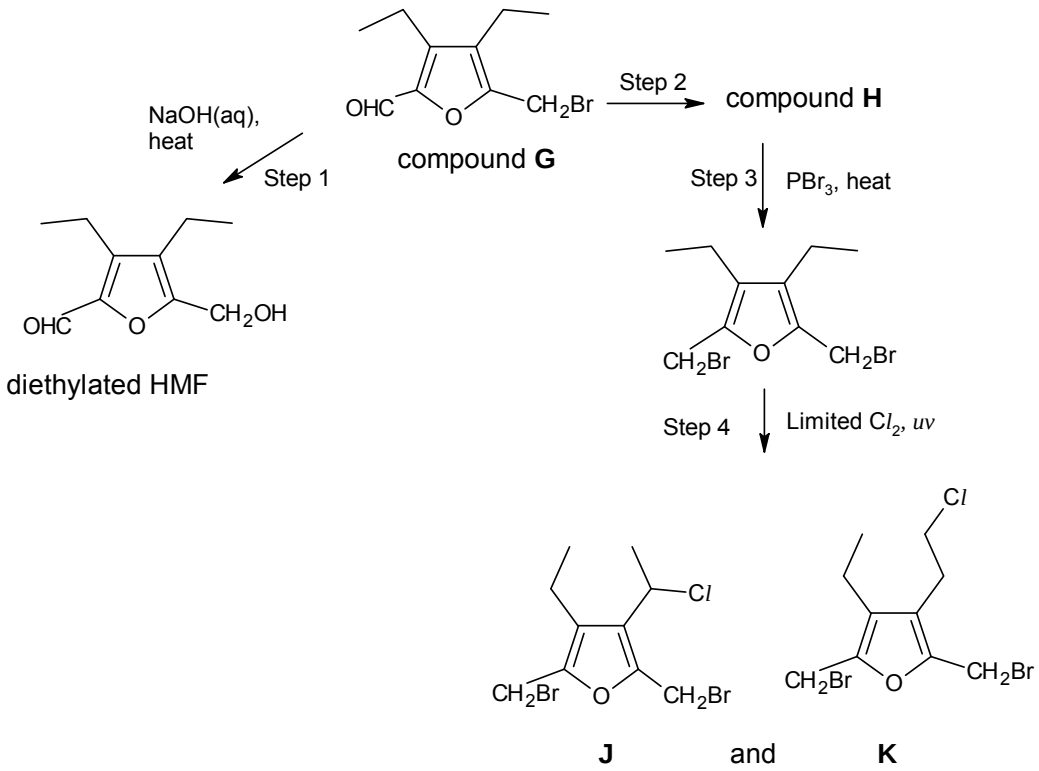
Since S contains one N-N single bond, E will contain 2 N atoms.
Molecular formula of E = $P_2N_2Cl_6$ and correct structures of E:



or



(e) Diethylated HMF is used to synthesize a variety of pharmaceuticals. The flow-scheme below shows the reactions involving diethylated HMF and compound **G**, its precursor. Assume the C-O-C ether group is inert.

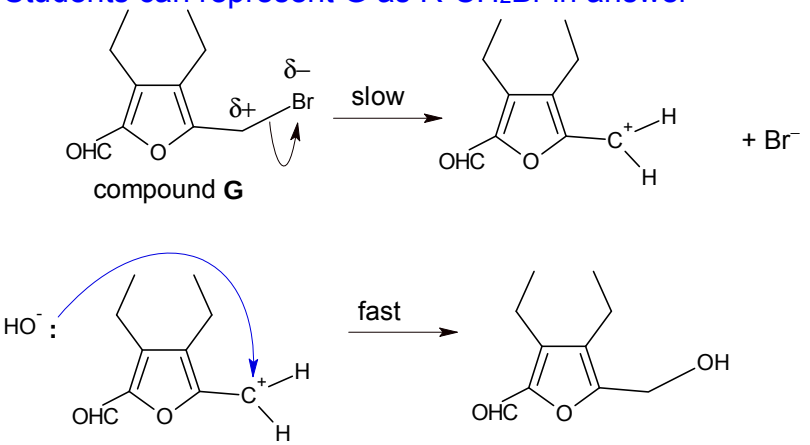


(i) When the reaction in step **1** was investigated kinetically, it was found that its rate was independent of [OH^-], but was first order with respect to [compound **G**].

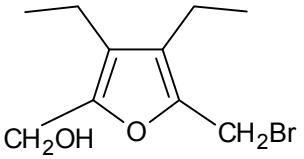
Name and describe a mechanism for this reaction, showing curly arrows in your answer. [3]

You may represent compound **G** as R-CH_2Br.
Nucleophilic substitution (S_N1)

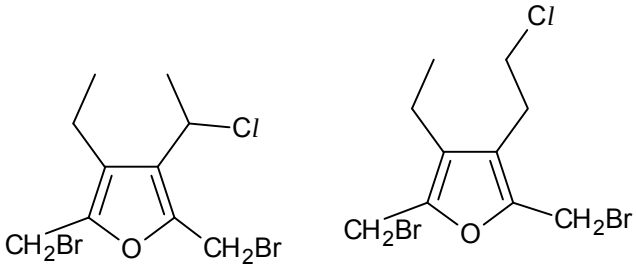
Students can represent G as R-CH_2Br in answer



(ii) Draw the structure of compound **H**. [1]



(iii) When the mono-chlorination is carried out in step **4**, two possible monochloroalkanes **J** and **K** can be formed.



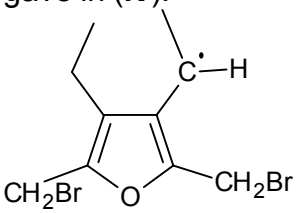
J and **K**

Predict the relative proportions of **J** and **K** formed. [1]

J : K
4: :6
OR 2: 3

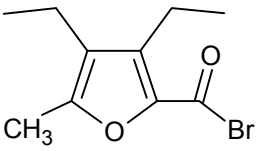
(iv) When the monochlorinated products of step **4** were analysed, it is found that the mole ratio of **J: K** formed was about 97: 3.

Suggest a reason for the difference between this ratio and the one you gave in (**iv**). [1]

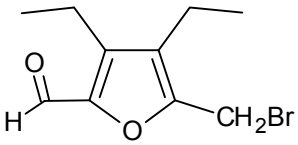


is exceptionally stable due to the overlap of p-orbital between the Carbon with unpaired electron (or resonance stabilised), and the p-orbitals of the adjacent alkene carbon atoms. This is an allylic radical. Being highly stable, it is formed in greater amount / faster and leads to major product.

(v) Compounds **M** and **G** are both bromine-containing compounds that are isomers of each other.



Compound **M**



Compound **G**

Compare the reactivities of **M** and **G** with water. Explain your answer. [2]

- Rate/ ease of hydrolysis: M > G

M, an acyl bromide is most reactive; it undergoes hydrolysis most readily

Reason

- The additional strongly electronegative oxygen atom in acyl bromide M further increases the partial positive charge on carbon atom (of COBr) or make it more delta δ+ positive compared to carbon atom (of C-Br) in G.

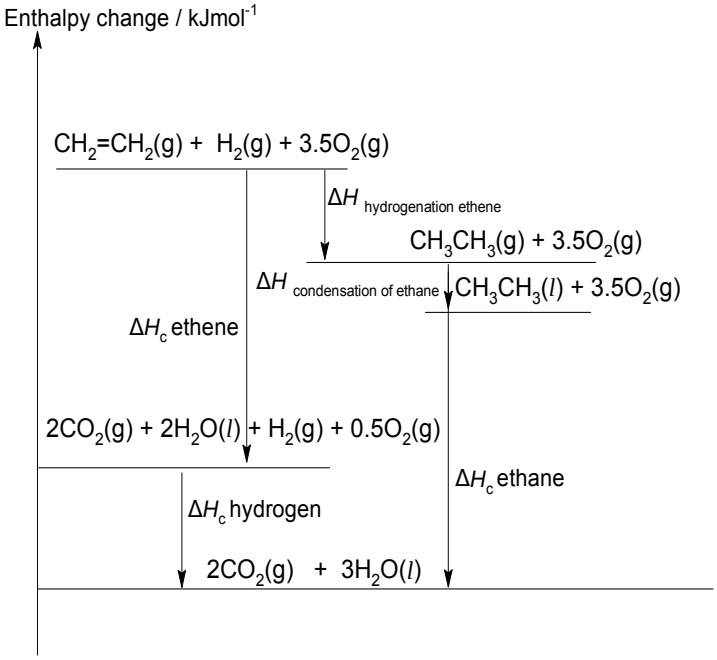
Thus the carbon atom in X is *more* readily attacked by nucleophile or X undergoes hydrolysis by water readily to give bromide ions.

[Total:20]

3 **(a)** **(i)** Use the following data to construct an energy level diagram and hence calculate the enthalpy change for the hydrogenation of ethene gas ($CH_2=CH_2$) to ethane gas (CH_3CH_3).

	ΔH / kJ mol^{-1}
Enthalpy change of combustion of $CH_3CH_3(l)$	-1545
Enthalpy change of condensation of $CH_3CH_3(g)$	-15
Enthalpy change of combustion of $H_2(g)$	−286
Enthalpy change of combustion of $CH_2=CH_2(g)$	−1411

[4]



By Hess' Law,

$\Delta H_{hydrogenation}$ + (– 15) + (– 1545) = (– 1411) + (– 286)

$\Delta H_{hydrogenation}$ = –137 kJ mol^{-1}

(ii) Define the term bond energy. [1]

Bond energy is the energy absorbed to break one mole of a covalent bond between two atoms in the gaseous state.

(iii) Using appropriate bond energy values from the *Data Booklet* alone, calculate another value for the enthalpy change of the reaction in **(a)(i)**.

ΔH = ∑B.E.(reactants) – ∑B.E.(products)

= B.E.(C=C) + 4B.E.(C-H) + B.E.(H-H) – [6B.E.(C-H) + B.E.(C-C)]

= (+610) + 4(+410) – [(+350) + 6(+410)]= – 124 kJ mol^{-1}

[2]

(iv) Suggest a reason for the discrepancy between the enthalpy change for the hydrogenation of ethene gas to ethane gas you calculated in **(a)(i)** and **(a)(iii)**.

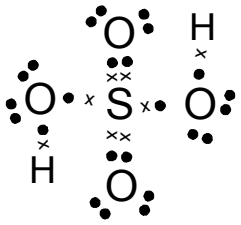
[1]

The bond energy values given in the Data Booklet are average values.

(b) Hot sulfuric acid, H_2SO_4 is added to ethanol, to produce ethene.

Draw a 'dot-and-cross' diagram showing the electrons (outer shell only) in a H_2SO_4 molecule.

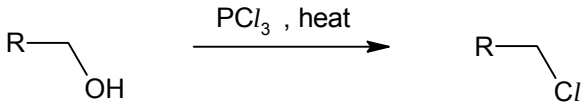
Use the VSEPR (valence shell electron pair repulsion) theory to predict the bond angle around sulfur in H_2SO_4. [3]



According to VSEPR, order of repulsion is given by: Lone pair – lone pair electrons > Lone pair – bond pair electrons > Bond pair – bond pair electrons

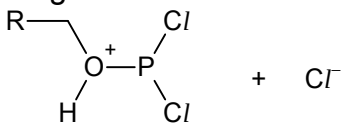
- The S atom has 4 bond pairs of electrons, no lone pair of electrons
- The bond angle is 109.5°

(c) Phosphorous halides such as PX_3 can function as both Lewis acids or Lewis bases. PCl_3 is used to convert an alcohol to an alkyl chloride.



The mechanism of the above reaction involves two steps:

- Step **1**: The nucleophilic alcohol attacks PCl_3 to form the following intermediate, along with a chloride ion:



- Step **2**: (slow step) the chloride ion attacks the electrophilic carbon on the intermediate, at the same time the C–O bond breaks heterolytically.

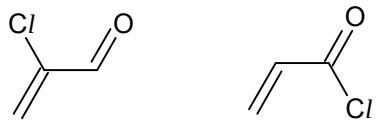
(i) State and explain if PCl_3 acts as a Lewis acid or Lewis base in step **1** of the mechanism. [1]

PCl_3 is a Lewis acid because it accepted lone pair of electrons.

(d) For the following pairs of compounds, describe one chemical test which would enable you to distinguish clearly between them.

State the observations for each compound.

State the type of reaction undergone for the compound that shows a positive test.



compound **N** compound **O**

Distinguishing test: Add Tollens' reagent, warm

Observations: Silver mirror for N, no silver mirror for O

Type of reaction: Oxidation

OR

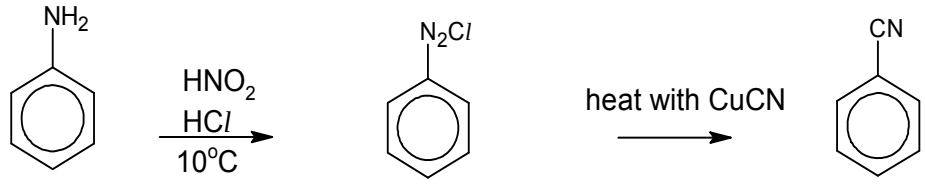
Distinguishing test: Add $AgNO_3$(aq), r.t.p

Observations: White ppt for O, no white ppt for N

Type of reaction: Nucleophilic acyl substitution [3]

(e) Phenylamine reacts with nitrous acid, HNO_2, and hydrochloric acid at 10°C to form benzenediazonium chloride, $C_6H_5N_2Cl$.

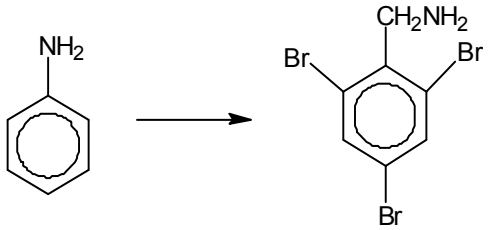
This is an important intermediate in the synthesis of aromatic compounds. It undergoes the Sandmeyer reaction, shown below, in the presence of a copper(I) catalyst to form aryl nitriles.



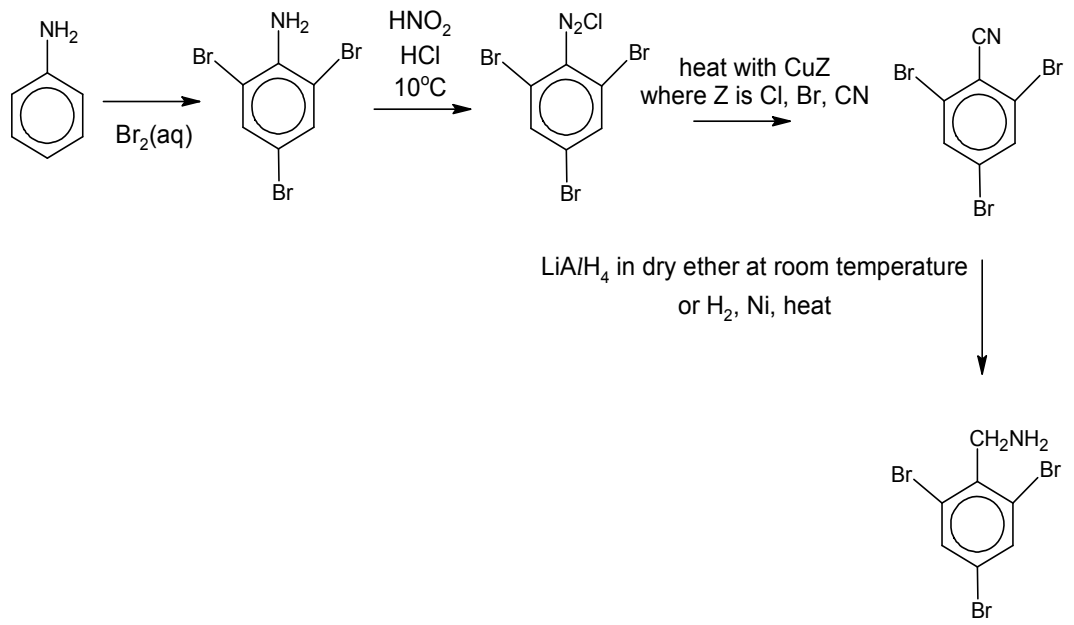
benzenediazonium chloride

aryl nitrile

Suggest a four-step reaction sequence for the following conversion. You are to make use of the Sandmeyer reaction in one of the steps.



[4]

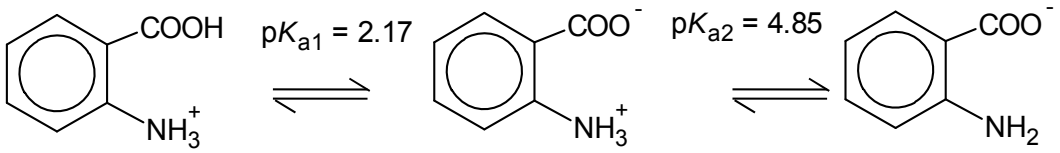

NH2
Br2(aq)
NH2
Br
Br
Br
HNO2
HCl
10°C
N2Cl
Br
Br
Br
heat with CuZ
where Z is Cl, Br, CN
CN
Br
Br
Br
LiAlH4 in dry ether at room temperature
or H2, Ni, heat
CH2NH2
Br
Br
Br

[Total:19]

Section **B**
Answer **one** question from this section.

4 **(a)** Vitamin L1, also known as 2-aminobenzoic acid, can be obtained from bovine liver, and its deficiency has been associated with lactation issues in females.

The diagram below shows how the protonated form of Vitamin L1 acts as a dibasic acid, which dissociates in two stages:



Protonated form
of Vitamin L1

(i) Calculate the pH of 10 cm^3 of 0.100 mol dm^{-3} of the protonated form of Vitamin L1. Ignore the effect of pK_{a2} on the pH of the sample. [1]

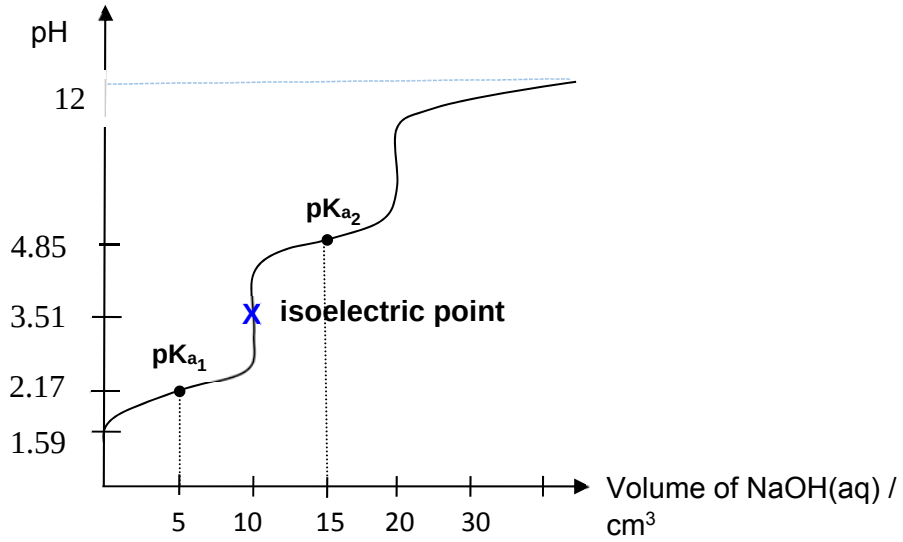
Given pK_{a1} = 2.17
$K_{a1} = 10^{-2.17}$
$K_{a1} \approx [H^+]^2 / (0.100)$
$[H^+]$ = 0.02600 $moldm^{-3}$
pH = 1.59

(ii) A sample containing 10 cm^3 of 0.100 mol dm^{-3} of the protonated form of Vitamin L1 was titrated with 30 cm^3 of 0.100 mol dm^{-3} of NaOH.

Sketch clearly the titration curve obtained, which should include the following key points:

- initial pH;
- points where pK_{a1} and pK_{a2} occur;
- isoelectric point of Vitamin L1 and its estimated value, given that: isoelectric point = $(pK_{a1} + pK_{a2}) / 2$

[4]

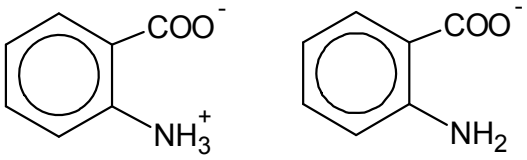


Correct shape of graph with correct axes
Correct locations of pK_{a1} and pK_{a2}
Correct initial pH AND correct equivalence volumes
Credit for show pH tapering off at about 12-13 at about 30 cm^3 value of pH at isoelectric point
isoelectric point = (pK_{a1} + pK_{a2}) / 2 = (2.17+4.85)/2 = 3.51

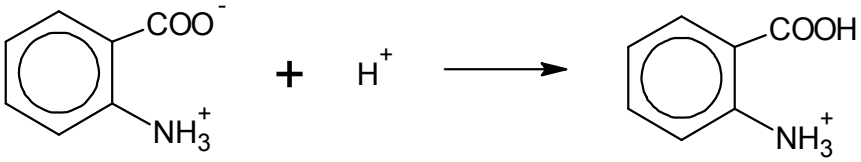
(iii) Define what is meant by a buffer. [1]
A buffer resists change to pH when small amount of acid or base is added to it and upon dilution.

(iv) Draw the structures of the two chemical species present in a solution of Vitamin L1 at pH 5.00.

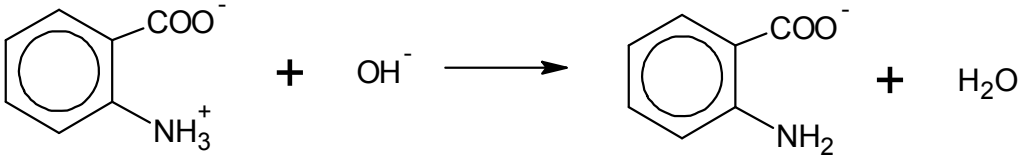
Hence, show by means of balanced equations, how this solution regulates the acidity on addition of H^+ ions and OH^- ions. [3]



When a small amount of acid is added,



When a small amount of base is added,



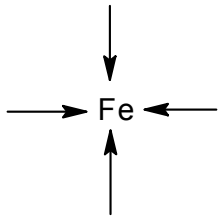
(b) Iron ions can form transition metal complexes with the basic form of the amino acid, alanine. The formula of the complex formed is $Fe(CH_3CH(NH_2)COO)_2$.

(i) State the oxidation state of Fe in the transition complex. [1]

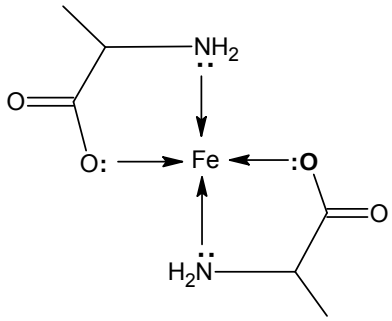
+2

Since the charge of each $CH_3CH_2(NH_2)COO^-$ is -1, iron has to be +2 for the complex to be electrically neutral as given.

(ii) The diagram below shows the incomplete structure of the complex. Copy the diagram and draw the complete structure of this complex.

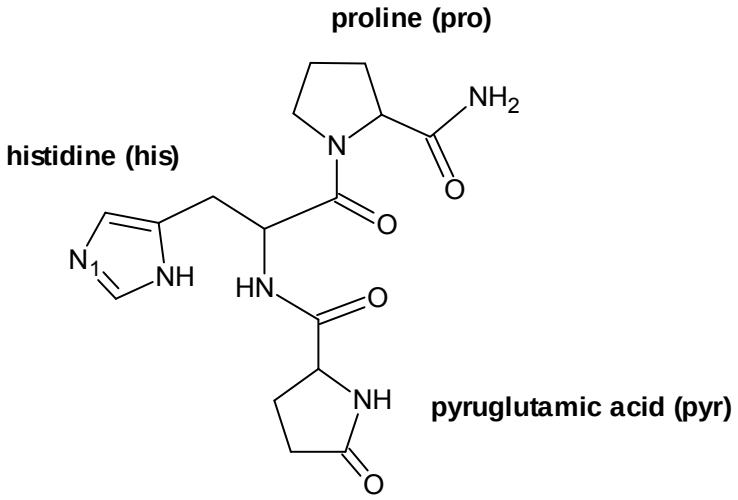


[1]



(c) Thyrotropin-releasing hormone (TRH) is a hormone that is produced by the hypothalamus in the brain. TRH has been used clinically for the treatment of the disturbance of consciousness in humans.

TRH is a tripeptide that is made of three amino acids proline, histidine and pyruglutamic acid, as shown in the diagram below.



TRH tripeptide

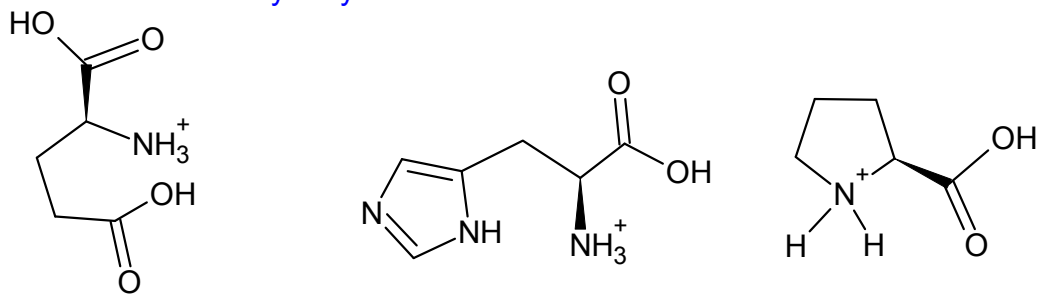
In the questions below, assume that the side chain for histidine (his) is inert.

(i) State the reagents and conditions for TRH to undergo hydrolysis. [1]

H_2SO_4(aq), heat
OR
NaOH(aq), heat

(ii) Draw the structures of the amino acids formed when TRH undergoes hydrolysis using the reagents and conditions stated in **(c)(i)**. [3]

Products of acidic hydrolysis:



pyroglutamic acid (pyr) **histidine (his)** **proline (pro)**

**accept products of alkaline hydrolysis, if the candidate indicated that in (c)(i).*

(iii) Explain why amino acids exist as solids with high melting points. [1]

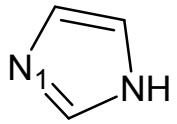
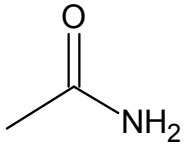
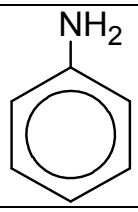
Amino acids can exist as zwitterions, with strong ionic bonds/electrostatic forces of attractions between oppositely charged ions.

(iv) State the hybridisation state of nitrogen atom labeled N_1 in TRH. [1]

nitrogen atom 1: sp^2

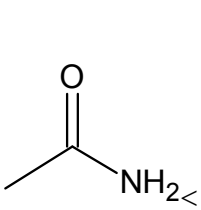
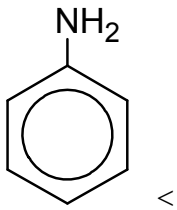
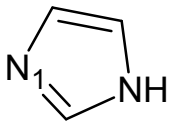
(v) The amino acid histidine has a cyclic imidazole side-chain.

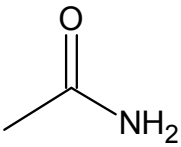
The table below compares the pK_b value of N_1 nitrogen atom of imidazole ring, with the pK_b values of ethanamide and phenylamine.

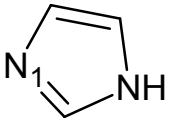
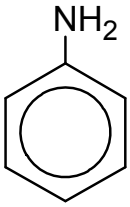
Compound name	**Structure**	**pK_b**
imidazole		8.8 (pK_b of N_1)
ethanamide		14.5
phenylamine		9.4

Using the data provided, list the 3 compounds in increasing basicity, and suggest explanations for their relative basicities. [3]

Basicity increases from:

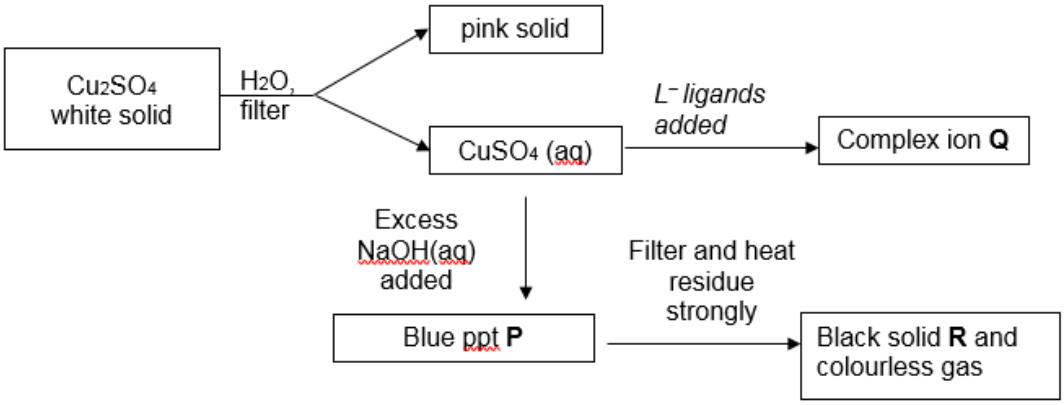
 <  < 

 is neutral as the lone pair of electrons on N is delocalised into C=O. Hence, the lone pair of electrons on the N atom is not available for protonation.

 is more basic than  as the p orbital of nitrogen lies perpendicular to the plane of the C=N bond, hence, the lone pair of electrons are not delocalized and are readily available for protonation, compared to the lone pair of electrons on N atom in phenylamine which is delocalized into the benzene ring and not so readily available.

[Total: 20]

5 **(a)** The scheme below shows the reactions of different compounds of copper.



(a) **(i)** Suggest the formulae of blue ppt **P** and black solid **R**. [2]

P: $Cu(OH)_2$

R: CuO

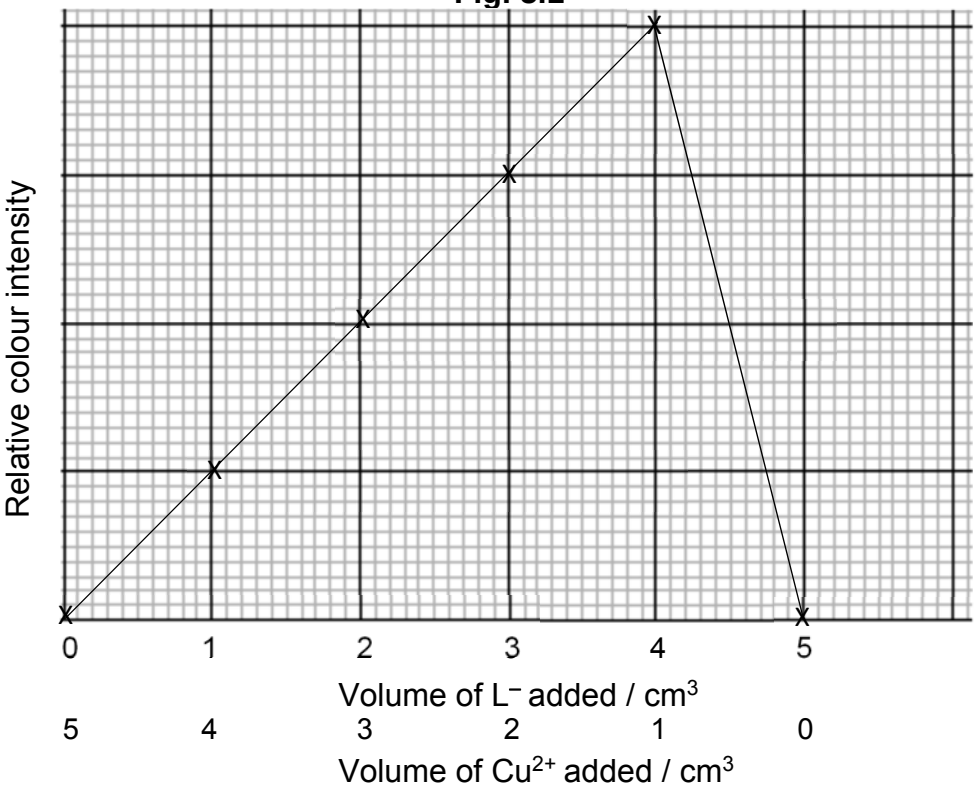
(ii) Write an equation to show how the pink solid and $CuSO_4$ are obtained when Cu_2SO_4 is added to water. [1]

Cu_2SO_4 (s) → $CuSO_4$(aq) + Cu(s)

To determine the stoichiometry of the green complex ion **Q** formed between aqueous copper (II) sulfate and L^- ligands, the colour intensities of solutions containing different proportions of the ligand, L^-, and Cu^{2+} ion were measured.

The intensity of the green colour is directly proportional to the concentration of the complex ion. The higher the concentration of the complex, the higher is the colour intensity. In one such experiment, the results obtained for different volume mixtures of 1.0×10^{-3} mol dm^{-3} $Cu^{2+}(aq)$ and 1.0×10^{-3} mol dm^{-3} $L^-(aq)$ were plotted below.

Fig. 5.1



(iii) State the type of reaction that occurs when complex ion **Q** is formed from aqueous $CuSO_4$. [1]

Ligand exchange

(iv) Based on the plotted graph in **Fig. 5.1**, determine the mole ratio of $Cu^{2+}(aq)$ to L^- (aq) in the complex **Q**.

Given that complex **Q** has an octahedral shape and it retains some water molecules as ligands, suggest a formula for the complex **Q**, including its overall charge. [2]

Mole ratio of $Cu^{2+}(aq)$ to L^- (aq) in the complex Q: 1:4

$[Cu(H_2O)_2(L)_4]^{2-}$

(b) Explain why complexes of Cu(II) are coloured whereas complexes of Cu(I) are colourless. [4]

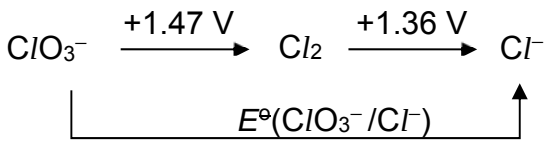
Cu(I) has fully filled 3 d-orbitals ($3d^{10}$). Hence, d-to-d electron transition cannot occur, and no visible light is absorbed, which accounts for it being colourless and Cu(II) has partially filled 3d-orbitals

- In presence of ligands,
- the originally degenerate 3d orbitals split into 2 sets of different energy levels, separated
- by a small energy gap (ΔE).
- ΔE corresponds to the energy of visible light.
- An electron from the lower energy d orbital absorbs a specific wavelength of visible light and
- is promoted to a half-filled, higher energy 3d orbital. d-to-d transition can take place and
- colour observed is complementary to the colour absorbed.

(c) Chlorine can exist in different oxidation states.

Half-equation	***E*ᵉ / V**
$2ClO_3^- + 12H^+ + 10e^- \rightleftharpoons Cl_2 + 6H_2O$	+1.47
$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$	+1.36

A Latimer diagram shown below, summarises the standard electrode potential, $E^{\ominus}$ of different chlorine-containing species in acidic medium. The most highly oxidised form of the element is on the left, with successively lower oxidation states to the right. The electrode potentials are shown on the arrows.



The standard electrode potential of converting ClO_3^- to Cl^-, $E^{\ominus}(ClO_3^-/Cl^-)$ is **NOT** the summation of +1.47 V and +1.36 V.

Determine the number of electrons involved in the conversion of 1 mole of ClO_3^- to 1 mole of Cl^-.

Hence, given that $\Delta G^{\ominus}$ for the conversion of ClO_3^- to Cl^- is -150 kJ mol^{-1}, calculate $E^{\ominus}(ClO_3^-/Cl^-)$. [2]

No of electrons involved = 6 (+5 to -1)

$\Delta G^{\ominus} = -nFE^{\ominus}$

$-150\,000 = -(6)(96500)\,E^{\ominus}$

$E^{\ominus} = +0.259$ V

(d) *Use of the Data Booklet is relevant to this question.*

X, $C_5H_6O_3$, is soluble in dilute NaOH. **X** gives an orange precipitate with 2,4-dinitrophenylhydrazine reagent, and a yellow precipitate with warm alkaline aqueous iodine. **X** decolourises aqueous bromine.

When it is reacted with a methanolic solution of $NaBH_4$ it gives **Y**, $C_5H_8O_3$. Catalytic hydrogenation of **X** gives **Z**, $C_5H_{10}O_3$. When **Z** is reacted with alkaline aqueous iodine, it gives $^-O_2C(CH_2)_2CO_2^-$.

Oxidation of 1 mole of **X** with hot acidified potassium manganate(VII) gives 1 mole of CH_3COCO_2H and 2 moles of CO_2 gas.

*Additional optional information: **X**, **Y** and **Z** have a proton (^1H) chemical shift value of 13.0 ppm. (Refer to Data Booklet Section 6: Typical proton (^1H) chemical shift values (δ))*

Suggest structures for **X**, **Y** and **Z**. Explain your reasoning clearly. [8]

- **X** is a carboxylic acid which undergoes acid base with NaOH.
- **X** is a ketone or aldehyde compound as it undergoes condensation reaction with 2,4-dinitrophenylhydrazine to form an orange ppt.
- **X** undergoes oxidation with warm alkaline aqueous iodine to form a yellow ppt, CHI_3. **X** has CH_3CO– structure.
- **X** is an alkene as it undergoes electrophilic addition with Br_2.
- Ketone or aldehyde group in **X** is reduced by $NaBH_4$ to give **Y** as no. of H atoms increases by 2.
- Both alkene and ketone group in **X** are reduced by hydrogen to give **Z** as no. of H atoms increases by 4.
- **Z** contains $CH_3CH(OH)$– structure (not CH_3CO–) as it undergoes oxidation by alkaline aqueous iodine to give $^-O_2C(CH_2)_2CO_2^-$.

X is $CH_3COCH{=}CHCO_2H$
Y is $CH_3CH(OH)CH{=}CHCO_2H$
Z is $CH_3CH(OH)CH_2CH_2CO_2H$

[Total: 20]

End of paper

PIONEER JUNIOR COLLEGE

JC2 Prelim Practical Exam
HIGHER 2

CANDIDATE NAME

CT GROUP | 1 | 7 | | | |

INDEX NUMBER | | | | |

CHEMISTRY **9729/04**

Paper 4 Practical **14 August 2018**

2 hours 30 min

Candidates answer on the Question Paper
Additional Materials: As listed in your apparatus list

READ THESE INSTRUCTIONS FIRST

Write your CT group, index number and name on all work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough workings.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift: _____

Lab: _____

For Examiner's Use	
Q1	/26
Q2	/13
Q3	/16
Total	/55

This document consists of **11** printed pages.

1		**FA 1** is an aqueous solution prepared by mixing equal volumes of **y** mol dm^{-3} hydrochloric acid, HCl, and **y** mol dm^{-3} of sulfuric acid, H_2SO_4. **FA 2** is 2.00 mol dm^{-3} sodium hydroxide, NaOH. **Take care as aqueous solutions of sodium hydroxide are corrosive.** When an alkali is run into an acid, an exothermic reaction takes place and the temperature of the mixture increases until the end-point is reached. If alkali is added beyond the end-point, the temperature will decrease as no further reaction takes place and the alkali is at a lower temperature than the mixture. You are to follow the neutralisation of the acids in **FA 1** by measuring the temperature as known volumes of **FA 2** are added.
	(a)	Fill the burette to 0.00 cm^3 with **FA 2**. Place the Styrofoam cup in a 250 cm^3 beaker to provide support for the cup. Use the measuring cylinder to place 50.0 cm^3 of **FA 1** into the cup and record the steady temperature of the acid in Table 1.1 on page 3. **Read through the following instructions before starting the experiment.** Record all temperatures in Table 1.1 on page 3. Run 3.00 cm^3 of **FA 2** from the burette into the cup, stir the solution with the thermometer and record the maximum temperature. Immediately run a further 3.00 cm^3 of **FA 2** from the burette into the cup, stir and record the maximum temperature as before. Continue the addition of **FA 2**, in 3.00 cm^3 portions, until 48.00 cm^3 of solution have been run from the burette.

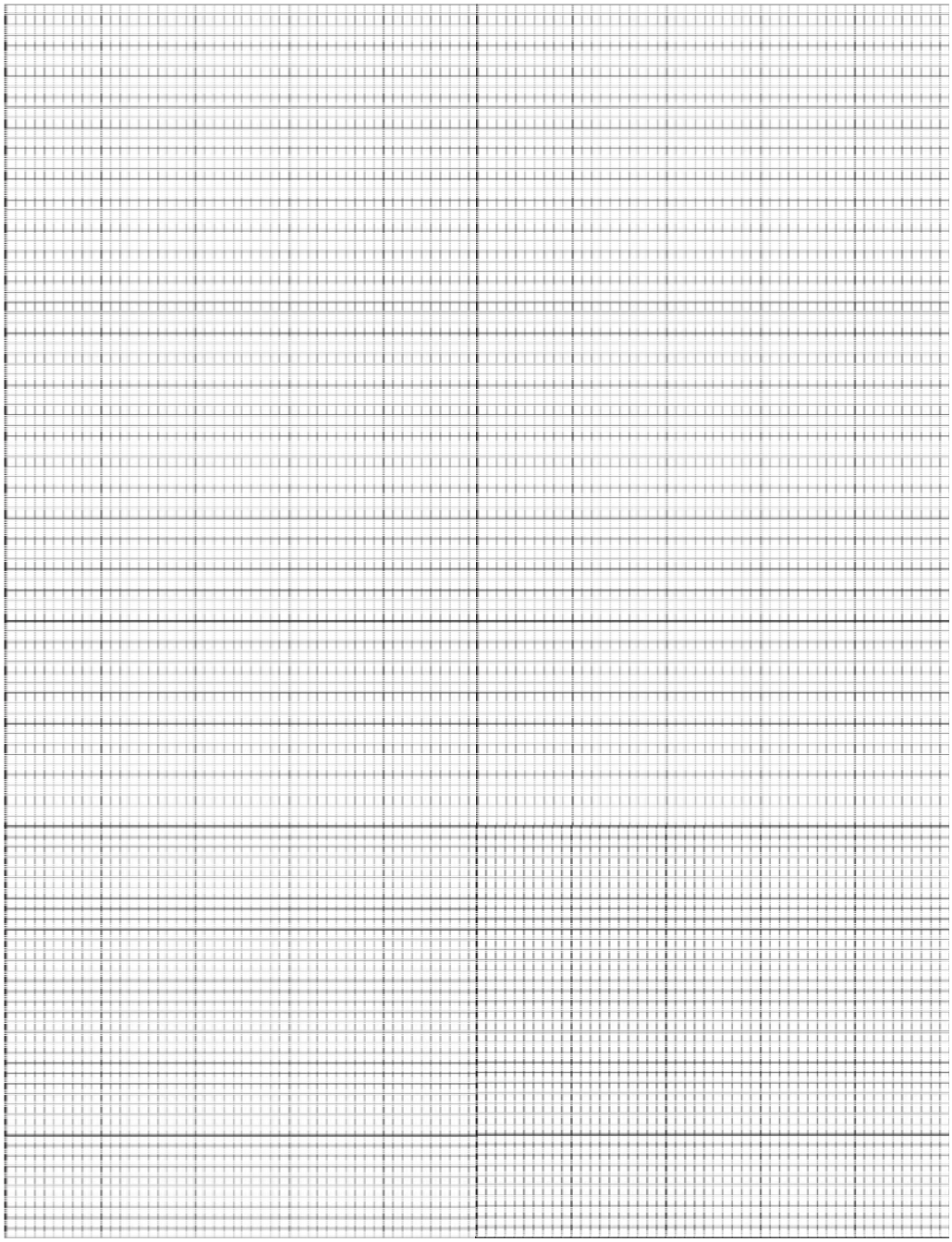
Table 1.1

Volume of **FA 2** added / cm^3	Total volume of solution in cup / cm^3	Temperature / °C		Δt (t_x – t_0) / °C	Total volume x Δt / …….
0.00	50.0	t_0	30.4	0.0	0.0
3.00	53.0	t_3	31.9		
6.00	56.0	t_6	33.3		
9.00	59.0	t_9	34.5		
12.00	62.0	t_{12}	35.6		
15.00	65.0	t_{15}	36.6		
18.00	68.0	t_{18}	37.7		
21.00	71.0	t_{21}	38.4		
24.00	74.0	t_{24}	37.8		
27.00	77.0	t_{27}	37.2		
30.00	80.0	t_{30}	36.8		
33.00	83.0	t_{33}	36.4		
36.00	86.0	t_{36}	36.0		
39.00	89.0	t_{39}	35.6		
42.00	92.0	t_{42}	35.2		
45.00	95.0	t_{45}	34.9		
48.00	98.0	t_{48}	34.6		

[3]

Complete the table by calculating Δt and (total volume x Δt) for each measurement.
Determine the units for the final column.
Units for (total volume x Δt): …….[1]

(b) Plot (total volume x Δt) against the volume of **FA 2** added.
Draw two straight lines of best-fit through the plotted points to find the end-point for the titration.



[4]

(c) Read from the graph the end-point of the titration: ……20.80……. cm^3

[3]

(d) **(i)** Calculate the amount of **FA 2** used to reach the end-point of the titration.

nNaOH = 20.80 / 1000 x 2.00 = 0.0416 mol

amount of **FA 2** for end-point = ... [1]

(ii) Calculate the concentration, in mol dm^{-3}, of the hydrogen ions in **FA 1**. [1]

$[H^+]$ = 0.0416 / 0.050 = 0.832 mol dm^{-3}

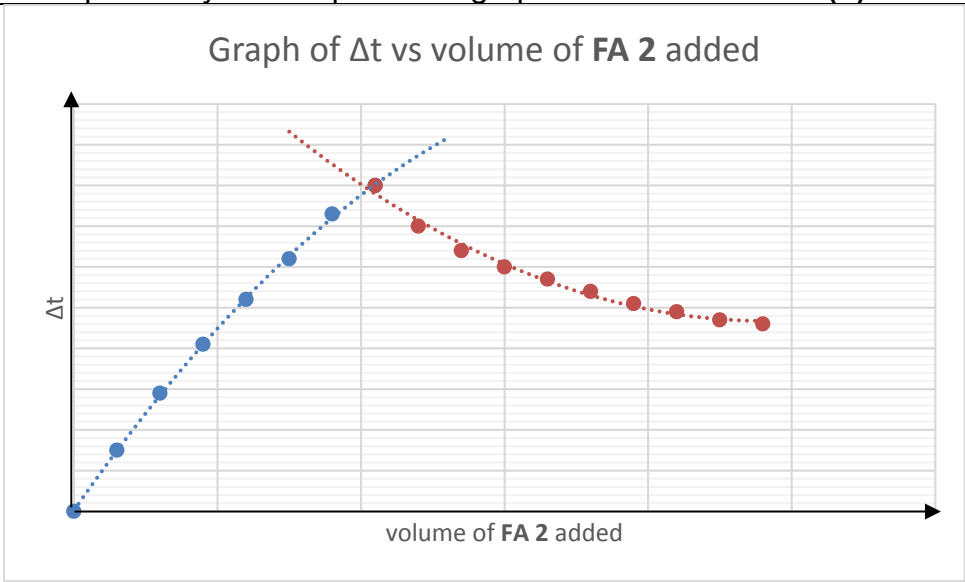
concentration of H^+ in **FA 1** = ... [1]

(iii) Equal volumes of y mol dm^{-3} H_2SO_4 and y mol dm^{-3} HC*l* were mixed to produce **FA 1**. Use your answer to **(d)(ii)** to calculate the value of y.

3y/2 = 0.832
y = 0.555 mol dm^{-3}

y = ... [1]

(e) When Δt was plotted against the volume of **FA 2** added, the following graph is obtained. Explain why the shape of this graph differs from that in **(b)**.



The heat evolved from the neutralization is spread over an increasing volume of solution, leading to a smaller Δt, hence curved lines are obtained instead.

[1]

(f) In the experiment you have performed, determine whether using a measuring cylinder or a burette to measure each 3.00 cm^3 portion will be more accurate.

Show calculations to justify your answer.

% error of measuring cylinder = 0.5 / 3 x 100 = +/- 16.7%
% error of burette = 2 x 0.05 / 3 x 100 = +/- 3.34%

The burette would be a better apparatus as it has a smaller percentage error.

[5]

(g) **Plan**

The reaction between an acid and a metal hydroxide is exothermic.
The experimental procedure used in **1(a)** is known as a thermometric titration where the equivalence-point of a neutralisation reaction can be determined without the use of an indicator. This process can also be used to calculate the basicity of an acid.

A modification of the thermometric titration can be done by performing several experiments in which varied volumes of acid and base are mixed together, keeping the total volume constant. The highest temperature for each experiment is then recorded.

The data obtained can then be used to plot a graph of Δt against volume of NaOH used to determine the basicity of an acid.

Using the informaton above, plan an investigation to determine the basicity of an unknown acid H_nA of concentration 2.00 mol dm^{-3} (where n = 1 or 2).

You may assume that you are provided with
- 2.00 mol dm^{-3} sodium hydroxide, NaOH
- the equipment normally found in a school or college laboratory.

In your plan you should include brief details of
- the volumes of reactants that you would use,
- the apparatus that you would use
- the procedure that you would follow and the measurements that you would take,
- how you would determine the basicity of the unknown acid, H_nA via sketches of the graphs you would expect to obtain.

1. Fill up one 50 cm^3 burette with the unknown acid, and another burette with 2.00 mol dm^{-3} NaOH.

2. Using a burette, measure 10.00 cm^3 of acid into a Styrofoam cup labelled acid. Place the cup inside a second styrofoam cup which is placed in a 250 cm^3 beaker to support it.

3. Using another burette, measure out 50.00 cm^3 of NaOH into another styrofoam cup labelled FA 2.

4. Record the initial temperature of acid solution, and record the initial temperature of NaOH solution separately with a thermometer of 0.2 ºC interval.

5. Add the NaOH(aq) from the cup containing NaOH, into the Styrofoam cup containing the acid and cover with a plastic lid.

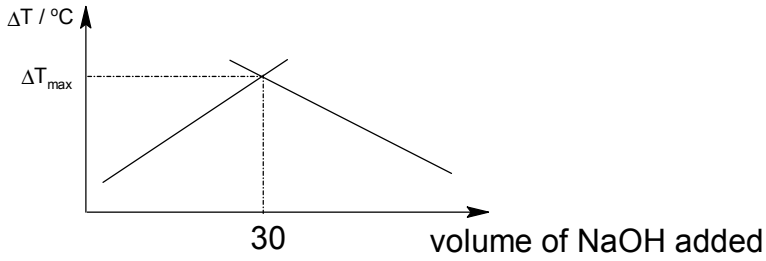
6. Stir gently the mixture with the thermometer and record the highest temperature reached

7. Wash the cups and dry them carefully with paper.

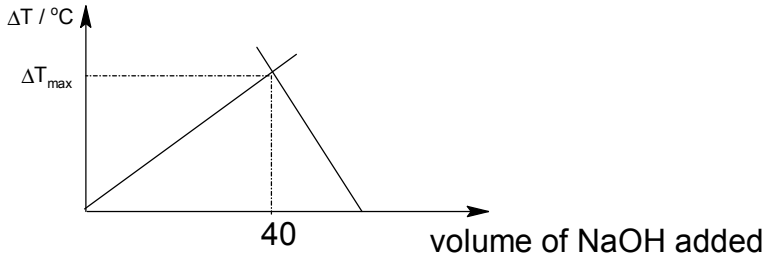
8. Repeat steps 1 to 6 for 15, 30, 40 and 50 cm^3 of acid and varying volumes of NaOH(aq) to make the total volume of mixture constant at 60 cm^3.

9. Sketch a graph of Δt vs volume of NaOH used.

If HA,



If H_2A,



[6]

[Total: 26]

2 **Determination of the rate equation for the reaction between peroxodisulfate ions and iodide ions.**

FA 3 is 0.200 mol dm^{-3} aqueous ammonium peroxodisulfate, $(NH_4)_2S_2O_8$.
FA 4 is an aqueous solution of 1:1 mixture of 0.300 mol dm^{-3} aqueous potassium iodide, KI and 0.00800 mol dm^{-3} aqueous sodium thiosulfate, $Na_2S_2O_3$.

If potassium iodide and ammonium peroxodisulfate are mixed in the presence of starch and sodium thiosulfate, the iodine liberated reacts with the thiosulfate ions until they are all used up.

$S_2O_8^{2-} + 2I^- \rightarrow I_2 + 2SO_4^{2-}$
$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$

When no thiosulfate ions are left, any iodine formed reacts with starch and the dark blue colour of the starch-iodine complex appears. The time taken for the dark blue colour to appear with a constant quantity of sodium thiosulfate present depends on the rate of formation of iodine

You are required to carry out a total of **four** experiments at different concentration of peroxodisulfate ions and note the time taken, ***t***, for the solutions to turn dark blue.

The end-point of the reaction is the first appearance of a dark blue colour.
You need to swirl the reaction mixture well as insufficient swirling will lead to a dark blue colour appearing before the true end-point is reached. Keep to the same number of swirls in each experiment.

Prepare a table in the space provided on page 10 in which to record, for each experiment:

- volume of **FA 3**
- volume of deionised water
- values of ***t***
- calculated values of **1/t**

*Note: As the volume of **FA 4** is constant for each experiment, you do not need to record its volume in your table.*

You are advised to read the procedure and to prepare a table for your results before starting the practical work.

	(a)	**Procedure**		
		Experiment 1		
		1.	Fill the burette labelled **FA 3** with **FA 3**.	
		2.	Run 20.00 cm^3 of **FA 3** into a 100 cm^3 beaker.	
		3.	Using a 25 cm^3 measuring cylinder, measure out 20 cm^3 of **FA 4** and add 10 drops of starch solution.	

		4.	Add the contents of the measuring cylinder to the beaker and start the stopwatch when half of the contents has been added.
		5.	Swirl the mixture and place the beaker on a white tile.
		6.	Stop the stopwatch as soon as the dark blue colour appears. Record the time, ***t***, to the nearest second.
		7.	Wash both the measuring cylinder and the beaker with water and wipe dry.
		Experiment 2	
		1.	Run 10.00 cm^3 of **FA 3** into a 100 cm^3 beaker.
		2.	Using a 25 cm^3 measuring cylinder, measure out 10 cm^3 of deionised water into the beaker containing **FA 3**.
		3.	Using another 25 cm^3 measuring cylinder, measure out 20 cm^3 of **FA 4** and add 10 drops of starch solution.
		4.	Add the contents of the measuring cylinder to the beaker and start the stopwatch when half of the contents has been added.
		5.	Swirl the mixture and place the beaker on a white tile.
		6.	Stop the stopwatch as soon as the dark blue colour appears. Record the time, ***t***, to the nearest second.
		7.	Wash both the measuring cylinder and the beaker with water and wipe dry.
		Experiment 3 – 4	
		Perform **two** additional experiments using different volume of the peroxodisulfate solution and the deionised water. Note that the combined volume of **FA 3** and deionised water must always be 20 cm^3. Do not use a volume of **FA 3** that is less than 6 cm^3.	
	(b)	In the series of experiments where the total volume of the mixture is kept constant and the same end-point (appearance of dark blue colour) is timed at different concentrations of peroxodisulfate solution, • $[S_2O_8^{2-}] \propto V_{\mathbf{FA3}}$ used • rate $\alpha \frac{1}{t}$ Record the results of your four experiments below. **Table of results**	

Experiment	Volume of FA3/ cm^3	Volume of deionised water/ cm^3	*t* / *s*	1/t s^{-1}
1	20.00	0.0	23	
2	10.00	10.0	49	
3	17.00	3.0	27	
4	13.00	7.0	31	
5	7.00	13.0	71	

[5]

(c) Using the results in your table, deduce the order of the reaction with respect to the peroxodisulfate ions. Explain clearly how you arrived at your answer.

Order is 1 .

Comparing expt 1 and 2,
Halve [$S_2O_8^{2-}$], time is doubled

[1]

(d) **(i)** Based on experiments 1 – 4, indicate, with reasoning, which experiment is most likely to have the largest error in the time measured.

The time measured for experiment 1 is the shortest and hence have the greatest percentage error.

[1]

(ii) Instead of washing the beaker as required before performing the next experiment, a student simply just poured away the reaction mixture. There were some left over reaction mixture in the beaker when he performed the subsequent experiment. State and explain what will happen to the time, ***t***.

The excess I_2 left in the flask will react with the $S_2O_3^{2-}$ in the new experiment. As there is lesser $S_2O_3^{2-}$ for the new experiment, less I_2 is reacted. Given that the rate of reaction is the same, the time taken to produce the I_2 will be shorter and hence observe the blue colour faster.

[2]

(e) **(i)** Explain why a fixed amount of sodium thiosulfate is required.

To ensure an equal amount of iodine is reacted before the solution turns dark blue in each experiment.

[1]

(ii) If the concentration of sodium thiosulfate used in **FA 4** is changed to 0.0160 mol dm^{-3}, state and explain the effect on the time taken to reach the end-point?

Longer time required to reach end-point.

There is a larger amount of sodium thiosulfate, so it will take more time to produce enough iodine to reach the end point.

[1]

(f) Two other experiments were carried out to determine the order of reaction with respect to iodide ions and the following results were obtained.

Experiment	volume of $(NH_4)_2S_2O_8$ / cm^3	volume of KI / cm^3	volume of H_2O / cm^3	volume of $Na_2S_2O_3$ / cm^3	time / s
5	50	40	0	10	40
6	50	20	20	10	82

From the data given above, state the order of reaction with respect to KI. Explain clearly how you arrived at your answer.

Order of reaction = 1

Since total volume of reaction mixture is kept constant,

- **[KI]∝ V_{KI} used**

Also since rate α $\frac{1}{t}$

AND

- **when the volume of KI is doubled, the time taken for the iodine to appear is halved. Rate of reaction is directly proportional to [KI].**

OR

- **V_{KI} x t = constant**

[1]

(g) Write the rate equation for the reaction between peroxodisulfate ions and iodide ions.

Rate = $k[S_2O_8^{2-}][I^-]$

[1]

[Total: 13]

3 **FA 5** contains Ni^{2+} and one other cation and one anion.

In all tests, the reagents should be added gradually until no further change is observed after shaking with each addition.
Record your observations and the deductions you make from them in the spaces provided
Your answers should include

- Details of colour changes and precipitates formed
- The names of gases evolved and details of the test used to identify each one.

You should indicate clearly at what stage in a test, an observation occurs
No additional or confirmatory tests for ions present should be attempted

Test	Observations
(i) Test the **FA 5** solution with Universal Indicator paper.	pH is 3
(ii) To 2 cm depth of **FA 5** in a test tube, add aqueous sodium carbonate until no further change is observed.	green ppt Effervescence seen , gas forms white ppt when passes through limewater
(iii) To 3 cm depth of **FA 5** in a boiling tube, add aqueous sodium hydroxide until no further change is observed. Filter the mixture and collect the filtrate, label it **FA 6**. State the colour of the residue and filtrate. Divide **FA 6** into two portions in two separate test tubes for use in **(iv)** and **(v)**.	Green ppt <u>insoluble</u> in excess aqueous sodium hydroxide (light) Green residue and Colourless filtrate
(iv) To 2 cm depth of **FA 6** in a test-tube, add dilute nitric acid, drop by drop, until no further change is observed.	No effervescence / no gas evolved (Thin cloudy) White ppt appears which is soluble in excess nitric acid
(v) To 2 cm depth of **FA 6** add aqueous silver nitrate.	White ppt forms
Add an excess of dilute aqueous ammonia.	<u>soluble</u> in excess aqueous ammonia

[5]

	Conclusion		
	(a)	Consider your observations in **(ii)**. Suggest an explanation for the evolution of gas observed. Write an equation, including state symbols in your answer.	
		FA 5 contains an **acidic salt** which undergoes hydrolysis to produce H^+. The H^+ would react with carbonate to produce CO_2 **$2H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O(l)$** [2]	
	(b)	Consider your observations in **(v)**. Suggest an explanation for the observations in terms of the chemistry involved.	
		Cl^- reacts with $AgNO_3$ to form white ppt of $AgCl$ or show equation With $NH_3(aq)$, complex $[Ag(NH_3)_2]^+$ is formed or show equation . This reduces $[Ag^+]$ and shifts the equilibrium: $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$ to the right OR ionic product becomes lower than K_{sp}, so $AgCl$ solid dissolves. [2]	
	(c)	**(i)**	**FA 5** contains the cations: Ni^{2+} and **Al^{3+}** [1]
		(ii)	**FA 5** contains the anion: **Cl^-** [1]
	(d)	**Plan** **FA 7** is a solution that contains Fe^{2+} and Al^{3+} ions Plan a sequence of steps by which the two ions could be separated so that each ion is present in a separate precipitate. For each of the steps, you are to specify the location of the ions and their formulae. You are also required to specify the amount (dropwise or excess) of reagents that you add. You may assume that the usual bench reagents and apparatus are available for use.	
		1. Add <u>excess</u> NaOH (aq) to the mixture. **Carry out filtration to separate the insoluble ppt / $Fe(OH)_2$ from the solution** **Residue: $Fe(OH)_2$ (s)** **Filtrate: $Al(OH)_4^-$ (aq)** **2. To the filtrate[1], Add HCl dropwise** **3. Carry out filtration to separate the insoluble ppt/$Al(OH)_3$(s) from the solution** **Residue: <u>$Al(OH)_3$</u>**	

			[5]
			[Total: 16]

ANDERSON JUNIOR COLLEGE

2018 JC 2 PRELIMINARY EXAMINATION

CHEMISTRY **8873/01**

Paper 1 Multiple Choice **17 September 2018**

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, PDG and NRIC / FIN number on the Answer Sheet in the spaces provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the Multiple Choice Answer Sheet.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

Multiple Choice Answer Sheet

Write your name, PDG and NRIC / FIN number, **including** the reference letter.

Shade the NRIC / FIN number.

Exam Title: JC2 PRELIM

Exam Details: H1 Chemistry / Paper 1

Date: 17/09/2018

This document consists of **11** printed pages.

1 An unknown gaseous hydrocarbon C_xH_y of volume V is mixed with oxygen and then completely combusted.

Which volume of oxygen reacts with the hydrocarbon?

A $(\frac{x}{2} + \frac{y}{4})V$ **B** xV **C** $(x + \frac{y}{2})V$ **D** $(x + \frac{y}{4})V$

2 A sample of silicon contains three naturally occurring isotopes, ^{28}Si, ^{29}Si and ^{30}Si.

The sample is made up of 92.23% ^{28}Si and the relative atomic mass of silicon in this sample is 28.10.

What is the percentage of the isotope ^{29}Si in the sample?

A 2.23% **B** 3.89% **C** 5.54% **D** 7.77%

3 *Use of the Data Booklet is relevant to this question.*

How many hydrogen atoms are present in 15 g of ethanoic acid?

[L = Avogadro constant]

A $\frac{1}{L}$ **B** $\frac{L}{4}$ **C** L **D** $60L$

4 The space shuttle's upward thrust, on lift off, came from the reaction between aluminium and ammonium perchlorate.

$$10Al + 6NH_4ClO_4 \longrightarrow 4Al_2O_3 + 2AlCl_3 + 12H_2O + 3N_2$$

Which statement about the overall reaction is correct?

1 Aluminium is oxidised.

2 Chlorine is reduced.

3 Hydrogen is oxidised.

4 Nitrogen is reduced.

5 Oxygen is oxidised.

A 1 and 2 only

B 2 and 5 only

C 1, 2 and 3 only

D 3, 4 and 5 only

5 Which of the following statements about isotopes is correct?

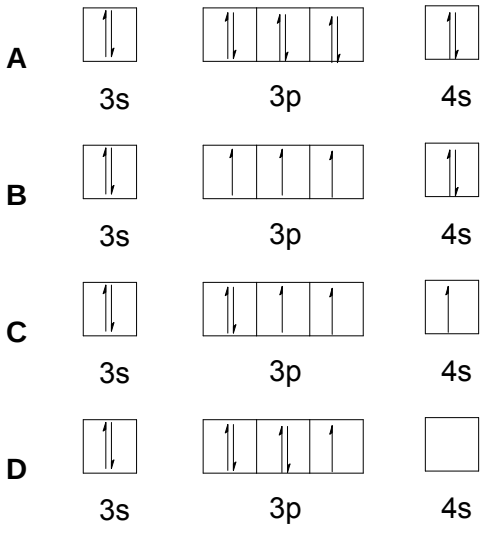
A They have the same number of protons but different number of electrons.

B They have the same number of protons but different number of neutrons.

C They have the same number of neutrons but different number of electrons.

D They have the same number of neutrons but different number of protons.

6 Which diagram represents the arrangement of electrons in the 3rd and 4th quantum shell of a Ca^{3+} ion?



7 *Use of the Data Booklet is relevant to this question.*

The successive ionisation energies, in kJ mol^{-1}, of an element **D** are given below.

900 1730 2570 3830 4860 6950 8210 12600

What is **D**?

A $_{52}Te$ **B** $_{53}I$ **C** $_{84}Po$ **D** $_{85}At$

8 Argon has the following electronic configuration:

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

Which of the following ions does **not** have the same electronic configuration as argon?

A P^{3-} **B** Cl^- **C** Ca^+ **D** Ti^{4+}

9 Which of the following molecules has the greatest polarity?

A BF_3 **B** NCl_3 **C** $SiCl_4$ **D** SF_6

10 As a fixed mass of ice melts at 0 °C, which of the following statements are true?

1 The weak covalent bonds between H_2O molecules are broken.

2 There is a contraction in volume.

3 The temperature of the ice–water mixture increases.

4 The average number of hydrogen bonds per H_2O molecule remains unchanged.

A 1 and 2 only

B 3 and 4 only

C 2 and 3 only

D 2 and 4 only

11 In which pair of species are the values of the bond angles the most different?

A PF_3 and NH_3

B NH_4^+ and SO_4^{2-}

C NH_2^- and H_2S

D CH_3^- and CH_3^+

12 The Brønsted–Lowry theory describes acid and base character.

When concentrated sulfuric acid and concentrated nitric acid are mixed, the following reactions occur.

$$H_2SO_4 + HNO_3 \rightleftharpoons HSO_4^- + H_2NO_3^+$$

$$H_2NO_3^+ \rightleftharpoons H_2O + NO_2^+$$

$$H_2O + H_2SO_4 \rightleftharpoons HSO_4^- + H_3O^+$$

Which species are bases in these reactions?

1 HSO_4^-

2 HNO_3

3 NO_2^+

A 1 only

B 2 only

C 3 only

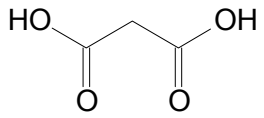
D 1 and 2 only

13 A solution was made by mixing equal volumes of two acids of pH 1 and pH 3.

What is the pH of the resulting solution?

A 1.0 **B** 1.3 **C** 2.0 **D** 2.5

14 Malonic acid is a weak dibasic acid and has the structure shown below.



The concentration of a solution of malonic acid was determined by titrating it against a standard solution of aqueous sodium hydroxide in a burette. The pH of the first and second equivalence points are found to be 4.5 and 9.1 respectively.

Which of the following is a suitable indicator for part of this titration?

	indicator	*pH range*
A	thymol blue	1.2 to 2.8
B	methyl orange	3.2 to 4.4
C	bromocresol green	3.8 to 5.5
D	phenol red	6.4 to 8.0

15 The main buffering agent to maintain the blood pH at 7.4 is the H_2CO_3/HCO_3^- system. The following two equations show the equilibria of H_2CO_3/HCO_3^- system in the body.

$$H_2O(l) + CO_2(g) \rightleftharpoons H_2CO_3(aq) \quad \text{..... (1)}$$

$$H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq) \quad \text{..... (2)}$$

During strenuous exercise, the blood pH may fall below 7.4.

Which of the following actions will help the body increase the blood pH?

1 Breathing into a paper bag.

2 Removing H^+ ions from the blood.

3 Secreting HCO_3^- ions into the blood.

A 1 and 2 only **B** 2 and 3 only **C** 1 and 3 only **D** 1, 2 and 3

16 Which series is correctly arranged in order of increasing values?

A atomic radius of P, S, C*l*

B ionic radius of Na^+, Mg^{2+}, Al^{3+}

C melting point of A*l*, Si, P

D second ionisation energy of Si, P, S

17 An element *X* in Period 3 is a semiconductor and has a chloride which reacts with water to form an acidic solution.

An element *Y* has an atomic number one less than element *X*.

What is a property of the oxide of element *Y*?

A It is a gas at room temperature.

B It is amphoteric.

C It is covalent.

D Its formula is YO_2.

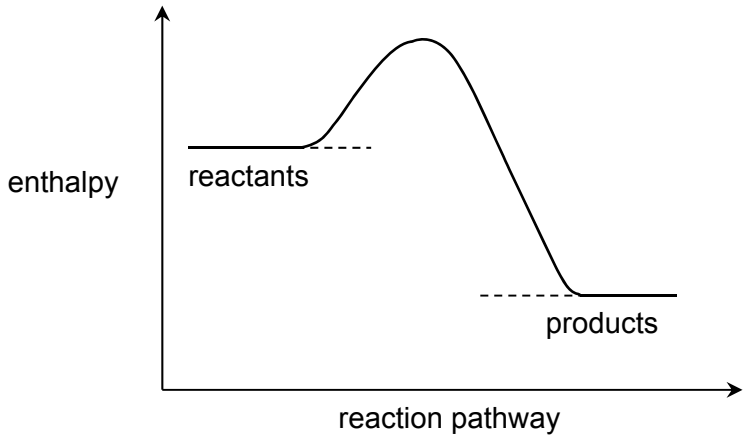
18 The information relates to element *Z*.

- *Z* is in Period 3 of the Periodic Table.
- *Z* has a lower electrical conductivity than Mg.
- A *Z* atom has a half–filled subshell in its ground state.
- *Z* forms an acidic oxide on exposure to air.

What is *Z*?

A Na **B** Si **C** P **D** C*l*

19 Which enthalpy change could **never** be correctly represented by the following enthalpy diagram?



A standard enthalpy change of combustion

B standard enthalpy change of formation

C standard enthalpy change of neutralisation

D standard enthalpy change of vapourisation

20 Which statement best defines the term bond energy for a diatomic gaseous molecule PQ?

A energy released when one mole of PQ is formed from its gaseous ions

B energy released when one molecule of PQ is formed from its gaseous atoms

C energy required when one molecule of PQ is broken into its gaseous atoms

D energy required when one mole of PQ is broken into its gaseous atoms

21 N_2O_5 decomposes according to the equation.

$$N_2O_5 \longrightarrow 2NO_2 + \frac{1}{2}O_2$$

The decomposition is first order and the half–life of N_2O_5 is 150 s.

When a sample containing 0.10 mol of N_2O_5 was placed in a 1 dm^3 vessel, what is the concentration of NO_2 after 5 minutes?

A 0.150 mol dm^{-3}

B 0.100 mol dm^{-3}

C 0.050 mol dm^{-3}

D 0.025 mol dm^{-3}

22 The following reaction is first order with respect to P and zero order with respect to Q.

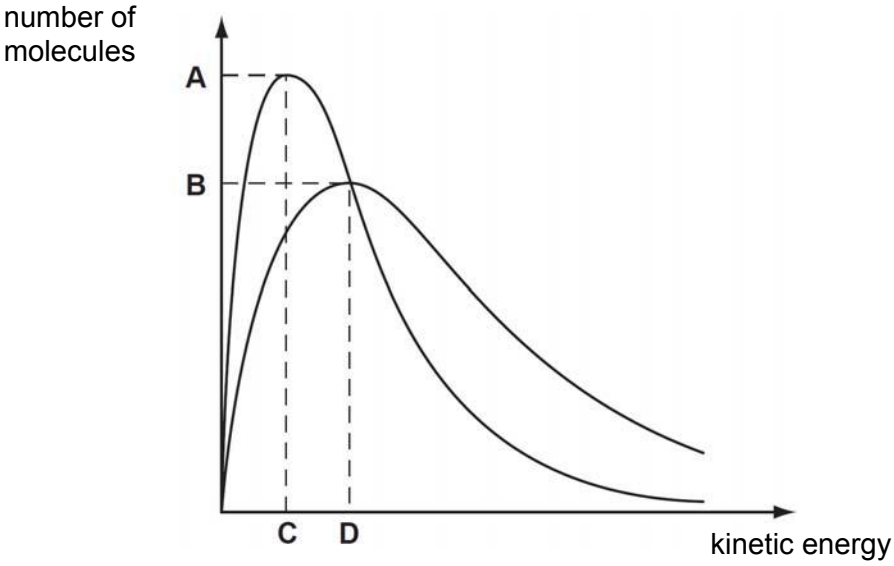
$$P + Q \longrightarrow \text{products}$$

If the rate constant doubles for each 10 °C rise in temperature, which of the following sets of conditions will give the greatest rate of reaction?

	[P] / mol dm^{-3}	[Q] / mol dm^{-3}	T / °C
A	0.1	0.2	40
B	0.1	0.3	30
C	0.2	0.2	30
D	0.3	0.1	20

23 The diagram shows the Maxwell–Boltzmann energy distribution curves for molecules of a sample of a gas at two different temperatures.

Which letter on the axes represents the proportion of molecules with the most probable energy at the lower temperature?



24 Metals such as rhodium (Rh), palladium (Pd) and platinum (Pt) are surface catalysts used in the catalytic converter to convert unburnt hydrocarbon, CO and oxides of nitrogen to less harmful gases such as CO_2, H_2O and N_2 to reduce air pollution.

Which of the following statements are correct?

1 The metals increase the rate of reaction by providing an alternative pathway of lower activation energy and make the reaction more exothermic.

2 The metals act as heterogeneous catalysts.

3 The metals in the catalytic convertor will be depleted with time and needs to be replaced.

4 Rh, Pd and Pt are inert metals with high melting points.

A 1 and 3 only

B 2 and 4 only

C 2 only

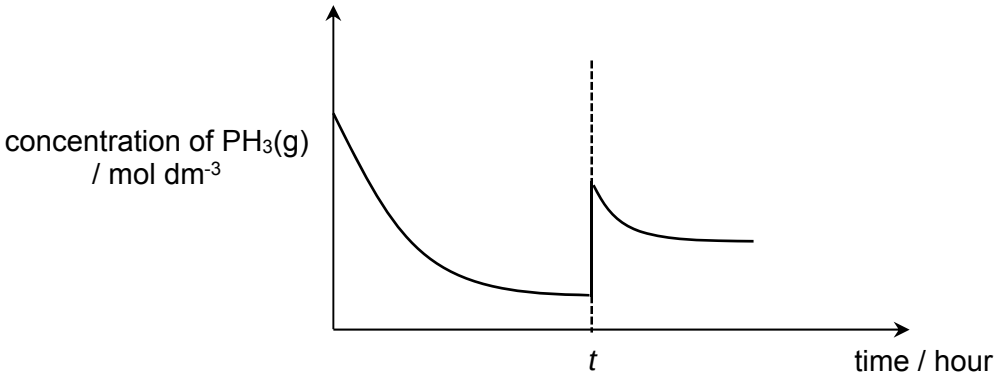
D 3 only

25 Phosphine, PH_3, decomposes to give phosphorus and hydrogen gas.

$$4PH_3(g) \rightleftharpoons P_4(g) + 6H_2(g) \qquad \Delta H > 0$$

The graph below shows the change in concentration of PH_3 over time until the reaction mixture reaches equilibrium at a constant temperature of 400 K.

Which of the following are **not** possible changes made at *t* hour?



1 Addition of PH_3 to the reaction mixture

2 Reduction in the volume of the vessel

3 Removal of P_4 from the reaction mixture

4 Addition of a catalyst

A 1 and 2 only **B** 3 and 4 only **C** 2 and 4 only **D** 2, 3 and 4 only

26 Which of the following statements about graphene is true?

A Each carbon atoms form σ bonds with 6 neighbouring carbon atoms.

B It is an extremely thin 3–dimensional layer of carbon atoms.

C It is a good thermal conductor.

D Weak instantaneous dipole–induced dipole forces of attraction exist between the layers of graphene.

27 "Clearfilm" is manufactured from a polymer made by copolymerizing $CH_2{=}CHCl$ with $CH_2{=}CCl_2$ in a regular "head to tail" linkage where CH_2 is taken as the "head" of the monomer.

Which of the following could represent part of the polymer chain in "clearfilm"?

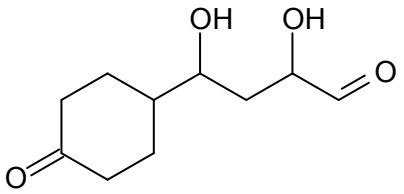
A $–CHCl–CH_2–CCl_2–$

B $–CCl_2–CCl_2–CH_2–CHCl–$

C $–CH_2–CHCl–CCl_2–$

D $–CH_2–CCl_2–CHCl–CH_2–$

28 Which of the following statements are true about the following compound?



1 Its molecular formula is $C_{10}H_{14}O_4$.

2 It reacts with sodium hydrogen carbonate to give carbon dioxide gas.

3 It reacts with hot acidified potassium dichromate to form a product with 5 O atoms.

4 It reacts with 2 mol of sodium metal to form 1 mol of hydrogen gas.

A 1 and 2 only

B 3 and 4 only

C 2 and 4 only

D 1 and 3 only

29 Part of the structure of a polyester is shown below:

$$–O–CH(CH_3)–CO_2–CH(CH_3)–CO–$$

Which of the following statements are true?

1 It is a thermoplastic.

2 The polymer chains are held together by hydrogen bonds.

3 The C–O–C angle in the polymer is 120°.

4 It undergoes acid hydrolysis to give $HOCH(CH_3)CO_2H$.

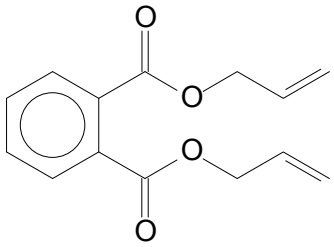
A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

D 3 and 4 only

30 Diallyl phthalate (DAP) has a structure shown below. As a monomer, it is used as a cross-linking agent in unsaturated polyesters. When it undergoes polymerisation to form poly(diallyl phthalate), one of the two >C=C< is first used to join up the DAP monomers into a pre-polymer. During the molding process, the second >C=C< polymerises leading to a highly cross-linked thermoset polymer.



DAP

Its polymer is used in the production of thermosetting molding powders.

Which of the following statements is **not** true?

A Cross–linkages with unsaturated polyesters are formed by the unsaturated >C=C< bonds of DAP monomers.

B Poly(diallyl phthalate) is soft and flexible.

C Poly(diallyl phthalate) is an electrical insulator.

D Poly(diallyl phthalate) is resistant to high temperature.

H1 Chemistry 8873 **AJC 2018 JC2 PRELIM** **Paper 1 – 30 marks**

Question Number	*Key*	*Question Number*	*Key*
1	**D**	16	**D**
2	**C**	17	**B**
3	**C**	18	**C**
4	**A**	19	**D**
5	**B**	20	**D**
6	**D**	21	**A**
7	**D**	22	**A**
8	**C**	23	**A**
9	**B**	24	**B**
10	**D**	25	**D**
11	**D**	26	**C**
12	**D**	27	**A**
13	**B**	28	**B**
14	**C**	29	**B**
15	**B**	30	**B**

A	**5**
B	**9**
C	**6**
D	**10**

ANDERSON JUNIOR COLLEGE

2018 JC 2 PRELIMINARY EXAMINATION

NAME:_____ **PDG:**____ /17

CHEMISTRY **8873/02**

Paper 2 Structured Questions **12 September 2018**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, PDG and register number on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use							
Paper 1 (33%)	Paper 2 (67%)						
	Section A				Section B		Total
	Q1	Q2	Q3	Q4	Q5*	Q6*	
/30							/ 80
			Final marks				/ 100
			Grade				

* Circle the question you have attempted

This document consists of **21** printed pages.

Section A

Answer **all** the questions in this section, in the spaces provided.

1 Ethanol, CH_3CH_2OH, is a renewable biofuel which is made from the starch in corn grain or from the glucose in sugar cane.

(a) What is meant by the term *standard enthalpy change of combustion*?

……

……[2]

(b) When 1 g of ethanol was burned under a container of water, it was found that 100 g of water was heated from 20 °C to 65 °C. The process was known to be only 65 % efficient.

Use these data and values from the *Data Booklet* to calculate the enthalpy change of combustion of ethanol.

[3]

(c) Fig 1.1 shows an energy cycle involving ethanol.

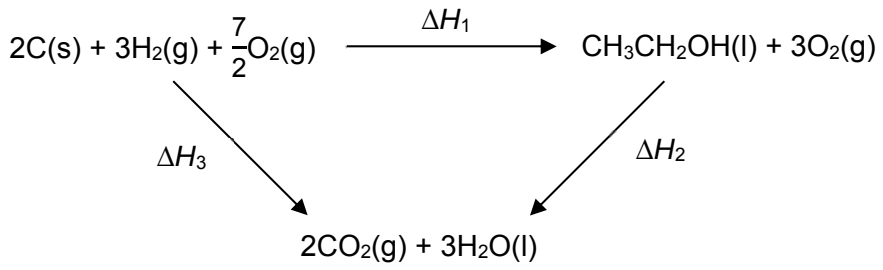


Fig 1.1

(i) Name the enthalpy change represented by ΔH_1.

……..[1]

(ii) Given that the enthalpy change of combustion of carbon and hydrogen are –393.5 kJ mol^{-1} and –285.8 kJ mol^{-1} respectively, use the energy cycle given above and your answer to **(b)** to calculate ΔH_1.

[3]

(d) In some countries, ethanol is blended with petrol for use in cars. Ethanol blended petrol can significantly reduce the greenhouse gas emissions. The carbon dioxide released by a vehicle when ethanol is burned is offset by the carbon dioxide captured when the feedstock crops are grown to produce ethanol.

Petrol which contains 10% ethanol by volume is named E10 and it is the most widely used around the world. On average, 2.33 kg of carbon dioxide is emitted for every one litre of petrol combusted in a car engine. In contrast, every one litre of ethanol combusted in the car engine reduces mass of carbon dioxide emitted by 99 % compared to petrol.

According to oil industry data, cars in Singapore consumed about 6,453,600 barrels of petrol in 2017. Each barrel is approximately 159 litres.

(i) Calculate the total mass of CO_2, in kg, emitted by cars in Singapore in 2017.

[1]

(ii) Calculate the mass of CO_2, in kg, emitted for every litre of ethanol combusted in the car engine.

[1]

(iii) Calculate the mass of CO_2, in kg, emitted for every litre of E10 petrol combusted in the car engine.

[1]

(iv) Hence, calculate the reduction in mass of CO_2, in kg, emitted if E10 was used by cars in Singapore in 2017 instead of regular petrol.

[1]

(e) Poly(vinyl alcohol) (PVA) is used to make film laundry bags which are used in hospitals to minimise the contact hospital workers have with contaminated clothing and bedding. The dirty items are put into these special bags, which are then placed directly into the washing machine. As the bags are water–soluble, they dissolve and are washed down the drain with the dirty water.

Fig 1.2 shows part of the PVA structure with three repeat units.

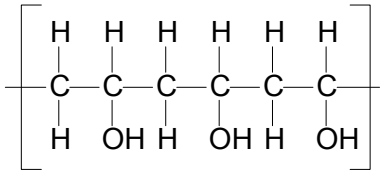


Fig 1.2

(i) Draw the full displayed formula of the monomer of PVA.

[1]

(ii) State the reagent and conditions required to convert the monomer of PVA to ethanol.

…… [1]

(iii) State the type of intermolecular forces that can be formed between PVA polymer and water molecules.

…… [1]

(iv) Copy the structure of PVA in the space below and use it to illustrate the type of attraction between PVA polymer and **one** water molecule.

[2]

(v) When borax, $Na_2B_4O_7.10H_2O$ was gradually added to PVA solution and stirred, the mixture thickens and eventually forms slime. When dissolved in solution, borax forms the borate ion, $B(OH)_4^-$, which has the structure given in Fig 1.4.

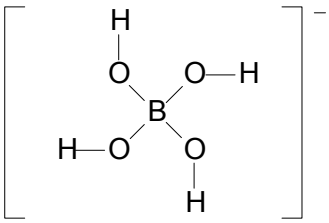


Fig 1.4

Suggest a reason why the presence of borate ions causes mixture to thicken and form slime.

……..

…… [1]

(vi) PVA cannot be synthesised directly from its monomer. Instead, it is formed from poly(vinyl acetate). Part of the structure of poly(vinyl acetate) is shown in Fig 1.3.

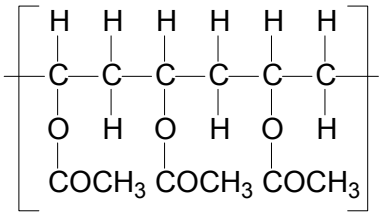


Fig 1.3

Suggest the reagent and condition required to form PVA from poly(vinyl acetate).

…… [1]

[Total: 20]

2 **(a)** Poly(ethene) is a *thermoplastic*.

Explain what you understand of the word in *italics*.

……

……[1]

(b) Ethene can be polymerised in slightly different ways to make low–density poly(ethene) (LDPE) and high–density poly(ethene) (HDPE). These polymers have different physical properties because of the structure of their molecules. LDPE is flexible whereas HDPE is relatively more rigid.

(i) Describe the structure and bonding in LDPE and HDPE and explain how they affect their physical properties.

……..

……..

……..

……..

……..

……..

……..

……..[4]

(ii) Suggest a use for each polymer in consideration of its physical properties.

HDPE: …….

LDPE: ……[2]

(c) An experiment was carried out to determine the relative oxidising power of three unknown halogens X_2, Y_2 and Z_2. Table 2.1 shows the results of experiments in which the halogens X_2, Y_2 and Z_2 were added to separate aqueous solutions containing X^-, Y^- and Z^- ions.

Table 2.1

	X^- (aq)	**Y^- (aq)**	**Z^- (aq)**
X_2		no reaction	no reaction
Y_2	brown solution formed		orange solution formed
Z_2	brown solution formed	no reaction	

(i) Using the results given in Table 2.1, suggest the identity of X_2, Y_2 and Z_2.

X_2: ……

Y_2: ……

Z_2: …… [2]

(ii) Hence, state the most powerful oxidising agent among the halogens.

…… [1]

(iii) Explain, in terms of ease of gain of electrons, why the element you have identified in **(c)(ii)** is the most powerful oxidising agent.

……..

……..

……..

……..

……..

……..[2]

(d) Three Group 17 hydrides were separately heated in an experiment. Their bond energy values and the observations of the experiment are given in Table 2.2.

Table 2.2

H–X	**bond energy / kJ mol^{-1}**	**observation**
H–C*l*	431	no visible change
H–Br	366	brown fumes of Br_2
H–I	299	dense purple fumes of I_2 on gentle heating

(i) Using the observations of the experiment, state the thermal stability of the Group 17 hydrides in decreasing order.

……. [1]

(ii) Explain, in terms of their bond energies, the trend in the thermal stability of Group 17 hydrides.

……..

……..

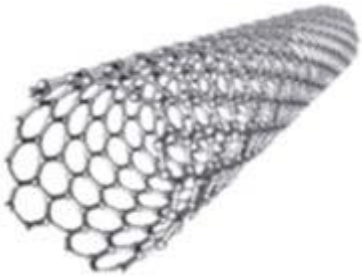
……..

……..

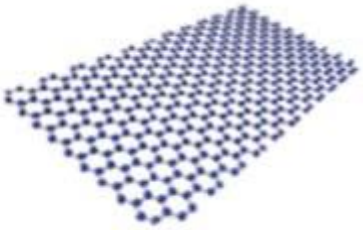
……..

…….[2]

(e) A carbon nanotube (CNT) resembles a sheet of graphene rolled up to form a tiny cylindrical tube, with a diameter in the nanometer scale. They are used to manufacture professional tennis rackets and hockey sticks to make them lighter and more durable under constant forceful impacts by the players.



Carbon nanotube (CNT)



Graphene

(i) Suggest one similarity and one difference in terms of physical property between CNT and graphene.

Similarity: ……..

……..

Difference: ……..

……..[2]

(ii) State what is meant by the term "*nanometer scale*".

……..[1]

(iii) As nanotechnology continues to expand into every industrial sector, workers will be at an increased risk of exposure to new nanomaterials. Consumers also face increased exposure to nanomaterials as they are found in hundreds of products, ranging from cosmetics, to clothing, to industrial and biomedical applications. A number of recent research studies with rodents have shown that CNTs may pose a respiratory hazard to human beings.

State two other ways in which nanomaterials may enter the human body, other than through inhalation.

……..

……..[2]

[Total: 20]

3 **(a)** Beams of particles travelling at the same speed from different sources are subjected to an electric field. Fig 3.1 shows the experimental set–up where protons are found to be deflected through an angle of $+x°$.

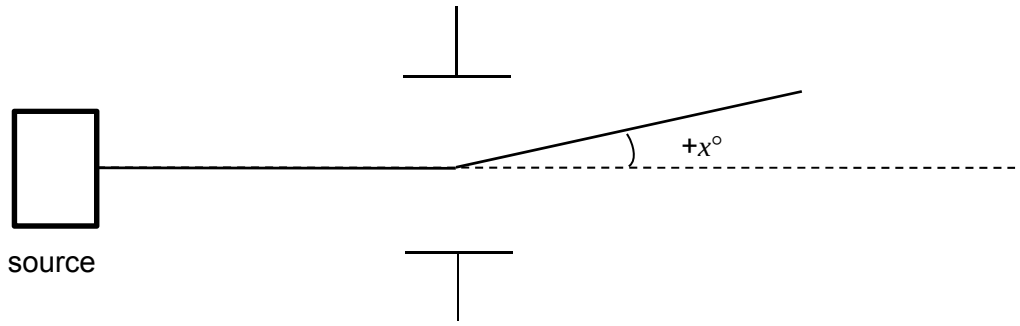


Fig 3.1

(i) Indicate, in Fig 3.1, the polarity of the plates and explain your answer.

……..

…… [2]

(ii) Assuming an identical set of experimental conditions, state and explain the **angle** and **direction** of deflection for the following particles.

I: $^{16}O^{2-}$ ion

……..

……..

……..

……..

II: ^{4}He nuclei

……..

……..

……..

……..

III: ^{2}H atom

……..

……..

……..

……..[5]

(b) Fig 3.2 shows a scheme of the 17 lowest energy subshells, which can be used to show the order in which the subshells are filled by electrons (the Aufbau principle).

1s	2s	3s	4s	5s	6s	7s
	2p	3p	4p	5p	6p	
		3d	4d	5d		
			4f	5f		

Fig 3.2

(i) List the order of filling subshells for an atom of a d–block element in the **fourth** period of the Periodic Table.

…….....[1]

(ii) Hence, write the electronic configuration of the copper atom.

…….....[1]

(iii) An electron of the copper atom undergoes excitation from the ground state. What is the lowest energy, empty orbital that the electron can be promoted to?

…….....[1]

[Total: 10]

4 A laboratory technician found a bottle in the school laboratory that contained a white crystalline solid. The label on the bottle was smudged such that he could only make out the words “acid” and “104 g mol^{-1}”. To investigate, he decided to conduct a titration using 0.100 mol dm^{-3} sodium hydroxide.

He dissolved 2.29 g of the unknown acid in 250 cm^3 of deionised water and pipetted 25.0 cm^3 of this solution into a conical flask. He gradually added 0.100 mol dm^{-3} NaOH(aq) solution from a burette and monitored the pH of the reaction mixture in the conical flask using a pH meter after each addition.

Fig 4.1 shows the pH–volume added curve he obtained.

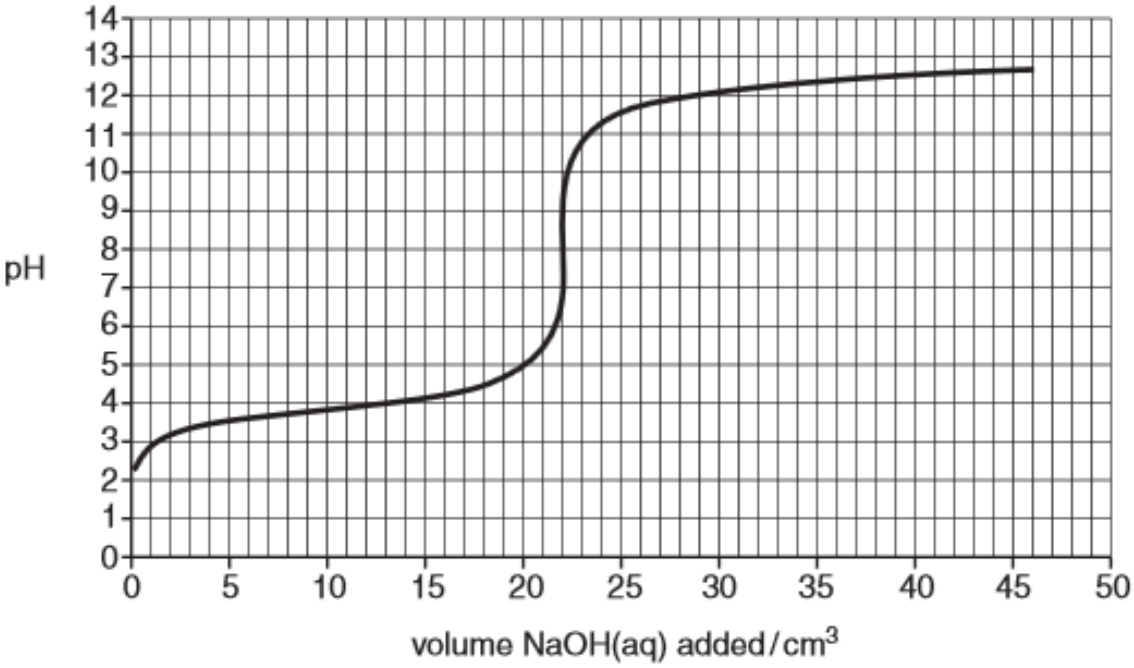


Fig 4.1

(a) Calculate the number of moles of the unknown acid transferred to the conical flask.

[2]

(b) Calculate the number of moles of sodium hydroxide that reacted with the unknown acid in the conical flask.

[1]

(c) Hence, using your answers to **(a)** and **(b)**, determine if the unknown acid is monobasic or dibasic.

[1]

(d) Given that the initial pH is 2.2, explain why the unknown acid is a weak acid.

……

……[2]

(e) Hence, or otherwise, deduce the acid dissociation constant, K_a of the unknown acid.

[2]

(f) Show that the concentration of excess unreacted hydroxide ions when 45 cm^3 of sodium hydroxide was added to the conical flask is 0.0329 mol dm^{-3}.

[1]

(g) Hence, calculate the pH of the solution after 45 cm^3 of sodium hydroxide was added.

[1]

[Total: 10]

Section B

Answer **one** question from this section, in the spaces provided.

5 **(a)** The oxides of Period 3 elements Na_2O, Al_2O_3 and P_4O_{10} show different physical and chemical properties. Some information on these oxides is given in Table 5.1.

Table 5.1

oxide	melting point / ˚C	pH of the resulting solution from the reaction with H_2O
A	2040	7
B	24	2
C	1132	13

(i) Describe the reactions, if any, of the oxides Na_2O and P_4O_{10} with water. Include the approximate pH value of any resulting solutions, and write equations for any reactions that occur.

……

……

……

……

……

……

……[4]

(ii) Hence, suggest the identity of **A, B** and **C**.

A	**B**	**C**

[2]

(iii) Explain, in terms of structure and bonding, why **A** has a higher melting point than **C**.

……

……

……

……

……

……[3]

(b) SO_2 is another oxide of a Period 3 element.

Draw a dot–and–cross diagram to show the bonding in a molecule of SO_2.

[1]

(c) When ethanoic acid reacts with ethanol, in the presence of concentrated sulfuric acid, to form ethyl ethanoate and water, the following equilibrium is established.

$$CH_3CO_2H(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3CO_2CH_2CH_3(l) + H_2O(l)$$

(i) Explain the purposes of adding concentrated sulfuric acid.

……..……...

……..……...

……..…...[2]

(ii) Write an expression for the equilibrium constant, K_c, for the reaction between ethanoic acid and ethanol.

[1]

(iii) Equimolar amounts of ethanoic acid and ethanol were mixed and at equilibrium, 1.00 mol of ethyl ethanoate is present.

Given that the value of K_c is 4.0, determine the initial amount (in mole) of ethanoic acid.

[2]

(iv) Predict what would happen to the amount of ethyl ethanoate if sodium hydroxide was added to the reaction mixture at equilibrium. Explain your answer.

Prediction: ……..

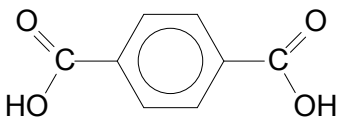
…….

Explanation: ……..

……[2]

(d) Polyesters are polymers formed from a dicarboxylic acid and a diol and they are mostly used in clothing, food packaging and plastic water and carbonated soft drinks bottles.

An example of a polyester is poly(ethylene terephthalate) (PET). Its monomer is synthesised from a condensation reaction between 1 mol of ethane–1,2–diol and 1 mol of benzene–1,4–dicarboxylic acid in the presence of a catalyst.



benzene–1,4–dicarboxylic acid

$HO—CH_2—CH_2—OH$

ethane–1,2–diol

(i) Write a balanced equation for the formation of the PET monomer.

……[1]

(ii) Bottles that are made of PET cannot be used to store alkaline cleaning solution. Bottles that are made of poly(propene) are used instead.

Explain, in terms of the bonds present in both polymers, why the above statements are true.

…….

…….

…….

…….....[2]

[Total: 20]

6 **(a)** The Russian composer Borodin was also a research chemist who discovered a reaction in which two ethanal molecules combine to form an aldol, 2–hydroxybutanal.

$$\underset{\text{ethanal}}{2CH_3CHO} \longrightarrow \underset{\text{2–hydroxybutanal}}{CH_3CH(OH)CH_2CHO}$$

(i) Suggest the type of reaction which takes place in the formation of 2–hydroxybutanal from ethanal. Explain your answer.

……

……

……[2]

(ii) Draw the displayed formula of 2–hydroxybutanal. Indicate clearly, in your answer, one bond angle which is 105° and one which is 120°.

[3]

On heating, 2–hydroxybutanal, $CH_3CH(OH)CH_2CHO$, forms compound **X**, C_4H_6O, which exists as a pair of isomers.

When compound **X** was heated with acidified $K_2Cr_2O_7$, compound **Y,** $C_4H_6O_2$ is formed. **Y** with reacts with sodium carbonate to produce carbon dioxide gas.

(iii) Suggest the type of reaction which occurs upon heating 2–hydroxybutanal.

……[1]

(iv) Draw the full structural formulae of the pair of isomers of **X**. Indicate clearly the type of isomerism by labelling the isomers.

[2]

(v) Suggest the structural formula of **Y**.

[1]

(b) An experiment was carried out to determine the order of reaction with respect to bromoethane in the following hydrolysis reaction with 0.10 mol dm^{-3} NaOH(aq).

$$CH_3CH_2Br + NaOH \longrightarrow CH_3CH_2OH + NaBr$$

Table 6.1 shows the data that was obtained from this experiment.

Table 6.1

time / min	$[CH_3CH_2Br]$ / mol dm^{-3}
0	0.0100
30	0.0084
60	0.0070
90	0.0058
120	0.0049
150	0.0041
180	0.0034

(i) The concentration of NaOH(aq) used in the experiment was in large excess relative to that of bromoethane. Suggest a reason why this is so.

……

……[1]

(ii) Plot a suitable graph using the grid provided on page 19 to determine the order of reaction with respect to the bromoethane. Show your working clearly.

order with respect to bromoethane: ……[3]

6 (b) (ii)

(iii) The order of reaction with respect to sodium hydroxide is found to be first order. Hence, construct a rate equation for the hydrolysis reaction.

……[1]

(iv) Use your graph to determine the initial rate of reaction.

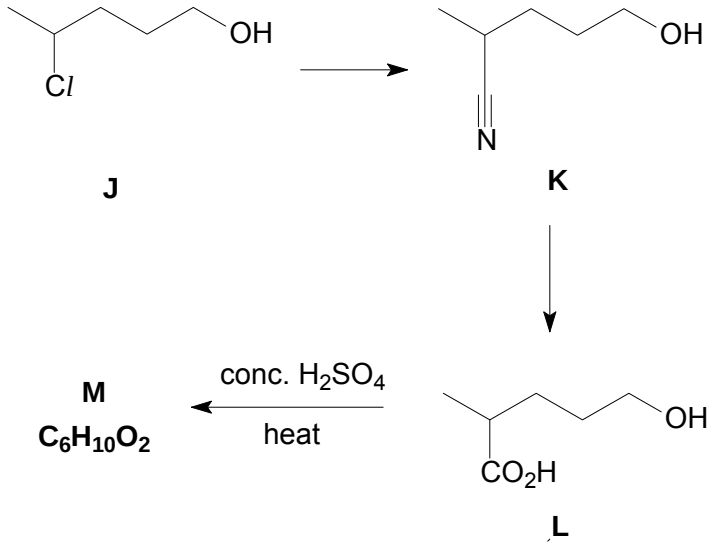
[1]

(v) Using your answer in **(b)(iv)** and other relevant experiment data given, calculate a value for the rate constant, stating its units.

[1]

(c) Use the table of characteristic values for infra–red absorption in the *Data Booklet* to answer this question.

Compound **J** undergoes a series of transformation as shown.



Infra–red absorptions can be used to identify functional groups in organic compounds. For example, compound **J** shows absorptions at 700 – 800 cm^{-1}, but not compounds **K** and **L**.

(i) Identify **two** infra–red absorption ranges that will be shown by **J**, **K** and **L**.

……[1]

(ii) Identify an infra–red absorption range that will be shown by **L** but not by **J** and **K**.

……[1]

(iii) The infra–red spectrum of **M** shows absorption in two ranges, 1050–1330 cm^{-1} and 1710–1750 cm^{-1}.

Suggest a structural formula for **M** and name the type of reaction which occurs in the last transformation step from **L** to **M**.

Type of reaction: …… [2]

[Total:20]

1 **(a)** Standard enthalpy change of combustion is the heat evolved when one mole of substance, in its standard state, is burnt in excess oxygen under standard conditions of 298 K and 1 bar. [2]

[1]: "heat evolved", "one mole", "excess oxygen"
[1]: 298 K and 1 bar

(b) ($CH_3CH_2OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$)

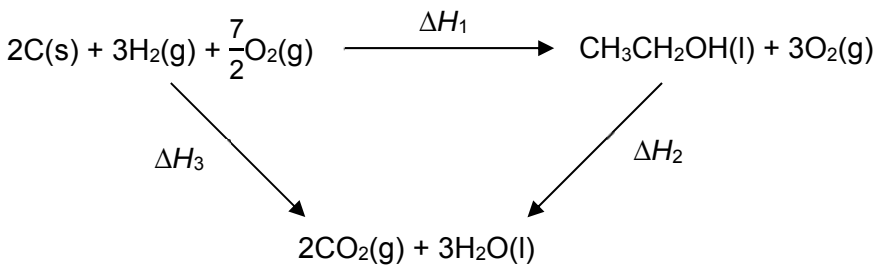
Heat absorbed by water (65% efficient) = $mc\Delta T$
= (100)(4.18)(65 – 20)
= 18810 J [1]

Heat evolved by combustion of ethanol (100%) = $\frac{18810}{0.65}$
= 28938 J
= 28.94 kJ [1]

Enthalpy change of combustion of ethanol = $-\frac{28.94}{\frac{1}{46}}$
= -1330 kJ mol^{-1} [1]

(c) **(i)** (standard) enthalpy change of formation of ethanol [1]

(ii) [3]



$\Delta H_1 = \Delta H_3 - \Delta H_2$
= [2(–393.5) + 3(–285.8)] – (–1330)
= –1644.4 + 1330
= –314 kJ mol^{-1}

[1]: application of Hess' Law
[1]: correct answer with sign (ecf)
[1]: correct units

(d) **(i)** 6 453 600 x 159 x 2.33 = 2.39 x 10^9 kg (3 s.f.) [1]

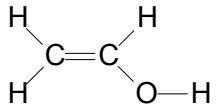
(ii) 1/100 x 2.33 = 0.0233 kg [1]

(iii) 0.1 x 0.0233 + 0.9 x 2.33 = 2.10 kg (3 s.f.) or 2.099 kg [1]

(iv) 6 453 600 x 159 x 2.10 / 1000 = 2.15 x 10^9 kg (3 s.f.) [1]

Reduction in CO_2 emission = 2.39 x 10^9 – 2.15 x 10^9 = 2.40 x 10^8 kg

Alternative
[(2.33 – 2.10) x 6 453 600 x 159] kg

(e) **(i)**  [1]

(ii) H_2 with Ni at high temperature and pressure [1]
or
H_2 with Pt / Pd, r.t.p

(iii) Hydrogen bonding [1]

(iv) [1]: Partial charges on O–H bond of PVA + O–H bond of water [2]
[1]: Show attraction between lone pair on O atom with H atom of O–H group

(v) The borate ion forms cross linkages via hydrogen bonds between PVA polymer molecules. [1]

(vi) dilute H_2SO_4, heat (accept NaOH(aq)) [1]

2 **(a)** A thermoplastic is a substance / polymer that softens on heated and hardens when cooled. [1]

(b) **(i)** LDPE has branched polymer chains; [1]
less close / less regular packing so weaker instantaneous dipole – induced dipole attraction [1]

HDPE has no / little branching in polymer chains; [1]
closer and regular packing so stronger instantaneous dipole – induced dipole attraction [1]

(ii) LDPE: plastic carrier bags or other similar low strength and flexible sheet materials [1]

HDPE: milk bottles and similar containers, washing up bowls, plastic pipes [1]

(c) **(i)** X: I_2 or iodine
Y: Cl_2 or chlorine (accept F_2 or fluorine)
Z: Br_2 or bromine

[2]: all correct
[1]: 1 or 2 correct

(ii) Chlorine, Cl_2 (accept Y_2) [1]

Chloride or Y^- not accepted

(iii) Although chlorine has the smallest nuclear charge, it has the least shielding effect / least number of electron shells. [1]

Valence shell of chlorine atom is closest to the nucleus hence the incoming electron that resides in it will be more strongly attracted / easily gained. [1]

(d) **(i)** Thermal stability: HC*l* > HBr > HI [1]

(ii) Down the group, H–X bond energy decreases from 431 to 299 kJ mol^{-1}. [1]

Reason:
- size of halogen atom increases
- bonding electrons are further from both nuclei
- and less strongly attracted to the two nuclei
- (H–X bond strength decreases)

[1]

(e) **(i)** Similarity: both are electrical conductors [1]

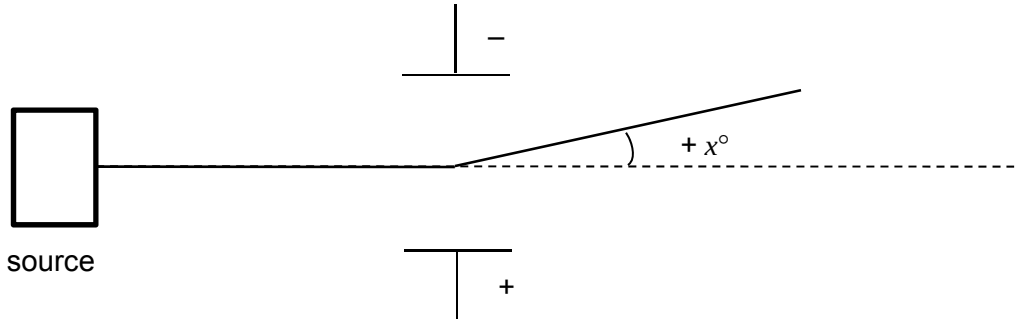
Difference: CNT is rigid but graphene is flexible. [1]

(ii) A dimension between 1 – 100 nm [1]

(iii) Via digestive tract / oral uptake [1]

Via the skin / dermal uptake [1]

3 (a) (i) [1]



The plate on top is negatively charged as the positively charged proton is attracted to it. [1]

(ii) **I**: $^{16}O^{2-}$ ions
q/m of proton = 1/1 [1]
q/m of $^{16}O^{2-}$ ions = 2/16 = 1/8 [1]
Hence, angle of deflection is 1/8 that of proton, and in the opposite direction / (towards positive plate),
$-x/8°$.

II: ^{4}He nuclei
q/m = 2/4 = ½ [1]
Hence, angle of deflection is 1/2 that of proton, $+x/2°$ (towards negative plate) [1]

III: ^{2}H atom
0°. The atom has no net charge and hence remains undeflected. [1]

(b) (i) **1s 2s 2p 3s 3p 4s 3d** [1]

(ii) **$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$** [1]

(iii) **4p** [1]

4 **(a)** n(acid) in 250 cm^3 = 2.29 / 104 = <u>0.0220 mol</u> [1]

n(acid) in 25 cm^3 = 0.0220 / 10 = <u>0.00220 mol</u> [1]

(b) Vol of NaOH needed for complete neutralisation = 22.00 cm^3 [1]

n(NaOH) = 22/1000 × 0.100 = <u>0.00220 mol</u>

(c) Since <u>n(acid) = n(NaOH)</u> [1]

It is a <u>monobasic</u> acid.

(d) $[H^+] = 10^{-2.2}$ = <u>6.31×10^{-3} mol dm^{-3}</u> [2]

[acid] = (2.29/104) / (250/1000) = <u>0.0881 mol dm^{-3}</u>

Since <u>$[H^+]$ < [acid]</u>, It only partially ionises in water, thus it is a weak acid.

[1]: $[H^+]$ and [acid]
[1]: link $[H^+]$ < [acid] to strength

(e) [2]

$$K_a = \frac{(6.31 \times 10^{-3})^2}{0.0881 - 6.31 \times 10^{-3}} \qquad \text{(accept} \approx \frac{(6.31 \times 10^{-3})^2}{0.0881}\text{)}$$

= <u>4.5×10^{-4} mol dm^{-3}</u>

Read from graph, when 11 cm^3 of NaOH(aq) was added, pH = pK_a (MBC occurs)
pK_a = 4.0 (accept 3.8 – 4.0)
$K_a = 1.0 – 1.6 \times 10^{-4}$

[1]: use K_a expression in working / recognise pH = pK_a at MBC
[1]: correct answer

(f) Volume of excess NaOH added = 45 – 22 = 23 cm^3 [1]
Amount of excess NaOH = 23/1000 x 0.100 = 2.30×10^{-3} mol

Total volume of solution = 25 + 45 = 70 cm^3
$[OH^-]$ = 0.0023/(70/1000)
= <u>0.0329 mol dm^{-3}</u>

(g) $[H^+][OH^-] = 1 \times 10^{-14}$
$[H^+] = (1 \times 10^{-14}) / 0.0329 = 3.04 \times 10^{-13}$ mol dm^{-3}

pH = – log (3.04×10^{-13}) = <u>12.5</u> [1]

(alternatively, find pOH and then 14 – pOH to get the pH)

5 **(a)** **(i)** Na_2O, dissolves readily in water to give an alkaline solution of pH 13 [1]

P_4O_{10} dissolves readily in water to give an acidic solution of pH 2. [1]

$Na_2O + H_2O \longrightarrow 2NaOH$ [1]

$P_4O_{10} + 6H_2O \longrightarrow 4H_3PO_4$ [1]

(ii) [2]

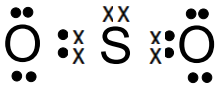
A	B	C
Al_2O_3	P_4O_{10}	Na_2O

1 mark for 1 correct identity
2 mark for 3 correct identity

(iii) Both Na_2O and Al_2O_3 have giant ionic structures with strong electrostatic forces of attraction between the oppositely charged ions. [1]

Since Al^{3+} has a higher charge and a smaller ionic radius than Na^+, [1]

the electrostatic attraction between Al^{3+} and O^{2-} is stronger. Hence more energy is required to break the stronger ionic bond resulting in a higher melting point for Al_2O_3. [1]

(b)  [1]

(c) **(i)** It acts as a catalyst that speeds up the forward and backward reaction such that the equilibrium can be achieved faster. [1]

Is a drying agent and remove water and shift position of equilibrium to the right. Yield of ester increases. [1]

(ii) $K_c = \dfrac{[CH_3CO_2CH_2CH_3][H_2O]}{[CH_3CO_2H][CH_3CH_2OH]}$ [1]

(iii)

	CH_3COOH (l)	+ CH_3CH_2OH (l)	$\rightleftharpoons$ $CH_3COOCH_2CH_3$ (l)	+ H_2O (l)
I / mol	x	x	0	0
C / mol	–1	–1	+1	+1
E / mol	x – 1	x–1	1	1

Let the volume of the reaction mixture be V dm^3

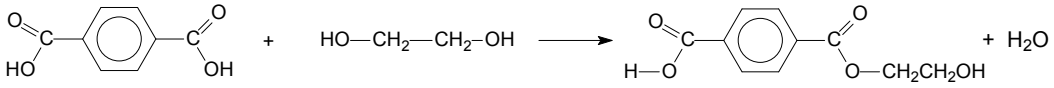
$$4 = \frac{\frac{1}{V} \times \frac{1}{V}}{\frac{x-1}{V} \times \frac{x-1}{V}}$$ [1]

4 = 1 / (x–1)(x–1)

(x–1)(x–1) = ¼
x –1 = ½
x = 1.5 mol
n(ethanoic acid) = 1.5 mol [1]

(iv) Amount of ethyl ethanoate would <u>decrease</u>. [1]

When sodium hydroxide is added, an <u>acid–base reaction</u> would take place between sodium hydroxide and ethanoic acid. This decreases the concentration of ethanoic acid which will <u>shift the POE to the left</u> to increase the concentration of ethanoic acid. [1]

(d) **(i)**  [1]

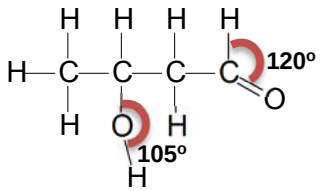
(ii) PET contains <u>ester bonds</u> which will be <u>hydrolysed</u> in the presence of alkaline solution. [1]

Poly(propene) contains <u>non polar C–C and C–H bonds</u> which are <u>inert</u> to alkaline solution. [1]

6 **(a)** **(i)** Addition [1]

Two molecules of ethanal react together to form one molecule of 2–hydroxybutanal. [1]

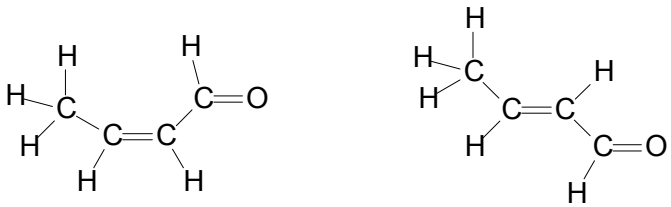
(ii)



Correct displayed formula [1]
Correct 120° bond angle [1]
Correct 105° bond angle [1]

(iii) Elimination of water [1]

(iv)



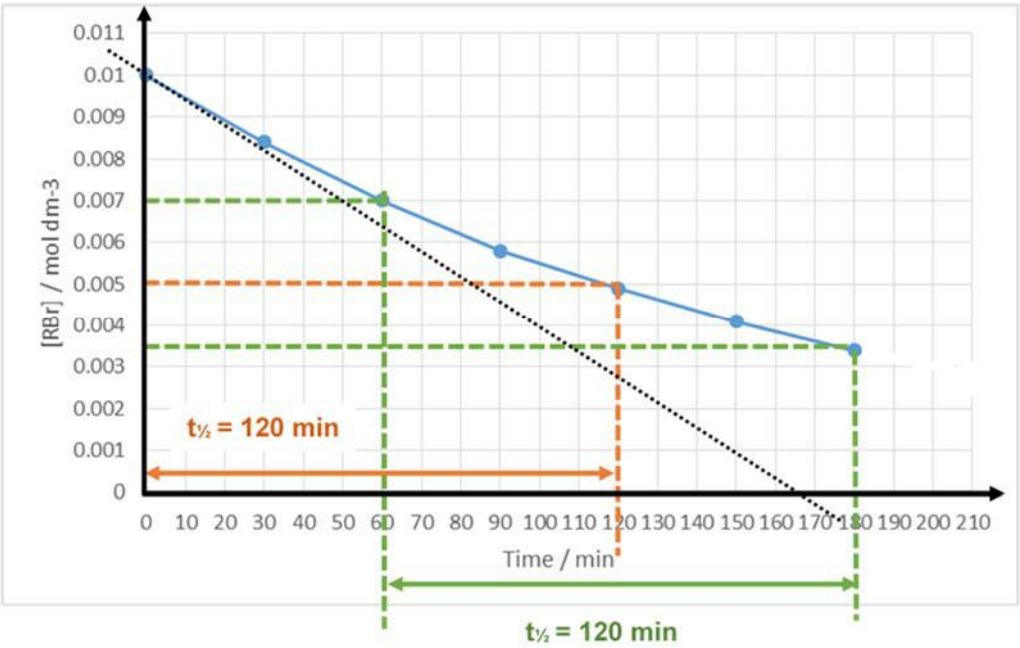
cis *trans*

Correct isomer and label [1] × 2 [2]

(v) **Y** is **$CH_3CH{=}CHCO_2H$** [1]

(b) **(i)** So that [NaOH] remains relatively constant and any change in rate of reaction is only due to change in [bromoalkane] [1]

(ii)



Correct axes with labels and units + smooth curve [1]
Construction lines to obtain of at least two $t_{½}$ + read $t_{½}$ correctly [1]
Explain that two or more $t_{1/2}$ are constant hence first order w.r.t. bromoethane [1]

(iii) **Rate = *k* [RBr] [NaOH]** [1]

(iv) From graph, initial rate = $\left(\frac{0.0100}{165}\right)$ [1]

= $\mathbf{6.06 \times 10^{-5}}$ (mol dm^{-3} min^{-1}) (ignore units)

- Draw gradient at t=0 min to determine initial rate and obtain value of 10^{-5}

(v) $k = \frac{6.06\times10^{-5}}{0.01\times0.10} \quad \frac{\text{mol dm}^{-3}\ \text{min}^{-1}}{\left(\text{mol dm}^{-3}\right)^2}$ [1]

= **0.0606 mol^{-1} dm^{3} min^{-1}**

- Correct k and units (allow ecf)

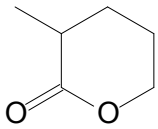
(c) **(i)** C–O bond of alcohol: 970–1260 (cm^{-1}) [1]
O–H bond of alcohol: 3580–3650 (cm^{-1})
C–H bond of alky group: 2850 – 2950 (cm^{-1})

[1]: any 2

(ii) C–O bond of carboxylic acids: 1210–1440 (cm^{-1}) [1]
C=O bond of carboxylic acids: 1680–1730 (cm^{-1})
O–H bond of carboxylic acids: 2500–3000 (cm^{-1})

[1]: any 1

(iii) [1]

M is 

Type of reaction: condensation / esterification

[1]

Catholic Junior College

JC 2 Preliminary Examinations

Higher 1

CHEMISTRY

8873/01

Paper 1 Multiple Choice

29 August 2018

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, HT group and NRIC/FIN number on the Answer Sheet in the spaces provided.
Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **12** printed pages

For each question there are ***four*** possible answers, ***A***, ***B***, ***C*** and ***D***. Choose the **one** you consider to be correct.

1 Rubidium is a soft, metallic element that has a relative atomic mass of 85.47. There are two forms of naturally occurring rubidium isotopes, ^{85}Rb and ^{87}Rb.
^{87}Rb is slightly radioactive.
What percentage of naturally occurring rubidium is radioactive?

A 11.8 **B** 23.5 **C** 35.3 **D** 76.5

2 10 cm^3 of hydrocarbon was burnt with 100 cm^3 of oxygen gas which is in excess. The resulting mixture was cooled to room temperature and the residual gases occupied a volume of 80 cm^3. After passing through sodium hydroxide, the volume of gas remaining is 40 cm^3.
What is the formula of the hydrocarbon?

A C_3H_6 **B** C_3H_8 **C** C_4H_8 **D** C_4H_{10}

3 Which of the following is true when equimolar amounts of NH_3 and BF_3 is reacted?

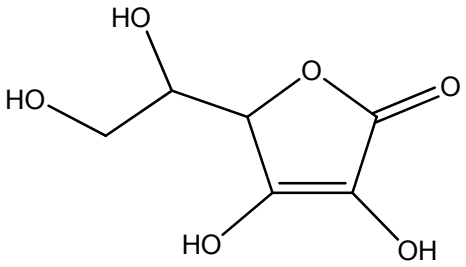
1 a dative covalent bond is formed between NH_3 and BF_3
2 N in NH_3 accepts a lone pair of electrons from B in BF_3
3 the shape around N in NH_3 changes from trigonal planar to tetrahedral
4 after mixing, the bond angle around B in BF_3 decreased from 120° to 109°

A 1 and 2 only
B 1 and 4 only
C 1, 3 and 4 only
D 3 and 4 only

4 *Use of Data Booklet is relevant to this question.*
How many hydrogen atoms are present in 111 g of propanoic acid?
[*L* = Avogadro constant]

A *L* **B** 1.5*L* **C** 7.5*L* **D** 9*L*

5 Ascorbic acid, commonly known as vitamin C, is an important dietary supplement as it is essential in the repairing of tissues and can also function as an antioxidant.



vitamin C

Which of the following shows the correct number of sigma and pi bonds present in one molecule of vitamin C?

	sigma bonds	pi bonds
A	11	2
B	16	2
C	20	1
D	20	2

6 The table below shows the boiling points of some halogenoalkanes.

halogenoalkane	boiling point/^{o}C
CH_3CH_2Cl	12.3
CH_3CH_2Br	34.8
CH_3CH_2I	70.0

Which of the following statements correctly explains the difference in the boiling point?

A the bond energy of C-X bond decreases from C-C*l* to C-I

B the strength of instantaneous dipole-induced dipole attraction increases from CH_3CH_2Cl to CH_3CH_2I

C the strength of permanent dipole-permanent dipole attraction increases from C-C*l* to C-I

D the electronegativity difference between the halogen and carbon increases from C-C*l* to C-I

7 The following information is true for substance **Z**.

- It exists as a solid state at room temperature and pressure
- It has a regular lattice structure at room temperature and pressure
- It does not conduct electricity in both solid and molten state

Which of the following could be substance **Z**?

A iodine
B graphene
C aluminium
D sodium chloride

8 *Use of the Data Booklet is relevant to this question.*

Radioactive carbon-14, ^{14}C, is often used to date archaeological and geological samples. Which species has the same number of neutrons and the same number of electrons as an atom of ^{14}C?

A $^{18}Ne^{2+}$ **B** $^{17}F^{+}$ **C** $^{16}O^{2+}$ **D** $^{14}N^{+}$

9 *Use of the Data Booklet is relevant to this question.*

The successive ionisation energies, in kJ mol^{-1}, of an element **X** are given below.

940 2045 3060 4140 6590 7895 14990

What is **X**?

A $_{33}As$ **B** $_{34}Se$ **C** $_{39}Y$ **D** $_{85}At$

10 Element **Y** is in period 3 and has melting point higher than the element before it. **Y** forms a chloride with low melting point which dissolves in water giving a solution of pH 2. What is **Y**?

A magnesium **B** aluminium **C** silicon **D** phosphorus

11 Which of the following statements about Group 17 elements and its compounds are true?

1 Atomic radius increases from chlorine to iodine mainly due to increasing number of electronic shells.
2 Iodine has a higher boiling point compared to chlorine because of stronger instantaneous dipole-induced dipole attraction
3 Hydrogen iodide is less stable to heat than hydrogen chloride due to weaker iodine-iodine bonds.

A 1 and 2 only
B 1 and 3 only
C 2 only
D 2 and 3 only

12 Which of the following will have the least exothermic lattice energy?

A barium oxide
B magnesium oxide
C barium sulfide
D magnesium sulfide

13 Hydrazine, N_2H_4, was used as fuel for the Apollo space mission, and it can be synthesised in an environmentally friendly manner according to the following reaction.

$$2NH_3(aq) + H_2O_2(l) \longrightarrow N_2H_4(l) + 2H_2O(l)$$

substance	**$\Delta H_f^{\ominus}$/ kJ mol^{-1}**
$H_2O(l)$	–286
$N_2H_4(l)$	+51
$NH_3(aq)$	–80
$H_2O_2(l)$	–174

Given the above enthalpy changes of formation, what is the enthalpy change of the above reaction in kJ mol^{-1}?

A −187
B −19
C +19
D +187

14 *Use of the Data Booklet is relevant to this question.*

Methanol (M_r 32) is a preferred fuel for high performance racing cars. When 1.00 g of methanol was burnt to heat up a copper can with 200 g of water, it was found that the temperature of the water rose by 27 °C.

Assuming there is no heat lost to the copper can or surrounding, which value for the enthalpy change of combustion of methanol is given by these results?

A −8026 kJ mol^{-1}
B −722 kJ mol^{-1}
C −251 kJ mol^{-1}
D −113 kJ mol^{-1}

15 Equal amounts of hydrogen and iodine were kept at a constant temperature of 723 K until equilibrium was reached. After which, rapid cooling was conducted to extract the iodine present for titration, and it was found that 0.07 mol of iodine was present.

$$I_2(g) + H_2(g) \rightleftharpoons 2HI(g) \qquad K_c = 48.2 \text{ at } 723 \text{ K}$$

What is the amount in moles of HI at equilibrium?

A 0.236 **B** 0.243 **C** 0.486 **D** 1.84

16 Methanol can be manufactured industrially, using a copper oxide catalyst at temperature of 575 K, according to the following reaction.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

Which of the following statements are correct?

1 The catalyst increases the equilibrium constant.
2 The catalyst increases the equilibrium yield.
3 At lower temperature the equilibrium yield will increase.
4 At lower temperature the equilibrium constant will increase.

A 1 and 2 only
B 2 and 3 only
C 1 and 4 only
D 3 and 4 only

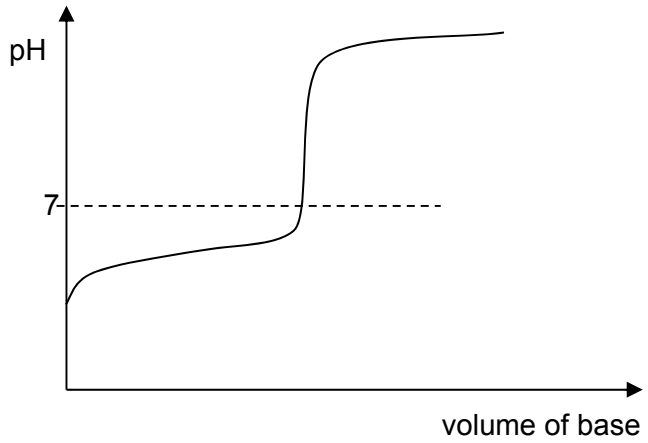
17 The Haber process is a key reaction in the industry for producing ammonia.
Which statement about Haber process is **not** correct?

A Iron is used as a heterogeneous catalyst to increase rate of production.
B Temperature of around 500 °C is used to increase the yield of ammonia.
C High pressure is preferred for this reaction as it increases the yield of ammonia.
D High pressure and temperature leads to an increase in the rate of production.

18 What is the final pH of the solution when equal volumes of 0.030 mol dm^{-3} of $Ba(OH)_2(aq)$ is mixed with 0.030 mol dm^{-3} of $HCl(aq)$?

A 1.5 **B** 1.8 **C** 12.2 **D** 12.5

19 Visual indicators are often used to determine the end point of acid-base titrations. A titration was carried out between a weak acid and a strong base and the titration graph obtained is shown below:



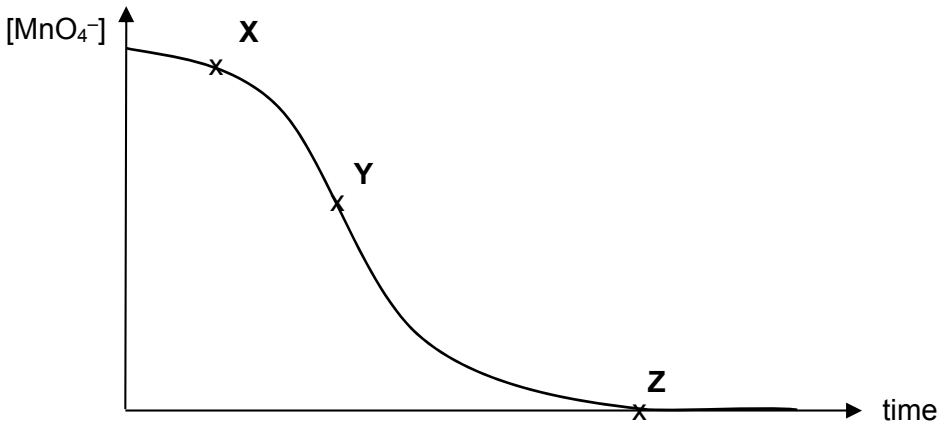
Which of the following is a suitable indicator for the above titration?

	Indicator	pH at which colour changes
A	Methyl violet	0 - 1
B	Bromocresol green	3 - 6
C	Bromothymol blue	6 - 7
D	Thymolphthalein	9 - 11

20 The reaction of manganate(VII), MnO_4^-, with oxalate, $C_2O_4^{2-}$ is a type of autocatalytic reaction whereby the product, manganate(II) ions, is the catalyst for the reaction.

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

The following graph was obtained when $[MnO_4^-]$ was plotted against time.



Which of the following can be deduced from the graph?

A Rate at point **X** is very slow indicating that the temperature is low.
B Rate at point **Y** fast due to the production of the catalyst.
C Rate at point **Z** is slow as the catalyst is saturated.
D Rate at point **Z** is slow as the reaction is zero order with respect to $[MnO_4^-]$.

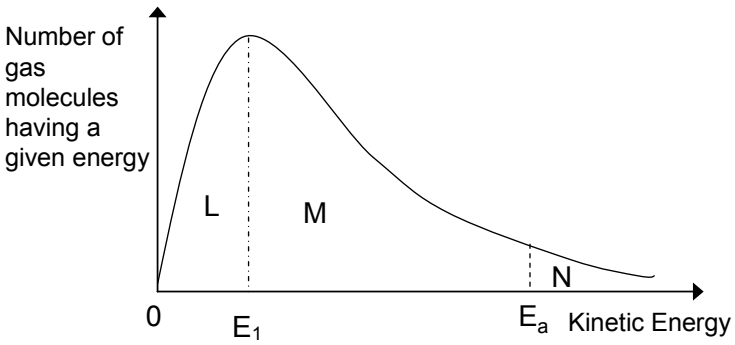
21 When aqueous solutions of HCO_2H and Br_2 are reacted together, initial rate of reaction was found to be 0.080 mol dm^{-3} s^{-1}.
Given that the rate equation is:

$$\text{rate} = k[Br_2][HCO_2H]$$

Which of the following shows the initial rate of reaction when the original reaction mixture was mixed with an equal volume of water?

A 0.010 mol dm^{-3} s^{-1}
B 0.020 mol dm^{-3} s^{-1}
C 0.040 mol dm^{-3} s^{-1}
D 0.080 mol dm^{-3} s^{-1}

22 The Boltzmann distribution at a constant temperature is shown below:
E_1 and E_a are fixed energy values.



If the temperature is decreased by 10 ºC, what happens to the size of the areas labelled **L**, **M** and **N**?

	L	**M**	**N**
A	decreases	decreases	decreases
B	decreases	increases	decreases
C	increases	decreases	decreases
D	increases	decreases	increases

23 The following table gives the approximate dimensions of certain substances.

	substance	**dimensions**
1	Fullerene (buckyball)	Diameter 0.71 nm
2	Red blood cell	Diameter of 8 μm, thickness of 2.5 μm
3	DNA strand	Diameter 2 nm, length up to 5 cm
4	Adenovirus	Diameter 90 nm

(1 μm = 1000 nm)

Which of these would be considered nanoparticles?

A 1 and 2 only
B 1, 2 and 4 only
C 1 and 4 only
D 2 and 3 only

24 Dishwasher pouches are small convenient packets that contain the detergent needed to be used in dishwashers. Such pouches are sturdy enough to be easily transported and safely handled by hand, yet dissolve easily when it is time to wash dishes. What could be the polymer that is used for the pouches?

A Polyvinyl alcohol
B Polyvinyl chloride
C Poly(diallyl phthalate)
D Poly(ethylene terephthalate)

25 The reaction scheme outlines the production of one of the monomers of nylon 66 from $Cl(CH_2)_4Br$.

$$Cl(CH_2)_4Br \xrightarrow{\text{step 1}} NC(CH_2)_4CN \xrightarrow{\text{step 2}} H_2N(CH_2)_6NH_2$$

What are the types of reactions for each stage?

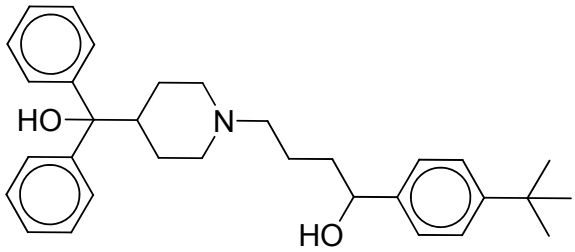
	step 1	**step 2**
A	substitution	oxidation
B	substitution	reduction
C	addition	addition
D	addition	reduction

26 Which of the following are true regarding polyester fabrics in comparison to polyamide fabrics?

1 Polyester fabrics tend to crease less easily than polyamide fabrics.
2 Polyester fabrics tend to be more easily stained by oil than polyamide fabrics.
3 Polyester fabrics tend to absorb more sweat than polyamide fabrics.

A 1 and 2 only
B 2 and 3 only
C 3 only
D 1, 2 and 3 only

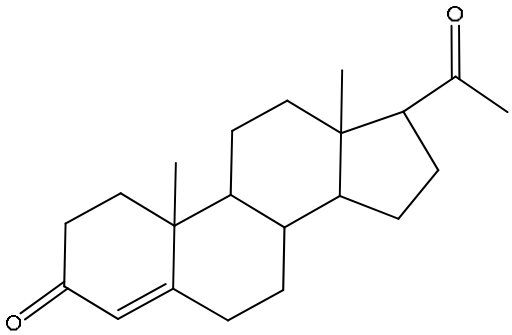
27 *Terfenadine* is an antihistamine formerly used for the treatment of allergic conditions. The structure of *terfenadine* is shown below:



Which functional group is not present in *terfenadine*?

A amine
B tertiary alcohol
C secondary alcohol
D phenol

28 Progesterone is a hormone which is involved in menstrual cycle and pregnancy. The following structure shows one molecule of progesterone.



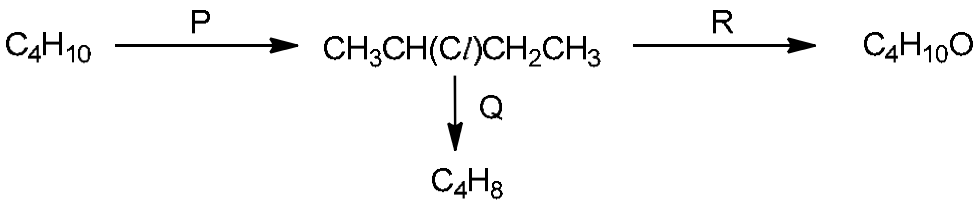
What is the molecular formula for the progesterone hormone?

A $C_{19}H_{14}O_2$ **B** $C_{19}H_{22}O_2$ **C** $C_{20}H_{30}O_2$ **D** $C_{21}H_{30}O_2$

29 Which of the following alcohols can be formed when a ketone is reduced with $NaBH_4$ dissolved in methanol?

A 2-methylpropan-1-ol
B 2-methylbutan-2-ol
C 3-methylbutan-2-ol
D 2,3-dimethylbutan-2-ol

30 The diagram shows a reaction scheme involving 2-chlorobutane, $CH_3CH(Cl)CH_2CH_3$.



Which of the following is true regarding the reaction scheme above?

1 both reactions P and R are substitution reactions
2 reaction Q is a reduction reaction
3 NaOH can be used in both reactions Q and R
4 two constitutional isomers with the molecular formula of C_4H_8 can be formed from reaction Q

A 1 and 2 only
B 1 and 3 only
C 1 ,3 and 4 only
D 2, 3 and 4 only

Catholic Junior College

JC2 Preliminary Examinations

Higher 1

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

Structured Questions

8873/02
17 August 2018
2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A – Answer **all** the questions**.**
Section B – Answer **one** question.

The use of an approved scientific calculator is expected where appropriate.
You are reminded of the need for good English and clear presentation in your answers.

A Data Booklet is provided.

The number of marks is given in brackets [ ] at the end of each question or part of the question.

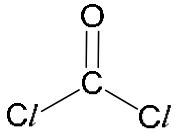
Section A	**Q1**	12
	Q2	6
	Q3	15
	Q4	6
	Q5	6
	Q6	15
Section B	**Q7**	20
	Q8	20
	Paper 2	80
	Paper 1	30
	Percentage	
	Grade	

This document consists of **20** printed pages

Section A

Answer **all** the questions in this section in the spaces provided.

1 (a) Phosgene, $COCl_2$ is a gas with many industrial uses. At high temperature, gaseous phosgene decomposes to carbon dioxide and chlorine in a dynamic equilibrium according to the following equation:



phosgene

$$(g) \rightleftharpoons CO(g) + Cl_2(g)$$

(i) Explain what is meant by the term *dynamic equilibrium.*

.....

.....

.....[1]

(ii) Write an expression for the equilibrium constant, K_c, for the reaction.

Calculate its value when, at equilibrium, the concentrations of $COCl_2(g)$, $CO(g)$, and $Cl_2(g)$ are 0.219 mol dm^{-3}, 0.530 mol dm^{-3} and 0.530 mol dm^{-3} respectively.

[2]

(iii) A certain amount of phosgene was added and the new equilibrium concentration of phosgene is 0.290 mol dm^{-3}. Calculate the new equilibrium concentration of CO(g).

[1]

(iv) Calculate the amount in moles of phosgene added in part **(iii)**, given that the volume of the container is 3 dm^3.

[2]

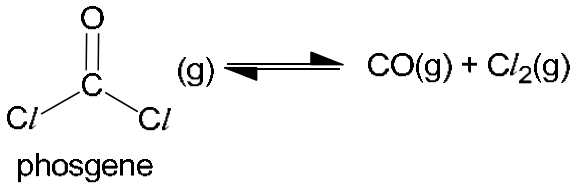
(b) Predict and explain how a decrease in pressure of the system will affect the position of equilibrium.

.....

.....

.....[2]

(c) **(i)** By using bond energy values from the *Data Booklet,* calculate the enthalpy change for the decomposition of phosgene as shown below:



[2]

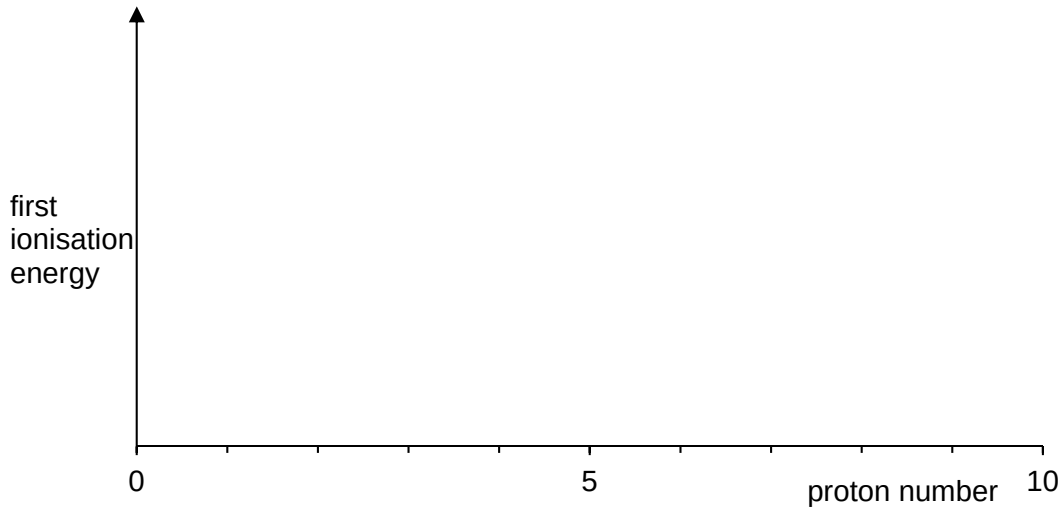
(ii) Use your answer from part **(i)** to sketch a reaction pathway diagram for the decomposition of phosgene. Draw a labelled arrow to show the enthalpy change on your diagram.

[2]
[Total: 12]

2(a) Write an equation to show the first ionisation energy of oxygen.

……[1]

(b) Sketch how the first ionisation energies of the elements change from lithium to fluorine.



[1]

(c) Explain why the first ionisation energy of oxygen is lower than

- nitrogen

.....

.....

.....

.....

.....[2]

- fluorine

.....

.....

.....

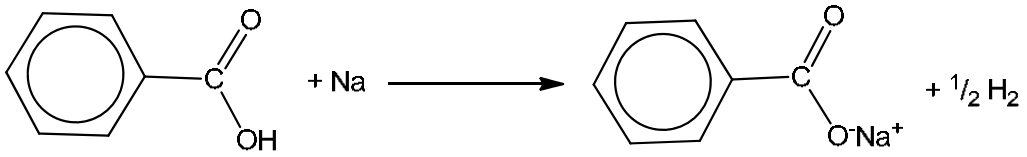
.....

.....[2]

[Total: 6]

3 Benzoic acid, $C_6H_5CO_2H$, and its salts are often used as food preservatives in fruit juices and other acidic food. They are represented by the E-numbers, E210 to E213 when added as preservatives since they are able to inhibit the growth of mould, yeast and some forms of bacteria.

(a) Sodium metal is added to form the salt of benzoic acid, as shown in the following equation.



benzoic acid sodium benzoate

(i) 5.00 g of sodium metal was added to 0.01 moles of benzoic acid. Calculate the volume of gas produced at standard temperature and pressure for the above reaction.

[2]

(ii) Explain why sodium benzoate is highly soluble in water but benzoic acid is only partially soluble in water.

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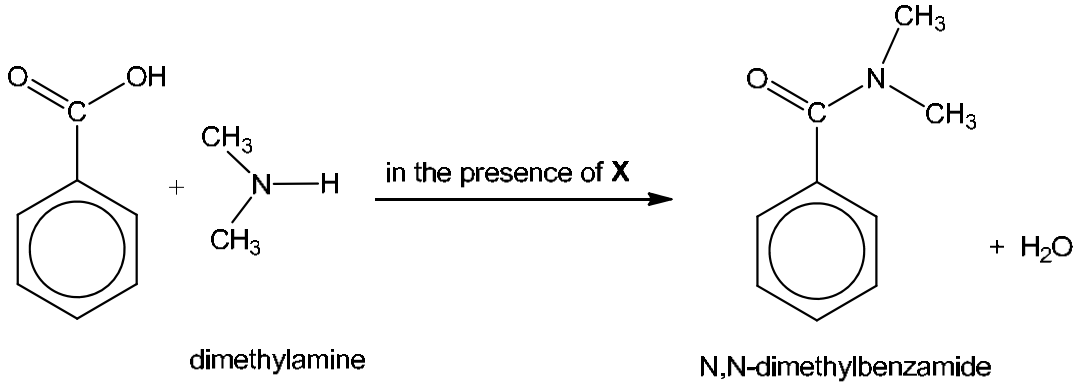
.....[4]

(b) Benzoic acid can also react with amines to produce amides as shown in the following equation.



(i) Name the type of reaction shown by the above equation.

.....[1]

(ii) Identify **X** which is required for the above reaction to occur.

.....[1]

(iii) State the shape and bond angle around the N atom in dimethylamine.

Shape: ……

Bond angle: ……

[1]

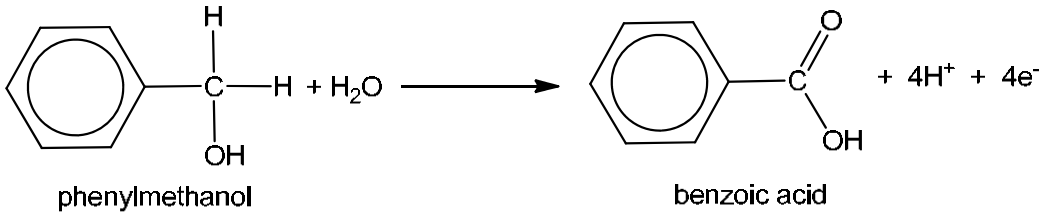
(iv) Suggest a reason why the reaction above would **not** occur if dimethylamine is replaced by trimethylamine, $(CH_3)_3N$.

.....

.....[1]

(c) Benzoic acid can be produced by oxidising phenylmethanol, $C_6H_5CH_2OH$. A suitable oxidising agent for this reaction is hot acidified $KMnO_4$.

The half equation for the oxidation of phenylmethanol is as follows:



(i) State the colour change observed when phenylmethanol reacts with hot acidified $KMnO_4$.

.....[1]

(ii) Use the *Data Booklet* and the half equation given above to construct a balanced equation for the oxidation of phenylmethanol by hot acidified $KMnO_4$.

.....[1]

(iii) A pipette was used to transfer 25.0 cm^3 of 0.15 mol dm^{-3} of phenylmethanol into a conical flask. Calculate the minimum volume of 0.20 mol dm^{-3} of acidified $KMnO_4$ required to completely oxidise the phenylmethanol in the conical flask.

[2]

(iv) Draw the structure of the product formed when phenylmethanol reacts with acidified $K_2Cr_2O_7$ with immediate distillation (controlled oxidation).

[1]

[Total: 15]

4 Carbon monoxide is a reagent used in an industrial process called hydroformylation. During hydroformylation, high pressure is used and the carbon monoxide reacts with an alkene and hydrogen gas to form an aldehyde.

The equation below shows an example of this process.

$$CO(g) + CH_3CH{=}CH_2(g) + H_2(g) \rightleftharpoons \underset{\text{aldehyde}}{C_4H_8O(g)}$$

(a) In the space below, draw the two possible constitutional isomers of C_4H_8O that are produced in the reaction above.

[2]

(b) The hydroformylation process is important because aldehydes are easily converted into many products. State the type of reaction that has occurred when an aldehyde is converted to a carboxylic acid.

……[1]

(c) While the hydroformylation process uses rhodium catalyst in its soluble form, elemental rhodium is used in its nanoparticle form as a *heterogeneous catalyst* for other reactants. Explain the term *heterogeneous catalyst* as fully as you can.
Briefly explain why rhodium in its nanoparticle form works as a better catalyst than in its bulk form.

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……[3]

[Total: 6]

5 Poly(diallyl phthalate) is an example of a cross linked, thermoset polymer. It is suitable for use in high-performance military electrical components because of its ability to retain its properties when subjected to extreme environmental conditions of high temperature and high humidity.

(a) **(i)** Draw the structure of the monomer of poly(diallyl phthalate) and state the functional group that allows the monomer to become a cross-linked polymer.

[2]

(ii) Explain, with reference to its structure and bonding, why it is able to retain its properties under the extreme environmental conditions stated above.

……

……

……

……

……

……[2]

(b) Calcium alginate is also a cross-linked polymer but its properties vary greatly from poly(diallyl phthalate). Each calcium ion can attach to two alginate polymer strands to form cross-links. Calcium alginate is used in wound dressings. When the dressing needs to be changed, the wound can be rinsed with a solution that will break the cross-links. Suggest a suitable solution that can be used and briefly explain why the cross links are broken.

……

……

……

……[2]

[Total: 6]

6 Oleic acid is a type of fatty acid that is present in avocados. Oleic acid has the following structure:

$$CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$$

Oleic acid has the cis configuration around the C=C double bond, whereas elaidic acid is the trans isomer of oleic acid.

(a) Draw the condensed structural formulae of oleic acid and elaidic acid, showing clearly the configuration about the C=C in each acid.

oleic acid:

elaidic acid:

[2]

Avocado flesh turns brown rapidly upon exposure to oxygen in the air. In the presence of oxygen, enzymes in the avocado help in the formation of a class of compounds called quinones. Quinones are capable of producing polymers called polyphenols that give the brown colour.

(b)(i) Suggest a simple method that can be done at home to slow down the browning of avocado flesh. Give a brief explanation to support your suggestion.

……

……

……[1]

(ii) Define the term, *polymer*.

……

……[1]

(iii) 1,2-benzoquinone is an example of a quinone. It contains 66.7% carbon and 3.7% hydrogen. The rest of the molecule comprises of oxygen which is present as two ketone functional groups in a molecule of 1,2-benzoquinone.
Calculate the empirical formula of 1,2-benzoquinone. Hence, deduce the molecular formula of 1,2-benzoquinone, stating clearly how you arrived at your answer.

[3]

(iv) In a molecule of 1,2-benzoquinone, the two ketone functional groups are on adjacent carbon atoms in a cyclic structure. Using this information and your answer in **(iii)**, draw the skeletal structure of 1,2-benzoquinone.

[1]

Avocados ripen faster if they are put in a plastic bag with some bananas. Bananas produce trace amounts of ethene gas which functions as a ripening hormone in fruits.

(c) Draw a dot-and-cross diagram to show the bonding in ethene. Describe this bonding in terms of orbital overlap.

[4]

Bananas are usually picked from their plantations when they are unripe. But the production of ethene can quickly ripen the fruits during transportation. Hence, to slow down the ripening process, 1-methylcyclopropene is used because it binds tightly to the ethene receptor in the fruits and therefore blocks the effect of ethene.

(d) **(i)** Draw the structure of 1-methylcyclopropene.

[1]

(ii) Explain why 1-methylcyclopropene has a higher boiling point than ethene.

……

……

……

……

[2]

[Total: 15]

Section B

Answer **one** question in the spaces provided.

7(a) Carbonic acid is a weak acid that partially dissociates in water according to the following equation:

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$

The K_a of carbonic acid is 4.5×10^{-7} mol dm^{-3}.

The hydrogencarbonate ion, $HCO_3^-(aq)$, can also behave as weak acid in water:

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq)$$

The K_a of hydrogencarbonate is 5.0×10^{-11} mol dm^{-3}.

(i) State the relationship between carbonic acid and the hydrogencarbonate ion.

……

……

…… [1]

(ii) Write the K_a expression for hydrogencarbonate ion and briefly explain why this K_a value is much smaller than the K_a value for carbonic acid.

……

……

…… [2]

(iii) The hydrogencarbonate ion is part of the buffer in the blood.
Define *buffer* and explain how $HCO_3^-(aq)$ reacts with acid in the blood. Support your answer with a suitable equation.

……

……

……

…… [2]

(b) The hydroxyl radical, represented by •OH, is highly reactive and short lived. It is often referred to as the "detergent" of the atmosphere because it reacts with greenhouse gases such as methane.

$$CH_4 + \bullet OH \rightarrow \bullet CH_3 + H_2O$$

A study of the rate of this reaction in a mixture, gave the following results. The initial concentration of methane for this study was much larger than concentration of hydroxyl radical and assumed to be constant throughout the reaction.

Time after start of reaction / x 10^{-4} s	**relative [•OH]**
0.0	10.0
1.0	7.0
2.0	5.0
3.0	3.5
4.0	2.5
5.0	1.8

(i) Define the term *half-life* of a reaction.

Use the data in the table to deduce the half-life of the reaction and to show that the reaction is first order with respect to [•OH].

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……[3]

(ii) Assume that the order of reaction with respect to [CH_4] is 1, state how the half-life of the reaction would change if:

Initial [CH_4] is doubled:

……

Initial relative [•OH] is halved:

……[2]

(c) Describe reactions that illustrate the variation in acid-base behaviour of the oxides of the elements in Period 3, using MgO, Al_2O_3, and SO_3 as examples.
Write equations for all the reactions you describe.

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.....[5]

(d) Alkane **A**, C_4H_{10}, reacts with bromine under UV light to produce only two different mono-brominated products, **B** and **C** in the likely ratio of 9:1. When reacted with alcoholic KOH, both **B** and **C** produce hydrocarbon **D**, C_4H_8.

(i) Suggest structures for **A**, **B**, **C** and **D**. Label the structures clearly.

[3]

(ii) Describe a simple chemical test to distinguish between **A** and **D**.

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.....[2]

[Total: 20]

8(a) The table below gives the acid dissociation constants, K_a, of three acids at 25 °C.

Acid	Formula	K_a / mol dm^{-3}
Methanoic acid	HCO_2H	1.8×10^{-4}
Ethanoic acid	CH_3CO_2H	1.5×10^{-5}
Chloroethanoic acid	CH_2ClCO_2H	1.3×10^{-3}

(i) From the K_a values, identify the strongest of the three acids and write the K_a expression for the acid you identified.

[2]

(ii) A student needed to select one of the three acids above to prepare a buffer solution of pH 3.80. The acid chosen has to have a pK_a that is closest to the pH value of the buffer solution.

Define the term *buffer*.
Identify the acid chosen for the preparation of the buffer and briefly explain how the buffer can be prepared (calculation of actual amounts is not required.)

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…… [3]

(b) 2-bromopropane, $CH_3CHBrCH_3$, can be hydrolysed by KOH(aq) to form propan-2-ol. Results of an investigation into the kinetics of this reaction are given below.

Expt number	$[CH_3CHBrCH_3]$ / mol dm^{-3}	[KOH] / mol dm^{-3}	Relative initial rate
1	0.10	0.20	1.00
2	0.60	0.40	6.00
3	0.30	0.20	3.00

(i) Define the term *order of reaction*.
Use the data in the table to deduce the order of reaction with respect to each reagent.

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……[3]

(ii) Write an overall rate equation for the reaction between $CH_3CHBrCH_3$ and KOH and state the units of the rate constant.

……..

……[2]

(c) The oxides Na_2O, Al_2O_3, and P_4O_{10} differ considerably in their chemical properties. Describe what happens when separate samples of each oxide are added to water Give equations where appropriate and state clearly why if no reactions occur.

What is the effect of adding universal indicator to each resulting solution?

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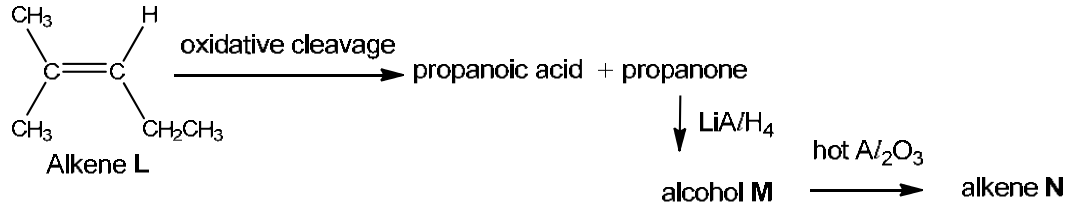
.....[5]

(d) When reacted with a strong oxidising agents under high temperature, alkenes can undergo *oxidative cleavage* reactions. Such reactions involve the complete breaking of the C=C bonds in the alkenes to give carbon-oxygen bonds such as C-O or C=O. These new bonds are part of functional groups such as carboxylic acids and ketones.

Alkene **L** undergoes oxidative cleavage to produce propanoic acid and propanone. Propanone is able to undergo further reactions. The reaction scheme is shown below.



(i) Deduce the structures of **M** and **N**. [2]

Propanoic acid produced from alkene **L** reacts with alcohol **M** to give a sweet smelling organic compound.

(ii) State the type of reaction that has taken place.

.....[1]

(iii) Draw the structure of the organic product produced. [1]

(iv) Draw the structure of the organic product produced when alkene **N** undergoes oxidative cleavage. [1]

[Total: 20]

Catholic Junior College

JC 2 Preliminary Examinations

Higher 1

CHEMISTRY

8873/01

Paper 1 Multiple Choice

29 August 2018

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, HT group and NRIC/FIN number on the Answer Sheet in the spaces provided.
Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

WORKED SOLUTIONS

This document consists of **12** printed pages

For each question there are ***four*** possible answers, ***A***, ***B***, ***C*** and ***D***. Choose the **one** you consider to be correct.

1 Rubidium is a soft, metallic element that has a relative atomic mass of 85.47. There are two forms of naturally occurring rubidium isotopes, ^{85}Rb and ^{87}Rb.
^{87}Rb is slightly radioactive.
What percentage of naturally occurring rubidium is radioactive?

A 11.8 **B** 23.5 **C** 35.3 **D** 76.5

Concept: calculate the relative atomic mass of an element given the relative abundances of its isotopes

Answer: **B**

Let the % of ^{87}Rb be *x*.

Hence, the % of ^{85}Rb is (100-*x*).

A_r of Rb = $\frac{87x+85(100-x)}{100}=85.47$

x = 23.5%

2 10 cm^3 of hydrocarbon was burnt with 100 cm^3 of oxygen gas which is in excess. The resulting mixture was cooled to room temperature and the residual gases occupied a volume of 80 cm^3. After passing through sodium hydroxide, the volume of gas remaining is 40 cm^3.
What is the formula of the hydrocarbon?

A C_3H_6 **B** C_3H_8 **C** C_4H_8 **D** C_4H_{10}

Concept: perform calculations, including use of the mole concept, involving: volumes of gases (e.g. in the burning of hydrocarbons)

Answer: C

	C_xH_y	+ (x+y/4) O_2	→	xCO_2	+ (y/2) H_2O
Initial vol/cm^3:	10	100		0	
Final vol/cm^3:	0	40		80-40=40	
Change in vol/cm^3:	10	60		40	
Ratio:	1	6		4	

By inspection, x = 4,
(x+y/4) = 6,
Solving for y, y=8.
Therefore, the hydrocarbon is C_4H_8.

3 Which of the following is true when equimolar amounts of NH_3 and BF_3 is reacted?

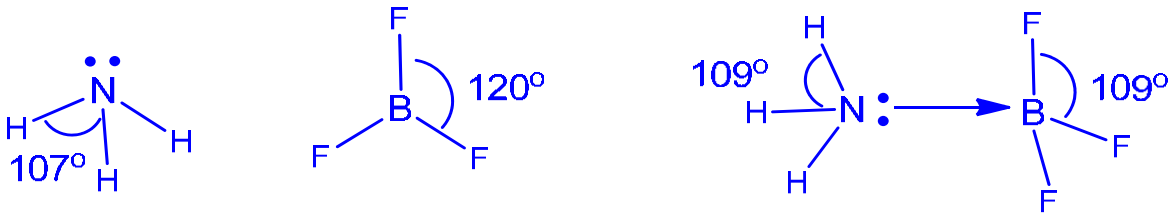
1 a dative covalent bond is formed between NH_3 and BF_3
2 N in NH_3 accepts a lone pair of electrons from B in BF_3
3 the shape around N in NH_3 changes from trigonal planar to tetrahedral
4 after mixing, the bond angle around B in BF_3 decreased from 120° to 109°

A 1 and 2 only
B 1 and 4 only
C 1, 3 and 4 only
D 3 and 4 only

Concept: dative covalent bonds, bond angles and shapes

Answer: B (1 and 4 only)

Since B in BF_3 only has 6 valence electrons, it can form a dative covalent bond with NH_3 where N donates a lone pair of electrons to B.



before mixing

after mixing

	NH_3	BF_3
Before mixing	Shape: trigonal pyramidal Bond angle: 107°	Shape: trigonal planar Bond angle: 120°
After mixing	Shape: tetrahedral Bond angle: 109°	Shape: tetrahedral Bond angle: 109°

4 *Use of Data Booklet is relevant to this question.*
How many hydrogen atoms are present in 111g of propanoic acid?
[*L* = Avogadro constant]

A *L* **B** 1.5*L* **C** 7.5*L* **D** 9*L*

Concept: MCS, understanding of Avogadro's constant

Answer: D

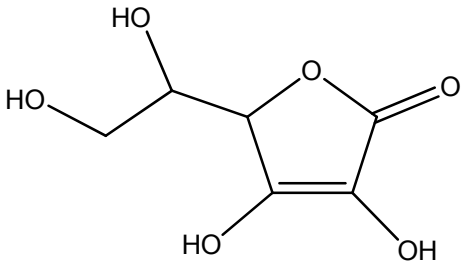
No. of moles of $CH_3CH_2CO_2H$ = 111 ÷ (12x3+ 6(1)+2(16)) = 1.5

$CH_3CH_2CO_2H$ ≡ 6H

No. of moles of H = 6(1.5) = 9

No. of H atoms = 9*L*

5 Ascorbic acid, commonly known as vitamin C, is an important dietary supplement as it is essential in the repairing of tissues and can also function as an antioxidant.



vitamin C

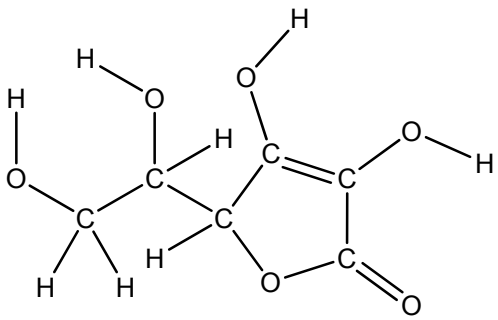
Which of the following shows the correct number of sigma and pi bonds present in one molecule of vitamin C?

	sigma bonds	pi bonds
A	11	2
B	16	2
C	20	1
D	20	2

Concept: identifying sigma and pi bonds in covalent bonds

Answer: D

All single bonds are sigma bonds. The double bonds are each one sigma and one pi. Hence, there are 20 sigma bonds and 2 pi bonds (1 in C=C and 1 in C=O) in one molecule of vitamin C.



6 The table below shows the boiling points of some halogenoalkanes.

halogenoalkane	boiling point/°C
CH_3CH_2Cl	12.3
CH_3CH_2Br	34.8
CH_3CH_2I	70.0

Which of the following statements correctly explains the difference in the boiling point?

A the bond energy of C-X bond decreases from C-C*l* to C-I

B the strength of instantaneous dipole-induced dipole attraction increases from CH_3CH_2Cl to CH_3CH_2I

C the strength of permanent dipole-permanent dipole attraction increases from C-C*l* to C-I

D the electronegativity difference between the halogen and carbon increases from C-C*l* to C-I

Concept: Chemical bonding (IMF), using IMF to explain for the trend of boiling point

Answer: B

A the bond energy of C-X bond decreases from C-C*l* to C-I

Statement is correct but boiling does not break the C-X bond, so this **does not** explain for the trend of **increasing** boiling point from CH_3CH_2Cl to CH_3CH_2I.

B the strength of instantaneous dipole-induced dipole attraction increases from CH_3CH_2Cl to CH_3CH_2I

Statement is **correct** as the total number of electrons increases from CH_3CH_2Cl to CH_3CH_2I and due to the increase in strength of id-id attraction. Hence, the boiling point increases from CH_3CH_2Cl to CH_3CH_2I.

C the strength of permanent dipole-permanent dipole attraction increases from C-C*l* to C-I

The C-C*l* bond is the most polar (compared to C-Br and C-I) hence the chloroalkane is expected to have the strongest intermolecular pdpd. Hence this statement is incorrect. But students need to note that in spite of the chloroalkane being expected to have the strongest intermolecular pdpd, the trend shows that the increase in idid strength due to the increase in number of electrons is the dominant factor that gives rise to the observed trend.

D the electronegativity difference between the halogen and carbon should **decrease** from C-C*l* to C-I

Also, the statement **does not** explain for the trend of increasing boiling point from CH_3CH_2Cl to CH_3CH_2I.

7 The following information is true for substance **Z**.

- It exists as a solid state at room temperature and pressure
- It has a regular lattice structure at room temperature and pressure
- It does not conduct electricity in both solid and molten state

Which of the following could be substance **Z**?

A iodine

B graphene

C aluminium

D sodium chloride

Concept: describe, interpret and/or predict the effect of different types of structure and bonding on the physical properties of substances

Answer: A

B graphene (conducts electricity in solid state)

C aluminium (conducts electricity in solid state)

D sodium chloride (conducts electricity in molten state)

8 *Use of the Data Booklet is relevant to this question.*

Radioactive carbon-14, ^{14}C, is often used to date archaeological and geological samples. Which species has the same number of neutrons and the same number of electrons as an atom of ^{14}C?

A $^{18}Ne^{2+}$ **B** $^{17}F^{+}$ **C** $^{16}O^{2+}$ **D** $^{14}N^{+}$

Concept: Atomic Structure, deduce the numbers of neutrons and electrons in given species.

Answer: C

	^{14}C	$^{18}Ne^{2+}$	$^{17}F^{+}$	$^{16}O^{2+}$	$^{14}N^{+}$
No. of Protons	6	10	9	8	7
No. of Neutrons	14 – 6 = 8	18 – 10 = 8	17 – 9 = 8	16 – 8 = 8	14 – 7 = 7
No. of Electrons	6	10 – 2 = 8	9 – 1 = 8	8 – 2 = 6	7 –1 = 6

9 *Use of the Data Booklet is relevant to this question.*

The successive ionisation energies, in kJ mol^{-1}, of an element **X** are given below.

940 2045 3060 4140 6590 7895 14990

What is **X**?

A $_{33}As$ **B** $_{34}Se$ **C** $_{39}Y$ **D** $_{85}At$

Concept: Atomic Structure, interpret successive ionisation energy data of an element in terms of the position of that element within the Periodic Table

Answer: B
The successive ionisation energies show a large increase from the sixth to seventh ionisation energy, hence there are six valence electrons, indicating that it should be element of Group 16.

10 Element **Y** is in period 3 and has melting point higher than the element before it. **Y** forms a chloride with low melting point which dissolves in water giving a solution of pH 2. What is **Y**?

A magnesium **B** aluminium **C** silicon **D** phosphorus

Concept: Periodic Table
Answer: C

Magnesium, aluminium and silicon all have melting points higher than the respective elements before them. But only the chlorides of aluminium and silicon have low melting points (covalent chlorides). The pH of the solution of aluminium chloride will be about pH 4 or 3. Silicon chloride undergoes complete hydrolysis to produce HCl, hence resulting in a solution of pH 2 or less.

11 Which of the following statements about Group 17 elements and its compounds are true?

1 Atomic radius increases from chlorine to iodine mainly due to increasing number of electronic shells.
2 Iodine has a higher boiling point compared to chlorine because of stronger instantaneous dipole-induced dipole attraction
3 Hydrogen iodide is less stable to heat than hydrogen chloride due to weaker iodine-iodine bonds.

A 1 and 2 only
B 1 and 3 only
C 2 only
D 2 and 3 only

Concept: Periodic Table – Group 17
Answer: A

1 True. An atom of fluorine has 2 electron shells, chlorine has 3 electron shells etc.

2 Group 17 elements exist as non-polar molecules, which have intermolecular instantaneous dipole-induced dipole attractions. Due to the increase in number of electrons, the idid gets stronger down the group and more energy is required to overcome these. Hence, the higher boiling point of iodine compared to chlorine.

3 The thermal stability of hydrogen halides decreases down the group, due to decrease in bond strength of the H–X bond, not the X-X bond.

12 Which of the following will have the least exothermic lattice energy?

A barium oxide
B magnesium oxide
C barium sulfide
D magnesium sulfide

Concept: Energetics, effect of ionic radius on the numerical magnitude of lattice energy

Answer: C

LE $\propto -\left|\frac{q^+q^-}{r^++r^-}\right|$, in this case, both q^+ and q^- are the same at +2 and –2 respectively. However, comparing sulfide, S^{2-} and oxide O^{2-}, **sulfide will have the larger ionic radius**, r_-, while barium ion, **Ba^{2+} will also have the larger ionic radius**, r^+, due to **increased shielding effect** as there are more electron shells which is **more significant than the increase in nuclear charge**, as compared to O^{2-} and Mg^{2+} respectively.

13 Hydrazine, N_2H_4, was used as fuel for the Apollo space mission, and it can be synthesised in an environmentally friendly manner according to the following reaction.

$$2NH_3(aq) + H_2O_2(l) \longrightarrow N_2H_4(l) + 2H_2O(l)$$

substance	**$\Delta H_f^\ominus$/ kJ mol^{-1}**
$H_2O(l)$	–286
$N_2H_4(l)$	+51
$NH_3(aq)$	–80
$H_2O_2(l)$	–174

Given the above enthalpy changes of formation, what is the enthalpy change of the above reaction in kJ mol^{-1}?

A −187
B −19
C +19
D +187

Concept: Energetics, apply Hess' Law to carry out calculations involving given simple energy cycles and relevant energy terms (restricted to enthalpy changes of formation

Answer: A

$\Delta H_r^\ominus = \sum\Delta H_f^\ominus(\text{products}) - \sum\Delta H_f^\ominus(\text{reactants})$
$= [+51 + 2(-286)] - [2(-80) + (-174)] = \underline{-187 \text{ kJ mol}^{-1}}$

14 *Use of the Data Booklet is relevant to this question.*

Methanol (M_r 32) is a preferred fuel for high performance racing cars. When 1.00 g of methanol was burnt to heat up a copper can with 200 g of water, it was found that the temperature of the water rose by 27 °C.

Assuming there is no heat lost to the copper can or surrounding, which value for the enthalpy change of combustion of methanol is given by these results?

A −8026 kJ mol^{-1}
B −722 kJ mol^{-1}
C −251 kJ mol^{-1}
D −113 kJ mol^{-1}

Concept: Energetics, calculate enthalpy changes with the use heat change = *mcΔT*
Answer: B

$\Delta H_c = \frac{-mc\Delta T}{n} = \frac{-200 \times 4.18 \times 27}{\frac{1}{32}}$ = –722305 J mol^{-1} = –722 kJ mol^{-1}

15 Equal amounts of hydrogen and iodine were kept at a constant temperature of 723 K until equilibrium was reached. After which, rapid cooling was conducted to extract the iodine present for titration, and it was found that 0.07 mol of iodine was present.

$$I_2(g) + H_2(g) \rightleftharpoons 2HI(g) \qquad K_c = 48.2 \text{ at } 723 \text{ K}$$

What is the amount in moles of HI at equilibrium?

A 0.236 **B** 0.243 **C** 0.486 **D** 1.84

Concept: Equilibrium, calculation of the quantities present at equilibrium, given appropriate data.

Answer: C

$K_c = \frac{[HI]^2}{[I_2][H_2]} = \frac{\left(\frac{n_{HI}}{V}\right)^2}{\left(\frac{n_{I_2}}{V}\right)\left(\frac{n_{H_2}}{V}\right)}$

$= \frac{(n_{HI})^2}{(n_{I_2})(n_{H_2})} = \frac{(n_{HI})^2}{(0.07)(0.07)}$ = 48.2 (note that the volume need not be known in this case)

$\therefore n_{HI} = \sqrt[2]{48.2}$ = 0.486

16 Methanol can be manufactured industrially, using a copper oxide catalyst at temperature of 575 K, according to the following reaction.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

Which of the following statements are correct?

1 The catalyst increases the equilibrium constant.
2 The catalyst increases the equilibrium yield.
3 At lower temperature the equilibrium yield will increase.
4 At lower temperature the equilibrium constant will increase.

A 1 and 2 only
B 2 and 3 only
C 1 and 4 only
D 3 and 4 only

Concept: Equilibrium, effects of temperature, or the presence of a catalyst on an equilibrium and value of the equilibrium constant.

Answer: D
Catalyst increases the rate of reaction by increasing the rate constant, but does not affect equilibrium position or equilibrium constant.

Decrease in temperature in this case will result in the system to counteract the change by favoring the exothermic forward reaction, hence POE shifts to the right, and that change will also result in an increase in equilibrium constant (only change in temperature will change the equilibrium constant)

17 The Haber process is a key reaction in the industry for producing ammonia.
Which statement about Haber process is **not** correct?

A Iron is used as a heterogeneous catalyst to increase rate of production.
B Temperature of around 500 °C is used to increase the yield of ammonia.
C High pressure is preferred for this reaction as it increases the yield of ammonia.
D High pressure and temperature leads to an increase in the rate of production.

Concept: Equilibrium, describe and explain conditions used in the Haber process
Answer: B (not correct)
B Temperature of around 500 °C is used to **increase rate** and will **decrease the yield** of ammonia instead, as the forward reaction is exothermic in nature, which means that lower temperature will favour the forward reaction and results in higher yield instead.

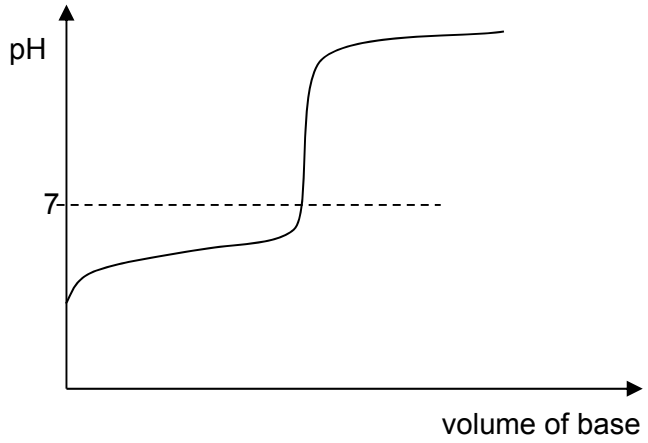
18 What is the final pH of the solution when equal volumes of 0.030 mol dm^{-3} of $Ba(OH)_2(aq)$ is mixed with 0.030 mol dm^{-3} of $HCl(aq)$?

A 1.5 **B** 1.8 **C** 12.2 **D** 12.5

Concept: pH calculation
Answer: C
Let the volume of each solution used be *v* dm^3. Total volume after mixing = 2*v*
Amt of $Ba(OH)_2$ = Amt of HCl = concentration x volume = 0.030*v*
$Ba(OH)_2 \equiv 2OH^- \equiv 2HCl$
Amt of OH^-= 2 x 0.030v = 0.060v

OH^- is in excess. Amt of OH^- that remains = $0.060v - 0.030v = 0.030v$
$[OH^-]$ in solution = $\frac{0.030v}{2v} = 0.015$ mol dm^{-3}
pOH = -lg(0.015) = 1.82
pH = 14 – 1.82 = 12.2

19 Visual indicators are often used to determine the end point of acid-base titrations. A titration was carried out between a weak acid and a strong base and the titration graph obtained is shown below:



Which of the following is a suitable indicator for the above titration?

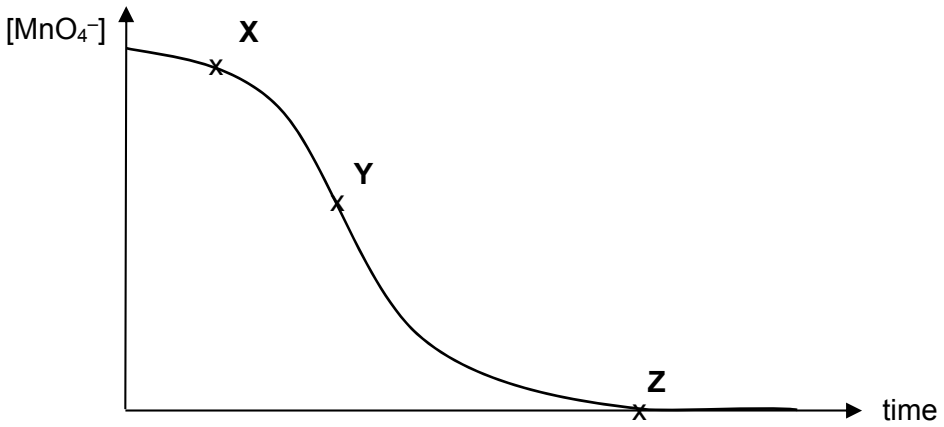
	Indicator	pH at which colour changes
A	Methyl violet	0 - 1
B	Bromocresol green	3 - 6
C	Bromothymol blue	6 - 7
D	Thymolphthalein	9 - 11

Concept: explain the choice of suitable indicators for acid-base titrations.
Answer: D
The indicator needs to have a distinct colour change were there is rapid pH change during the titration (vertical part of the graph). So a suitable indicator needs to change colour above pH 7.0.

20 The reaction of manganate(VII), MnO_4^-, with oxalate, $C_2O_4^{2-}$ is a type of autocatalytic reaction whereby the product, manganate(II) ions, is the catalyst for the reaction.

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

The following graph was obtained when $[MnO_4^-]$ was plotted against time.



Which of the following can be deduced from the graph?

A Rate at point **X** is very slow indicating that the temperature is low.
B Rate at point **Y** fast due to the production of the catalyst.
C Rate at point **Z** is slow as the catalyst is saturated.
D Rate at point **Z** is slow as the reaction is zero order with respect to $[MnO_4^-]$.

Concept: interpretation of concentration-time graph
Answer: B
Options A incorrect. Rate at point A is very slow as two anions are reacted together, not because the temperature is low.
Options C and D are incorrect because rate at point Z is zero as the reaction is complete.

21 When aqueous solutions of HCO_2H and Br_2 are reacted together, initial rate of reaction was found to be 0.080 mol dm^{-3} s^{-1}.
Given that the rate equation is:

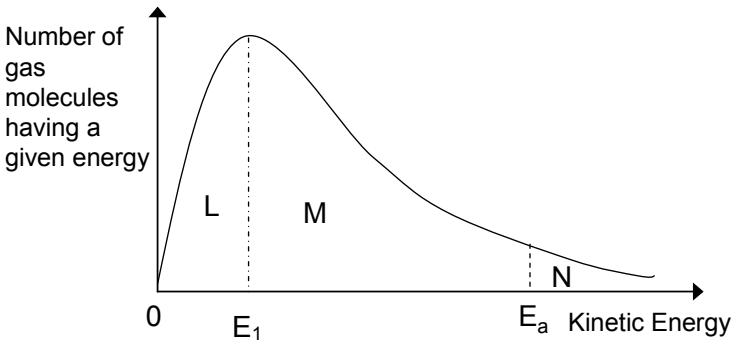
$$\text{rate} = k[Br_2][HCO_2H]$$

Which of the following shows the initial rate of reaction when the original reaction mixture was mixed with an equal volume of water?

A 0.010 mol dm^{-3} s^{-1}
B 0.020 mol dm^{-3} s^{-1}
C 0.040 mol dm^{-3} s^{-1}
D 0.080 mol dm^{-3} s^{-1}

Concept: use rate equations to determine initial rate using concentration information
Answer: B
Let the original initial value of $[Br_2]$ be *x* and $[HCO_2H]$ be *y*.
When the reaction mixture was mixed with an equal volume of water, the concentration of each reagent falls to half the original value, i.e. ½x and ½y respectively.
New rate = $k \times \frac{1}{2}x \times \frac{1}{2}y$
$= \frac{1}{4} k\,xy$
$= \frac{1}{4}(0.080) =$ <u>0.020 mol dm^{-3} s^{-1}</u>

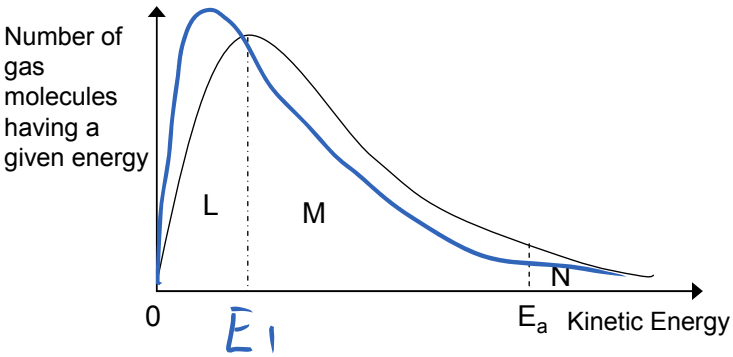
22 The Boltzmann distribution at a constant temperature is shown below:
E_1 and E_a are fixed energy values.



If the temperature is decreased by 10 ºC, what happens to the size of the areas labelled **L**, **M** and **N**?

	L	**M**	**N**
A	decreases	decreases	decreases
B	decreases	increases	decreases
C	increases	decreases	decreases
D	increases	decreases	increases

Concept: Explain in terms of the Boltzmann distribution the effect of temperature change.
Answer: C



23 The following table gives the approximate dimensions of certain substances.

	substance	dimensions
1	Fullerene (buckyball)	Diameter 0.71 nm
2	Red blood cell	Diameter of 8 μm, thickness of 2.5 μm
3	DNA strand	Diameter 2 nm, length up to 5 cm
4	Adenovirus	Diameter 90 nm

(1 μm = 1000 nm)

Which of these would be considered nanoparticles?

A 1 and 2 only
B 1, 2 and 4 only
C 1 and 4 only
D 2 and 3 only

Concept: Define the term nanoparticle
Answer: C
Nanoparticle – Material with <u>all three dimensions</u> on the nanoscale of 1-100 nm. 1 μm is 1000 nm, hence a red blood cell is already 8000 nm in diameter and 2500 nm in thickness.

24 Dishwasher pouches are small convenient packets that contain the detergent needed to be used in dishwashers. Such pouches are sturdy enough to be easily transported and safely handled by hand, yet dissolve easily when it is time to wash dishes. What could be the polymer that is used for the pouches?

A Polyvinyl alcohol
B Polyvinyl chloride
C Poly(diallyl phthalate)
D Poly(ethylene terephthalate)

Concept: Structure of polymer.
Answer: A
Only polyvinyl alcohol has the –OH functional group that can form extensive hydrogen bonding with water and is thus the most (only) water soluble polymer among the options.

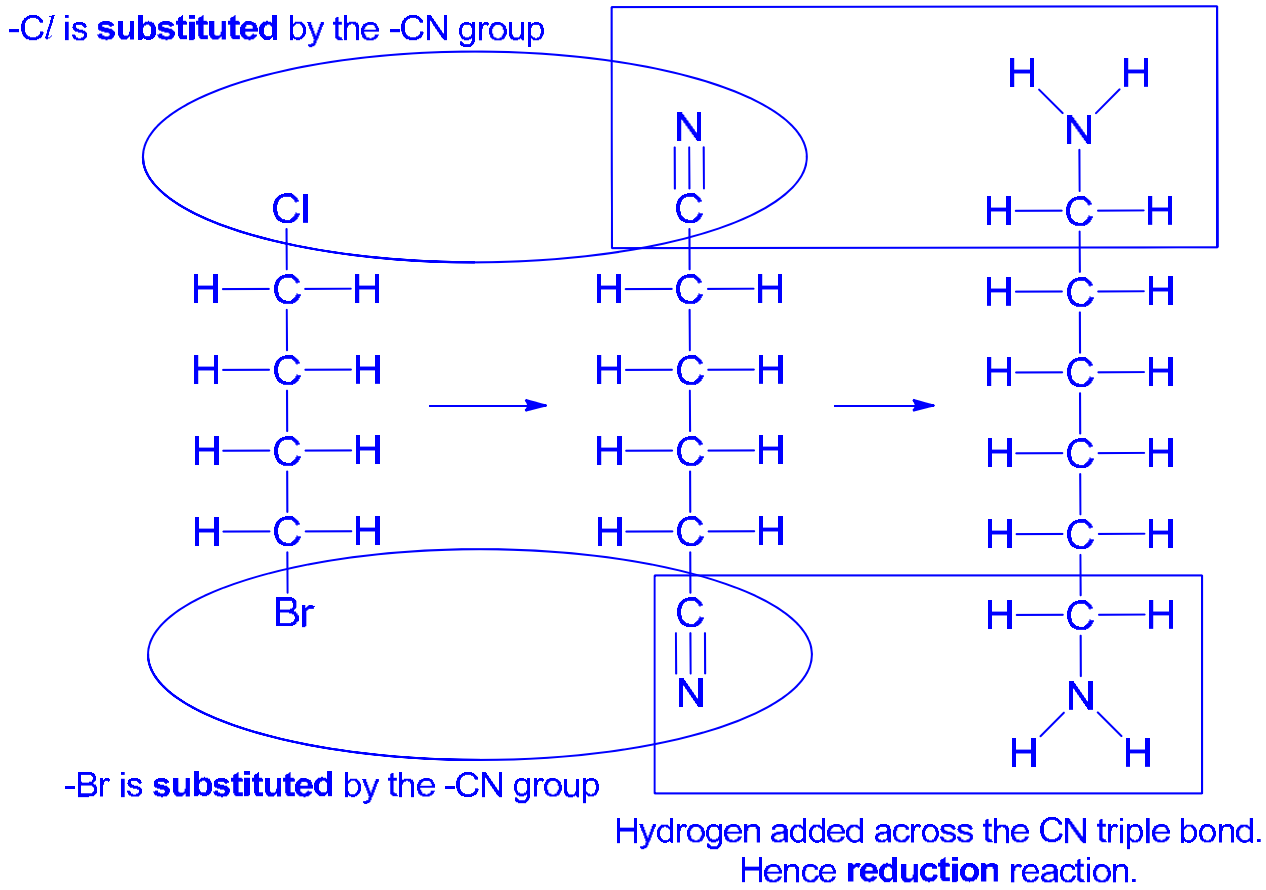
25 The reaction scheme outlines the production of one of the monomers of nylon 66 from $Cl(CH_2)_4Br$.

$$Cl(CH_2)_4Br \xrightarrow{\text{step 1}} NC(CH_2)_4CN \xrightarrow{\text{step 2}} H_2N(CH_2)_6NH_2$$

What are the types of reactions for each stage?

	step 1	**step 2**
A	substitution	oxidation
B	substitution	reduction
C	addition	addition
D	addition	reduction

Concept: interpret the type of reaction for organic reactions
Answer: B



26 Which of the following are true regarding polyester fabrics in comparison to polyamide fabrics?

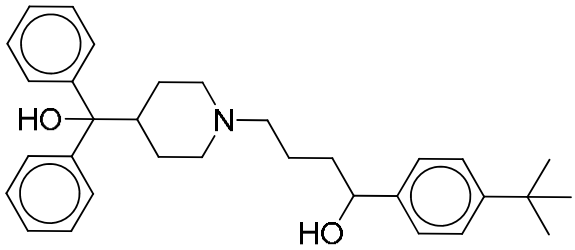
1 Polyester fabrics tend to crease less easily than polyamide fabrics.
2 Polyester fabrics tend to be more easily stained by oil than polyamide fabrics.
3 Polyester fabrics tend to absorb more sweat than polyamide fabrics.

A 1 and 2 only
B 2 and 3 only
C 3 only
D 1, 2 and 3 only

Concept: Polyamide and polyester structures in terms of interaction with water.
Answer: A
Polyesters have the ester functional group that is able to form less extensive hydrogen bonding compared to the amide functional group.

Refer to page 11 of Polymer part 3 notes:
Hence, polyesters do not absorb water well (statement 3 is thus incorrect and statement 2 is correct) and hence are used to produce fabrics to make clothes that are generally dry faster and are wrinkle free (statement 1 is correct).
Refer to page 13 of Polymer part 3 notes:
As polyamide chains are bonded to one another via hydrogen bonding, washing polyamide fabrics allow water to form hydrogen bonds with the polymer chains and temporarily change the way the polymer chains are lined up. As the water evaporates, new hydrogen bonds lock in places any creases that formed when the fabric was wet.

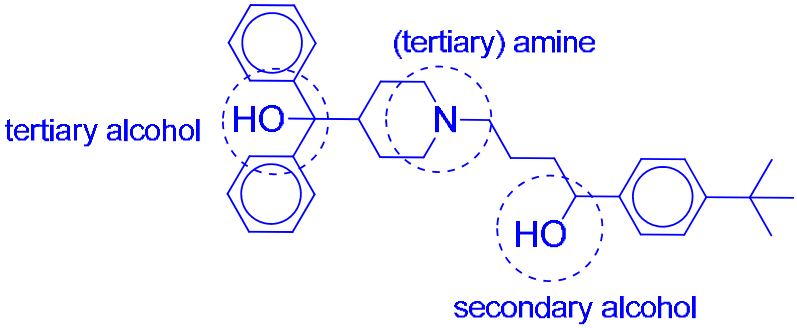
27 *Terfenadine* is an antihistamine formerly used for the treatment of allergic conditions. The structure of *terfenadine* is shown below:



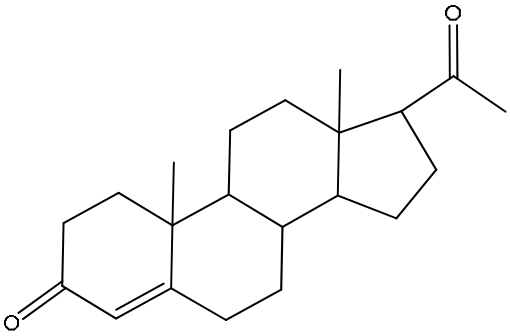
Which functional group is not present in *terfenadine*?

A amine
B tertiary alcohol
C secondary alcohol
D phenol

Concept: Interpret the structural formula of organic classes of compounds..
Answer: D



28 Progesterone is a hormone which is involved in menstrual cycle and pregnancy. The following structure shows one molecule of progesterone.



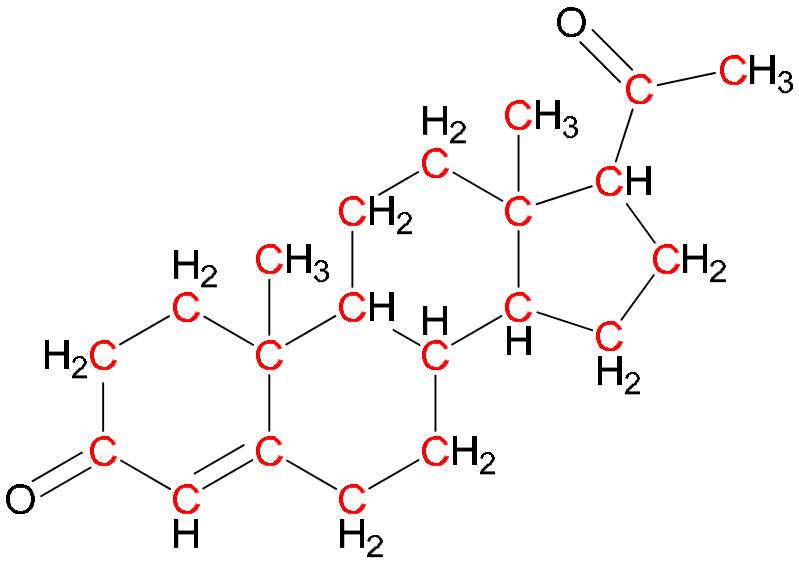
What is the molecular formula for the progesterone hormone?

A $C_{19}H_{14}O_2$ **B** $C_{19}H_{22}O_2$ **C** $C_{20}H_{30}O_2$ **D** $C_{21}H_{30}O_2$

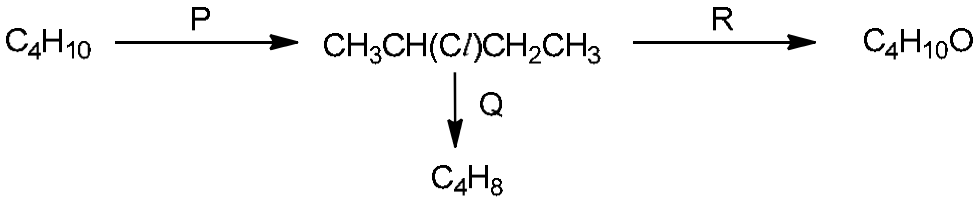
Concept: Skeletal formula, Mr of organic compounds

Answer: D

There should be 21 carbons (in red) and 30 H.



29 The diagram shows a reaction scheme involving 2-chlorobutane, $CH_3CH(Cl)CH_2CH_3$.



Which of the following is true regarding the reaction scheme above?

1 both reactions P and R are substitution reactions
2 reaction Q is a reduction reaction
3 NaOH can be used in both reactions Q and R
4 two constitutional isomers with the molecular formula of C_4H_8 can be formed from reaction Q

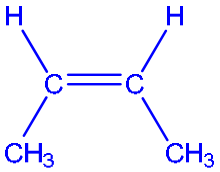
A 1 and 2 only
B 1 and 3 only
C 1 ,3 and 4 only
D 2, 3 and 4 only

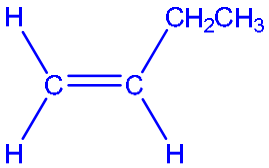
Concept: reaction of alkane and halogenoalkanes

Answer: C (1,3 and 4 only)

	Reaction P	**Reaction Q**	**Reaction R**
Type of reaction	**substitution**	**elimination**	**substitution**
Reagent and condition	**Cl_2 under uv light**	**NaOH(alcoholic), heat under reflux**	**NaOH(aq), heat under reflux**

reaction Q can produce two constitutional isomers:





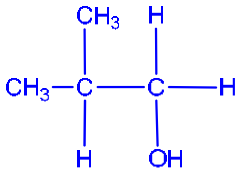
30 Which of the following alcohols can be formed when a ketone is reduced with $NaBH_4$ dissolved in methanol?

A 2-methylpropan-1-ol
B 2-methylbutan-2-ol
C 3-methylbutan-2-ol
D 2,3-dimethylbutan-2-ol

Concept: nomenclature of alcohols, classification of primary, secondary and tertiary alcohols, reduction of ketones to form secondary alcohols

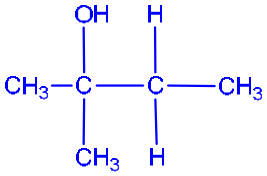
Answer: C

Ketones will be reduced to only **secondary** alcohols.



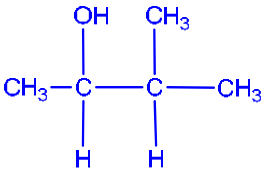
2-methylpropan-1-ol

primary alcohol



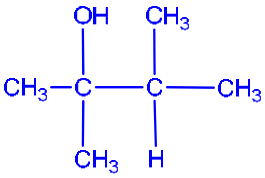
2-methylbutan-2-ol

tertiary alcohol



3-methylbutan-2-ol

secondary alcohol



2,3-dimethylbutan-2-ol

tertiary alcohol

Catholic Junior College

JC2 Preliminary Examinations

Higher 1

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

Structured Questions

8873/02
17 August 2018
2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A – Answer **all** the questions**.**
Section B – Answer **one** question.

The use of an approved scientific calculator is expected where appropriate.
You are reminded of the need for good English and clear presentation in your answers.

A Data Booklet is provided.

The number of marks is given in brackets [ ] at the end of each question or part of the question.

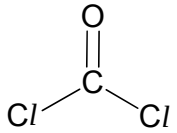
Section A	**Q1**	12
	Q2	6
	Q3	15
	Q4	6
	Q5	6
	Q6	15
Section B	**Q7**	20
	Q8	20
	Paper 2	80
	Paper 1	30
	Percentage	
	Grade	

This document consists of **20** printed pages

Section A

Answer **all** the questions in this section in the spaces provided.

1 (a) Phosgene, $COCl_2$ is a gas with many industrial uses. At high temperature, gaseous phosgene decomposes to carbon dioxide and chlorine in a dynamic equilibrium according to the following equation:



phosgene

$$(g) \rightleftharpoons CO(g) + Cl_2(g)$$

(i) Explain what is meant by the term *dynamic equilibrium.*

At dynamic equilibrium, the **rates of the forward and reverse reactions are equal** while there is **no change** in concentration/no. of mole of reactants and products.

(ii) Write an expression for the equilibrium constant, K_c, for the reaction.

Calculate its value when, at equilibrium, the concentrations of $COCl_2(g)$, $CO(g)$, and $Cl_2(g)$ are 0.219 mol dm^{-3}, 0.530 mol dm^{-3} and 0.530 mol dm^{-3} respectively.

$$K_c = \frac{[CO][Cl_2]}{[COCl_2]}$$

$$K_c = \frac{(0.530)(0.530)}{(0.219)} = 1.28 \text{ mol dm}^{-3}$$

[2]

(iii) A certain amount of phosgene was added and the new equilibrium concentration of phosgene is 0.290 mol dm^{-3}. Calculate the new equilibrium concentration of $CO(g)$.

Concentration of $CO(g)$ and $Cl_2(g)$ are equal as seen in part (ii)

$$K_c = \frac{[CO]^2}{[COCl_2]} = \frac{[CO]^2}{0.290} = 1.28 \text{ mol dm}^{-3}$$

new equilibrium concentration of $CO(g)$ = 0.609 mol dm^{-3}

(iv) Calculate the amount in moles of phosgene added in part **(iii)**, given that the volume of the container is 3 dm^3.

	$COCl_2(g)$	⇌	$CO(g)$ +	$Cl_2(g)$
Initial amount / mol	3(0.219) + n = 0.657 + n		3(0.530) = 1.59	3(0.530) = 1.59
Change / mol	– 0.237		+0.237	+0.237
Equilibrium amount / mol	3(0.290) = 0.870		3(0.609) = 1.827	3(0.609) = 1.827

[The ICE table is not necessary. It helps to visualise the changes]

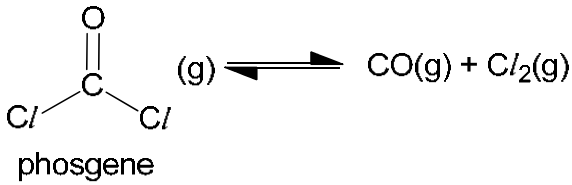
Let the amount added be n.
0.657 + n – 0.237 = 0.870
n = 0.450 mol

[2]

(b) Predict and explain how a decrease in pressure of the system will affect the position of equilibrium.

When the pressure of the system is decreased, the system will react to increase the pressure by increasing the number of moles of gas , thus the position of equilibrium will shift to the right. [2]

(c) **(i)** By using bond energy values from the *Data Booklet,* calculate the enthalpy change for the decomposition of phosgene as shown below:



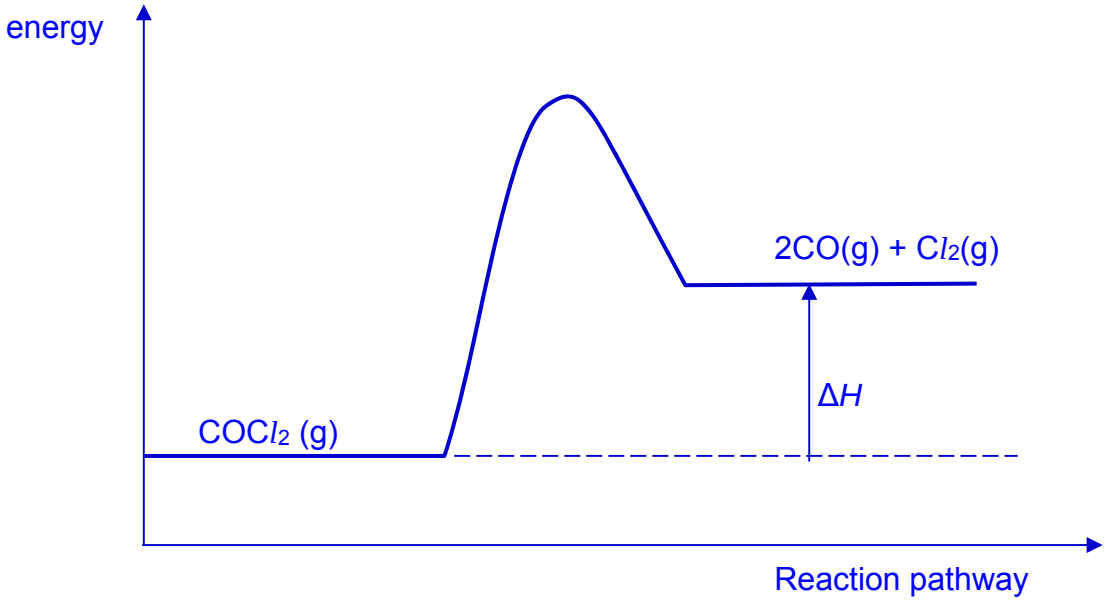
Bonds broken		Bonds formed	
1 C=O	**740**	1 C≡O	1077
2 C-Cl	2(340)	1 Cl-Cl	244

ΔH = (740 + 2 × 340) – (1077 + 244)

= 1420 – 1321 = + 99.0 kJ mol^{-1}

[2]

(ii) Use your answer from part **(i)** to sketch a reaction pathway diagram for the decomposition of phosgene. Draw a labelled arrow to show the enthalpy change on your diagram.



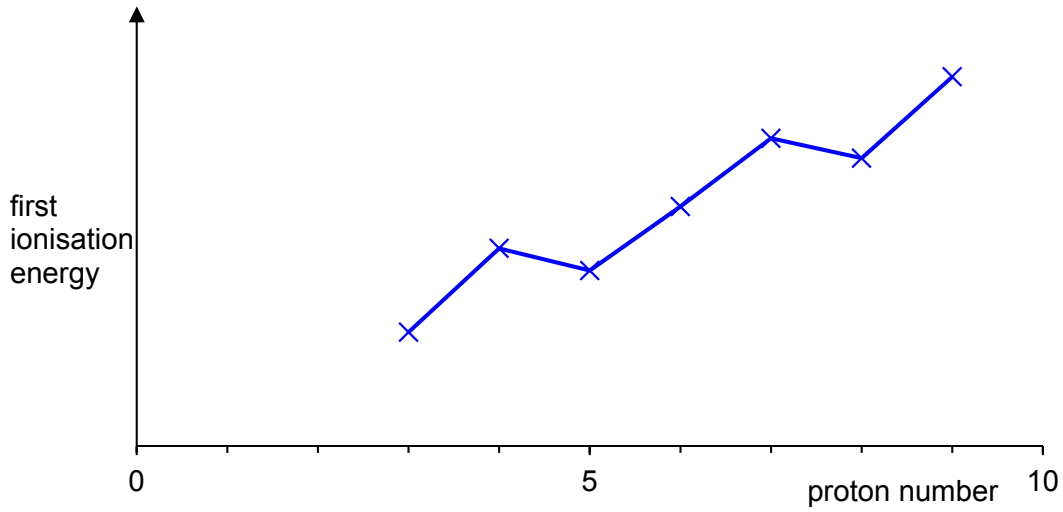
[2]

[Total: 12]

2(a) Write an equation to show the first ionisation energy of oxygen.

$O(g) \rightarrow O^+(g) + e^-$ **[with state symbols]**

(b) Sketch how the first ionisation energies of the elements change from lithium to fluorine.



(c) Explain why the first ionisation energy of oxygen is lower than

- nitrogen

N $1s^2\ 2s^2\ 2p_x^1\ 2p_y^1\ 2p_z^1$

O $1s^2\ 2s^2\ 2p_x^2\ 2p_y^1\ 2p_z^1$

Oxygen has a lower first ionisation energy than nitrogen, as less energy is required to remove an electron from paired $2p_x$ electrons in oxygen since **inter-electron repulsion** is experienced between the paired electrons. [2]

- fluorine

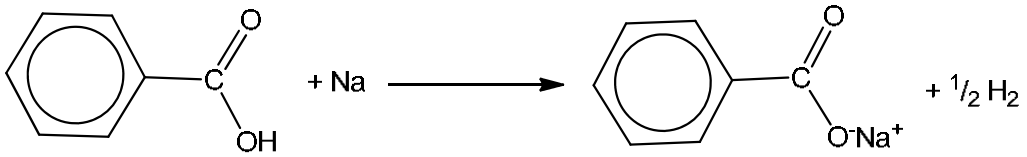
The valence electrons of both oxygen and fluorine atoms experience **similar shielding effect,** but oxygen has **and larger size**, and **smaller nuclear charge** The **attraction** between outermost electrons and nucleus **is lower for oxygen** , resulting in less energy required to remove the outermost electron.

[2]

[Total: 6]

3 Benzoic acid, $C_6H_5CO_2H$, and its salts are often used as food preservatives in fruit juices and other acidic food. They are represented by the E-numbers, E210 to E213 when added as preservatives since they are able to inhibit the growth of mould, yeast and some forms of bacteria.

(a) Sodium metal is added to form the salt of benzoic acid, as shown in the following equation.



benzoic acid sodium benzoate

(i) 5.00 g of sodium metal was added to 0.01 moles of benzoic acid. Calculate the volume of gas produced at standard temperature and pressure for the above reaction.

No. of moles of Na = $\frac{5.00}{23.0}$ = 0.2174

No. of moles of benzoic acid given as 0.01 moles (limiting reagent)

No. of moles of gas formed = 0.01 x 0.5 x **22.7**
=0.114 dm^3 (to 3 s.f)

[2]

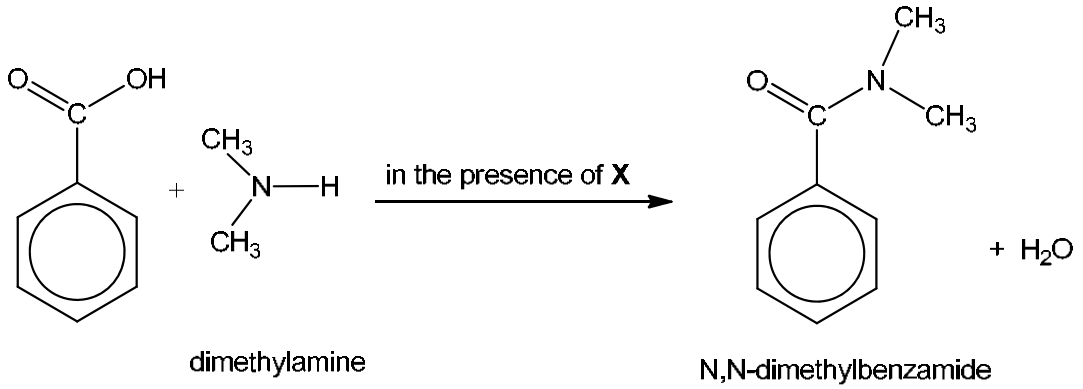
(ii) Explain why sodium benzoate is highly soluble in water but benzoic acid is only partially soluble in water.

Sodium benzoate is able to form ion-dipole interactions with water while the $-CO_2H$ group of the benzoic acid molecule is only able to form hydrogen bonds with water. The phenyl group of the benzoic acid molecule is non-polar and hence is only able to form instantaneous dipole-induced dipole interaction with water.

Hence, more energy is released in the formation of ion-dipole interaction between sodium benzoate and water which is sufficient to overcome the ionic bonds in sodium benzoate and hydrogen bonding between water.

[4]

(b) Benzoic acid can also react with amines to produce amides as shown in the following equation.



(i) Name the type of reaction shown by the above equation.

Condensation reaction

(ii) Identify **X** which is required for the above reaction to occur.

DCC

(iii) State the shape and bond angle around the N atom in dimethylamine.

Shape: Trigonal pyramidal

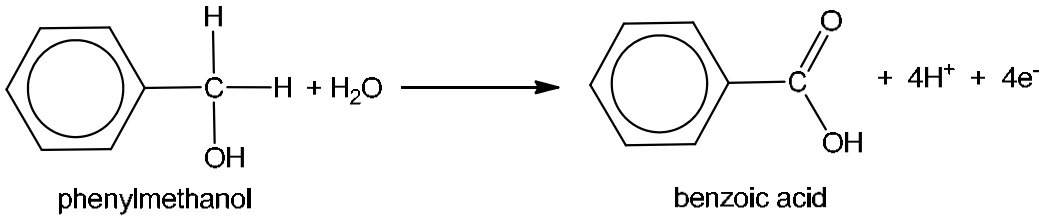
Bond angle: 107° **[accept anything btw 105 ° to 109°]**

(iv) Suggest a reason why the reaction above would **not** occur if dimethylamine is replaced by trimethylamine, $(CH_3)_3N$.

There is no H atom bonded to nitrogen in $(CH_3)_3N$ and a removal of H bonded to nitrogen is required to form H_2O in the amide formation

(c) Benzoic acid can be produced by oxidising phenylmethanol, $C_6H_5CH_2OH$. A suitable oxidising agent for this reaction is hot acidified $KMnO_4$.

The half equation for the oxidation of phenylmethanol is as follows:



(i) State the colour change observed when phenylmethanol reacts with hot acidified $KMnO_4$.

Purple $KMnO_4$ decolourises/ turns colourless

(ii) Use the *Data Booklet* and the half equation given above to construct a balanced equation for the oxidation of phenylmethanol by hot acidified $KMnO_4$.

$4MnO_4^- + 5C_6H_5CH_2OH + 12H^+ \rightarrow 4Mn^{2+} + 5C_6H_5CO_2H + 11\ H_2O$

(iii) A pipette was used to transfer 25.0 cm^3 of 0.15 mol dm^{-3} of phenylmethanol into a conical flask. Calculate the minimum volume of 0.20 mol dm^{-3} of acidified $KMnO_4$ required to completely oxidise the phenylmethanol in the conical flask.

No. of moles of $C_6H_5CH_2OH$ = 25/1000 x 0.15 = **3.75×10^{-3}**

From (ii), 4 $KMnO_4$ ≡ 5 $C_6H_5CH_2OH$

No. of moles of $KMnO_4$= 4/5 x 3.75 x 10^{-3}

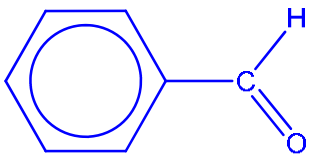
= 0.00300

Min. vol. of $KMnO_4$= 0.00300 ÷ 0.2

=0.0150 dm^3 or 15.0 cm^3

[2]

(iv) Draw the structure of the product formed when phenylmethanol reacts with acidified $K_2Cr_2O_7$ with immediate distillation (controlled oxidation).



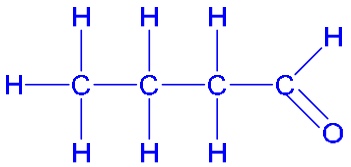
[Total: 15]

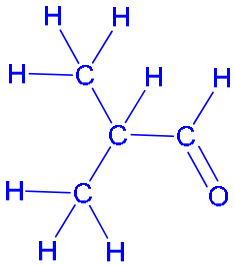
4 Carbon monoxide is a reagent used in an industrial process called hydroformylation. During hydroformylation, high pressure is used and the carbon monoxide reacts with an alkene and hydrogen gas to form an aldehyde.

The equation below shows an example of this process.

$$CO(g) + CH_3CH{=}CH_2(g) + H_2(g) \rightleftharpoons \underset{\text{aldehyde}}{C_4H_8O(g)}$$

(a) In the space below, draw the two possible constitutional isomers of C_4H_8O that are produced in the reaction above.





[2]

(b) The hydroformylation process is important because aldehydes are easily converted into many products. State the type of reaction that has occurred when an aldehyde is converted to a carboxylic acid.

Oxidation

(c) While the hydroformylation process uses rhodium catalyst in its soluble form, elemental rhodium is used in its nanoparticle form as a *heterogeneous catalyst* for other reactants. Explain the term *heterogeneous catalyst* as fully as you can.
Briefly explain why rhodium in its nanoparticle form works as a better catalyst than in its bulk form.

A catalyst is a substance that increases the rate of reaction by providing an **alternative reaction pathway with a lower energy barrier** (lower Ea) for the reaction to take place.

A heterogeneous catalyst is a catalyst that is in a **different phase** from the reactants.

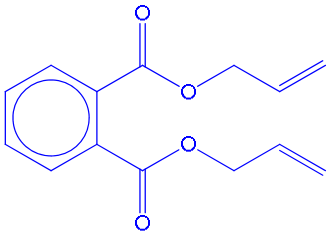
Rhodium in its nanoparticle form has a **large surface area** (or large surface to volume ratio) **for reaction to take place more quickly**.

[3]

[Total: 6]

5 Poly(diallyl phthalate) is an example of a cross linked, thermoset polymer. It is suitable for use in high-performance military electrical components because of its ability to retain its properties when subjected to extreme environmental conditions of high temperature and high humidity.

(a) **(i)** Draw the structure of the monomer of poly(diallyl phthalate) and state the functional group that allows the monomer to become a cross-linked polymer.



Alkene

[2]

(ii) Explain, with reference to its structure and bonding, why it is able to retain its properties under the extreme environmental conditions stated above.

The polymer is **macromolecular with extensive covalent bonds** in the cross links that are **strong and hard to break. Hence the polymer is able to withstand high temperatures**. The polymer is largely **unable to form** extensive **hydrogen bonds with water molecules** and hence it is able to withstand high humidity without degrading.

[2]

(b) Calcium alginate is also a cross-linked polymer but its properties vary greatly from poly(diallyl phthalate). Each calcium ion can attach to two alginate polymer strands to form cross-links. Calcium alginate is used in wound dressings. When the dressing needs to be changed, the wound can be rinsed with a solution that will break the cross-links. Suggest a suitable solution that can be used and briefly explain why the cross links are broken.

Sodium chloride solution. **[any group 1 metal salt solution]**

The sodium ions displace the calcium ions. As each **sodium ion is singly charged and unable to attach two polymer strands** , the cross-links begin to fall apart.

[2]

[Total: 6]

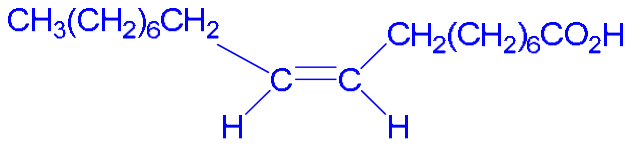
6 Oleic acid is a type of fatty acid that is present in avocados. Oleic acid has the following structure:

$$CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$$

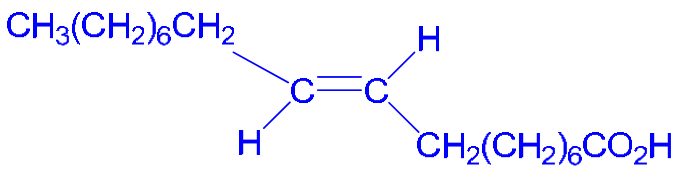
Oleic acid has the cis configuration around the C=C double bond, whereas elaidic acid is the trans isomer of oleic acid.

(a) Draw the condensed structural formulae of oleic acid and elaidic acid, showing clearly the configuration about the C=C in each acid.

oleic acid:



elaidic acid:



[2]

Avocado flesh turns brown rapidly upon exposure to oxygen in the air. In the presence of oxygen, enzymes in the avocado help in the formation of a class of compounds called quinones. Quinones are capable of producing polymers called polyphenols that give the brown colour.

(b)(i) Suggest a simple method that can be done at home to slow down the browning of avocado flesh. Give a brief explanation to support your suggestion.

Wrap it in cling wrap such that a barrier prevents oxygen from reacting with the enzymes. **Or** put the avocado in the fridge as the lowered temperature slows down the browning reaction / inhibits the enzyme from working as quickly. **Or** squeeze lemon / lime juice on the avocado as the lowered pH inhibits the enzyme from working as quickly. **[or any other *logical* suggestion that prevents oxygen from reaching the avocado flesh.] No credit given if the suggestion is correct but the reasoning is wrong.**

(ii) Define the term, *polymer*.

A polymer molecule is a macromolecule made up of monomers, with average molar mass of at least 1000 or at least 100 repeat units.

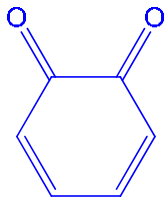
(iii) 1,2-benzoquinone is an example of a quinone. It contains 66.7% carbon and 3.7% hydrogen. The rest of the molecule comprises of oxygen which is present as two ketone functional groups in a molecule of 1,2-benzoquinone.
Calculate the empirical formula of 1,2-benzoquinone. Hence, deduce the molecular formula of 1,2-benzoquinone, stating clearly how you arrived at your answer.

	C	**H**	**O**
%	66.7	3.7	**29.6**
%/A_r	$\frac{66.7}{12.0}$ **=5.56**	$\frac{3.7}{1.0}$ **= 3.70**	$\frac{29.6}{16.0}$ **=1.85**
Simplest ratio	3	2	1

Empirical formula is C_3H_2O
As each ketone functional group contains one oxygen atom and there are two ketone functional groups, the molecular formula is $C_6H_4O_2$. **[with valid explanation]**

[3]

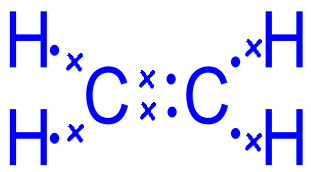
(iv) In a molecule of 1,2-benzoquinone, the two ketone functional groups are on adjacent carbon atoms in a cyclic structure. Using this information and your answer in **(iii)**, draw the skeletal structure of 1,2-benzoquinone.

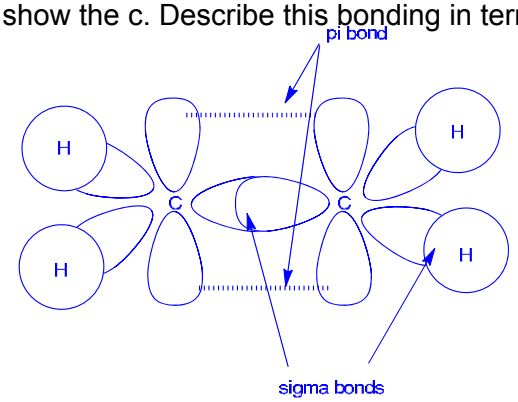


Other structures that are cyclic that satisfy the descriptions are accepted.

Avocados ripen faster if they are put in a plastic bag with some bananas. Bananas produce trace amounts of ethene gas which functions as a ripening hormone in fruits.

(c) Draw a dot-and-cross diagram to show the c. Describe this bonding in terms of orbital overlap.





The drawing is not necessary but clearly a labelled drawing may help in the descriptions.

Ethene has **5 sigma bonds and 1 pi bond**. **[or implied in description]**

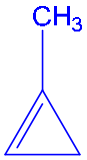
Sigma bonds are formed when an **s orbital of H head-on overlaps** with **an** (sp^2) **orbital of C** and when **an** (sp^2) **orbital of C head-on overlaps with an** (sp^2) **orbital of a neighbouring C.**

[4]

Pi bond is formed when the parallel ***p* orbital** of one C atom, **overlaps side-ways** with the *p* orbital of another C.

Bananas are usually picked from their plantations when they are unripe. But the production of ethene can quickly ripen the fruits during transportation. Hence, to slow down the ripening process, 1-methylcyclopropene is used because it binds tightly to the ethene receptor in the fruits and therefore blocks the effect of ethene.

(d) **(i)** Draw the structure of 1-methylcyclopropene.



(ii) Explain why 1-methylcyclopropene has a higher boiling point than ethene.

Both are simple molecules but **1-methylcyclopropene has more electrons** ….

hence it has **stronger instantaneous dipole – induced dipole forces of** …..

attraction between molecules that need more energy to overcome. ….

[2]

[Total: 15]

Section B

Answer **one** question in the spaces provided.

7(a) Carbonic acid is a weak acid that partially dissociates in water according to the following equation:

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$

The K_a of carbonic acid is 4.5×10^{-7} mol dm^{-3}.

The hydrogencarbonate ion, $HCO_3^-(aq)$, can also behave as weak acid in water:

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq)$$

The K_a of hydrogencarbonate is 5.0×10^{-11} mol dm^{-3}.

(i) State the relationship between carbonic acid and the hydrogencarbonate ion.

Conjugate acid-base pair / hydrogencarbonate is the conjugate base of carbonic acid, and the difference between the two is only one proton.

(ii) Write the K_a expression for hydrogencarbonate ion and briefly explain why this K_a value is much smaller than the K_a value for carbonic acid.

$$K_a = \frac{[CO_3^{2-}][H_3O^+]}{[HCO_3^-]}$$

It is **more difficult for a positive H^+ to be lost from an negatively charged ion** HCO_3^- due to stronger electrostatic forces of attraction, than from a neutral molecule H_2CO_3. [2]

(iii) The hydrogencarbonate ion is part of the buffer in the blood.
Define *buffer* and explain how $HCO_3^-(aq)$ reacts with acid in the blood. Support your answer with a suitable equation.

A buffer is a solution that maintains a fairly constant pH when small amounts of acid or alkali are added to it.

When blood gets more acidic, the H^+ is removed by HCO_3^-, hence keeping the pH of blood almost constant. $HCO_3^- + H^+ \rightarrow H_2O + CO_2$ [2]

(b) The hydroxyl radical, represented by •OH, is highly reactive and short lived. It is often referred to as the "detergent" of the atmosphere because it reacts with greenhouse gases such as methane.

$$CH_4 + \bullet OH \rightarrow \bullet CH_3 + H_2O$$

A study of the rate of this reaction in a mixture, gave the following results. The initial concentration of methane for this study was much larger than concentration of hydroxyl radical and assumed to be constant throughout the reaction.

Time after start of reaction / x 10^{-4} s	**relative [•OH]**
0.0	10.0
1.0	7.0
2.0	5.0
3.0	3.5
4.0	2.5
5.0	1.8

(i) Define the term *half-life* of a reaction.
Use the data in the table to deduce the half-life of the reaction and to show that the reaction is first order with respect to [•OH].

Half-life is the time taken for the concentration of reactant to fall to half its original value.

The half-life of the reaction is 2.0 x 10^{-4} s.

Time taken for the relative [•OH] to fall from 10.0 to 5.0 and from 5.0 to 2.5 is constant at 2.0 x 10^{-4} s hence the reaction is first order with respect to [•OH].

[3]

(ii) Assume that the order of reaction with respect to [CH_4] is 1, state how the half-life of the reaction would change if:

Initial [CH_4] is doubled:

Half-life will be halved the original value (or half-life will be 1.0 x 10^{-4} s)

Initial relative [•OH] is halved:

Half-life will stay the same (or half-life will still be 2.0 x 10^{-4} s) [2]

(c) Describe reactions that illustrate the variation in acid-base behaviour of the oxides of the elements in Period 3, using MgO, Al_2O_3, and SO_3 as examples.
Write equations for all the reactions you describe.

Across Period 3, the oxides vary **from basic to amphoteric to acidic**.

MgO is a basic oxide which reacts with acid to give salt and water.

$MgO + 2HCl \rightarrow MgCl_2 + H_2O$

Al_2O_3 is an amphoteric oxide which reacts with both acids and alkalis.

$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$

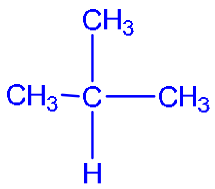
$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$

SO_3 is an acidic oxide which reacts with alkali to give salt and water.

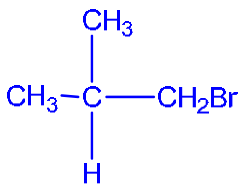
$SO_3 + 2NaOH \rightarrow Na_2SO_4 + H_2O$ [5]

(d) Alkane **A**, C_4H_{10}, reacts with bromine under ultraviolet light to produce only two different mono-brominated products, **B** and **C** in the likely ratio of 9:1. When reacted with alcoholic KOH, both **B** and **C** produce hydrocarbon **D**, C_4H_8.

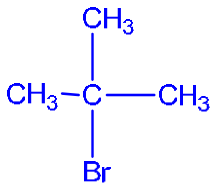
(i) Suggest structures for **A**, **B**, **C** and **D**. Label the structures clearly.



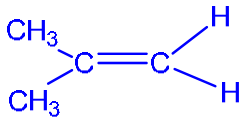
A: C_4H_{10}



B



C



D: C_4H_8

[3]

(ii) Describe a simple chemical test to distinguish between **A** and **D**.

To separate test tubes containing aqueous bromine , bubble gases **A** and **D** into two different test tubes. Orange aqueous bromine decolourises in the presence of **D** but remains orange in the presence of **A**. [2]

OR To separate test tubes containing bromine in CCl_4, bubble gases **A** and **D** into two different test tubes. Reddish-brown bromine decolourises in the presence of **D** but remains reddish-brown in the presence of **A**.

[Total: 20]

8(a) The table below gives the acid dissociation constants, K_a, of three acids at 25 °C.

Acid	Formula	K_a / mol dm^{-3}
Methanoic acid	HCO_2H	1.8×10^{-4}
Ethanoic acid	CH_3CO_2H	1.5×10^{-5}
Chloroethanoic acid	CH_2ClCO_2H	1.3×10^{-3}

(i) From the K_a values, identify the strongest of the three acids and write the K_a expression for the acid you identified.

Chloroethanoic acid

$$K_a = \frac{[CH_2ClCO_2^-][H^+]}{[CH_2ClCO_2H]}$$

[2]

(ii) A student needed to select one of the three acids above to prepare a buffer solution of pH 3.80. The acid chosen has to have a pK_a that is closest to the pH value of the buffer solution.

Define the term *buffer*.
Identify the acid chosen for the preparation of the buffer and briefly explain how the buffer can be prepared (calculation of actual amounts is not required.)

A buffer is a solution that maintains a **fairly constant pH** when **small amounts** of acid or alkali are added to it.

Methanoic acid (pK_a is 3.74).

Add about an equal amount of **sodium methanoate or potassium methanoate to methanoic acid.** [3]

OR

Add **sodium hydroxide to a solution of methanoic acid ensuring that methanoic acid is in excess** (or sodium hydroxide is limiting.)

(b) 2-bromopropane, $CH_3CHBrCH_3$, can be hydrolysed by KOH(aq) to form propan-2-ol. Results of an investigation into the kinetics of this reaction are given below.

Expt number	$[CH_3CHBrCH_3]$ / mol dm^{-3}	[KOH] / mol dm^{-3}	Relative initial rate
1	0.10	0.20	1.00
2	0.60	0.40	6.00
3	0.30	0.20	3.00

(i) Define the term *order of reaction*.
Use the data in the table to deduce the order of reaction with respect to each reagent.

The order of reaction with respect to a given reactant is defined as the power to which the reactant concentration is raised to in the experimentally determined rate equation.

Comparing expts 1 and 3, when [KOH] is constant and $[CH_3CHBrCH_3]$ increases by 3 times, relative initial rate increases by 3 times. Hence reaction is first order with respect to $[CH_3CHBrCH_3]$.

Knowing that the reaction is first order with respect to $[CH_3CHBrCH_3]$, when comparing expts 1 and 2 where $[CH_3CHBrCH_3]$ increases by 6 times, rate increases by 6 times also. This indicates that the increase in [KOH] by 2 times has no impact on the rate. Hence reaction is zero order with respect to [KOH]. [or correct mathematical method]

[3]

(ii) Write an overall rate equation for the reaction between $CH_3CHBrCH_3$ and KOH and state the units of the rate constant.

rate = k $[CH_3CHBrCH_3]$ and units of k is s^{-1} (accept min^{-1}).

[2]

(c) The oxides Na_2O, Al_2O_3, and P_4O_{10} differ considerably in their chemical properties. Describe what happens when separate samples of each oxide are added to water Give equations where appropriate and state clearly why, if no reactions occur.

What is the effect of adding universal indicator to each resulting solution?

$Na_2O + H_2O \rightarrow 2NaOH$,

Na_2O **dissolves readily** in water to form an alkaline solution, which will turn universal indicator **purple/blue**.

Al_2O_3, has **does not dissolve** due to its **high lattice energy**, hence the universal indicator should **remain green.**

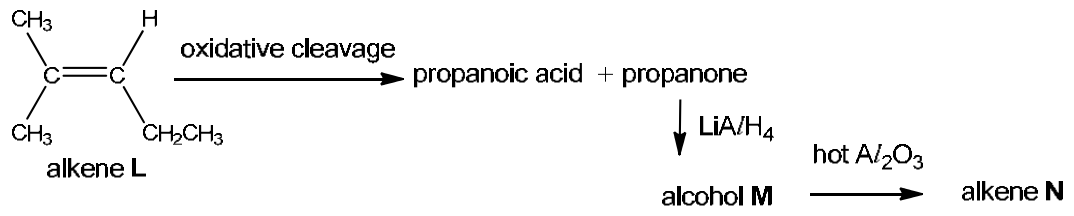
$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$

P_4O_{10} **hydrolyses readily in water** to form an acidic solution, which will turn universal indicator **red/orange**.

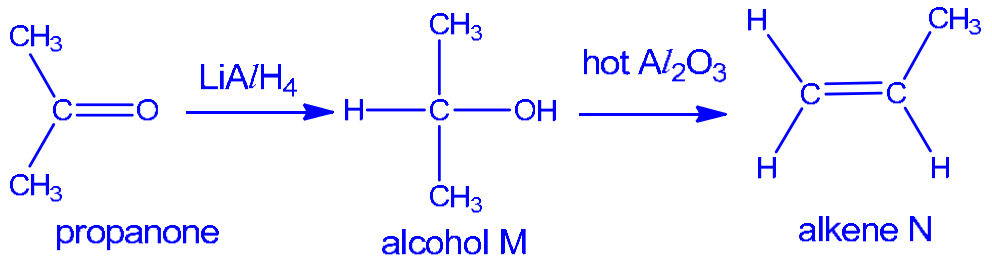
.....[5]

(d) When reacted with strong oxidising agents under high temperature, alkenes can undergo *oxidative cleavage* reactions. Such reactions involve the complete breaking of the C=C bonds in the alkenes to give carbon-oxygen bonds such as C-O or C=O. These new bonds are part of functional groups such as carboxylic acids and ketones.

Alkene **L** undergoes oxidative cleavage to produce propanoic acid and propanone. Propanone is able to undergo further reactions. The reaction scheme is shown below.



(i) Deduce the structures of **M** and **N**. [2]

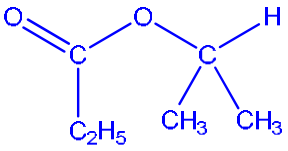


Propanoic acid produced from alkene **L** reacts with alcohol **M** to give a sweet smelling organic compound.

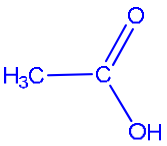
(ii) State the type of reaction that has taken place.

Condensation

(iii) Draw the structure of the organic product produced.



(iv) Draw the structure of the organic product produced when alkene **N** undergoes oxidative cleavage.



[Total: 20]

Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination 2018
Year 6

H1 CHEMISTRY 8873/01

Paper 1 Multiple Choice **24 September 2018**

1 hour

Additional Materials: Data Booklet
Optical Mark Sheet

INSTRUCTIONS TO CANDIDATES

1 Write your **name**, **index number** and **class** on this question paper and the OTAS Mark Sheet.

2 There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Optical Mark Sheet.

3 Each correct answer will score one mark. A mark will not be deducted for wrong answer.

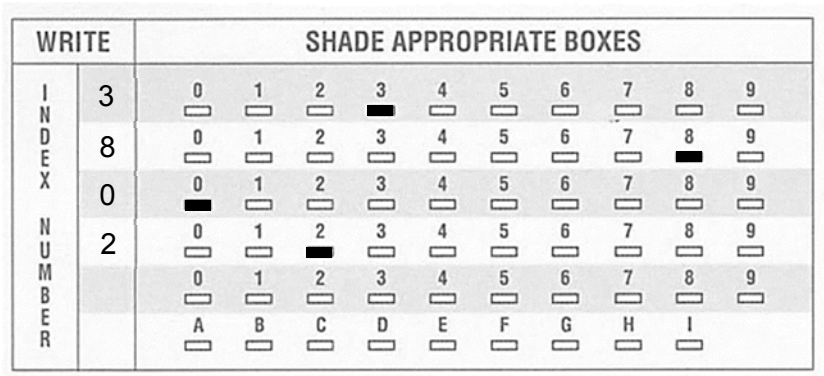
4 Any rough working should be done in this booklet.

5 The use of an approved scientific calculator is expected, where appropriate.

6 On the OTAS Mark Sheet, please shade the code as "Class/Index number".

For illustration only:

A student from class 6C38, with index number 02, should shade "3802".



This document consists of **13** printed pages and **1** blank page.

1 Which option contains one mole of the stated particles?
Note that D = $^{2}_{1}H$.

A carbonate ions in 60 g of sodium carbonate

B neutrons in 1.8 g of heavy water, D_2O

C electrons in 0.1 mol of OH^-

D oxygen atoms in 11.2 dm^3 of O_3, under s.t.p

2 NF_3 can be obtained from the reaction between ammonia and fluorine gas.

$$4NH_3 + 3F_2 \rightarrow NF_3 + 3NH_4F$$

Which statement about the reaction is correct?

A NH_3 undergoes disproportionation.

B The oxidation number of nitrogen in NF_3 is +3.

C NH_3 is a stronger oxidising agent than F_2.

D One mole of F_2 loses two moles of electrons.

3 *Use of the Data Booklet is relevant to this question.*

Which statement regarding $^{26}Mg^{2+}$ and $^{27}Al^{3+}$ ions is true?

1 $^{26}Mg^{2+}$ has more protons than $^{27}Al^{3+}$.

2 Both ions have more neutrons than protons in their nuclei.

3 Both ions have outer electronic configuration $2s^22p^6$.

4 Both ions have the same number of neutrons.

A 1 and 2 only

B 1 and 3 only

C 3 and 4 only

D 2, 3 and 4 only

4 In which substance must covalent bonds break on melting?

A calcium

B silicon

C sodium carbonate

D ice

5 Valence Shell Electron Pair Repulsion theory can be used to predict the shapes of molecules and ions.

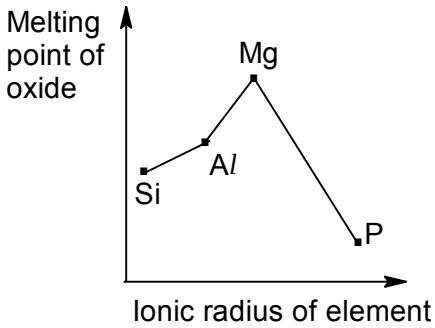
Which of the following are the shapes of NO_2 and NO_3^- respectively?

	NO_2	NO_3^-
A	linear	trigonal planar
B	linear	trigonal pyramidal
C	bent	trigonal planar
D	bent	trigonal pyramidal

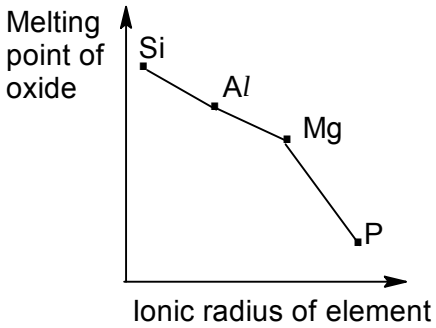
6 *Use of the Data Booklet is relevant to this question.*

Which graph shows the correct trend when the melting points of the oxides of elements Mg, A*l*, Si and P is plotted against its ionic radius?

A



B



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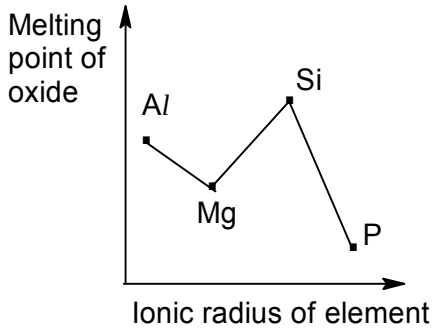
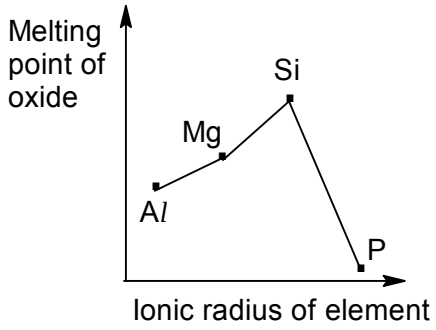


D



7 Two different Group 1 metals, **K** and **L**, were separately thrown into two beakers of cold water. **K** skipped on the water surface and effervesence was seen. **K** disappeared after sometime. **L** exploded upon contact with water.

Which statement is **false**?

A **L** could be rubidium if **K** is sodium.

B **K** is a stronger reducing agent than **L**.

C Hydrogen gas is given off when **L** came into contact with water.

D The water in the beaker becomes basic upon reacting with **K**.

8 $\mathbf{X_2}$, $\mathbf{Y_2}$ and $\mathbf{Z_2}$ are Cl_2, Br_2 and I_2 but are not necessarily in the given order.

The table below recorded observations when these halogens are separately added to aqueous solutions containing the halide ions followed by the addition of an organic solvent, CCl_4.

Experiment	Reactants	Observation after shaking with CCl_4
1	$\mathbf{X_2}$ (aq) + $\mathbf{Y^-}$ (aq)	Violet organic layer seen.
2	$\mathbf{Y_2}$ (aq) + $\mathbf{X^-}$ (aq)	*(Observations not recorded)*
3	$\mathbf{Z_2}$ (aq) + $\mathbf{X^-}$ (aq)	Orange-red organic layer seen.
4	$\mathbf{Z_2}$ (aq) + $\mathbf{Y^-}$ (aq)	Violet organic layer seen.

Which statement could be deduced from the above experiments, given $\mathbf{X_2}$ (aq) is an orange solution?

A The colour of the organic layer in Experiments 2 and 4 is the same.

B Identity of $\mathbf{Z_2}$ is Br_2.

C In Experiment 3, there is no redox reaction occurring.

D $\mathbf{X_2}$ is a stronger oxidising agent than $\mathbf{Z_2}$.

9 For which process is the enthalpy change always negative?

A Melting of ice.

B Reaction between an acid and a base.

C Breaking a covalent bond of a diatomic molecule.

D Forming a compound from its elements.

10 A rock sample was found to contain isotopes **T** and **U** which are radioactive. Initially, the ratio of the number of atoms of **T** to **U** in the rock sample is 1 : 16. The decay of isotopes **T** and **U** was found to follow first order kinetics. The half–life of **T** is 12 days while that of **U** is 3 days.

How long, in days, will it take for a rock sample to contain a molar ratio of **T** to **U** of 4 : 1?

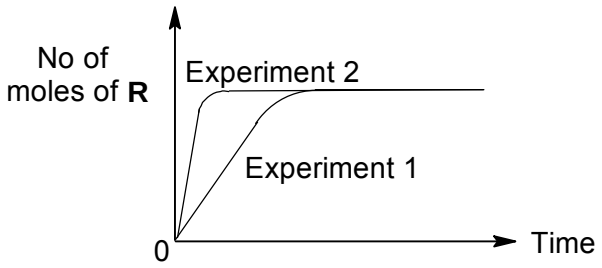
A 6 **B** 12

C 18 **D** 24

11 The stoichiometry of a reaction is shown by the equation below.

$$\mathbf{L}(g) + \mathbf{M}(g) \rightleftharpoons \mathbf{Q}(g) + \mathbf{R}(g) \qquad \Delta H = -20 \text{ kJ mol}^{-1}$$

Two experiments were carried out in enclosed vessels which the rate of production of **R** was measured. The results are shown in the diagram below.



Which changes in the conditions might explain the results shown?

1 Temperature of the vessel in Experiment 2 is higher.

2 A smaller vessel is used in Experiment 2.

3 A catalyst is used in Experiment 2.

A 1, 2 and 3 **B** 1 and 2 only

C 2 and 3 only **D** 1 only

12 In which reaction is the first reactant **not** acting as a Bronsted-Lowry base?

A $\underline{NH_3} + CH_3Cl \rightarrow CH_3NH_3^+ + Cl^-$

B $\underline{OH^-} + HSO_4^- \rightarrow H_2O + SO_4^{2-}$

C $\underline{CH_3OH} + HClO_4 \rightarrow CH_3OH_2^+ + ClO_4^-$

D $\underline{HNO_3} + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$

13 Nanoparticle zinc oxide is an ingredient found in most sunscreens. The white bulk powder form of zinc oxide is not used even though it can absorb UV rays.

Which statement about zinc oxide as a nanoparticle is true?

1 Zinc oxide is not white owing to the extremely small size of the nanoparticle.

2 Nanoparticle zinc oxide is water soluble.

3 Zinc oxide can absorb UV rays only when it is in nanoparticle form.

4 Since the surface area to volume ratio is very high, nanoparticle zinc oxide can be applied to the skin more evenly.

A 1, 2 and 4 only

B 2 and 3 only

C 1 and 4 only

D 3 and 4 only

14 Which statement explains why graphene is such a strong material?

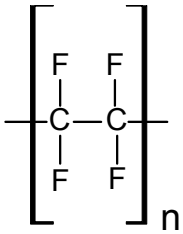
A Graphene is a crystalline allotrope of carbon.

B Graphene exists as a three dimensional structure.

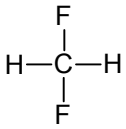
C The layered structure of graphene allows the layers to slide over each other.

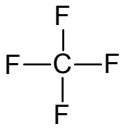
D The strong network of carbon–carbon covalent bonds that exists in graphene.

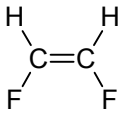
15 A polymer is formed as a result of addition polymerisation and it has the following structure.

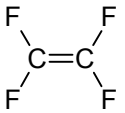


Which is the monomer?

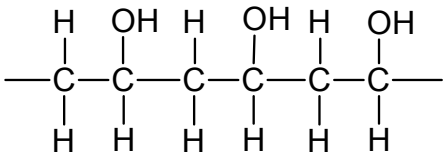
A 

B 

C 

D 

16 Poly(vinyl alcohol) is a commonly used eye drop and has the structure shown below.



poly(vinyl alcohol)

Which of the following properties makes poly(vinyl alcohol) suitable for its use?

1 The polymer is transparent.

2 It is fairly soluble in water.

3 It has high heat resistance.

4 It attracts water to itself.

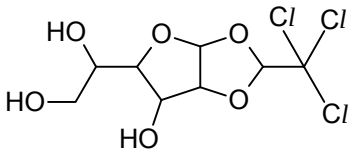
A 1, 2 and 4 only

B 2 and 3 only

C 1 and 4 only

D 3 and 4 only

17 Chloralose is a drug that is commonly used in neuroscience as an anesthetic.



chloralose

How many sp^2 hybridised carbon atoms and secondary alcohol does chloralose have?

	No. of sp^2 hybridised carbon atoms	No. of secondary alcohol
A	0	3
B	0	2
C	3	3
D	3	2

18 Which statement is correct regarding alkanes?

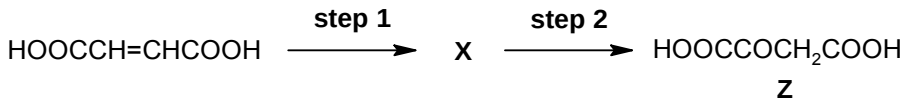
A They undergo substitution reactions.

B The carbon atoms in alkanes are sp^2 hybridised.

C They are generally unreactive due to the polar C–H bond.

D Propane reacts with chlorine gas to give three different mono–substituted products.

19 Compound **Z** can be obtained by a two-step process involving intermediate **X**.



What is the identity of intermediate **X**?

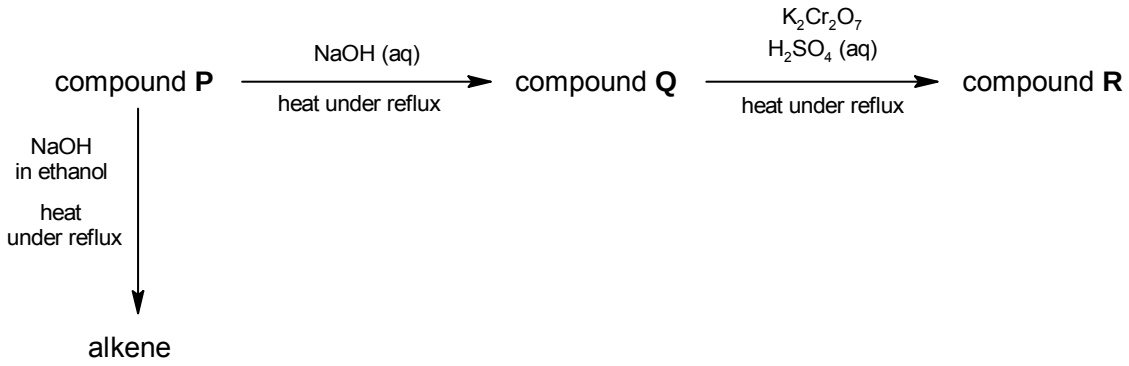
A $HOOCCH_2CH_2COOH$

B $HOOCCHBrCH_2COOH$

C $HOOCCH(OH)CH_2COOH$

D $HOOCCH(OH)CH_2OH$

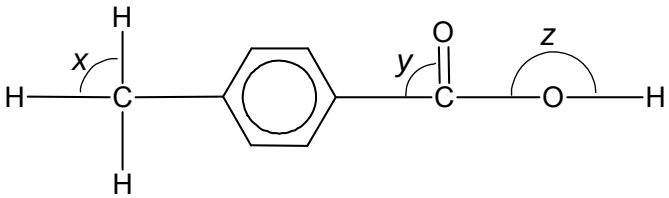
20 The flow chart shows a series of reactions.



Which class of compound are **P**, **Q** and **R**?

	P	**Q**	**R**
A	halogenoalkane	primary alcohol	carboxylic acid
B	halogenoalkane	primary alcohol	aldehyde
C	primary alcohol	aldehyde	carboxylic acid
D	primary alcohol	halogenoalkane	aldehyde

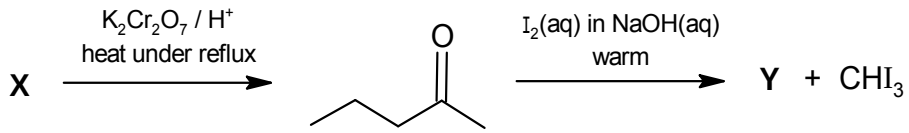
21 A compound has the structure shown.



What are the values of the bond angles *x*, *y* and *z*?

	x	*y*	*z*
A	90°	109.5°	104.5°
B	90°	120°	180°
C	109.5°	109.5°	180°
D	109.5°	120°	104.5°

22 The diagram shows reactions involving pentan–2–one.



Which row correctly identifies compounds **X** and **Y**?

	X	**Y**
A	pentan–1–ol	sodium butanoate
B	pentan–2–ol	sodium butanoate
C	pentan–1–ol	sodium pentanoate
D	pentan–2–ol	sodium pentanoate

23 Which reagent is able to distinguish between the following two compounds?

CH_3CONH_2 $CH_3OCOCH_2CH_3$

A Hot aqueous NaOH

B Liquid bromine

C 2,4–dinitrophenylhydrazine

D Concentrated H_2SO_4

24 Which products are formed when butanal reacts with Fehling's solution?

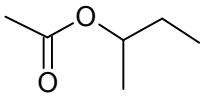
A Cu_2O and $CH_3CH_2COO^-$

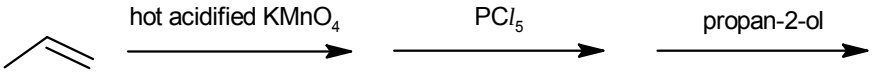
B Cu_2O and $CH_3CH_2CH_2CH_2OH$

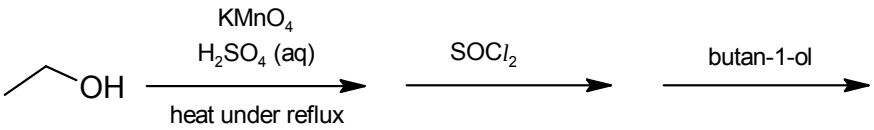
C Cu_2O and $CH_3CH_2CH_2COO^-$

D CuO and $CH_3CH_2CH_2COO^-$

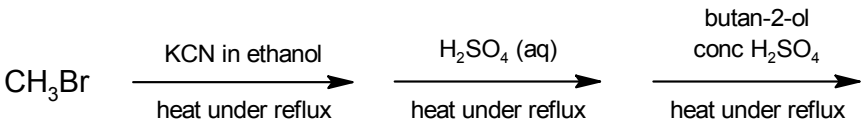
25 Which synthetic route will give the following ester as the product?



A 

B 

C

D 

26 Hoping to make ethyl propanoate, a student mixed propanoic acid and ethanol, added a little concentrated sodium hydroxide solution as catalyst and left the mixture in a sealed container in a warm water bath for several days. The experiment failed.

What was the only thing the student got wrong?

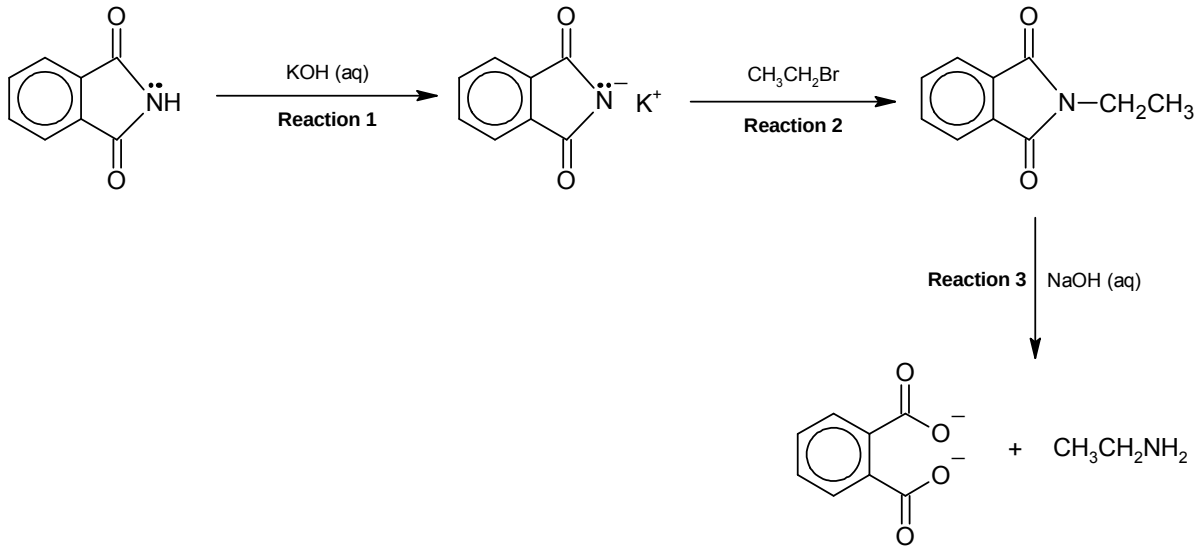
A the use of propanoic acid

B the use of ethanol

C the addition of a little concentrated sodium hydroxide solution

D leaving the mixture in a warm water bath for several days.

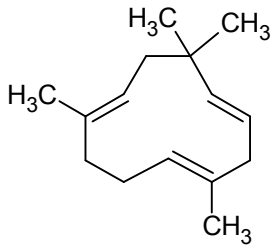
27 The diagram below shows a sequence of reactions.



How can the three reactions be classified?

	Reaction 1	Reaction 2	Reaction 3
A	hydrolysis	substitution	acid–base
B	hydrolysis	addition	acid–base
C	acid–base	substitution	hydrolysis
D	acid–base	addition	hydrolysis

28 Humulene can be extracted from carnation flowers.



Humulene is treated with hot, concentrated acidified $KMnO_4$.

Which compound will be found in the mixture of products?

1 $CH_3COCH_2CH_2CO_2H$

2 $CH_3COCH_2CO_2H$

3 $HO_2CCH_2C(CH_3)_2CO_2H$

4 $HO_2CC(CH_3)_2CO_2H$

A 1 and 4 only

B 2 and 3 only

C 1, 3 and 4 only

D 1, 2 and 3 only

29 One mole of compound **Q** reacts with an excess of sodium to produce one mole of hydrogen gas.

What could **Q** be?

1 HO_2CCH_2CHO

2 $HOCH_2CH_2OH$

3 CH_3CO_2H

A 1 only

B 2 only

C 2 and 3 only

D 1, 2 and 3 only

30 When one ethene molecule reacts with one bromine molecule by electrophilic addition, how many bonds are broken and formed?

	number of σ bonds broken	number of π bonds broken	number of σ bonds formed	number of π bonds formed
A	1	1	2	0
B	0	1	2	0
C	1	0	0	2
D	1	1	0	2

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2018 DHS YEAR 6 H1 CHEMISTRY (8873) Preliminary Examination
Paper 1 MCQ – Answers

1	2	3	4	5	6	7	8	9	10
C	**B**	**D**	**B**	**C**	**A**	**B**	**A**	**B**	**D**

11	12	13	14	15	16	17	18	19	20
C	**A**	**C**	**D**	**D**	**A**	**B**	**A**	**C**	**A**

21	22	23	24	25	26	27	28	29	30
D	**B**	**A**	**C**	**D**	**C**	**C**	**D**	**B**	**A**

Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination 2018
Year 6

H1 CHEMISTRY 8873/02

Paper 2 Structured Questions **13 September 2018**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Answer Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.

Write in dark blue or black pen

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Section A

Answer **all** the questions.

Section B

Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use								
P1	P2 Section A				P2 Section B		Total	%
	Q1	Q2	Q3	Q4	Q5	Q6		
30	13	9	20	18	20	20	110	

This document consists of **21** printed pages and **1** blank page.

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Section A

Answer **all** the questions in this section in the spaces provided.

1 **(a)** Group 1 elements are strong reducing agents. State and explain the trend of reducing power of Group 1 elements down the Group.

……

……

……

……

……[3]

(b) Group 1 elements and its compounds have many uses. Sodium hydrogencarbonate ($NaHCO_3$) is often used to treat ant stings which contains methanoic acid (HCOOH), a weak acid.

Write an equation for the dissociation of methanoic acid in water. Indicate which species are the acid, the base and their conjugate pairs in the reaction.

[2]

(c) When the ant bites, it injects a solution containing 50 % by volume of unionised methanoic acid. A typical ant may inject around 6.0×10^{-3} cm^3 of this solution.

(i) Given that the density of methanoic acid is 1.2 g cm^{-3}, what is the amount (in moles) of methanoic acid that a typical ant injects?

[1]

As soon as the methanoic acid is injected, it dissolves in water in the body to produce a solution of methanoic acid with pH 2.43.

(ii) Assuming that it dissolves fully in 1.0 cm^3 of water in the body, calculate the concentration of the methanoic acid solution that is formed initially.
You may ignore the volume of methanoic acid injected in this calculation.

[1]

(iii) Calculate the percentage of methanoic acid molecules which have dissociated in 1.0 cm^3 of water.

[2]

(d) A student was given an unlabelled bottle and was told that it contained pure sample of one of the following three compounds.

- methanol
- methanal
- propanone

(i) State the reagent used for a chemical test that could show that the sample can be either methanal and propanone but **not** methanol. Describe what would be observed.

Reagent: ……[1]

Observations: ……..……[1]

(ii) Describe one chemical test that could distinguish between methanal and propanone.

……

……

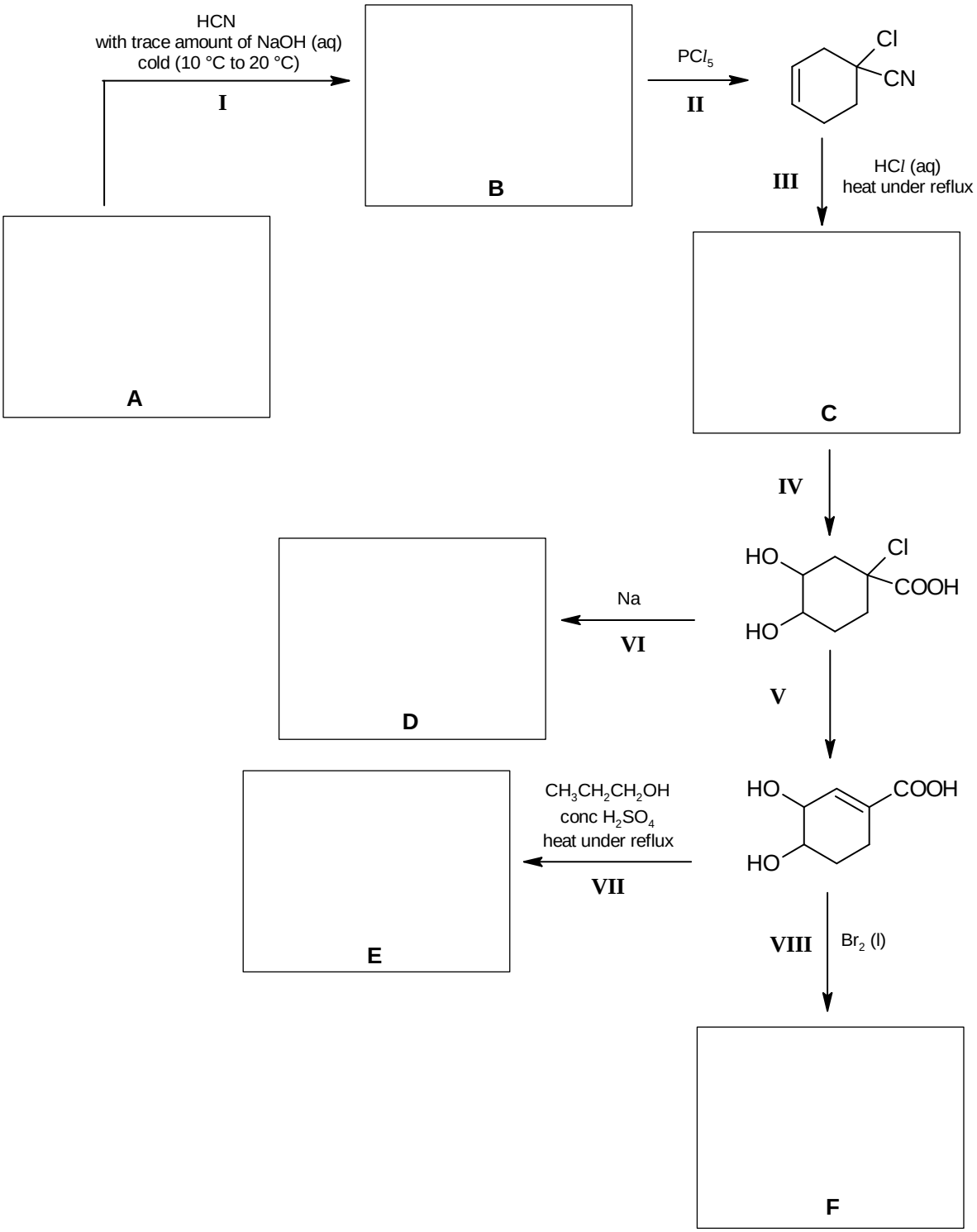
……

……..……[2]

[Total: 13]

2 A sequence of reactions starting from compound **A** is shown below.

(a) Draw the structures of compounds **A**, **B**, **C**, **D**, **E** and **F** in the boxes below.



[6]

(b) For the reaction scheme shown above, state

(i) the type of reaction occurring in reaction **I**.

……[1]

(ii) the reagents and conditions for reaction **V**.

……[1]

(c) The alcohol $CH_3CH_2CH_2OH$, used as the reagent in reaction **VII** above, can be converted into $CH_3CH{=}CH_2$. How may this conversion be achieved in a laboratory?

……

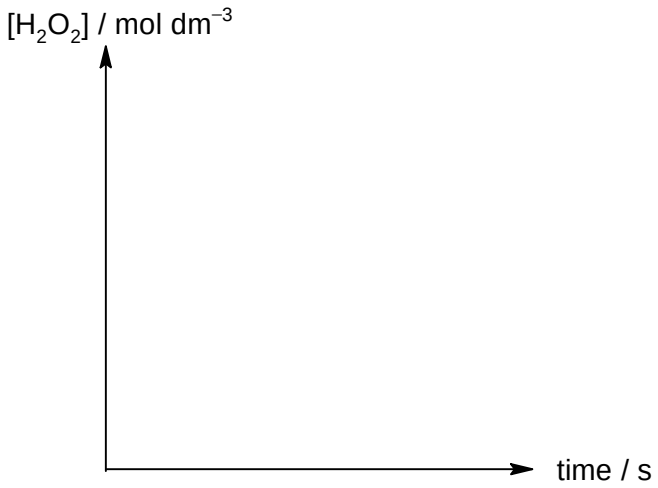
……[1]

[Total: 9]

3 **(a)** Pure hydrogen peroxide, H_2O_2, was long believed to be unstable. Its decomposition follows a first order reaction.

$$H_2O_2 \rightarrow H_2O + \tfrac{1}{2}O_2$$

(i) Sketch a graph of $[H_2O_2]$ against time to show that the reaction is first order with respect to H_2O_2.



[2]

(ii) As H_2O_2 decomposes slowly at room temperature, catalysts such as platinum metal are often added to lower the activation energy to increase the rate of reaction.

With reference to the information provided below, sketch the energy profile diagram showing the catalysed reaction only.

enthalpy change of the decomposition	–196 kJ mol^{-1}
activation energy (without catalyst)	+75 kJ mol^{-1}
activation energy (with catalyst)	+49 kJ mol^{-1}

[2]

(b) In the presence of UV light, H_2O_2 decomposes to form hydroxyl free radicals, •OH.

(i) Draw the 'dot–and–cross' diagram for H_2O_2.

[1]

(ii) Using relevant bond energy values from the *Data Booklet*, suggest the relative rate of the formation of •C*l* from chlorine gas as compared that of •OH from hydrogen peroxide.

……

……

……

……

……[2]

(iii) Propylamine, $CH_3CH_2CH_2NH_2$, may be formed via the following reaction pathway involving free radical substitution in the first step.

$$CH_3CH_2CH_3 \xrightarrow[Cl_2,\ uv]{\textbf{Step I}} CH_3CH_2CH_2Cl \xrightarrow{\textbf{Step II}} CH_3CH_2CH_2NH_2$$

Name the type of reaction occurring in **Step II**. State the reagent and conditions required for this step.

Type of reaction: ……..……..……

Reagent: ……..……...

Conditions: …….....

…….....

[2]

(iv) As the yield from the reaction in **(b)(iii)** is low, propose a 3-step synthetic route to produce propylamine from ethene instead. Show clearly the reagents and conditions as well as the intermediates involved.

[3]

(c) The kinetics of the reaction between hydrogen peroxide and iodide ions in acidic solution was studied.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow 2H_2O + I_2$$

Four separate experiments were carried out to determine the relative rates by varying the concentrations of the reactants. The results obtained are given in the table below.

Expt	$[H_2O_2]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	relative rate
1	0.03	0.03	0.03	1.0
2	0.05	0.03	0.03	1.6
3	0.05	0.01	0.06	0.53
4	0.03	0.01	0.03	0.33

(i) With reference to the overall equation given above, write the oxidation and reduction half-equations.

Oxidation half-equation: ……[1]

Reduction half-equation: ……[1]

(ii) Use the data to deduce the orders of reaction with respect to H_2O_2, I^- and H^+. Show your working clearly.

[3]

(iii) Hence, write the rate equation and state the units of the rate constant.

[2]

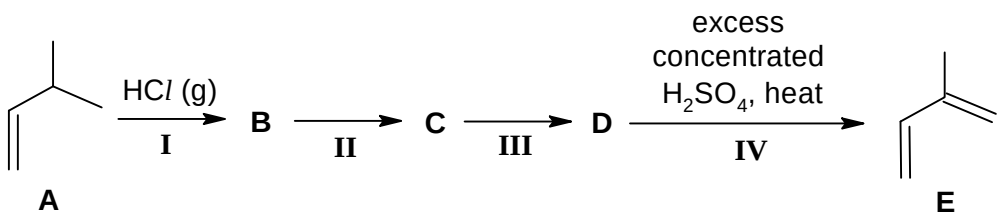
(iv) Unreacted iodide ions may be easily separated from the reaction mixture by adding silver nitrate solution, followed by filtration. State the identity and colour of the precipitate formed.

……[1]

[Total : 20]

4 Isoprene, **E**, is an organic compound that could be used to synthesise limonene, which is commonly used in fragrances.

(a) **E** can be synthesised from 3–methylbut–1–ene, **A**, in a 4–step process as follows.



(i) **B** is a major product of step **I**.

Draw the structures of compounds **B**, **C** and **D**.

[3]

B **C** **D**

(ii) Hydrogen chloride, the reagent in step **I**, is commonly used in organic synthesis.

State and explain how the thermal stabilities of hydrogen halides varies down the Group.

……..

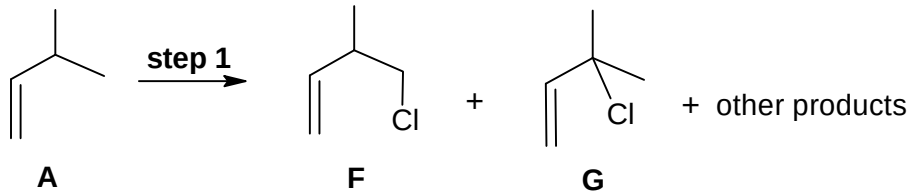
……

……

……

……[2]

(b) The following reaction shows an alternative route to form an intermediate for the synthesis of isoprene.



(i) State the reagent and condition of **step 1** which will result in formation of compounds **F** and **G**.

Reagent: ……....

Condition: ……..

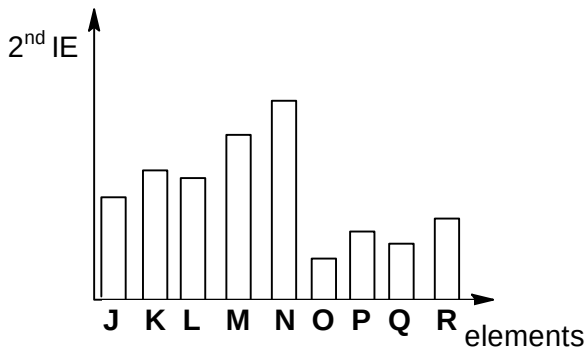
[1]

(ii) Predict the ratio in which **F** and **G** will be formed.

compound	**F**	**G**
ratio		

[1]

(c) The bar chart below shows the second ionisation energy (2nd IE) of nine consecutive elements (**J** to **R**) in Periods 2 and 3 of the Periodic Table.



(i) Write an equation for the second ionisation energy of element **J**.

……[1]

(ii) Identify element **N**.

Element **N** is ……..….[1]

(iii) Using your answers in **(c)(i)**, **(c)(ii)** and the electronic configurations of the species involved, explain the significantly higher 2nd IE of **N** compared to **O**.

……

……

……

……

……[2]

(d) The Periodic Table shows the element, Helium, placed at the top of Group 18.

(i) Suggest why the element Helium could be placed at the top of Group 2.

……

……[1]

(ii) Suggest why the element Helium is not placed at the top of Group 2, by comparing **one** physical property. Explain your answer.

……

……

……

……

……[2]

(e) Al_2O_3, SiO_2 and P_4O_{10} are oxides of Period 3 elements.

(i) Explain why both Al_2O_3 and SiO_2 are insoluble in water.

……

……

……

……

……[2]

(ii) Explain, with the aid of an equation, the reaction of P_4O_{10} with water.

……

……

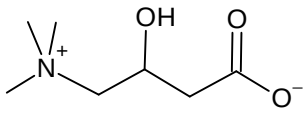
……[2]

[Total: 18]

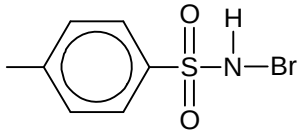
Section B

Answer **one** question from this section, in the spaces provided.

5 Levocarnitine is a quaternary ammonium compound involved in metabolism in most mammals.



levocarnitine



bromamine-T

(a) A kinetic study on the $RuCl_3$ catalysed reaction between levocarnitine and bromamine-T was carried out in aqueous hydrochloric acid.

(i) The following equilibrium exists for $RuCl_3$ in aqueous hydrochloric acid.

$$[RuCl_5(H_2O)]^{2-} + Cl^- \rightleftharpoons [RuCl_6]^{3-} + H_2O$$

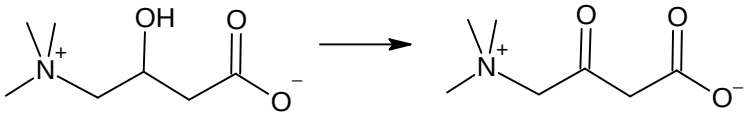
Explain why $[RuCl_6]^{3-}$ is likely to be the reactive species instead of $[RuCl_5(H_2O)]^{2-}$ in this study.

……

……

……[1]

(ii) Levocarnitine is converted into the following product by bromamine-T.



levocarnitine

State the type of reaction that levocarnitine had undergone and explain your answer in terms of changes in oxidation number.

……

……

……

……[2]

(b) A series of experiments were carried out at different temperatures under first order conditions with respect to bromamine-T.

The value of the observed rate constant, *k*, for the catalysed reaction was determined at each temperature and the results are summarised in the table below.

k / 10^4 s^{-1}	temperature, T / K
1.82	293
3.00	303
4.62	313
7.30	323

The activation energy, E_a, and the pre-exponential factor, *A*, which is a constant, for the reaction can be determined from the equation.

$$k = Ae^{\frac{-E_a}{RT}}$$

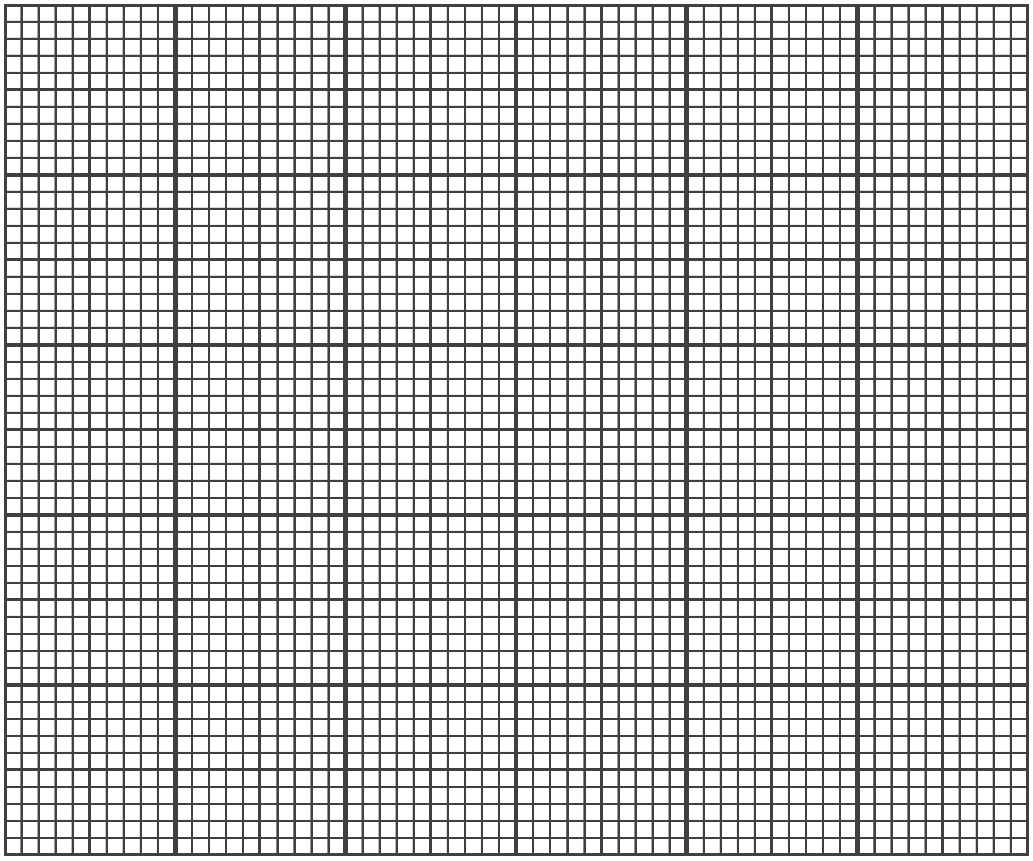
R is the molar gas constant.
T is the reaction temperature in kelvin.
k is the observed rate constant at a chosen temperature.

(i) Calculate the values of ln *k* and $\frac{1}{T}$ for each of the experiments above.

k / 10^4 s^{-1}	ln k	temperature, T / K	$\frac{1}{T}$ / K^{-1}
1.82		293	
3.00		303	
4.62		313	
7.30		323	

[2]

(ii) Hence plot a graph of ln k against $\frac{1}{T}$ and determine E_a from the gradient of the best-fit line which is $\frac{-E_a}{R}$.



Gradient ……..

E_a ……..

[4]

(iii) State the effect of temperature on the rate of the reaction and explain your answer with the aid of a Boltzmann distribution curve.

.....

.....

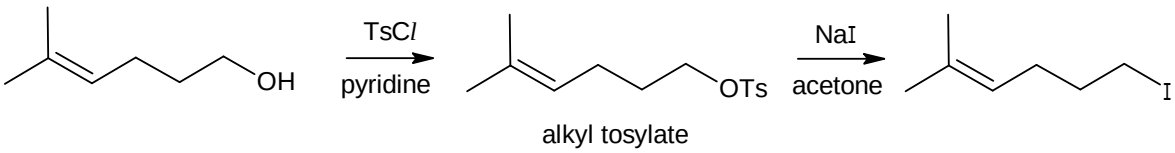
.....

.....

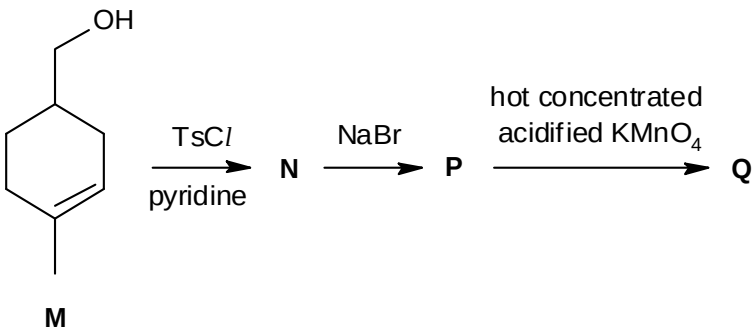
.....

.....[4]

Tosyl chlorides (TsC*l*) are often used to convert alcohols into alkyl tosylates which undergo substitution reactions. An example of this application is given below.



(c) Consider the reaction scheme below involving an alkyl tosylate **N**.



(i) State the functional group(s) present in the starting material, **M**.

.....[2]

(ii) Describe what will be observed when **M** is heated with acidified potassium dichromate(VI) and draw the structure of the organic product formed.

……

……

……

……[2]

(iii) Draw the structures of the compounds **N**, **P** and **Q**.

N	**P**	**Q**

[3]

[Total: 20]

6 Methanoic acid is the simplest carboxylic acid and is an important intermediate in chemical synthesis. It occurs naturally and is found notably in ants.

(a) **(i)** Methanoic acid is a *weak acid*. What do you understand by the term in *italics*?

……

……

……

……[2]

(ii) The acid dissociation constant, K_a, for methanoic acid is 1.6×10^{-4} mol dm^{-3}. Calculate the pH of a 0.100 mol dm^{-3} solution of methanoic acid, given that $[H^+] = \sqrt{K_a \times [HCOOH]}$.

[2]

(iii) A solution comprising methanoic acid and sodium methanoate can function as a buffer solution. With the aid of a balanced equation, describe how this buffer solution can resist pH changes when a small amount of sulfuric acid is added.

……

……

……

……[2]

(b) The energy contents of methanoic acid can be determined by means of calorimetric experiments. These experiments are usually carried out using polystyrene cup in a normal school laboratory. The standard enthalpy change of neutralisation can also be determined.

(i) Define what is meant by the *standard enthalpy change of neutralisation*.

……

……

……

……[1]

(ii) Write a balanced chemical equation for the neutralisation of methanoic acid with potassium hydroxide.

……[1]

(iii) How would you expect the enthalpy change of neutralisation in **(b)(ii)** to compare with the enthalpy change of neutralisation of nitric acid with potassium hydroxide? Explain your answer.

……

……

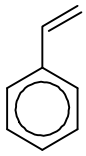
……

……[2]

(iv) Suggest a suitable indicator for the titration between methanoic acid and potassium hydroxide.

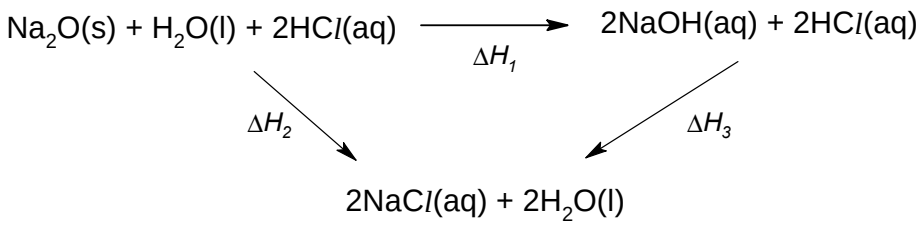
……[1]

(v) Draw the structure of polystyrene (with at least three repeating units) given that the monomer styrene has the structure as shown below.



[1]

(c) Enthalpy change of reaction 1, ΔH_1, can be determined using enthalpy change of reaction 2, ΔH_2, and enthalpy change of reaction 3, ΔH_3, in the energy cycle below.



When 6.2 g of $Na_2O(s)$ is dissolved in 250 cm^3 of 1.0 mol dm^{-3} HC*l*(aq), the temperature of the solution rose by 17 ºC.

(i) Using the cycle above, calculate ΔH_2.

[3]

(ii) The enthalpy change of neutralisation between NaOH(aq) and HC*l*(aq) is known to be –57.3 kJ mol^{-1}. Calculate ΔH_1.

[1]

(d) The German company BASF is a world leader in the production of methanoic acid. It has an efficient process of producing methanoic acid from methyl methanoate. The process is described below.

Step 1:
Methyl methanoate is mixed with water and allowed to react to produce methanol and methanoic acid.

Step 2:
Methanol is reacted with carbon monoxide and a catalyst to produce methanoic acid.

(i) State the type of reaction occurring in Step 1.

……[1]

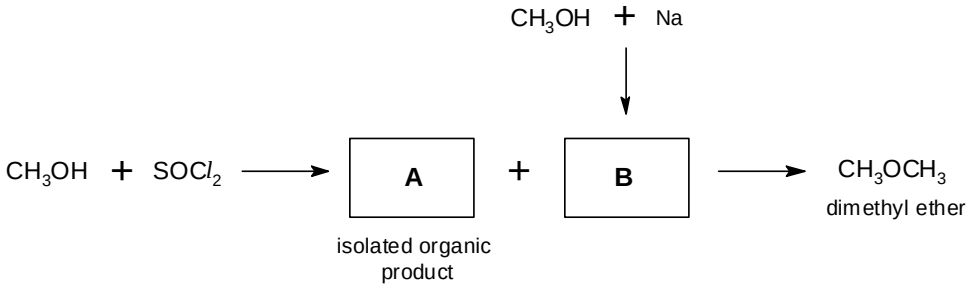
(ii) Suggest why a catalyst is used in Step 2.

……

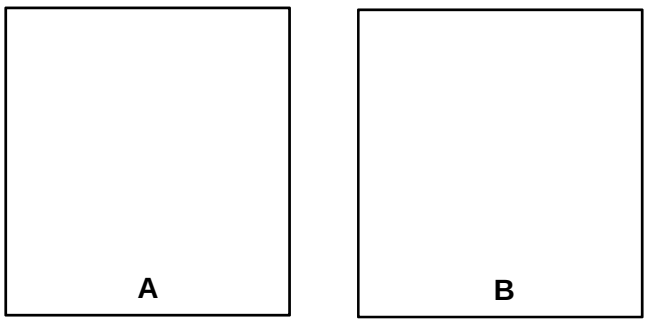
……

……[1]

(iii) Methanol produced using the process can also be used to produce dimethyl ether which is an alternative fuel to diesel.



Draw the displayed formulae of compounds **A** and **B**.



[2]

[Total: 20]

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Suggested Solutions

DUNMAN HIGH SCHOOL
Preliminary Examination 2018
Year 6

H1 CHEMISTRY 8873/02

Paper 2 Structured Questions **13 September 2018**

2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.

Write in dark blue or black pen

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Section A

Answer **all** the questions.

Section B

Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use								
P1		P2 Section A			P2 Section B		Total	%
	Q1	Q2	Q3	Q4	Q5	Q6		
30	13	9	20	18	20	20	110	

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Section A

Answer **all** the questions from this section, in the spaces provided.

1 **(a)** Group 1 elements are strong reducing agents. State and explain the trend of reducing power of Group 1 elements down the Group.

[3]

Reducing power of Group 1 elements **increases** down the group.

Number of filled principle quantum shell increases and **valence electrons are increasingly further away from the nucleus**

Valence electrons are **less strongly attracted** to the nucleus and **smaller amount of energy** is needed to remove the valence electron so it is **more easily oxidised**.

(b) Group 1 elements and its compounds have many uses. Sodium hydrogencarbonate ($NaHCO_3$) is often used to treat ant stings which contains methanoic acid (HCOOH), a weak acid.

Write an equation for the dissociation of methanoic acid in water. Indicate which species are the acid, the base and their conjugate pairs in the reaction.

[2]

$$HCOOH + H_2O \rightleftharpoons HCOO^- + H_3O^+$$

Acid: HCOOH
Conjugate base: $HCOO^-$
Base: H_2O
Conjugate acid: H_3O^+

(c) When the ant bites, it injects a solution containing 50 % by volume of unionised methanoic acid. A typical ant may inject around 6.0×10^{-3} cm^3 of this solution.

(i) Given that the density of methanoic acid is 1.2 g cm^{-3}, what is the amount (in moles) of methanoic acid that a typical ant injects?

[1]

volume of HCOOH = $6.0 \times 10^{-3} \times 0.5$
= 3.0×10^{-3} cm^3

mass of HCOOH = $3.0 \times 10^{-3} \times 1.2$
= 0.00360 g

no of moles of HCOOH = $\frac{0.00360}{46.0}$

= **7.83×10^{-5} mol** (3 s.f.)

As soon as the methanoic acid is injected, it dissolves in water in the body to produce a solution of methanoic acid with pH 2.43.

(ii) Assuming that it dissolves fully in 1.0 cm^3 of water in the body, calculate the concentration of the methanoic acid solution that is formed initially.
You may ignore the volume of methanoic acid injected in this calculation.

[1]

$[HCOOH] = \frac{7.826 \times 10^{-5}}{0.001}$

$= \underline{\mathbf{7.83 \times 10^{-2}}}$ mol dm^{-3} (3 s.f.)

(iii) Calculate the percentage of methanoic acid molecules which have dissociated in 1.0 cm^3 of water.

[2]

$[H^+] = 10^{-2.43}$

$= \underline{\mathbf{3.7154 \times 10^{-3}}}$ mol dm^{-3} (5 s.f.)

$\text{percentage} = \frac{[H^+]}{[HCOOH]} \times 100\%$

$= \frac{3.72 \times 10^{-3}}{7.826 \times 10^{-2}} \times 100\%$

$= \underline{\mathbf{4.75\ \%}}$ (3 s.f.)

(d) A student was given an unlabelled bottle and was told that it contained pure sample of one of the following three compounds.

- methanol
- methanal
- propanone

(i) State the reagent used for a chemical test that could show that the sample can be either methanal and propanone but **not** methanol. Describe what would be observed.

[2]

Reagent: **2,4–DNPH**

Observations: **orange precipitate observed.**

(ii) Describe one chemical test that could distinguish between methanal and propanone.

[2]

Add **Tollens' reagent and warm** to both samples. Only methanal will form **black/ grey solid** or **silver mirror**

OR

Add **Fehling's solution and warm** to both samples. Only methanal will form **reddish– brown precipitate**.

OR

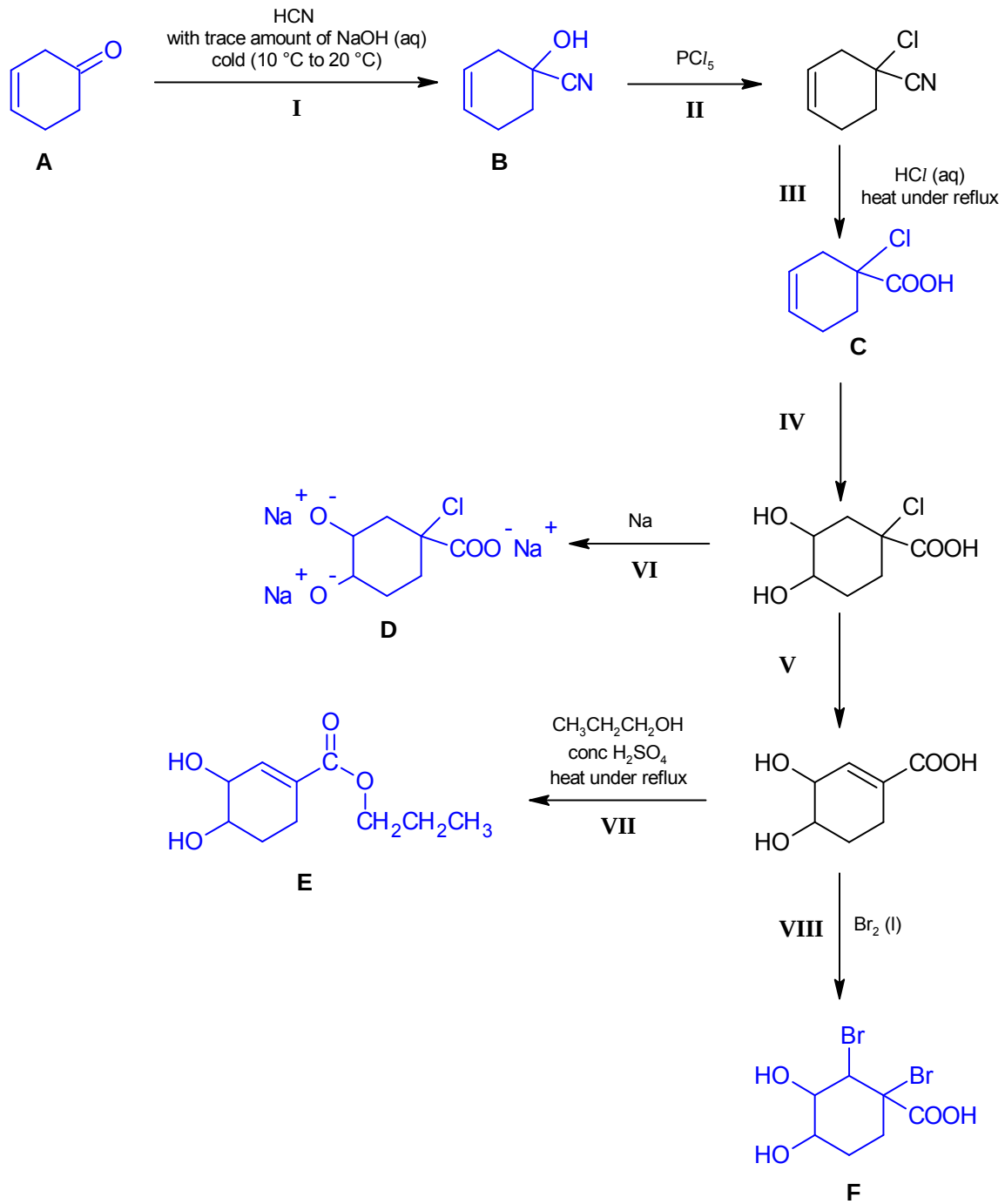
Add **alkaline aqueous iodine and warm** to both samples. Only propanone will form **yellow precipitate**.

[Total: 13]

2 A sequence of reactions starting from compound **A** is shown below.

(a) Draw the structures of compounds **A**, **B**, **C**, **D**, **E** and **F** in the boxes below.

[6]



(b) For the reaction scheme shown above, state

(i) the type of reaction occurring in reaction **I**.

[1]

(Nucleophilic) **Addition**

(ii) the reagents and conditions for reaction **V**.

[1]

KOH in alcohol, heat under reflux

(c) The alcohol $CH_3CH_2CH_2OH$, used as the reagent in reaction **VII** above, can be converted into $CH_3CH{=}CH_2$. How may this conversion be achieved in a laboratory?

[1]

Add **excess concentrated H_2SO_4** to a sample of $CH_3CH_2CH_2OH$ and **heat**.

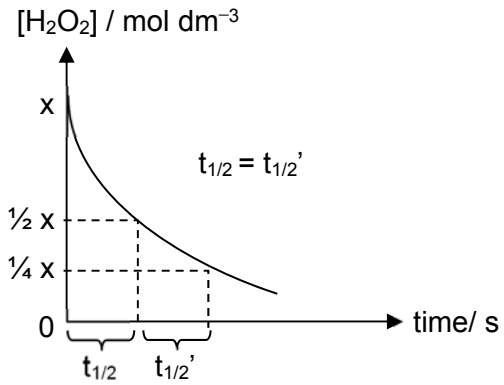
[Total: 9]

3 **(a)** Pure hydrogen peroxide, H_2O_2, was long believed to be unstable. Its decomposition follows a first order reaction.

$$H_2O_2 \rightarrow H_2O + \tfrac{1}{2}O_2$$

(i) Sketch a graph of $[H_2O_2]$ against time to show that the reaction is first order with respect to H_2O_2.

[2]

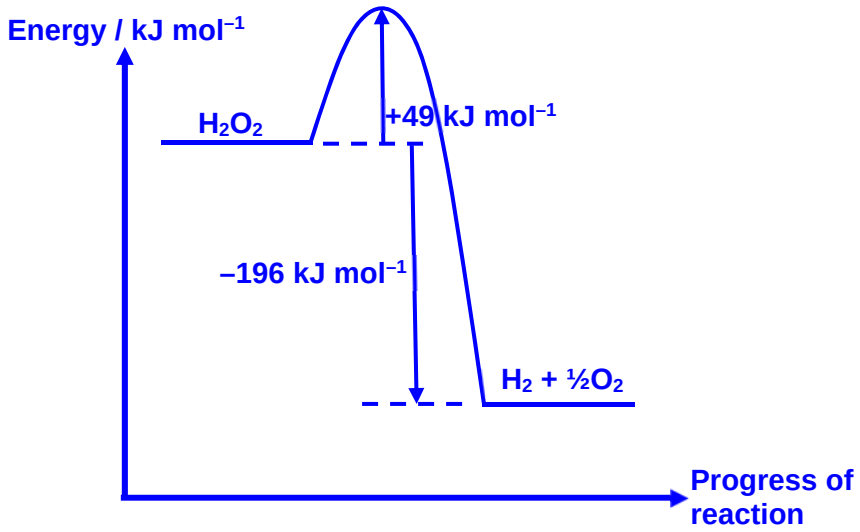


(ii) As H_2O_2 decomposes slowly at room temperature, catalysts such as platinum metal are often added to lower the activation energy to increase the rate of reaction.

With reference to the information provided below, sketch the energy profile diagram showing the catalysed reaction only.

enthalpy change of the decomposition	-196 kJ mol^{-1}
activation energy (without catalyst)	$+75$ kJ mol^{-1}
activation energy (with catalyst)	$+49$ kJ mol^{-1}

[2]



(b) In the presence of UV light, H_2O_2 decomposes to form hydroxyl free radicals, •OH.

(i) Draw the 'dot-and-cross' diagram for H_2O_2.

[1]

(ii) Using relevant bond energy values from the *Data Booklet*, suggest the relative rate of the formation of •C*l* from chlorine gas as compared that of •OH from hydrogen peroxide.

[2]

From the *Data Booklet*,
Bond energy of O–O = 150 kJ mol^{-1}
Bond energy of C*l*–C*l* = 244 kJ mol^{-1}

Ease of cleavage of bond: O–O > C*l*–C*l*

Rate of formation of •OH radicals is **faster** than •C*l*.

(iii) Propylamine, $CH_3CH_2CH_2NH_2$, may be formed via the following reaction pathway involving free radical substitution in the first step.

$$CH_3CH_2CH_3 \xrightarrow[Cl_2,\ uv]{\textbf{Step I}} CH_3CH_2CH_2Cl \xrightarrow{\textbf{Step II}} CH_3CH_2CH_2NH_2$$

Name the type of reaction occurring in **Step II**. State the reagent and conditions required for this step.

[2]

Type of reaction: (Nucleophilic) **Substitution**

Reagent: **NH_3 in excess**
Condition: **in ethanol, heat in sealed tube**

(iv) As the yield from the reaction in **(b)(iii)** is low, propose a 3-step synthetic route to produce propylamine from ethene instead. Show clearly the reagents and conditions as well as the intermediates involved.

[3]

$$H_2C{=}CH_2 \xrightarrow{HCl(g)} CH_3CH_2Cl \xrightarrow[\text{heat under reflux}]{\text{alcoholic KCN}} CH_3CH_2CN \xrightarrow[\text{dry ether}]{LiAlH_4 \text{ in}} CH_3CH_2CH_2NH_2$$

(c) The kinetics of the reaction between hydrogen peroxide and iodide ions in acidic solution was studied.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow 2H_2O + I_2$$

Four separate experiments were carried out to determine the relative rates by varying the concentrations of the reactants. The results obtained are given in the table below.

Expt	$[H_2O_2]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	relative rate
1	0.03	0.03	0.03	1.0
2	0.05	0.03	0.03	1.6
3	0.05	0.01	0.06	0.53
4	0.03	0.01	0.03	0.33

(i) With reference to the overall equation given above, write the oxidation and reduction half–equations.

[2]

[O]: $2I^- \rightarrow I_2 + 2e^-$
[R]: $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$

(ii) Use the data to deduce the orders of reaction with respect to H_2O_2, I^- and H^+. Show your working clearly.

[3]

Comparing Experiments 1 and 2, $[H_2O_2]$ increases by 1.6 times as rate also increases by 1.6 times whilst keeping $[I^-]$ and $[H^+]$ constant.

⇒ Order of reaction with respect to H_2O_2 is **1**.

Comparing Experiments 1 and 4, $[I^-]$ increases by 3 times as rate also increases by 3 times whilst keeping $[H_2O_2]$ and $[H^+]$ constant.

⇒ Order of reaction with respect to I^- is **1**.

Comparing Experiments 2 and 3, as $[H_2O_2]$ is constant while $[I^-]$ decreases by 3 times and $[H^+]$ increases by 2 times, rate decreases by 3 times. Hence, change in $[H^+]$ does not affect the rate.

⇒ Order of reaction with respect to H^+ is **0**.

(iii) Hence, write the rate equation and state the units of the rate constant.

[2]

rate = $k[H_2O_2][I^-]$

Units of rate constant = **mol^{-1} dm^3 s^{-1}**

(iv) Unreacted iodide ions may be easily separated from the reaction mixture by adding silver nitrate solution, followed by filtration. State the identity and colour of the precipitate formed.

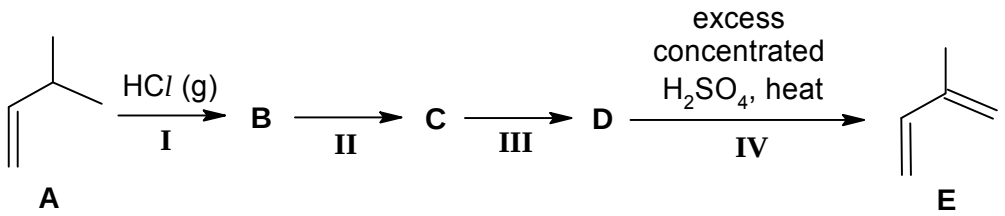
[1]

AgI and **yellow** ppt.

[Total : 20]

4 Isoprene, **E**, is an organic compound that could be used to synthesise limonene, which is commonly used in fragrances.

(a) **E** can be synthesised from 3–methylbut–1–ene, **A**, in a 4–step process as follows.

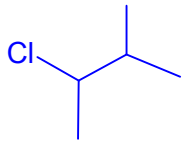


(i) **B** is a major product of step **I**.

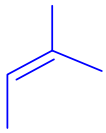
Draw the structures of compounds **B**, **C** and **D**.

[3]

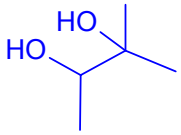
B :



C :



D :



(ii) Hydrogen chloride, the reagent in step **I**, is commonly used in organic synthesis.

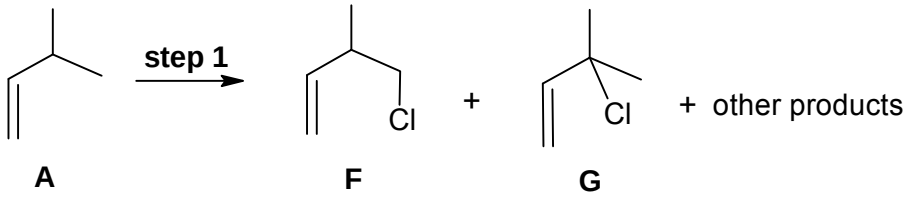
State and explain how the thermal stabilities of hydrogen halides varies down the Group.

[2]

Thermal stability of hydrogen halides **decreases** down the group

Down the group,
Bond energy decreases [BE (H–F) > BE (H–Cl) > BE (H–Br) > BE (H–I)].
Covalent bond strength also **decreases** [H–F > H–Cl > H–Br > H–I].
Hence hydrogen halides decompose more readily down the group.

(b) The following reaction shows an alternative route to form an intermediate for the synthesis of isoprene.



(i) State the reagents and conditions of **step 1** which will result in formation of compounds **F** and **G**.

[1]

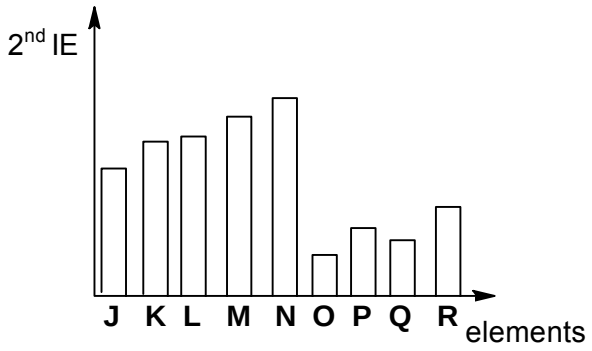
Limited Cl_2, uv

(ii) Predict the ratio in which **F** and **G** will be formed.

[1]

F : **G**
6 : 1

(c) The bar chart below shows the second ionisation energy (2nd IE) of nine consecutive elements (**J** to **R**) in Periods 2 and 3 of the Periodic Table.



(i) Write an equation for the second ionisation energy of element **J**.

[1]

$J^+(g) \rightarrow J^{2+}(g) + e^-$

(ii) Identify element **N**.

[1]

Na

(iii) Using your answers in **(c)(i)**, **(c)(ii)** and the electronic configurations of the species involved, explain the significantly higher 2nd IE of **N** compared to **O**.

[2]

Electronic configuration: **N^{2+} ($1s^2 2s^2 2p^6$)**; **O^{2+} ([Ne]$3s^1$)**

The 3rd ionisation energy of **N** involves the removal of a **2p** electron

The 3rd ionisation energy of **O** involves the removal of a **3s** electron

A **larger amount of energy** is required to remove the **2p** electron in **N^{2+}** which is in an **inner quantum shell** compared to **3s** electron in **O^{2+}**.

Hence 3rd ionisation energy of **N** is significantly higher than that of **O.**

(d) The Periodic Table shows the element, Helium, placed at the top of Group 18.

(i) Suggest why the element Helium could be placed at the top of Group 2.

[1]

Helium has **2 valence electrons** like all other Group 2 elements.

(ii) Suggest why the element Helium is not placed at the top of Group 2, by comparing **one** physical property. Explain your answer.

[2]

Helium atoms are held by **weak instantaneous dipole induced dipole interactions** while within group 2 elements exist **strong electrostatic forces of attraction between cations and a sea of delocalised electrons**.

Hence, helium has **low melting/boiling point** and it **exist as a gas** while group 2 elements has **high melting/boiling point and exist as a solid** at room temperature.

OR

Hence, **helium** is a **non-conductor of electricity** due to (**absence of mobile/delocalised electrons**) while **group 2 elements** are **good conductor** of **electricity** due to (**presence of delocalised electrons)**.

(e) Al_2O_3, SiO_2 and P_4O_{10} are oxides of Period 3 elements.

(i) Explain why both Al_2O_3 and SiO_2 are insoluble in water.

[2]

Al_2O_3 is insoluble in water due to a **very exothermic lattice energy** and hence, it is very **difficult to break down the ionic lattice structure**.

SiO_2 is insoluble in water due to **strong and extensive covalent bonds between Si and O atoms**.

(ii) Explain, with the aid of an equation, the reaction of P_4O_{10} with water.

[2]

P_4O_{10} is **covalent** in nature and reacts **readily** with water to form an **acidic** solution.

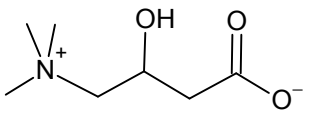
$$\mathbf{P_4O_{10}(s) + 6H_2O(\mathit{l}) \rightarrow 4H_3PO_4(aq)}$$

[Total: 18]

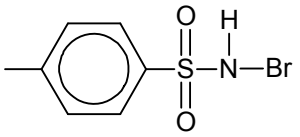
Section B

Answer **one** question from this section, in the spaces provided.

5 Levocarnitine is a quaternary ammonium compound involved in metabolism in most mammals.



levocarnitine



bromamine-T

(a) A kinetic study on the $RuCl_3$ catalysed reaction between levocarnitine and bromamine-T was carried out in aqueous hydrochloric acid.

(i) The following equilibrium exists for $RuCl_3$ in aqueous hydrochloric acid.

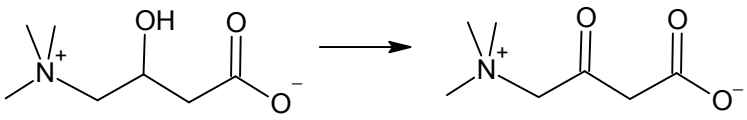
$$[RuCl_5(H_2O)]^{2-} + Cl^- \rightleftharpoons [RuCl_6]^{3-} + H_2O$$

Explain why $[RuCl_6]^{3-}$ is likely to be the reactive species instead of $[RuCl_5(H_2O)]^{2-}$ in this study.

[1]

By Le Chatelier's Principle, the presence of **chloride ions from aqueous HCl** will shift the **position of equilibrium to the right**, favouring the formation of $[RuCl_6]^{3-}$.

(ii) Levocarnitine is converted into the following product by bromamine-T.



levocarnitine

State the type of reaction that levocarnitine had undergone and explain your answer in terms of changes in oxidation number.

[2]

Oxidation

The oxidation number of **carbon** (bonded to -OH group) **increased from 0 in levocarnitine** to **+2 in the product**.

(b) A series of experiments were carried out at different temperatures under first order conditions with respect to bromamine-T.

The value of the observed rate constant, *k*, for the catalysed reaction was determined at each temperature and the results are summarised in the table below.

k / 10^4 s^{-1}	temperature, T / K
1.82	293
3.00	303
4.62	313
7.30	323

The activation energy, E_a, and the pre-exponential factor, *A*, which is a constant, for the reaction can be determined from the equation.

$$k = Ae^{\frac{-E_a}{RT}}$$

R is the molar gas constant.
T is the reaction temperature in kelvin.
k is the observed rate constant at a chosen temperature.

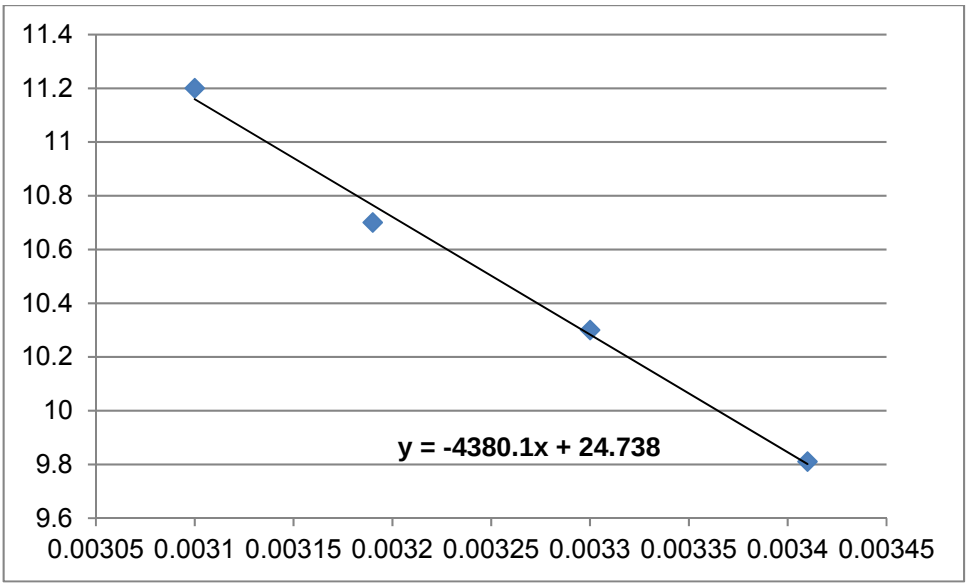
(i) Calculate the values of ln *k* and $\frac{1}{T}$ for each of the experiments above.

[2]

k / 10^4 s^{-1}	ln *k*	temperature, *T* / K	$\frac{1}{T}$ / K^{-1}
1.82	9.81	293	0.00341
3.00	10.3	303	0.00330
4.62	10.7	313	0.00319
7.30	11.2	323	0.00310

(ii) Hence plot a graph of ln *k* against $\frac{1}{T}$ and determine E_a from the gradient of the best-fit line which is $\frac{-E_a}{R}$.

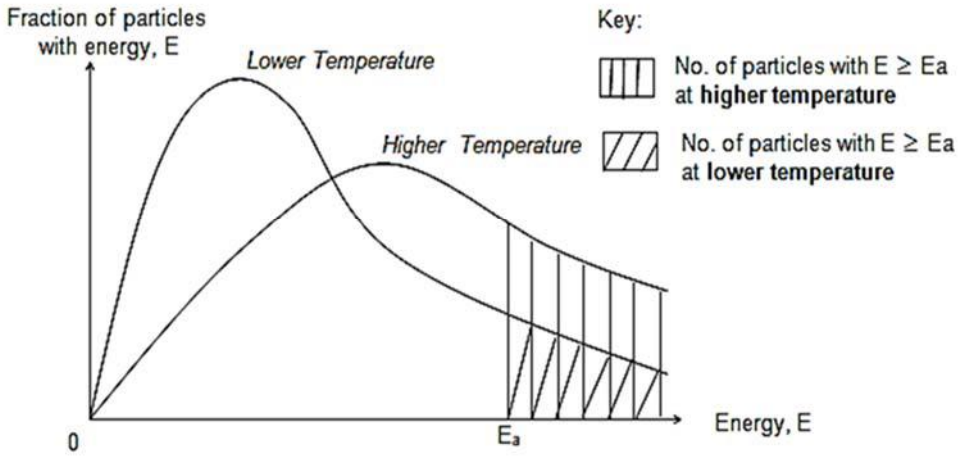
[4]



Gradient = $\frac{-E_a}{R}$ = –4380.1 K
Hence E_a = 36399 J mol^{-1} = **36.4 kJ mol^{-1}**

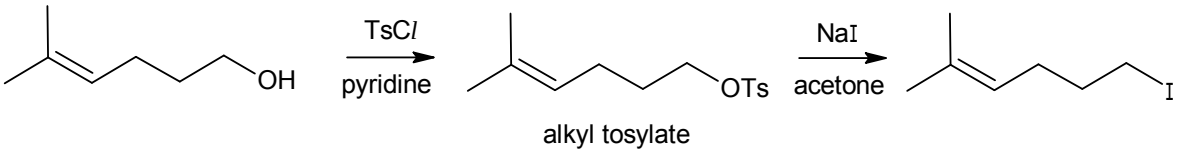
(iii) State the effect of temperature on the rate of the reaction and explain your answer with the aid of a Boltzmann distribution curve.

[4]

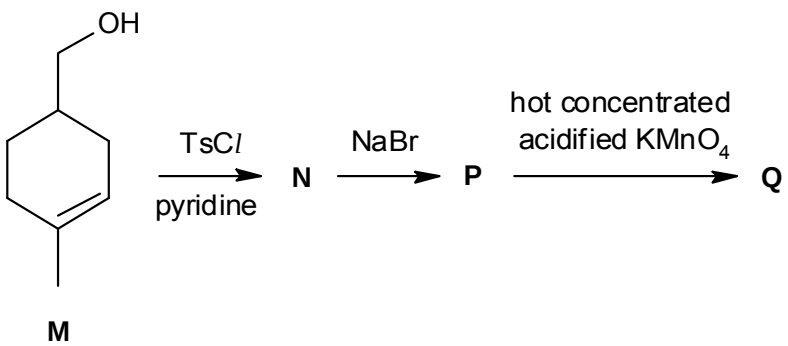


When temperature of the reaction increases,
- average kinetic energy of reactant particles increases
- there are more reactant particles with energy ≥ E_a
- number of effective collisions per unit time / frequency of effective collisions increases
- rate of reaction increases, since the rate of reaction is proportional to the frequency of effective collisions

Tosyl chlorides (TsC*l*) are often used to convert alcohols into alkyl tosylates which undergo substitution reactions. An example of this application is given below.



(c) Consider the reaction scheme below involving an alkyl tosylate **N**.



(i) State the functional group(s) present in the starting material, **M**.

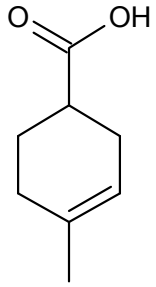
[2]

Primary alcohol and **alkene**

(ii) Describe what will be observed when **M** is heated with acidified potassium dichromate(VI) and draw the structure of the organic product formed.

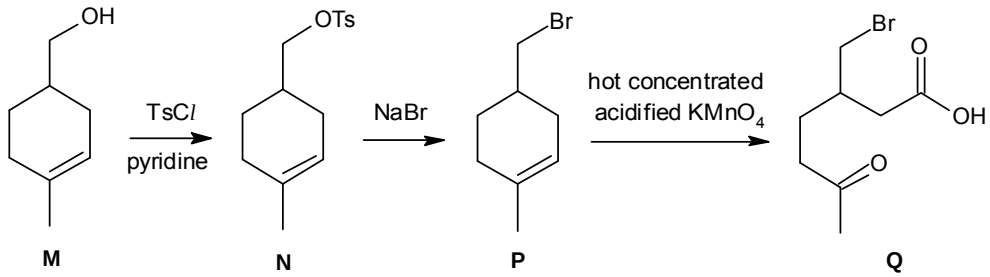
[2]

Orange acidified potassium dichromate(VI) **turns green**.



(iii) Draw the structures of the compounds **N**, **P** and **Q**.

[3]



[Total: 20]

6 Methanoic acid is the simplest carboxylic acid and is an important intermediate in chemical synthesis. It occurs naturally and is found notably in ants.

(a) **(i)** Methanoic acid is a *weak acid*. What do you understand by the term in *italics*?

[2]

An acid is a compound which is a **proton donor**. A weak acid is an acid which only **partially dissociates** in water to release proton.

(ii) The acid dissociation constant, K_a, for methanoic acid is 1.6×10^{-4} mol dm^{-3}. Calculate the pH of a 0.100 mol dm^{-3} solution of methanoic acid, given that $[H^+] = \sqrt{K_a \times [HCOOH]}$.

[2]

$[H^+] = \sqrt{1.6 \times 10^{-4} \times 0.100}$
$= 4.00 \times 10^{-3}$ mol dm^{-3}
pH = –log (4.00×10^{-3})
= 2.40 (3 sf)

(iii) A solution comprising methanoic acid and sodium methanoate can function as a buffer solution. With the aid of a balanced equation, describe how this buffer solution can resist pH changes when a small amount of sulfuric acid is added. [2]

$H^+ + HCOO^- \rightarrow HCOOH$

When a small amount of sulfuric acid is added, methanoate will react with and **remove the acid to form methanoic acid**. This ensures that the pH of the solution is maintained **fairly constant**.

(b) The energy contents of methanoic acid can be determined by means of calorimetric experiments. These experiments are usually carried out using polystyrene cup in a normal school laboratory. The standard enthalpy change of neutralisation can also be determined.

(i) Define what is meant by the *standard enthalpy change of neutralisation*. [1]

Standard enthalpy change of neutralisation is the energy evolved when one mole of water is formed when an acid is completely neutralised by a base under standard conditions.

(ii) Write a balanced chemical equation for the neutralisation of methanoic acid with potassium hydroxide. [1]

$HCOOH + KOH \rightarrow HCOO^-K^+ + H_2O$

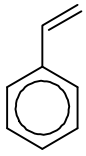
(iii) How would you expect the enthalpy change of neutralisation in **(b)(ii)** to compare with the enthalpy change of neutralisation of nitric acid with potassium hydroxide? Explain your answer. [2]

The enthalpy change of neutralisation in **(b)(ii)** will be **less exothermic**. Some of the heat evolved as a result of the neutralisation is **absorbed by the dissociation of methanoic acid, a weak acid**. Hence, less heat should be evolved.

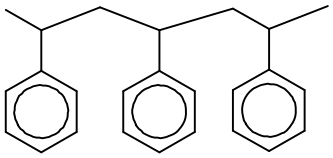
(iv) Suggest a suitable indicator for the titration between methanoic acid and potassium hydroxide. [1]

Phenolphthalein or any other suitable indicator (e.g. thymol blue)

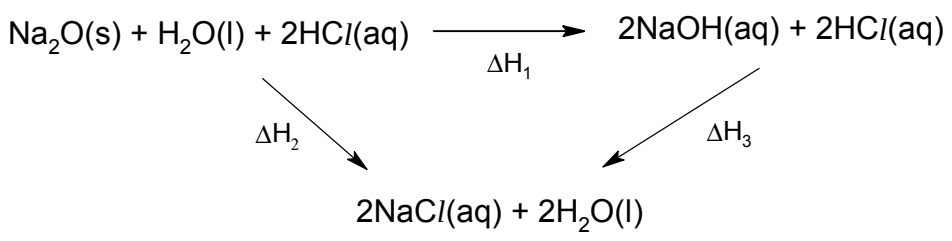
(v) Draw the structure of polystyrene (with at least three repeating units) given that the monomer styrene has the structure as shown below.



[1]



(c) Enthalpy change of reaction 1, ΔH_1, can be determined using enthalpy change of reaction 2, ΔH_2, and enthalpy change of reaction 3, ΔH_3, in the energy cycle below.



When 6.2 g of $Na_2O(s)$ is dissolved in 250 cm^3 of 1.0 mol dm^{-3} HC*l*(aq), the temperature of the solution rose by 17 °C.

(i) Using the cycle above, calculate ΔH_2.

[3]

No. of mol of Na_2O = $\frac{6.2}{(23 \times 2+16)}$ = 0.100 mol (exact)
No. of mol of HC*l* = 0.25 × 1.0 = 0.250 mol

Since n_{Na2O}: n_{HCl} = 1:2, HC*l* is in excess.
This means that 0.200 mol of H_2O was formed.

q = mcΔT = 250 × 4.18 × 17 = 17765 J

$\Delta H_2 = \frac{17765}{0.200} \times 2 = -177650$ J mol^{-1} = –178 kJ mol^{-1} (3 sf)

(ii) The enthalpy change of neutralisation between NaOH(aq) and HC*l*(aq) is known to be –57.3 kJ mol^{-1}. Calculate ΔH_1.

[1]

By Hess' Law,
ΔH_1 = –177.65 – (2)(–57.3)
= –63.1 kJ mol^{-1} (3 sf)

(d) The German company BASF is a world leader in the production of methanoic acid. It has an efficient process of producing methanoic acid from methyl methanoate. The process is described below.

Step 1:
Methyl methanoate is mixed with water and allowed to react to produce methanol and methanoic acid.

Step 2:
Methanol is reacted with carbon monoxide and a catalyst to produce methanoic acid.

(i) State the type of reaction occurring in Step 1.

[1]

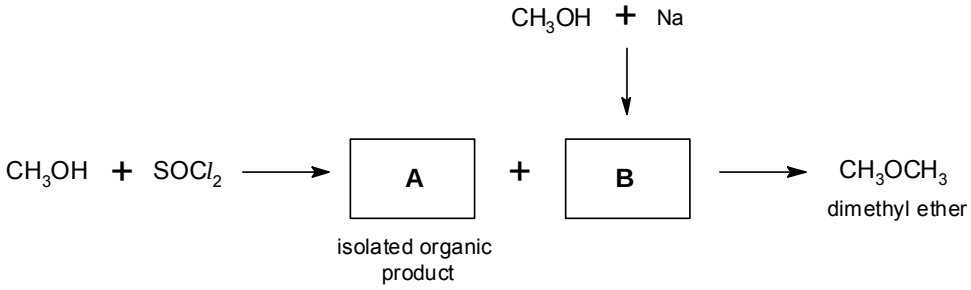
Step 1: Hydrolysis

(ii) Suggest why a catalyst is used in Step 2.

[1]

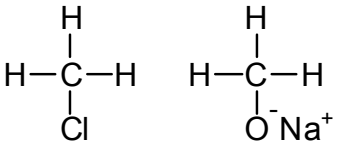
A catalyst is required to **speed up the reaction** because carbon monoxide has a very **strong triple bond** which must be weakened / broken in order for the reaction to occur.

(iii) Methanol produced using the process can also be used to produce dimethyl ether which is an alternative fuel to diesel.



Draw the displayed formulae of compounds **A** and **B**.

[2]



A **B**

[Total: 20]

INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME	
CLASS	
INDEX NUMBER	

CHEMISTRY 8873/01

Paper 1 Multiple Choice **14 Sep 2018**

1 hour

Additional Materials: Data Booklet
Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class on all the work you hand in.
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

This document consists of **12** printed pages.

Innova Junior College

For each question there are four possible answers, **A, B, C,** and **D**. Choose the **one** you consider to be correct.

1 A giant molecule contains a large amount of carbon, mainly of isotopes ^{12}C and ^{13}C. It was found that the relative atomic mass of carbon in the molecule is 12.20.

What is the ratio of ^{12}C and ^{13}C?

A 3:1 **B** 4:1 **C** 3:4 **D** 1:4

2 Which statements about relative molecular mass are correct?

1 It is the sum of the relative atomic masses of all the atoms within the molecule.

2 It is the ratio of the average mass of a molecule to the mass of a ^{12}C atom.

3 It is the ratio of the mass of 1 mol of molecules to the mass of 1 mol of ^{1}H atoms.

4 It is the ratio of the mass of 1 mol of molecules to the mass of 1 mol of ^{12}C atoms.

A 1 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 4 only

3 *Use of the Data Booklet is relevant to this question.*

Some isotopes are unstable and decompose naturally. In one type of decomposition, a neutron in the nucleus decomposes to form a proton, which is retained in the nucleus, and an electron, which is expelled from the atom.

Which change describes a process of this sort?

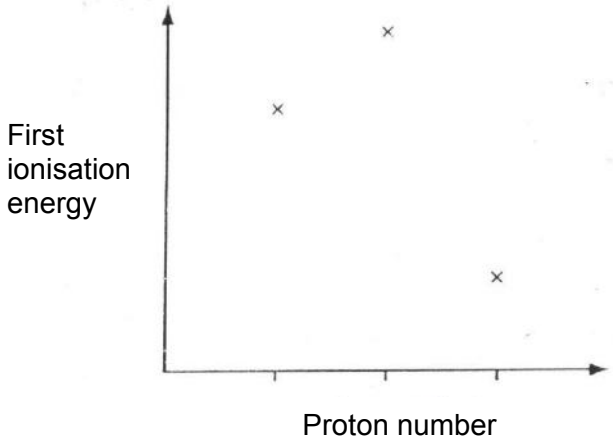
A $^{11}C \longrightarrow {}^{12}C$

B $^{22}Na \longrightarrow {}^{22}Ne$

C $^{32}P \longrightarrow {}^{31}P$

D $^{40}K \longrightarrow {}^{40}Ca$

4 Three successive elements in the Periodic Table have first ionisation energies which have the pattern shown in the diagram.



What could be the first element of this sequence?

A N

B O

C F

D Na

5 Which of the following ions contains half-filled d-orbitals?

1 Mn^{2+}

2 Cu^{+}

3 Fe^{2+}

4 Fe^{3+}

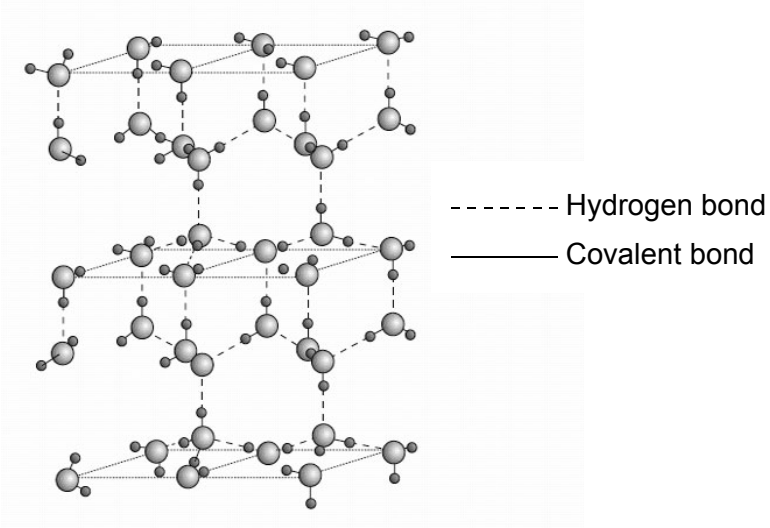
A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

D 3 and 4 only

6 Ice is the crystalline form of water. The diagram below shows part of the structure of ice.



Which of the following statements is **not** true about ice?

A Ice has a lower density than water at 0 °C due to its open structure.

B The bond angle about oxygen in ice is 109.5°.

C Ice does not conduct electricity.

D Ice has a giant covalent structure.

7 Which of the following pairs of substances **does not** include a giant structure and a simple molecular structure?

A aluminum and silicon(IV) oxide

B aluminium oxide and aluminium chloride

C silicon and chlorine

D silicon and silicon(IV) chloride

8 The reduction of ethanal to ethanol using $H_2(g)$ is shown in the equation below.

$$\underset{\text{ethanal}}{CH_3CHO(l)} + H_2(g) \rightarrow \underset{\text{ethanol}}{CH_3CH_2OH(l)}$$

substance	ΔH_c^θ / kJ mol^{-1}
ethanal	–1170
hydrogen	–286
ethanol	–1370

Given the standard enthalpy change of combustion in the table above, what is the enthalpy change of the reduction of ethanal to ethanol?

A +86 kJ mol^{-1} **B** –86 kJ mol^{-1} **C** –2826 kJ mol^{-1} **D** +2826 kJ mol^{-1}

9 The bond dissociation energy of H–F is 565 kJ mol^{-1}. Which equation correctly describes the reaction whereby 565 kJ of energy is released?

A $HF(l) \rightarrow HF(g)$

B $H(g) + F(g) \rightarrow HF(g)$

C $HF(g) \rightarrow H(g) + F(g)$

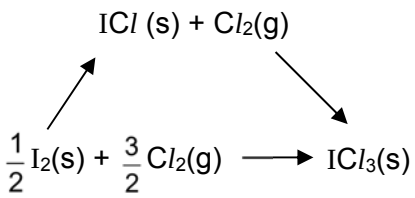
D $\frac{1}{2} H_2(g) + \frac{1}{2} F_2(g) \rightarrow HF(g)$

10 Iodine trichloide, ICl_3, is made by reacting iodine with chlorine.

$$I_2(s) + Cl_2(g) \rightarrow 2ICl(s); \quad \Delta H^{\theta} = +14 \text{ kJ mol}^{-1}$$

$$ICl(s) + Cl_2(g) \rightarrow ICl_3(s); \quad \Delta H^{\theta} = -88 \text{ kJ mol}^{-1}$$

By using the above data and the following energy cycle, what is the enthalpy change of the formation of solid iodine trichloride?



A –60 kJ mol^{-1} **B** –74 kJ mol^{-1} **C** –81 kJ mol^{-1} **D** –162 kJ mol^{-1}

11 The decomposition

$$2N_2O_5 \rightarrow 4NO_2 + O_2$$

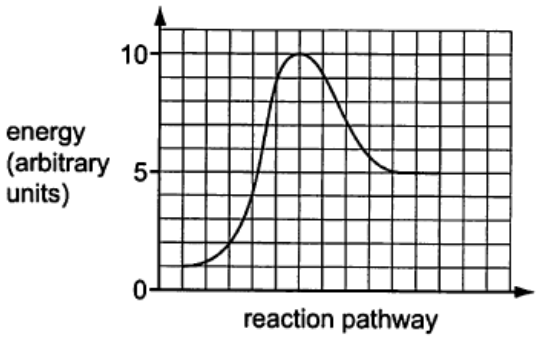
is first order with respect to N_2O_5.

In an experiment 0.10 mol of pure N_2O_5 was put into an evacuated flask. It was found that there was 0.025 mol of N_2O_5 left 34 minutes later.

What is the time taken for the amount of NO_2 to rise from 0 mol to 0.10 mol?

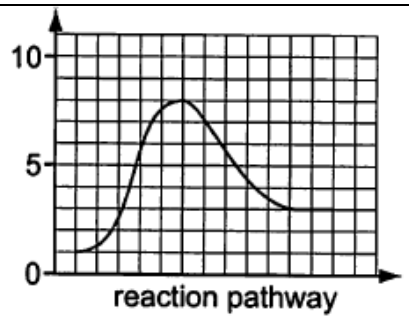
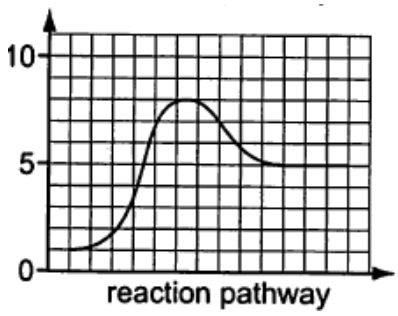
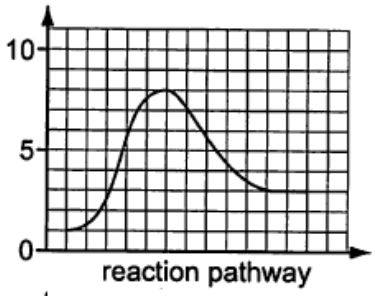
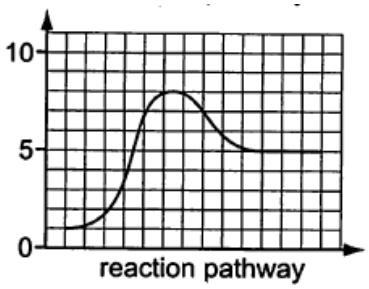
A 17 minutes **B** 34 minutes **C** 68 minutes **D** 136 minutes

12 The diagram shows the reaction pathway diagram for an uncatalysed reaction.



The reaction is then catalysed.

What are the changes in the rate constant and the reaction pathway diagram?

	rate constant	energy profile
A	decrease	
B	decrease	
C	increase	
D	increase	

13 Which one of the following statements about the forward and backward reactions, $P + Q \rightleftharpoons R + S$, is correct when the system is at equilibrium?

A The ratio of the rates of the forward reaction to that of the reverse reaction equals the equilibrium constant.

B The rates of both the forward and the reverse reactions are equal to zero.

C The rates of the forward and reverse reactions are equal.

D The rate constant for the forward reaction equals the rate constant for the reverse reaction.

14 Each of the following equilibria is subjected to two changes carried out separately:

(i) the pressure is reduced at constant temperature;
(ii) the temperature is increased at constant pressure.

For which equilibrium will both of these changes result in an increase in the proportion of products?

A $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$; $\Delta H = +53$ kJ mol^{-1}

B $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$; $\Delta H = -950$ kJ mol^{-1}

C $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$; $\Delta H = -92$ kJ mol^{-1}

D $N_2O_4(g) \rightleftharpoons 2NO_2(g)$; $\Delta H = +57$ kJ mol^{-1}

15 The value of the ionic product of water, K_w, varies with temperature.

Temperature / °C	K_w / mol^2 dm^{-6}
25	1.0×10^{-14}
62	1.0×10^{-13}

What can be deduced from this information?

A The ionic dissociation of water is an exothermic process.

B The association of water molecules by hydrogen bonding increases as temperature increases.

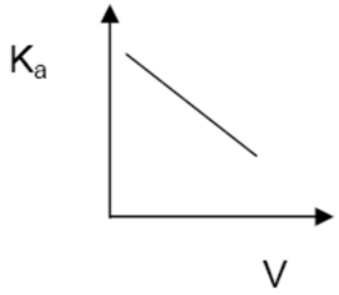
C The pH of pure water increases with temperature.

D At 62 °C, water with a pH of 6.5 is neutral.

16 1 mol sample of ethanoic acid is diluted at constant temperature to a volume V.

Which diagrams shows how K_a, the acid dissociation constant, varies with V?

A



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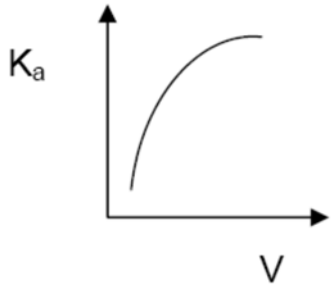

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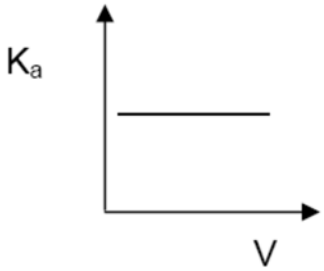

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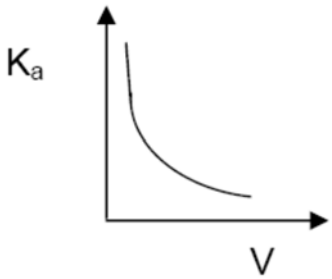


17 The table shows some data on two acid-base indicators.

indicator	approximate pH range	colour change	
		acid	alkali
bromocresol green	3.8 – 5.5	yellow	blue
phenol red	6.8 – 8.5	yellow	red

Which conclusion can be draw about a solution in which bromocresol green is blue and phenol red is yellow?

A It is weakly acidic.

B It is neutral.

C It is weakly alkaline.

D It is strongly alkaline.

18 Which of the following elements forms an insoluble oxide and a chloride which is readily hydrolysed?

A magnesium

B phosphorus

C silicon

D sodium

19 In the preparation of silicon, silicon dioxide is heated with magnesium.

$$SiO_2 + 2Mg \rightarrow 2MgO + Si$$

The product mixture contains MgO and Si only.

To separate the silicon from the product mixture, students proposed the following two possible methods.

1. Shake the mixture with aqueous hydrochloric acid and filter.
2. Heat the mixture gently and collect the evaporated silicon.

Which methods would work?

A 1 and 2 **B** 1 only **C** 2 only **D** neither 1 or 2

20 Which statements concerning the third period elements (sodium to argon) and their compounds are correct?

1 The elements become more electronegative from sodium to chlorine.

2 The melting points of the elements decrease across the period.

3 The maximum oxidation state is shown by silicon.

4 Aluminium oxide is the only oxide which is amphoteric.

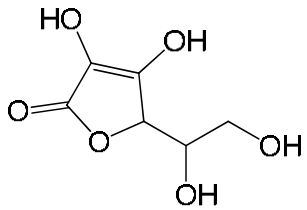
A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

D 3 and 4 only

21 Vitamin C has the following structure.



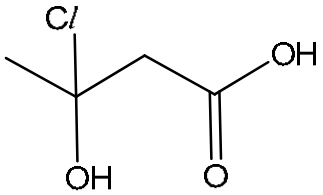
Vitamin C

How many sp^2 and sp^3 hybridised carbon atoms does this molecule have?

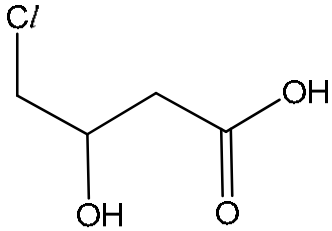
	sp^2	sp^3
A	6	0
B	4	2
C	3	3
D	2	4

22 Which structure correctly represents 4-chloro-3-hydroxybutanoic acid?

A



B



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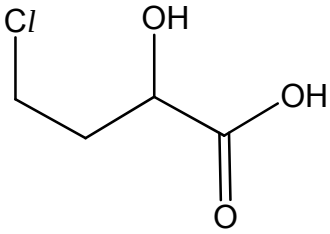

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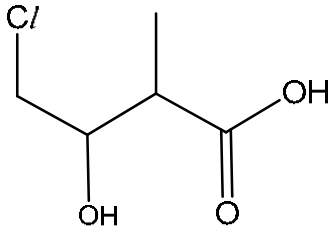


23 As the number of carbon atoms in a homologous series of alkane molecules **increases**, for which property of the alkanes does the numerical value **decrease**?

A density

B enthalpy change of vaporization

C number of isomers

D vapour pressure

24 Compound **E**, C_4H_{10}, reacts with chlorine gas in the presence of light to form two monochlorinated alkanes, **F** and **G**, in an approximate molar ratio of 2 : 3.

What are the structures of **E** and **F**?

	E	**F**
A	$CH_3CH(CH_3)CH_3$	$CH_3CH(CH_3)CH_2Cl$
B	$CH_3CH(CH_3)CH_3$	$CH_3CCl(CH_3)CH_3$
C	$CH_3CH_2CH_2CH_3$	$CH_3CH_2CHClCH_3$
D	$CH_3CH_2CH_2CH_3$	$CH_3CH_2CH_2CH_2Cl$

25 How many different alkenes, including cis-trans isomers, could be produced when 3-methylpentan-2-ol reacts with excess concentrated sulfuric acid at 170 ^{o}C?

A 2

B 3

C 4

D 5

26 Lactic acid builds up in muscles when oxygen is in short supply. It can cause muscular pain. Part of the reaction sequence is shown.

$$\underset{\text{glyceraldehyde}}{CH_2OHCH(OH)CHO} \rightarrow \underset{\text{pyruvic acid}}{CH_3COCO_2H} \rightarrow \underset{\text{lactic acid}}{CH_3CH(OH)CO_2H}$$

Which statements about the reaction sequence are correct?

1 A secondary alcohol is oxidised to a ketone.

2 A ketone is reduced to a secondary alcohol.

3 An aldehyde is oxidised to a carboxylic acid.

4 A carboxylic acid is reduced to a primary alcohol.

A 1 and 2 only

B 1 and 4 only

C 1, 2 and 3 only

D 2, 3 and 4 only

27 A food chemist wants to create the odour of green apples for a product. An ester with this odour has the formula $CH_3CH_2CO_2CH(CH_3)_2$. In which of the following will the substances react together to produce this ester?

A CH_3CH_2OH and $(CH_3)_2CHCOOH$

B CH_3COOH and $CH_3CH(OH)CH_2CH_3$

C CH_3CH_2COOH and $CH_3CH_2CH_2OH$

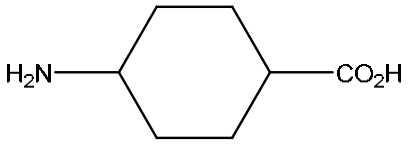
D CH_3CH_2COOH and $(CH_3)_2CHOH$

28 Which compound could be used by itself to form a condensation polymer?

A $HOCH_2CH_2OH$

B $HO_2C(CH_2)_4CO_2H$

C



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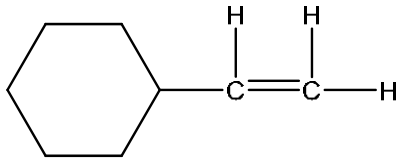
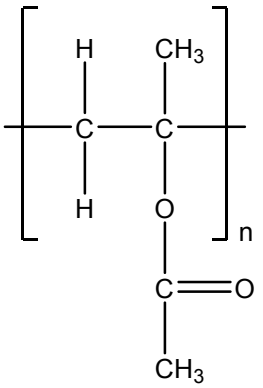
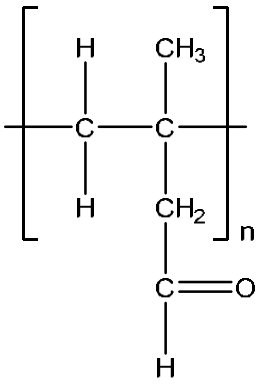


29 The following polymers could be used for contact lenses. Contact lenses have to absorb water so that they can fit comfortably in the eyes. Which polymer will be the most suitable to be used for contact lens?

A



B



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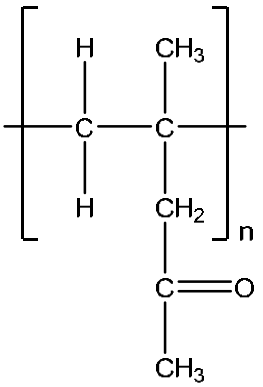

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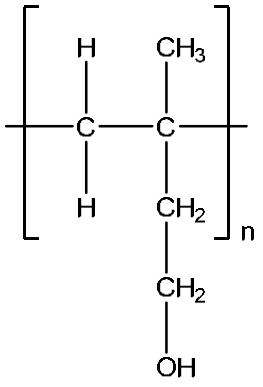


30 Which are the possible ways do nanomaterials enter the human body?

1 skin contact

2 inhalation

3 orally taken

A 1 only

B 1 and 2 only

C 2 and 3 only

D 1, 2 and 3 only

End of Paper

INNOVA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME	

CLASS		GROUP	**C / H / E / M**	INDEX NUMBER	

CHEMISTRY

8873/02

27 Aug 2018

2 hour

Paper 2 Structured Questions

Candidates answer on the question paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your index number, name and civics group.
Write in dark blue or black pen.
You may use pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions in the space provided.

Section B
Answer **1 out of 2** questions on writing paper provided..

A *Data Booklet* is provided.

You are advised to show all working in calculations.
You are reminded of the need for good English and clear presentation in your answers.
You are reminded of the need for good handwriting.
Your final answers should be in 3 significant figures.

You may use a calculator.

The number of marks is given in brackets [ ] at the end of each question or part question.

Paper 2	67
Paper 1	33
Overall	100
Overall Grade	

For Examiner's Use	
Section A	
1	12
2	12
3	8
4	14
5	14
Section B (Please circle)	
6 or 7	20
Significant figures and units	
Handwriting	
P2 Total	80
P1 Total	30

This document consists of **20** printed pages.

Section A

Answer all the questions.

1 Magnesium, the eighth most abundant element on Earth, has diverse applications such as in building or medicine.

(a) **(i)** Write equations for the reactions of the oxides of magnesium and phosphorus with water.

……..

……...[2]

(ii) Write equations for the reactions of magnesium chloride and phosphorus chloride with water respectively. Include in your answer, the pH of the resultant solutions.

……..

……..

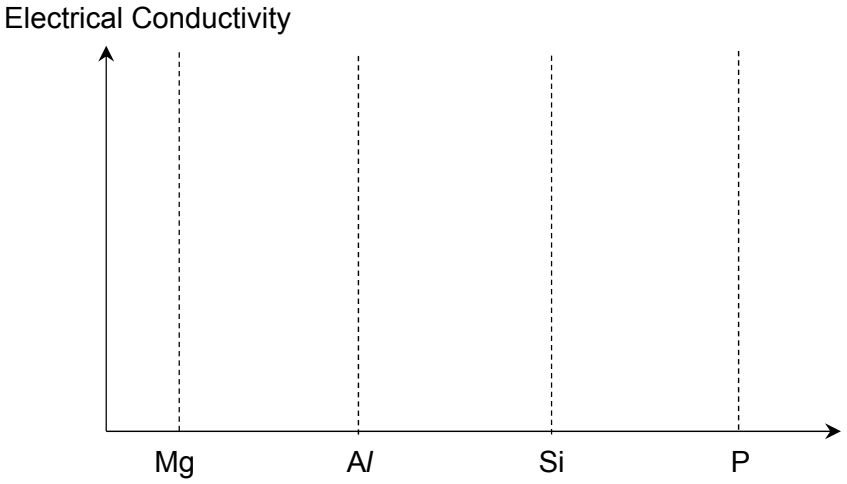
……..

……..

……..

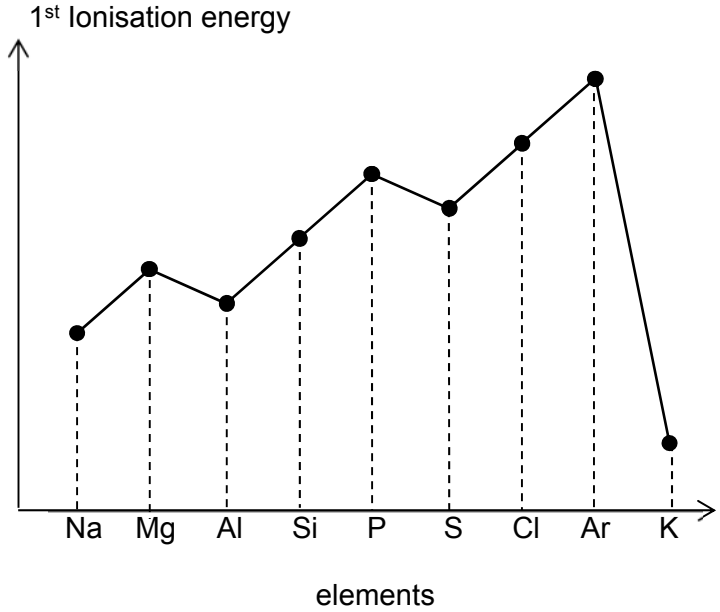
……...[4]

(iii) On the axes below, sketch the electrical conductivity of the period 3 elements from magnesium to phosphorous.



[1]

(b) The following graph shows the trend of the first ionisation energies of the elements from sodium to potassium.



(i) Explain the difference between the values of their first ionisation energies for **each** of the pairs of elements listed below. You should use a different explanation for each pair.

- sodium and potassium

……..

……..

……..

……..

……[2]

- magnesium and aluminium

……..

……..

……..

……..

……[1]

(ii) When a beam of $_{20}Ca^{2+}$ particles travels through a uniform electric field which is at right angles to its direction of travel, it is deflected at an angle of +10.0°.

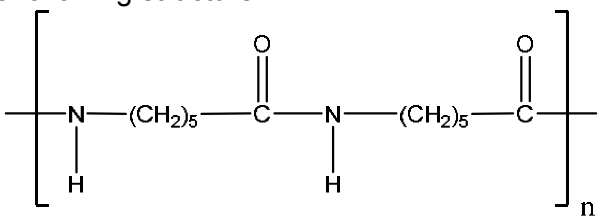
Determine the angle of deflection of a beam of $_{8}O^{2-}$ particles if it travels at the same speed through the same electric field.

[2]

[Total: 12]

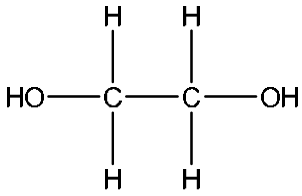
2 Synthetic polymer fibres are man-made, formed entirely by chemical synthesis. Demand for synthetic fibres has increased over the last few decades as they are durable, less expensive and more stain resistant than natural fibres. Terylene and Nylon 6 are examples of polymeric synthetic fibre.

- Nylon 6 has the following structure.

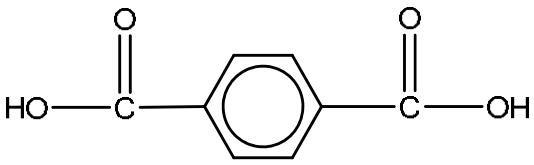


Nylon 6

- Terylene is made from ethane-1,2-diol and benzene-1,4-dicarboxylic acid:



and



(a) Draw the structural formula of the monomer from which Nylon 6 could be made. State the type of polymerisation involved.

Type of polymerisation: …… [2]

(b) Draw a displayed formula to show the simplest repeat unit of Terylene.

[1]

(c) Explain why nylon is prone to creasing while Terylene is wrinkle free.

……

……..……..

……

……..….. [2]

Poly(propene) is also a polymer like the synthetic fibre; it is lightweight, durable and widely used in industries for making home articles such as container, buckets and crates.

(d) Explain why dilute sodium hydroxide will cause holes to appear in containers made from polymers such as Terylene but a poly(propene) container can be used to store sodium hydroxide.

……

……..….. [1]

(e) State the reason why the disposal of poly(propene) containers in landfill sites is a problem.

……

……..….. [1]

(f) The following is an extract from an article "The safety of *nanoparticles* in sunscreens: An update for general practice" published on The Royal Australian College of General Practitioners 2016, June 2016.

"Recent media coverage has raised public awareness regarding the safety of sunscreens containing zinc (ZnO) and titanium (TiO_2) *nanoparticles*. The inorganic filters ZnO and TiO_2 are able to protect against UVA and UVB. As conventional micronised particles in sunscreen, they have several unfavourable characteristics, including difficulty in application, leaving white residue on the skin. This led to the development of smaller *nanoparticles*, the use of which vastly improves aesthetic and ease of application of sunscreens while maintaining photo-protective qualities."

(i) Define *nanoparticles*.

…….. [1]

(ii) Explain in your own words why the surface-to-volume ratios makes nanoscale sunscreen attractive.

……

……

……

…….. [2]

(iii) Explain why nanoparticles of TiO_2 in sunscreen could present a risk to human health.

…….. [1]

(iv) Sunscreen containing nanoparticles should be tested further.
Suggest one reason why some companies that make sunscreens might not want to do more tests.

……

…….. [1]

[Total: 12]

3 Citric acid, $C_6H_8O_7$, is a weak tribasic organic acid. It is used as an additive and preservative in various food and drinks to enhance flavour and taste. It provides a fruity tartness to complement fruit flavours and it is also used to mask the unpleasant taste of pharmaceutical products.

However, a high content of citric acid in foods and drinks could damage your teeth. Chemical erosion of the teeth occurs either by the hydrogen ions derived from citric acid or by the citric acid anions which can bind or complex calcium. The acceptable limit for the percentage composition by mass of citric acid in food is 2.5% as this is around the percentage composition commonly found in natural fruits.

A student wanted to find the out the mass of citric acid in a mint candy by doing a titration with sodium hydroxide solution. The equation for the titration is:

$$C_6H_8O_7 + 3NaOH \rightarrow C_6H_5O_7Na_3 + 3H_2O$$

He weighed out 5.00 g of the mint candy and crushed the candy into powder. He then dissolved the powder in 100 cm^3 of distilled water, stirred the mixture and filtered it forming solution **A**.

(a) The student then prepared a standard solution of sodium hydroxide by dissolving 0.104 g of sodium hydroxide pellets in 25.0 cm^3 of distilled water. He then made the volume up to 250 cm^3 forming solution **B**.

Calculate the concentration of sodium hydroxide in solution **B**.

[2]

(b) The student then found that 20.0 cm^3 of solution **A** required 10.40 cm^3 of solution **B** for a complete reaction.

(i) Suggest a suitable indicator for the titration.

…….. [1]

(ii) Calculate the mass of citric acid in the 20.0 cm^3 of solution **A**.

[2]

(iii) Given that the average weight of one piece of mint candy is 0.50 g, calculate the mass of citric acid in one piece of mint candy.

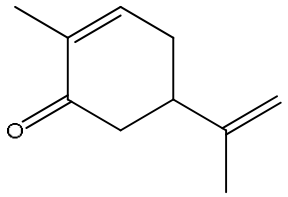
[2]

(c) From your answer in **(b) (iii)**, determine whether the percentage composition by mass of citric acid in the mint candy is above or below the acceptable limit.

[1]

[Total: 8]

4. Carvone is a natural oil produced by the plant *Mentha spicata.* It has the flavour of spearmint and it has important uses in food flavouring.



Carvone

(a) **(i)** Identify the functional groups present in Carvone.

……..[2]

(ii) Draw structures for the organic products of each compound with the following reagents. State the type of reaction in each case.

Reagent and conditions	**Type of reaction**	**Organic product**
Br_2 liquid, room temperature		
H_2 with Ni catalyst, high temperature and high pressure		
$LiAlH_4$ in dry ether, room temperature		

[7]

(b) Suggest why Carvone is highly soluble in hexane.

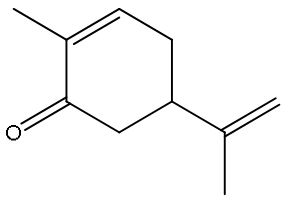
……

……

……

…… [2]

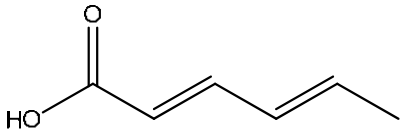
(c) On the above structure of Carvone, circle one sp^2 hybridised carbon atom.



Carvone

[1]

(d) Sorbic acid, or 2,4-hexadienoic acid, is a natural organic compound used as a food preservative.



Sorbic acid

Describe a chemical test that will help you distinguish Carvone from Sorbic acid, including all observations that would be made.

……

……

……

…… [2]

[Total: 14]

5 **(a)** Benzene undergoes complete combustion with oxygen as shown by the equation below.

$$C_6H_6(l) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$$

(i) Explain what is meant by *standard enthalpy change of combustion.*

……

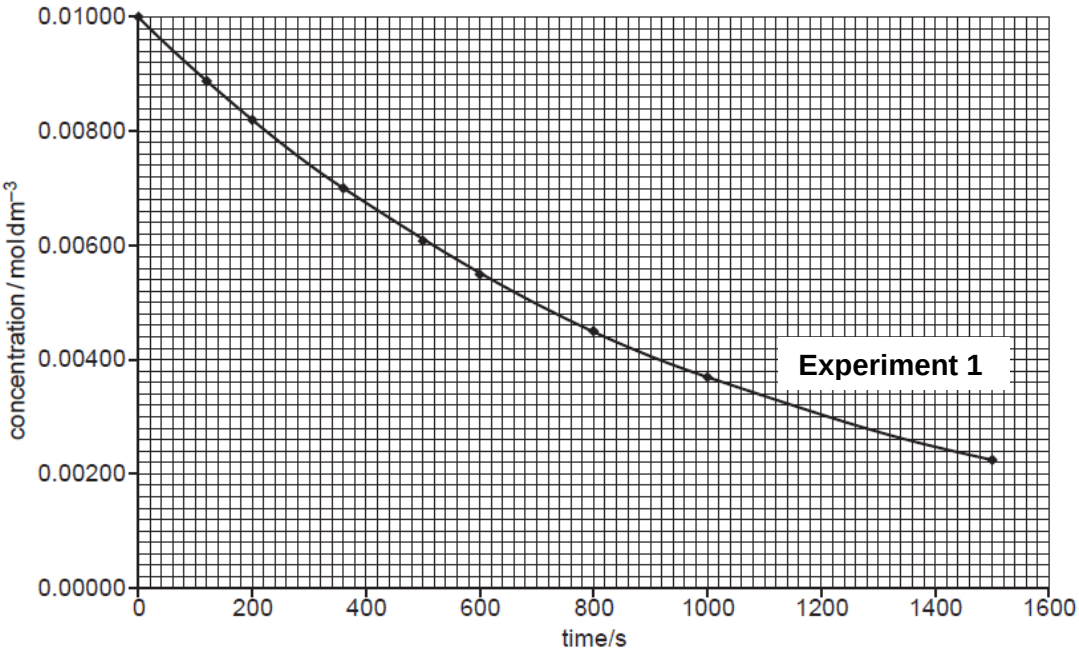
……...[1]

(ii) 1.17 g of benzene was burnt to heat up 250 g of water in a beaker. The initial temperature of the water was 27.6°C. Given that the standard enthalpy change of combustion of benzene is –3267 kJ mol^{-1} is and there is 20% heat loss to the surrounding, calculate the highest temperature reached by the water.

[3]

(b) 2–iodo–2–methylpropane undergoes a substitution reaction with hot aqueous sodium hydroxide. Two separate experiments were carried out to study the kinetics of this reaction.

In Experiment 1, sodium hydroxide was used in large excess and the concentration of 2–iodo–2–methylpropane was measured against time. A graph of concentration of 2–iodo–2–methylpropane against time was plotted and shown below.



(i) Use the half–life method to deduce the order of reaction with respect to 2–iodo–2–methylpropane. Show all your working clearly.

……..

……..

……[2]

In Experiment 2, 2–iodo–2–methylpropane was used in large excess and the concentration of sodium hydroxide was measured against time. The following results were obtained.

Time / s	[NaOH] / mol dm^{-3}
0	0.0100
100	0.0082
200	0.0064
380	0.0032
500	0.0010

(ii) Using the data provided above, plot a graph of [NaOH] vs time for Experiment 2 in the graph above.

[1]

(iii) Using the graph plotted in **(b)(ii)**, determine the order of reaction with respect to sodium hydroxide. Explain your answer.

……..

……..

……[2]

(iv) Hence, write an overall rate equation for the substitution reaction.

……[1]

(c) Colourless N_2O_4 and brown NO_2 are two oxides of nitrogen that can co-exist in equilibrium:

$$N_2O_4\ (g) \rightleftharpoons 2\ NO_2\ (g) \quad \Delta H = +\ 58\ kJ\ mol^{-1}$$

Predict and explain how the colour intensity of the mixture changes, when a reaction chamber containing an equilibrium mixture of N_2O_4 and NO_2 is:

(i) immersed in boiling water.

……

……

……

……

……[2]

(ii) subjected to a sudden compression in volume.

……

……

……

……

……[2]

[Total: 14]

Section B

Answer **one** question from this section, in the spaces provided.

6 **(a)** **(i)** Describe the structure of graphite. Explain how this structure gives graphite the properties of soft and high electrical conductivity.

You may include labelled diagrams in your answer.

……

……

……

……

……

……[3]

(ii) Another allotrope of carbon is diamond. State one physical property diamond has in common with graphite and relate the property to the bonding present in their structures.

……

……

……[2]

(b) **(i)** Write an equation, including state symbols, for the reaction with enthalpy change equal to the standard enthalpy of formation for ethane, $C_2H_6(g)$.

……[1]

(ii) Suggest in terms of bonding why ethane is a gas at room temperature.

……

……[1]

(iii) Ethane undergoes a reaction with chlorine. Name the type of reaction that occurs and the conditions used.

……

……[2]

(c) The enthalpy change for the following reaction is –2889 kJ mol^{-1}.

$$C_2H_6(g) + 7F_2(g) \longrightarrow 2CF_4(g) + 6HF(g)$$

Use this value and the standard enthalpies of formation given to calculate the standard enthalpy of formation of $C_2H_6(g)$.

Substance	$CF_4(g)$	$HF(g)$
ΔH_f^o / kJ mol^{-1}	–680	–269

[2]

(d) Methane reacts violently with fluorine according to the following equation.

$$CH_4(g) + 4F_2(g) \longrightarrow CF_4(g) + 4HF(g) \qquad \Delta H = -1904 \text{ kJ mol}^{-1}$$

(i) Using relevant bond energies in the Data Booklet, calculate the bond energy of F–F bond.

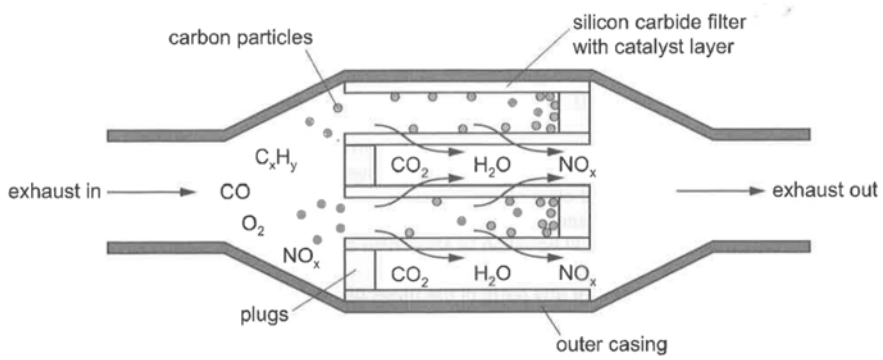
[2]

(ii) A student suggested that actual bond energy of F-F differs from theoretically calculated value in **(i)**. Explain if you agree or disagree with the student.

……

……[1]

(e) Catalyst are used in car exhaust of modern cars to speed up reaction between polluting gases such as carbon monoxide and dinitrogen oxide, before they reach the end of the exhaust pipe.



(i) State the type of catalyst involved in this reaction.

…….. [1]

(ii) Sketch a Boltzmann distribution curve for the reactants and use it to explain how the use of catalyst speeds up the reaction.

Explanation

……

……

……

……

……[4]

(iii) Suggest why car manufacturers are required to fit catalytic converters to car exhaust systems.

……

…….. [1]

[Total: 20]

7 **(a)** Phosphorus reacts with fluorine to form PF_3 and PF_5.

(i) Draw the dot-and-cross diagram for one molecule of PF_5. Show only the outer shell electrons.

[1]

(ii) Explain why the P–F bond is polar.

…….. [1]

(iii) Predict whether or not a molecule of PF_5 is polar. Explain your answer.

……

…….. [1]

(iv) Nitrogen reacts with fluorine to form NF_3 only.

Explain why PF_5 exists whereas NF_5 does not exist.

……

…….. [1]

(b) The reaction between sulfur dioxide and oxygen is a reversible reaction and can be described as being in dynamic equilibrium.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

A 2-dm^3 reaction vessel containing 0.80 mol of SO_2, 0.30 mol of O_2 and 1.40 mol of SO_3 is allowed to reach equilibrium at a constant temperature of 1000 K. It was determined that 0.42 mol of SO_2 is present at equilibrium.

(i) State the meaning of the term *dynamic equilibrium*.

……

…….. [1]

(ii) Use the information given to complete Table 6.1.

Table 6.1

	SO_2	O_2	SO_3
Initial amount/ mol			
Equilibrium amount/ mol			

[2]

(iii) Write an expression for the equilibrium constant K_c.

[1]

(iv) Calculate the value of K_c. State the units of K_c.

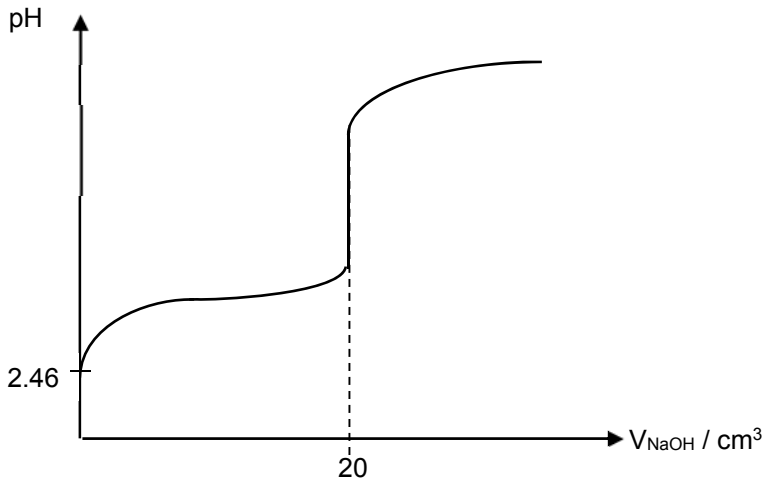
[2]

(c) **(i)** State the difference between a weak acid and a strong acid.

……

…….. [1]

20.0 cm^3 of 0.01 mol dm^{-3} propanoic acid, CH_3CH_2COOH was titrated against 0.01 mol dm^{-3} aqueous sodium hydroxide.



The initial pH of propanoic acid is 2.46.

(ii) Calculate the initial concentration of hydrogen ions before the titration.

[1]

During the addition of the first 20 cm^3 of sodium hydroxide the mixture is behaving as a buffer.

(iii) Explain how the shape of the graph show this.

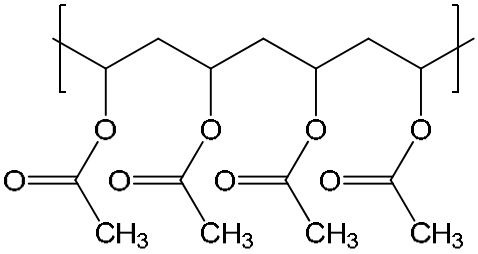
……

…….. [1]

(iv) Identify the two species present in the mixture that constitutes to it behaving as a buffer.

…….. [1]

(d) Polyvinyl acetate, PVAc, is a useful adhesive for gluing together articles made from wood, paper or cardboard. The diagram shows a section (not a repeat unit) of the PVAc.



PVAc

(i) What type of polymerisation made this polymer?

…….. [1]

(ii) PVAc is made from monomer **X**. Draw the structure of the **X**.

[1]

(iii) PVAc can be converted to polyvinyl alcohol, PVA.

Draw a section of PVA containing at least 2 repeat units and suggest the reagents and conditions needed to make PVA from PVAc in the laboratory.

Section of PVA:

Reagents and conditions: ……..

[2]

(e) The diagrams below are molecular representations of two types of plastics – thermoplastics and thermosets.

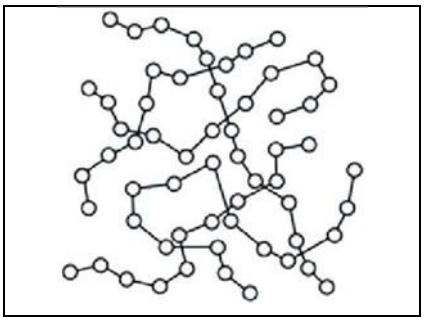


Diagram **A**

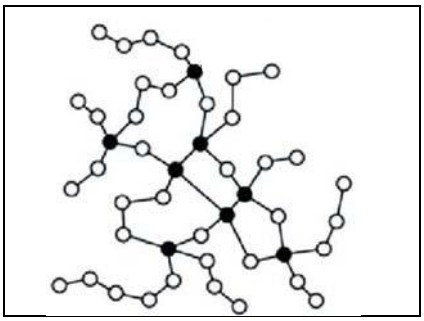


Diagram **B**

(i) State and explain which diagram could be the representation for thermosets.

……

…….. [1]

(ii) State a difference in physical properties between thermoplastics and thermosets.

……

…….. [1]

[Total: 20]

End of Paper

INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME	
CLASS	INDEX NUMBER

CHEMISTRY 8873/01

Paper 1 Multiple Choice **14 Sep 2018**

1 hour

Additional Materials: Data Booklet
Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class on all the work you hand in.
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

1	**B**	6	**D**	11	**A**	16	**B**	21	**C**	26	**C**
2	**A**	7	**A**	12	**D**	17	**A**	22	**B**	27	**D**
3	**D**	8	**B**	13	**C**	18	**C**	23	**D**	28	**C**
4	**C**	9	**B**	14	**D**	19	**B**	24	**C**	29	**D**
5	**B**	10	**C**	15	**D**	20	**B**	25	**B**	30	**D**

This document consists of **12** printed pages.

For each question there are four possible answers, **A, B, C,** and **D**. Choose the **one** you consider to be correct.

1 A giant molecule contains a large amount of carbon, mainly of isotopes ^{12}C and ^{13}C. It was found that the relative atomic mass of carbon in the molecule is 12.20.

What is the ratio of ^{12}C and ^{13}C?

A 3:1 **B** 4:1 **C** 3:4 **D** 1:4

Answer: B

Let the fraction of ^{12}C to be x and the fraction of ^{13}C to be 1-x

$12x + 13(1-x) = 12.2$

$12x + 13 – 13x = 12.2$

$x = 0.8$

$^{12}C : ^{13}C = 0.8 : 0.2 = 4 : 1$

2 Which statements about relative molecular mass are correct?

1 It is the sum of the relative atomic masses of all the atoms within the molecule.

2 It is the ratio of the average mass of a molecule to the mass of a ^{12}C atom.

3 It is the ratio of the mass of 1 mol of molecules to the mass of 1 mol of ^{1}H atoms.

4 It is the ratio of the mass of 1 mol of molecules to the mass of 1 mol of ^{12}C atoms.

A 1 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 4 only

Answer: A

Option 2 is wrong. It is the ratio of the average mass of a molecule to 1/12 of the mass of a ^{12}C atom.

Option 3 and 4 are wrong. It is the ratio of the mass of 1 mol of molecules to the mass of 1/12 of 1 mol of ^{12}C atoms.

3 *Use of the Data Booklet is relevant to this question.*

Some isotopes are unstable and decompose naturally. In one type of decomposition, a neutron in the nucleus decomposes to form a proton, which is retained in the nucleus, and an electron, which is expelled from the atom.

Which change describes a process of this sort?

A $^{11}C \longrightarrow {}^{12}C$

B $^{22}Na \longrightarrow {}^{22}Ne$

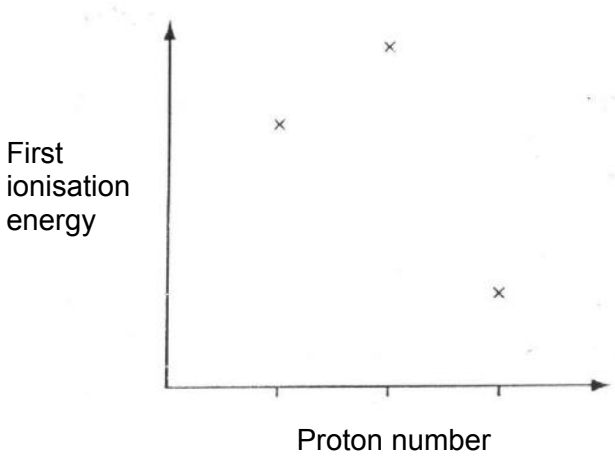
C $^{32}P \longrightarrow {}^{31}P$

D $^{40}K \longrightarrow {}^{40}Ca$

Answer: D

When a neutron in the nucleus decomposes to form a proton, mass number remains the same but proton number increases by 1.

4 Three successive elements in the Periodic Table have first ionisation energies which have the pattern shown in the diagram.



What could be the first element of this sequence?

A N

B O

C F

D Na

Answer: C

Option A is wrong. If N is the first element, the second element will be O. However, there is a decrease in first I.E. between N and O element as there is a pair of electrons in the same p orbital in O which experience inter-electronic repulsion.

Option B is wrong. If O is the first element, the second and third element is F and He which first I.E. increases from O to F to Ne.

Option D is wrong. If Na is the first element, the second element is Mg and Al. There is a slight decrease in I.E. between Mg and Al which is not as shown by the diagram above (large decrease in first I.E. between second and third element.

5 Which of the following ions contains half-filled d-orbitals?

1 Mn^{2+}

2 Cu^{+}

3 Fe^{2+}

4 Fe^{3+}

A 1 and 2 only

B 1 and 4 only

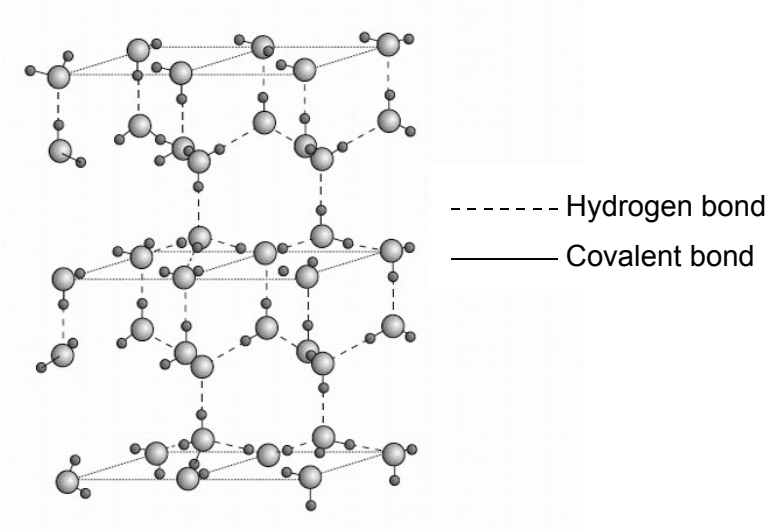
C 2 and 3 only

D 3 and 4 only

Answer: B

The valence electronic configuration of the following ions:
Mn^{2+}: $3d^5$
Cu^{+}: $3d^{10}$
Fe^{2+}: $3d^6$
Fe^{3+}: $3d^5$

6 Ice is the crystalline form of water. The diagram below shows part of the structure of ice.



Which of the following statements is **not** true about ice?

A Ice has a lower density than water at 0 °C due to its open structure.

B The bond angle about oxygen in ice is 109.5°.

C Ice does not conduct electricity.

D Ice has a giant covalent structure.

Answer: D

Ice has simple molecular structure.

7 Which of the following pairs of substances **does not** include a giant structure and a simple molecular structure?

A aluminum and silicon(IV) oxide

B aluminium oxide and aluminium chloride

C silicon and chlorine

D silicon and silicon(IV) chloride

Answer: A

Al_2O_3 has giant ionic structure and SiO_2 has giant covalent structure.
Al_2O_3 has giant ionic structure and $AlCl_3$ has simple molecular structure.
Si has giant covalent structure and Cl_2 has simple molecular structure.
Si has giant covalent structure and $SiCl_4$ has simple molecular structure.

8 The reduction of ethanal to ethanol using $H_2(g)$ is shown in the equation below.

$$\underset{\text{ethanal}}{CH_3CHO(l)} + H_2(g) \rightarrow \underset{\text{ethanol}}{CH_3CH_2OH(l)}$$

substance	ΔH_c^θ / kJ mol^{-1}
ethanal	–1170
hydrogen	–286
ethanol	–1370

Given the standard enthalpy change of combustion in the table above, what is the enthalpy change of the reduction of ethanal to ethanol?

A +86 kJ mol^{-1} **B** –86 kJ mol^{-1} **C** –2826 kJ mol^{-1} **D** +2826 kJ mol^{-1}

Answer: B

$\Delta H_r^\theta = \sum n\Delta H_c^\theta$ (reactants) $- \sum m\Delta H_c^\theta$ (products)
$= [-1170+(-286)] - (-1370) = -86$ kJ mol^{-1}

9 The bond dissociation energy of H–F is 565 kJ mol^{-1}. Which equation correctly describes the reaction whereby 565 kJ of energy is released?

A $HF(l) \rightarrow HF(g)$

B $H(g) + F(g) \rightarrow HF(g)$

C $HF(g) \rightarrow H(g) + F(g)$

D $\frac{1}{2} H_2(g) + \frac{1}{2} F_2(g) \rightarrow HF(g)$

Answer: B

Bond dissociation energy: $HF(g) \rightarrow H(g) + F(g)$ +565 kJ mol^{-1}

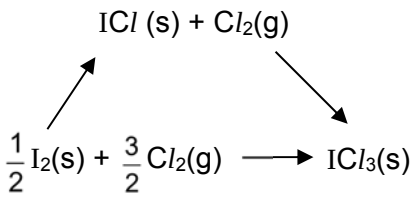
The reverse of the above reaction results in 565 kJ of energy is released.

10 Iodine trichloide, ICl_3, is made by reacting iodine with chlorine.

$$I_2(s) + Cl_2(g) \rightarrow 2ICl(s); \quad \Delta H^\theta = +14 \text{ kJ mol}^{-1}$$

$$ICl(s) + Cl_2(g) \rightarrow ICl_3(s); \quad \Delta H^\theta = -88 \text{ kJ mol}^{-1}$$

By using the above data and the following energy cycle, what is the enthalpy change of the formation of solid iodine trichloride?



A –60 kJ mol^{-1} **B** –74 kJ mol^{-1} **C** –81 kJ mol^{-1} **D** –162 kJ mol^{-1}

Answer: C

ΔH = +14/2 + (-88) = – 81 kJ mol^{-1}

11 The decomposition

$$2N_2O_5 \rightarrow 4NO_2 + O_2$$

is first order with respect to N_2O_5.

In an experiment 0.10 mol of pure N_2O_5 was put into an evacuated flask. It was found that there was 0.025 mol of N_2O_5 left 34 minutes later.

What is the time taken for the amount of NO_2 to rise from 0 mol to 0.10 mol?

A 17 minutes **B** 34 minutes **C** 68 minutes **D** 136 minutes

Answer: A

$$2N_2O_5 \rightarrow 4NO_2 + O_2$$

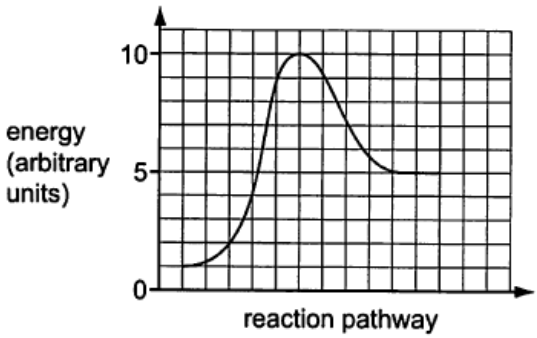
$N_2O_5 : NO_2 = 1 : 2$

For N_2O_5, 0.10 → 0.05 → 0.025 →0.0125 → 0.00625

For NO_2, 0 → 0.10 → 0.15 → 0.175 → 0.1875

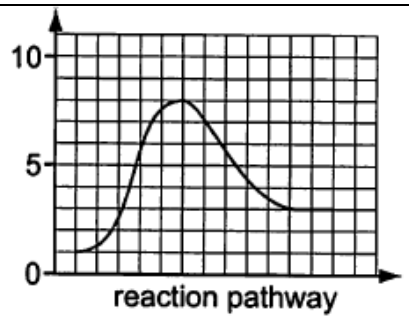
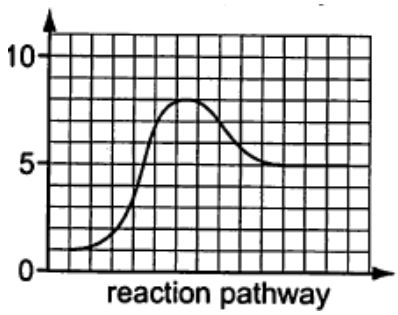
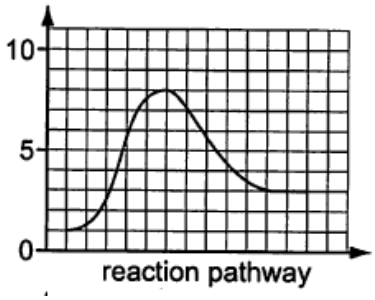
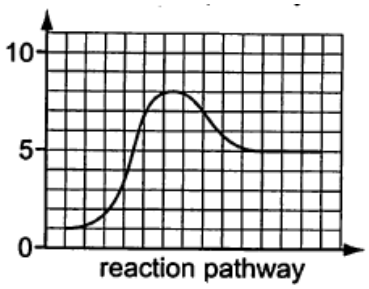
Every 1 → represents one half life (17 mins).

12 The diagram shows the reaction pathway diagram for an uncatalysed reaction.



The reaction is then catalysed.

What are the changes in the rate constant and the reaction pathway diagram?

	rate constant	energy profile
A	decrease	
B	decrease	
C	increase	
D	increase	

Answer: D

When catalyst is added, alternative pathway with lower activation energy is available. This also results in larger rate constant k. The enthalpy change of reaction remains the same.

13 Which one of the following statements about the forward and backward reactions, $P + Q \rightleftharpoons R + S$, is correct when the system is at equilibrium?

A The ratio of the rates of the forward reaction to that of the reverse reaction equals the equilibrium constant.

B The rates of both the forward and the reverse reactions are equal to zero.

C The rates of the forward and reverse reactions are equal.

D The rate constant for the forward reaction equals the rate constant for the reverse reaction.

Answer: C

Option A is wrong. The ratio of the forward rate constant to that of the reverse rate constant equals the equilibrium constant.

Option B is wrong. The rates of both the forward and the reverse reactions are equal (but not = 0).

Option D is wrong. The rate for the forward reaction equals the rate of the reverse reaction.

14 Each of the following equilibria is subjected to two changes carried out separately:

(i) the pressure is reduced at constant temperature;
(ii) the temperature is increased at constant pressure.

For which equilibrium will both of these changes result in an increase in the proportion of products?

A $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$; $\Delta H = +53$ kJ mol^{-1}

B $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$; $\Delta H = -950$ kJ mol^{-1}

C $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$; $\Delta H = -92$ kJ mol^{-1}

D $N_2O_4(g) \rightleftharpoons 2NO_2(g)$; $\Delta H = +57$ kJ mol^{-1}

Answer: D

When pressure is reduced, by Le Chatelier's Principle, the equilibrium position shifts to the side that have more gaseous molecules to increase the pressure. To increase the the proportion of products when pressure is reduced, the products must have more gaseous molecules than reactants. Only Option B and D satisfy this.

When temperature is increased, by Le Chatelier's Principle, the equilibrium position shifts to the side that favors endothermic reaction to decrease tempearture. To increase the the proportion of products when temperature is increased, the forward reaction must be endothermic. Hence, Option D is answer.

15 The value of the ionic product of water, K_w, varies with temperature.

Temperature / °C	K_w / mol^2 dm^{-6}
25	1.0×10^{-14}
62	1.0×10^{-13}

What can be deduced from this information?

A The ionic dissociation of water is an exothermic process.

B The association of water molecules by hydrogen bonding increases as temperature increases.

C The pH of pure water increases with temperature.

D At 62 °C, water with a pH of 6.5 is neutral.

Answer: D

Option A is wrong as ionic dissociation of water involves bond breaking of water molecules, this is an endothermic reaction.

Option B is wrong. As temperature increases, more hydrogen bonds between molecules are broken.

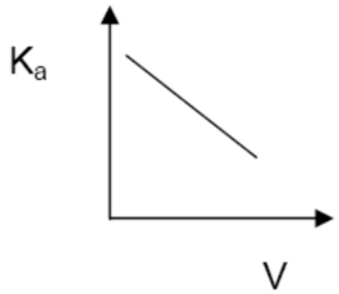
Option C is wrong. The pH of pure water decreases with temperature. (pH = 7 at 25 °C and pH = 6.5 at 62 °C)

Option D is correct as water is neutral at all temperature as $[H^+] = [OH^-]$.

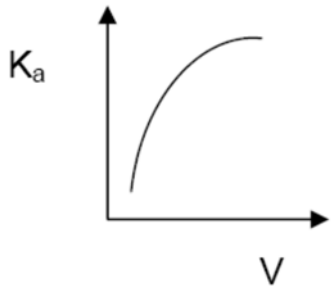
16 1 mol sample of ethanoic acid is diluted at constant temperature to a volume V.

Which diagrams shows how K_a, the acid dissociation constant, varies with V?

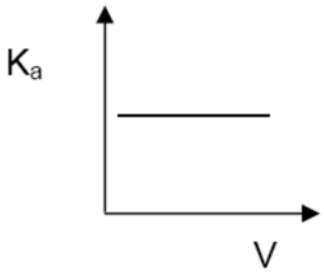
A



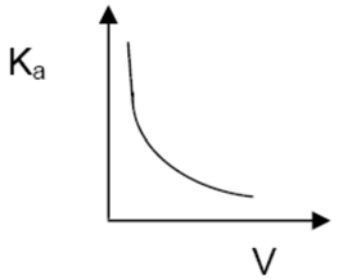
C



B



D



Answer: B Ka is temperature dependent only. (independent of volume of solution)

17 The table shows some data on two acid-base indicators.

indicator	approximate pH range	colour change	
		acid	alkali
bromocresol green	3.8 – 5.5	yellow	blue
phenol red	6.8 – 8.5	yellow	red

Which conclusion can be draw about a solution in which bromocresol green is blue and phenol red is yellow?

A It is weakly acidic.

B It is neutral.

C It is weakly alkaline.

D It is strongly alkaline.

Answer: A

When bromocresol green is added into the solution, the blue colour indicates that the pH of the solution is more than 5.5.

When phenol red is added into the solution, the yellow colour indicates that the pH of the solution is less than 6.8.

For a solution to have pH that is more than 5.5 and less than 6.8, the solution is weakly acidic.

18 Which of the following elements forms an insoluble oxide and a chloride which is readily hydrolysed?

A magnesium

B phosphorus

C silicon

D sodium

Answer: C

Option A is wrong. Magnesium oxide is slighly soluble in water and magnesium chloride undergoes hydration and partial hydrolysis.

Option B is wrong. Phosphorus pentoxide and phosphorus chloride is readily hydrolysed to form an acidic solution.

Option C is correct. Silicon dioxide is insoluble in water due to its giant covalent structure. Silicon tetrachloride is hydrolysed readily to form SiO_2 and HCl.

Option D is wrong. Sodium oxide reacts with water to form sodium hydroxide. Sodium chloride dissolves in water readily but does not undergo hydrolysis.

19 In the preparation of silicon, silicon dioxide is heated with magnesium.

$$SiO_2 + 2Mg \rightarrow 2MgO + Si$$

The product mixture contains MgO and Si only.

To separate the silicon from the product mixture, students proposed the following two possible methods.

1. Shake the mixture with aqueous hydrochloric acid and filter.
2. Heat the mixture gently and collect the evaporated silicon.

Which methods would work?

A 1 and 2 **B** 1 only **C** 2 only **D** neither 1 or 2

Answer: B

Option 1 is correct as MgO is a basic oxide that can react with HCl to undergo acid-base reaction to form salt and water. Si does not react with HCl(aq) due to its giant covalent structure.
$MgO + 2HCl \rightarrow MgCl_2 + H_2O$

Option 2 is wrong. It's almost impposible to collect evaporated silicon as it has extremely high boiling point.

20 Which statements concerning the third period elements (sodium to argon) and their compounds are correct?

1 The elements become more electronegative from sodium to chlorine.

2 The melting points of the elements decrease across the period.

3 The maximum oxidation state is shown by silicon.

4 Aluminium oxide is the only oxide which is amphoteric.

A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

D 3 and 4 only

Answer: B

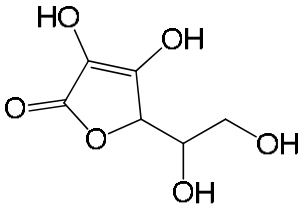
Option 1 is correct. Moving across period, nuclear charge increase, shielding effect remains relatively constant, effective nuclear charge increase. Valence electrons are more strongly attracted and electronegativity increases.

Option 2 is wrong. Melting point increases from Na to Si. Melting point of $S_8 > P_4 > Cl_2 > Ne$

Option 3 is wrong. The maximum oxidation state is shown by chlorine (+7).

Option 4 is correct. Aluminium oxide is the only oxide which is amphoteric as it can react with both acid and base.
$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$
$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$

21 Vitamin C has the following structure.

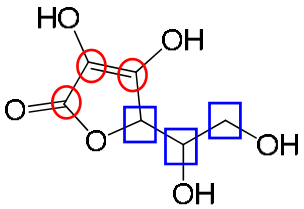


Vitamin C

How many sp^2 and sp^3 hybridised carbon atoms does this molecule have?

	sp^2	sp^3
A	6	0
B	4	2
C	3	3
D	2	4

Answer: C



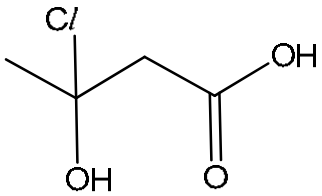
Vitamin C

sp^2 carbon: ◯

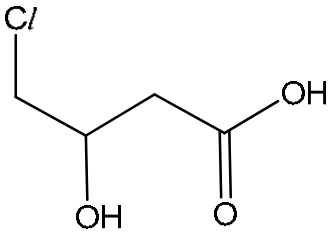
sp^3 carbon: □

22 Which structure correctly represents 4-chloro-3-hydroxybutanoic acid?

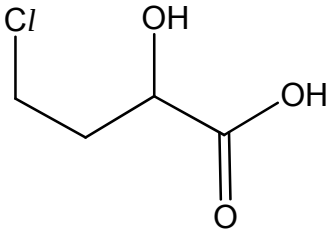
A



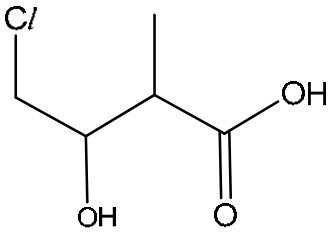
B



C



D



Answer: B

23 As the number of carbon atoms in a homologous series of alkane molecules **increases**, for which property of the alkanes does the numerical value **decrease**?

A density

B enthalpy change of vaporization

C number of isomers

D vapour pressure

Answer: D

Option A is wrong. As the number of carbon atom increases, the Mr of the molecule increases and density also increases.

Option B is wrong. As the number of carbon atom increases, the i.d.-i.d between the molecules increases as elctron cloud size increases, boiling point increases. The enthalpy change of vaporization also increases.

Option C is wrong. As the number of carbon atom increases, there are more number of isomers.

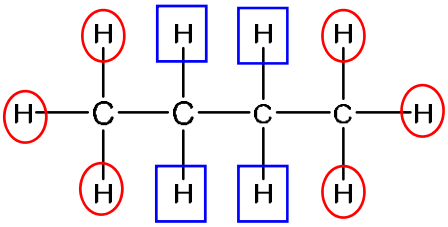
Option D is correct. As the number of carbon atom increases, the i.d.-i.d between the molecules increases as elctron cloud size increases, boiling point increases. Less molecules are vaporised and vapour pressure decreases.

24 Compound **E**, C_4H_{10}, reacts with chlorine gas in the presence of light to form two monochlorinated alkanes, **F** and **G**, in an approximate molar ratio of 2 : 3.

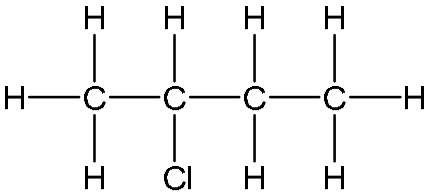
What are the structures of **E** and **F**?

	E	**F**
A	$CH_3CH(CH_3)CH_3$	$CH_3CH(CH_3)CH_2Cl$
B	$CH_3CH(CH_3)CH_3$	$CH_3CCl(CH_3)CH_3$
C	$CH_3CH_2CH_2CH_3$	$CH_3CH_2CHClCH_3$
D	$CH_3CH_2CH_2CH_3$	$CH_3CH_2CH_2CH_2Cl$

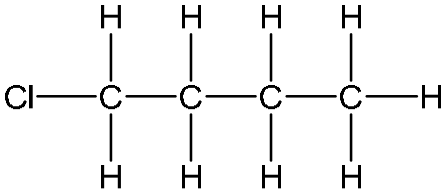
Answer: C



○ : □ = 3 : 2



F



G

25 How many different alkenes, including cis-trans isomers, could be produced when 3-methylpentan-2-ol reacts with excess concentrated sulfuric acid at 170 °C?

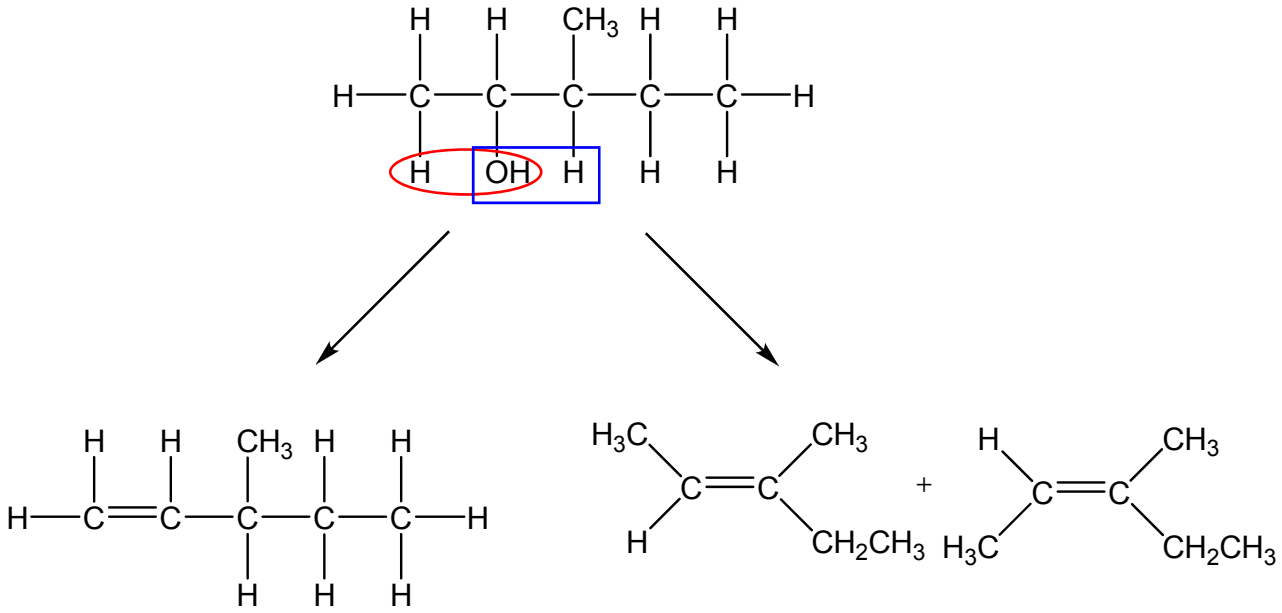
A 2

B 3

C 4

D 5

Answer: B



26 Lactic acid builds up in muscles when oxygen is in short supply. It can cause muscular pain. Part of the reaction sequence is shown.

$$\underset{\text{glyceraldehyde}}{CH_2OHCH(OH)CHO} \rightarrow \underset{\text{pyruvic acid}}{CH_3COCO_2H} \rightarrow \underset{\text{lactic acid}}{CH_3CH(OH)CO_2H}$$

Which statements about the reaction sequence are correct?

1 A secondary alcohol is oxidised to a ketone.

2 A ketone is reduced to a secondary alcohol.

3 An aldehyde is oxidised to a carboxylic acid.

4 A carboxylic acid is reduced to a primary alcohol.

A 1 and 2 only

B 1 and 4 only

C 1, 2 and 3 only

D 2, 3 and 4 only

Answer: C

Step 1: oxidation of secodary alcohol to ketone and oxidation of aldehyde to carboxylic acid

Step 2: reduction of ketone to secondary alcohol

27 A food chemist wants to create the odour of green apples for a product. An ester with this odour has the formula $CH_3CH_2CO_2CH(CH_3)_2$. In which of the following will the substances react together to produce this ester?

A CH_3CH_2OH and $(CH_3)_2CHCOOH$

B CH_3COOH and $CH_3CH(OH)CH_2CH_3$

C CH_3CH_2COOH and $CH_3CH_2CH_2OH$

D CH_3CH_2COOH and $(CH_3)_2CHOH$

Answer: D

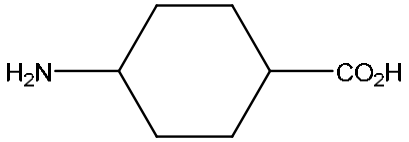
$CH_3CH_2CO_2CH(CH_3)_2 \rightarrow CH_3CH_2COOH + (CH_3)_2CHOH$ (acidic hydrolysis)

28 Which compound could be used by itself to form a condensation polymer?

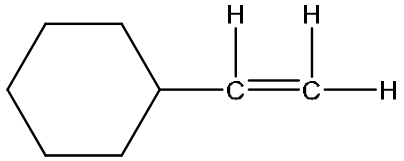
A $HOCH_2CH_2OH$

B $HO_2C(CH_2)_4CO_2H$

C



D



Answer: C

Option A cannot form condensation polymer as it only contains alcohol functional group.

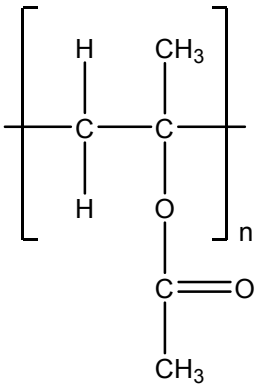
Option B cannot form condensation polymer as it only contains carboxylic acid functional group.

Option C can form condensation polymer as amine group and carboxylic acid group undergoes condensation to form amide.

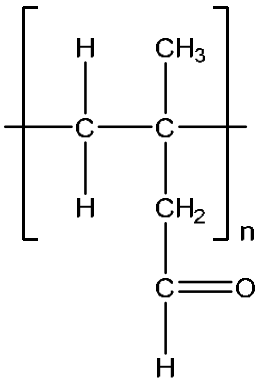
Option D cannot form condensation polymer but can form addition polymer.

29 The following polymers could be used for contact lenses. Contact lenses have to absorb water so that they can fit comfortably in the eyes. Which polymer will be the most suitable to be used for contact lens?

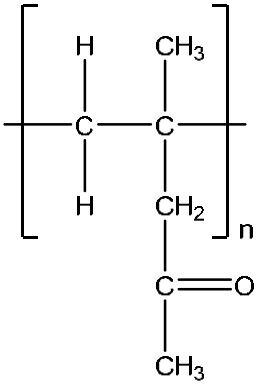
A



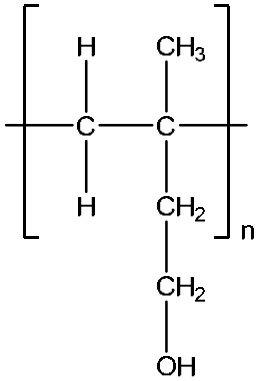
B



C



D



Answer: D

Structure D contains polar –OH group that can form hydrogen bonds with water, making it able to absorb water.

30 Which are the possible ways do nanomaterials enter the human body?

1 skin contact

2 inhalation

3 orally taken

A 1 only

B 1 and 2 only

C 2 and 3 only

D 1, 2 and 3 only

Answer: D

End of Paper

INNOVA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME	Suggested Answer		
CLASS		INDEX NUMBER	

CHEMISTRY

8873/02

XX XXX 2018

2 hour

Paper 2 Structured Questions

Candidates answer on the question paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your index number, name and civics group.
Write in dark blue or black pen.
You may use pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions in the space provided.

Section B
Answer **1 out of 2** questions on writing paper provided..

A *Data Booklet* is provided.

You are advised to show all working in calculations.
You are reminded of the need for good English and clear presentation in your answers.
You are reminded of the need for good handwriting.
Your final answers should be in 3 significant figures.

You may use a calculator.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	12
2	12
3	10
4	12
5	14
Section B (Please circle)	
6 or 7	20
Significant figures and units	
Handwriting	
P2 Total	80
P1 Total	30

Paper 2	67
Paper 1	33
Overall	100
Overall Grade	

This document consists of **12** printed pages.

Section A

Answer all the questions.

1 Magnesium, the eighth most abundant element on Earth, has diverse applications such as in building or medicine.

(a) **(i)** Write equations for the reactions of the oxides of magnesium and phosphorus with water.

.....

.....[2]

$MgO\ (s) + H_2O\ (l) \rightleftharpoons Mg(OH)_2\ (aq)$ **[1] (mark for reversible arrow)**

$P_4O_{10}\ (s) + 6H_2O(l) \rightarrow 4H_3PO_4\ (aq)$ **[1]**

(ii) Write equations for the reactions of magnesium chloride and phosphorus chloride with water respectively. Include in your answer, the pH of the resultant solutions.

.....

.....

.....

.....

.....

.....[4]

$MgCl_2 + 6H_2O \rightarrow [Mg(H_2O)_6]^{2+} + 2Cl^-$

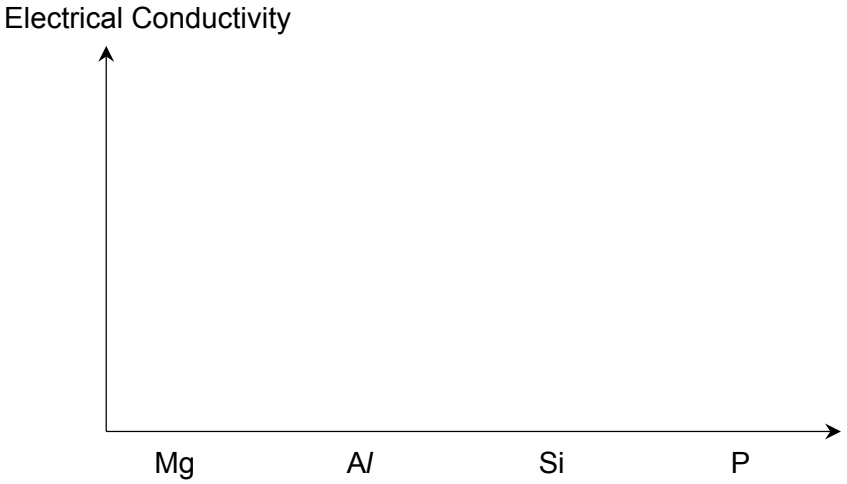
$[Mg(H_2O)_6]^{2+} + H_2O \rightleftharpoons [Mg(H_2O)_5(OH)]^+ + H_3O^+$

Magnesium chloride solution: **pH 6.5**.

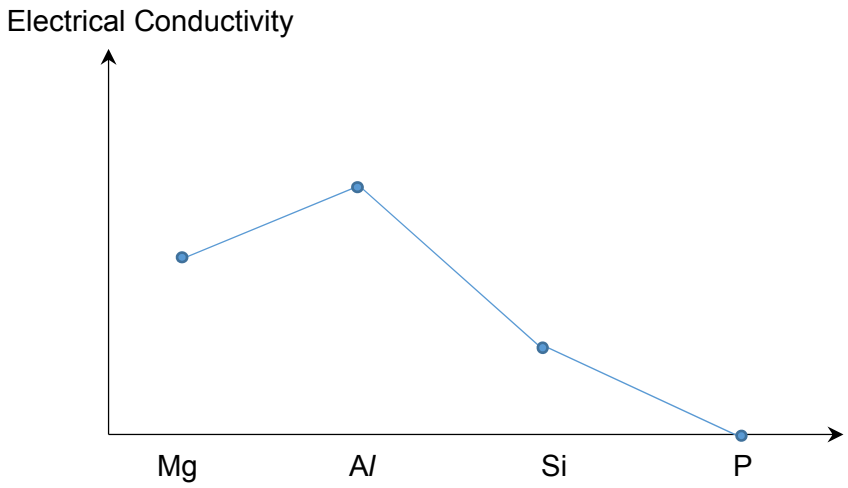
$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

Phosphorus chloride solution: **pH 1-2**.

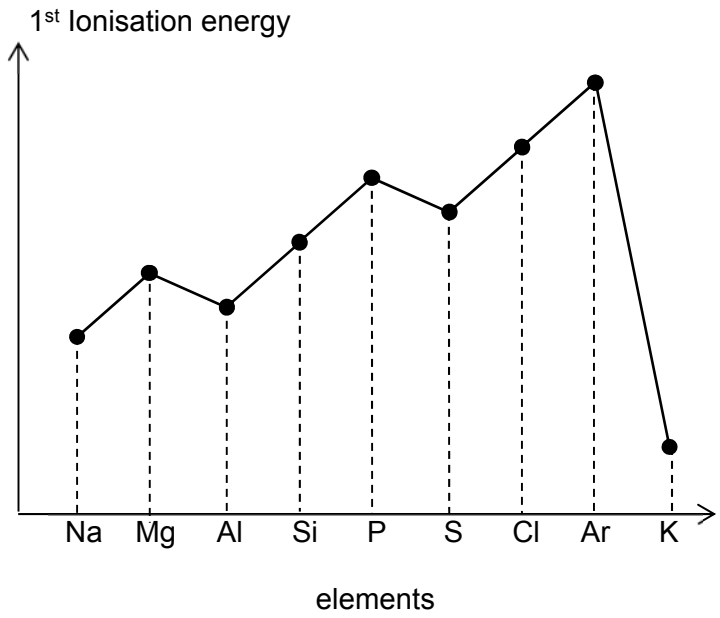
(ii) On the axes below, sketch the electrical conductivity of the period 3 elements from magnesium to phosphorous.



[1]



(b) The following graph shows the trend of the first ionisation energies of the elements from sodium to potassium.



(i) Explain the difference between the values of their first ionisation energies for **each** of the pairs of elements listed below. You should use a different explanation for each pair.

- sodium and potassium

……..

……..

……..

……..

……[2]

$_{11}Na$: $1s^2\ 2s^2\ 2p^6\ 3s^1$ $_{19}K$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$

K has one more quantum shell of electrons than Na, **valence electron of K is further away from the nucleus** and **less strongly attracted to the nucleus. Less energy is required to remove the valence electrons from K**.

Hence 1st IE of K is lower than that of Na.

- magnesium and aluminium

……..

……..

……..

……..

……[1]

Mg: $1s^2\ 2s^2\ 2p^6\ 3s^2$ Al: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

The **3p electron of Al is further away from the nucleus and has higher energy than the 3s electron of Mg**. **Less energy is required to remove the 3p electron from Al.** Thus, 1st IE of Mg is higher than that of Al.

(ii) When a beam of $_{20}Ca^{2+}$ particles travels through a uniform electric field which is at right angles to its direction of travel, it is deflected at an angle of +10.0°.

Determine the angle of deflection of a beam of $_{8}O^{2-}$ particles if it travels at the same speed through the same electric field.

[2]
[Total: 12]

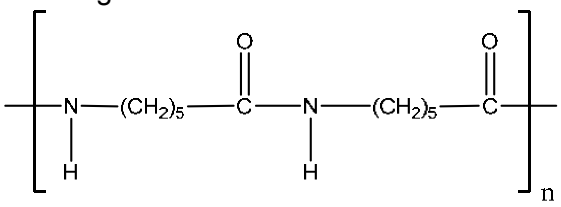
angle of deflection $\propto \frac{q}{m}$

Particle	z/m ratio	angle of deflection
Ca^{2+}	+2/40.1	+10.0°
O^{2-}	-2/16	[(-2/16 / (+2/40)] x (+10.0) = **-25°**

correct magnitude
correct sign

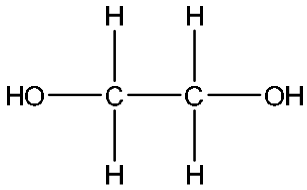
2 Synthetic polymer fibres are man-made, formed entirely by chemical synthesis. Demand for synthetic fibres has increased over the last few decades as they are durable, less expensive and more stain resistant than natural fibres. Terylene and Nylon 6 are examples of polymeric synthetic fibre.

- Nylon 6 has the following structure.

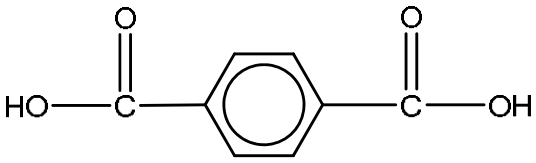


Nylon 6

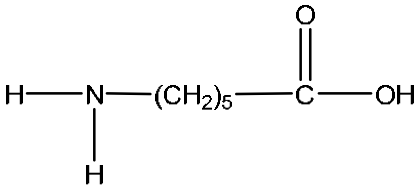
- Terylene is made from ethane-1,2-diol and benzene-1,4-dicarboxylic acid.



and



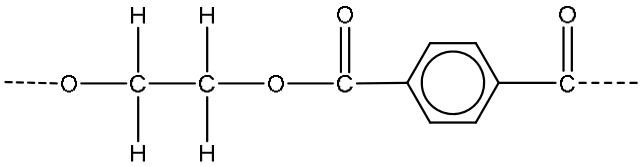
(a) Draw the structural formula of the monomers from which Nylon 6 could be made. State the type of polymerisation involved.



Type of polymerisation: Condensation polymerisation

[2]

(b) Draw a displayed formula to show the simplest repeat unit of Terylene. [1]



(c) Explain why nylon is prone to creasing while Terylene is wrinkle free.

……

……

……

…… [2]

Nylon: Polyamide chains are bonded to one another via hydrogen bonding. The hydrogen bonds are broken / disturbed when water penetrate the areas between the chains. New hydrogen bonds are formed while it dries up and form creases.

Terylene: a polyester which do not form hydrogen bonding between the chains, thus is less prone to crease.

Poly(propene) is also a polymer like the synthetic fibre; it is lightweight, durable and widely used in industries for making home articles such as container, buckets and crates.

(d) Explain why dilute sodium hydroxide will cause holes to appear in containers made from polymers such as Terylene but a poly(propene) container can be used to store sodium hydroxide. [1]

……

…… [1]

Terylene (Polyesters) are susceptible to/undergoes **hydrolysis** in presence of alkali but poly(propene) is unreactive towards alkali.

(e) State the reason why the disposal of poly(propene) containers in landfill sites is a problem. [1]

……

…… [1]

PP is not easily decomposed in nature/break down by microorganisms/non-biodegradable.
Thus, takes up land space.

(f) The following is an extract from an article "The safety of nanoparticles in sunscreens: An update for general practice" published on The Royal Australian College of General Practitioners 2016, June 2016.

"Recent media coverage has raised public awareness regarding the safety of sunscreens containing zinc (ZnO) and titanium (TiO_2) nanoparticles. The inorganic filters ZnO and TiO_2 are able to protect against UVA and UVB. As conventional micronised particles in sunscreen, they have several unfavourable characteristics, including difficulty in application, leaving white residue on the skin. This led to the development of smaller nanoparticles, the use of which vastly improves aesthetic and ease of application of sunscreens while maintaining photo-protective qualities."

(i) Define nanoparticles.

…… [1]

Material with all dimensions on 1-100 nm.

(ii) Explain in your own words why the surface-to-volume ratios makes nanoscale sunscreen attractive.

……

……

……

…… [2]

As surface area to volume ratio is high, a greater amount of a blocking agent (sunscreen) is in contact with the nanoparticle. The denser packing covers the skin more evenly/ does not leave bulky residue behind. (or words to the same effect)

(iii) Explain why nanoparticles of TiO_2 in sunscreen could present a risk to human health.

…… [1]

it can easily pass through/absorb into pores/ skin/ cell / membranes / veins/ capillaries/ into blood stream AND get into blood and cause cancer / toxic to cells

(iv) Sunscreen containing nanoparticles should be tested further.

Suggest one reason why some companies that make sunscreens might not want to do more tests.

……

…… [1]

1 of the possible answers:

- Testing is time-consuming
- Testing is expensive
- Testing may result in undesirable outcome / reduce sales (owtte)
- Accept other logical answers

3 Citric acid, $C_6H_8O_7$, is a weak tribasic organic acid. It is used as an additive and preservative in various food and drinks to enhance flavour and taste. It provides a fruity tartness to complement fruit flavours and it is also used to mask the unpleasant taste of pharmaceutical products.

However, a high content of citric acid in foods and drinks could damage your teeth. Chemical erosion of the teeth occurs either by the hydrogen ions derived from citric acid or by the citric acid anions which can bind or complex calcium. The acceptable limit for the percentage composition by mass of citric acid in food is 2.5% as this is around the percentage composition commonly found in natural fruits.

A student wanted to find the out the mass of citric acid in a mint candy by doing a titration with sodium hydroxide solution. The equation for the titration is:

$$C_6H_8O_7 + 3NaOH \rightarrow C_6H_5O_7Na_3 + 3H_2O$$

He weighed out 5.00 g of the mint candy and crushed the candy into powder. He then dissolved the powder in 100 cm^3 of distilled water, stirred the mixture and filtered it forming solution **A**.

(a) The student then prepared a standard solution of sodium hydroxide by dissolving 0.104 g of sodium hydroxide pellets in 25.0 cm^3 of distilled water. He then made the volume up to 250 cm^3 forming solution **B**.

Calculate the concentration of sodium hydroxide in solution **B**.

Amount of NaOH in 25.0 cm^3 of distilled water = 0.104/40.0 = 0.002594 mol

[NaOH] in solution B = 0.002594 x (1000/250) = 0.0104 mol dm^{-3}

[2]

(b) The student then found that 20.0 cm^3 of solution **A** required 10.40 cm^3 of solution **B** for a complete reaction.

(i) Suggest a suitable indicator for the titration.

Phenolphthalein.
Do not accept methyl orange or universal indicator.

[1]

(ii) Calculate the mass of citric acid in the 20.0 cm^3 of solution **A**.

ECF from (a)(i)

Amount of Citric acid in 20.0 cm^3 of **A** = (10.40/1000) x 0.0104 x (1/3)
= 3.605×10^{-5} mol

Molar mass of citric acid = 192.0 g mol^{-1}

Mass of citric acid in 20.0 cm^3 of **A** = 3.605×10^{-4} x 192.0
= 0.00692 g

[2]

(iii) Given that the average weight of one piece of mint candy is 0.50 g, calculate the mass of citric acid in one piece of mint candy.

Mass of citric acid in 100.0 cm^3 of **A** = 0.00692 x 5 = 0.0346g

Mass of citric acid in one piece of mint candy = (0.0346/5.00) x 0.5
= 0.00346 g

[2]

(c) From your answer in **(b) (iii)**, determine whether the percentage composition by mass of citric acid in the mint candy is above or below the acceptable limit.

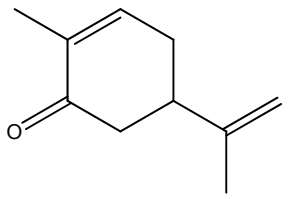
Percentage composition of citric acid by mass = 0.00346/0.5 x 100%
= 0.692 %

The percentage composition is **below** the acceptable limit.

[1]

[Total: 10]

4. Carvone is a natural oil produced by the plant *Mentha spicata.* It has the flavour of spearmint and it has important uses in food flavouring.



Carvone

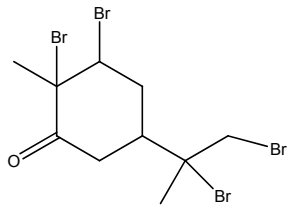
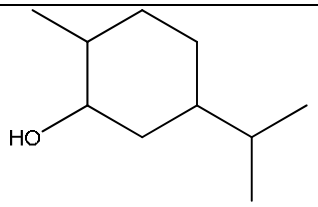
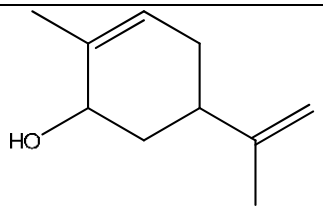
(a) Carvone reacts with different reagents

(i) Identify the functional groups present in Carvone.

Alkene and **ketone** (Do not accept alkane or carbonyl)

[2]

(ii) Draw structures for the organic products of each compound with the following reagents. State the type of reaction that is happening for each reagent.

Reagent and conditions	Type of reaction	Organic product
Br_2 liquid, room temperature	Addition	
H_2 with Ni catalyst, high temperature and high pressure	Reduction	
$LiAlH_4$ in dry ether, room temperature	Reduction	

[7]

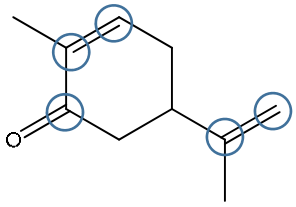
(b) Suggest why Carvone is highly soluble in hexane.

Carvone has **a bulky hydrocarbon chain/ many C-C and C-H bonds** that enables it to form **instantaneous dipole – induced dipole interactions** with hexane molecules.

[2]

(c) On the above structure of Carvone, circle one sp^2 hybridised carbon atom.

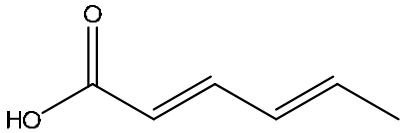
[1]



Carvone

Any one of the 5 circled Cs

(d) Sorbic acid, or 2,4-hexadienoic acid, is a natural organic compound used as a food preservative.



Sorbic acid

Describe a chemical test that will help you distinguish Carvone from Sorbic acid, including all observations that would be made.

Add **sodium carbonate** to both Carvone and sorbic acid.

Sorbic acid will give **effervescence**. Gas produced forms a white precipitate with calcium hydroxide.

No observable change will be seen for Carvone.

[2]
[Total: 14]

5 **(a)** Benzene undergoes complete combustion with oxygen as shown by the equation below.

$$C_6H_6(l) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$$

(i) Explain what is meant by *standard enthalpy change of combustion.*

……

……[1]

It is the enthalpy change when one mole of a compound is completely burnt in oxygen under standard conditions of 298K and 1 atm.

(ii) 1.17 g of benzene was burnt to heat up 250 g of water in a beaker. The initial temperature of the water was 27.6°C. Given that the standard enthalpy change of combustion of benzene is –3267 kJ mol^{-1} is and there is 20% heat loss to the surrounding, calculate the highest temperature reached by the water.

[3]

Amount of benzene = 1.17 / (12.0 × 6 + 1.0 × 6) = **0.0150 mol**

Total amount of heat evolved = 0.0150 × (-3267) = **- 49.01 kJ**

Amount of heat absorbed by the water = **0.80 × 49.005** = 39.20 kJ

Heat absorbed by water = mcΔT

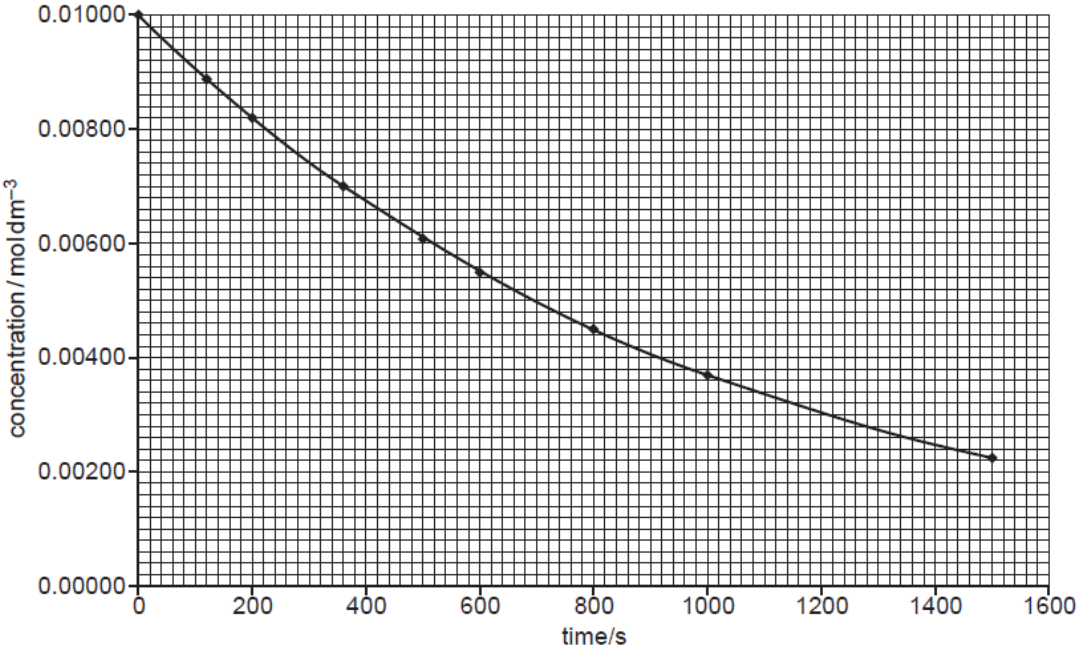
$39.20 \times 10^3 = 250 \times 4.18 \times \Delta T$

$\Delta T = 37.5°C$

Highest temperature reached = **27.6 + 37.5** = 65.1°C

(b) 2–iodo–2–methylpropane undergoes a substitution reaction with hot aqueous sodium hydroxide. Two separate experiments were carried out to study the kinetics of this reaction.

In Experiment 1, sodium hydroxide was used in large excess and the concentration of 2–iodo–2–methylpropane was measured against time. A graph of concentration of 2–iodo–2–methylpropane against time was plotted and shown below.



(i) Use the half–life method to deduce the order of reaction with respect to 2–iodo–2–methylpropane. Show all your working clearly.

……..

……..

……[2]

Show clear construction lines to obtain two half lives.

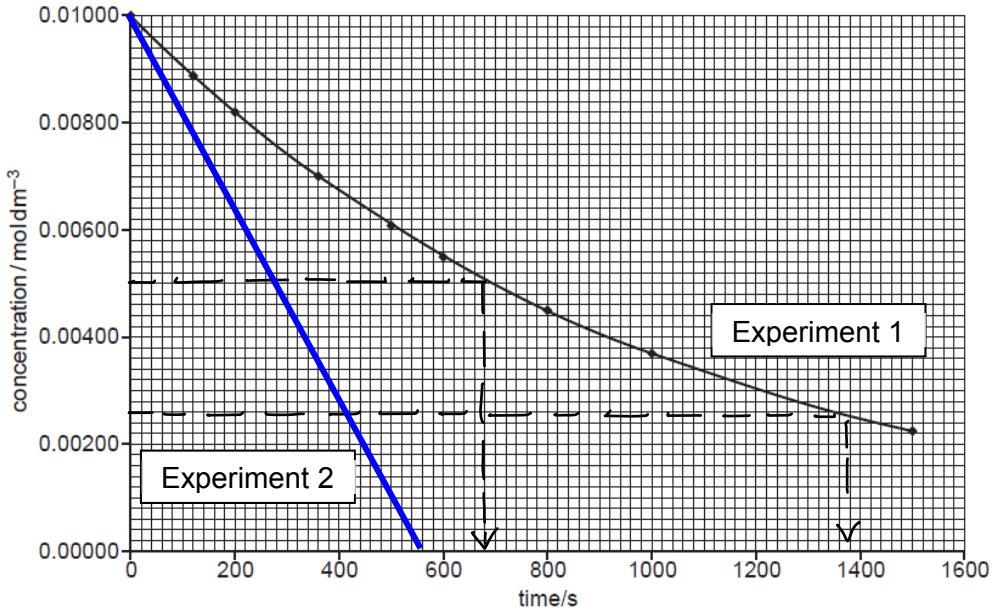
Two approximately constant half-lives obtained ≈ 690 ± 10 s

Order of reaction w.r.t 2-iodo-2-methylpropane = **1**

In Experiment 2, 2–iodo–2–methylpropane was used in large excess and the concentration of sodium hydroxide was measured against time. The following results were obtained.

Time / s	[NaOH] / mol dm^{-3}
0	0.0100
100	0.0082
200	0.0064
380	0.0032
500	0.0010

(ii) Using the data provided above, plot a graph for Experiment 2 in the graph above. [1]



Points correctly plotted.
Best fit straight line.

(iii) Using the graph plotted in **(b)(ii)**, determine the order of reaction with respect to sodium hydroxide. Explain your answer.

……..

……..

……[2]

From experiment 2,
[NaOH] vs time graph is a straight line
=> constant gradient => constant rate
(=> rate is independent of [NaOH])

Hence order of reaction w.r.t. NaOH = 0

(iv) Hence, write an overall rate equation for the substitution reaction.

……[1]

rate = k [2-iodo-2-methylpropane]

(c) Colourless N_2O_4 and brown NO_2 are two oxides of nitrogen that can co-exist in equilibrium:

$$N_2O_4\ (g) \rightleftharpoons 2\ NO_2\ (g) \quad \Delta H = +\ 58\ kJ\ mol^{-1}$$

Predict and explain how the colour intensity of the mixture changes, when a reaction chamber containing an equilibrium mixture of N_2O_4 and NO_2 is:

(i) immersed in boiling water.

.....

.....

.....

.....

.....[2]

When there is an increase in temperature, **equilibrium shifts right** to **favour the endothermic reaction** to **absorb the additional heat**, producing more NO_2, leading to an **increase in colour intensity**.

(ii) subjected to a sudden compression in volume.

.....

.....

.....

.....

.....[2]

When there is a sudden compression of the reaction chamber, the pressure of the system increase. By Le Chatelier's Principle, the **equilibrium position shifts to the left** , **favouring the production of fewer gaseous molecules**, producing more N_2O_4, leading to a **decrease in colour intensity**.

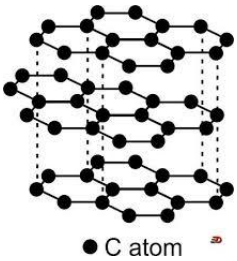
[Total: 14]

Section B

Answer one question from this section, in the spaces provided.

5 **(a)** Describe the structure of graphite. Explain how this structure gives graphite the properties of soft and high electrical conductivity.

You may include labelled diagrams in your answer.



- They have parallel layers of hexagons or shown in diagram
- **Soft:** The adjacent layers are held by **weak id–id interactions** and hence the layers **can slide easily over** one another.
- **Electrical conductivity**: One p electron per C atom (out of the 4 electrons) is **delocalised**, thus is able to conduct electricity well (parallel to layer).

.....

.....

.....

.....

.....[3]

(ii) Another allotrope of carbon is diamond. State one physical property diamond has in common with graphite and relate the property to the bonding present in their structures.

They have high melting points
due to the strong extensive covalent bonds between atoms

.....

.....

.....[2]

(b) **(i)** Write an equation, including state symbols, for the reaction with enthalpy change equal to the standard enthalpy of formation for ethane, $C_2H_6(g)$.

$$2C\ (s) + 3H_2(g) \longrightarrow C_2H_6(g)$$

.....[1]

(ii) Suggest in terms of bonding why ethane is a gas at room temperature.

Small amount of energy is required to break the weak instantaneous dipole induced dipole interactions between the ethane molecules.

id-id between molecules AND small amount of energy/weak bonds

……

……[1]

(iii) Ethane undergoes a reaction with chlorine. Name the type of reaction that occurs and the conditions used.

Substitution reaction Presence of uv light

……

……[2]

(b) **(i)** The enthalpy change for the following reaction is –2889 kJ mol^{-1}.

$$C_2H_6(g) + 7F_2(g) \longrightarrow 2CF_4(g) + 6HF(g)$$

Use this value and the standard enthalpies of formation given to calculate the standard enthalpy of formation of $C_2H_6(g)$.

Substance	$CF_4(g)$	$HF(g)$
ΔH_f^o / kJ mol^{-1}	–680	–269

$\Delta H_r^\theta = \sum n\Delta H_f^\theta$ **(products) –** $\sum m\Delta H_f^\theta$ **(reactants)**

–2889 = (2 x –680) + (6x–269) – ΔH_f^o $C_2H_6(g)$ mtd

ΔH_f^o $C_2H_6(g)$ = – 85 kJ mol^{-1} ans

[2]

(c) Methane reacts violently with fluorine according to the following equation.

$$CH_4(g) + 4F_2(g) \longrightarrow CF_4(g) + 4HF(g) \qquad \Delta H = -1904 \text{ kJ mol}^{-1}$$

(i) Using relevant bond energies in the Data Booklet, calculate the bond energy of F–F bond. [2]

Bonds broken (endothermic)	**No. of moles**	**Bond energy / kJ mol^{-1}**
C–H	4	4 X 410
F–F	4	4 X F–F

Bonds formed (exothermic)	**No. of moles**	**Bond energy / kJ mol^{-1}**
C–F	4	4 x 485
H–F	4	4 x 562

$\triangle H_{reaction}$ = Total bonds broken – total sum of bonds formed

–1904 = (4 X 410) + (8 X F–F) – [(4 x 485) + (4 x 562)] mtd [1] / shown in table

F–F bond = +161 kJ mol^{-1} ans with correct sign

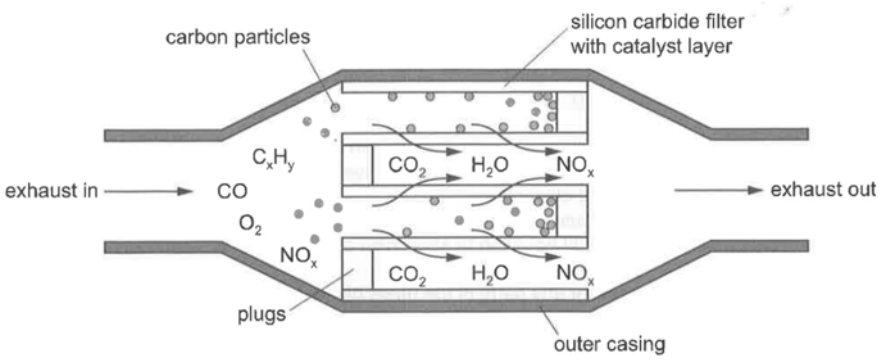
(ii) A student suggested that actual bond energy of F-F differs from theoretically calculated value in (i). Explain if you agree or disagree with the student.

I agree with the student.
The bond energies used to calculate the (i) are only average values obtained from the Data Booklet.

……

……[1]

(c) **(i)** Catalyst are used in car exhaust of modern cars to speed up reaction between polluting gases such as carbon monoxide and dinitrogen oxide, before they reach the end of the exhaust pipe.



(i) State the type of catalyst involved in this reaction.

…… [1]
Heterogeneous catalyst (catalyst and reactants are in **different** phase)

(ii) Sketch a Boltzmann distribution curve for the reactants and use it to explain how the use of catalyst speeds up the reaction.

Diagram

Explanation

.....

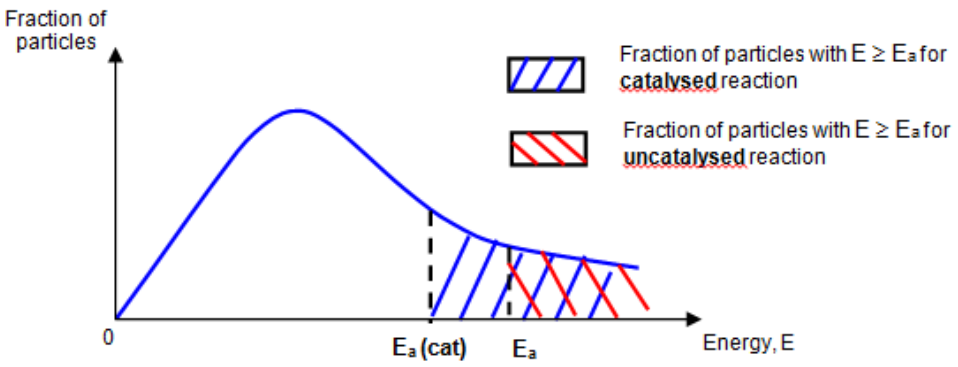
.....

.....

.....

.....

[4]



- Catalyst **lowers the activation energy by providing an alternative reaction pathway.** (shown in graph)

- **Fraction of particles with energy equal to or greater than the activation energy of the catalysed reaction, $E_{a(cat)}$ increases.**

- **Increased frequency of effective collisions** taking place in the reaction
- **rate of reaction increases**.

(ii) Suggest why car manufacturers are required to fit catalytic converters to car exhaust systems.

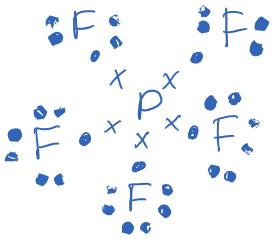
Catalytic converters can **remove air pollutants such as CO and NO_2** and convert them into **harmless gases such** as CO_2 and N_2.

CO will bind with haemoglobin thus preventing the transport of oxygen in humans, or that NO_2 forms photochemical smog or acid rain.

6 **(a)** Phosphorus reacts with fluorine to form PF_3 and PF_5.

(i) Draw the dot-and-cross diagram for one molecule of PF_5. Show only the outer shell electrons.

[1]



(ii) Explain why the P–F bond is polar.

…….. [1]

F is more electronegative than P / There is a **difference in electronegativity** between P and F.

(iii) Predict whether or not a molecule of PF_5 is polar. Explain your answer.

……

…….. [1]

Non-polar.
The **dipole moments cancel out** each other.
(specimen paper accepts the molecule is symmetrical)

(iv) Nitrogen reacts with fluorine to form NF_3 only.

Explain why PF_5 exists whereas NF_5 does not exist.

……

…….. [1]

P is a period 3 element which has **energetically accessible vacant 3d orbitals** for **expansion of octet/ to accommodate more than 8 electrons** whereas N is a period 2 element which does not have energetically accessible (3d) orbitals.

(b) The reaction between sulfur dioxide and oxygen is a reversible reaction and can be described as being in dynamic equilibrium.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

A 2-dm^3 reaction vessel containing 0.80 mol of SO_2, 0.30 mol of O_2 and 1.40 mol of SO_3 is allowed to reach equilibrium at a constant temperature of 1000 K. It was determined that 0.42 mol of SO_2 is present at equilibrium.

(i) State the meaning of the term *dynamic equilibrium*.

……

…….. [1]

Dynamic equilibrium is a state of reversible reaction in which the **forward and backward reaction occurs at the same rate** such that the **concentration of reactants and products remain constant**.

(i) Use the information given to complete Table 6.1.

Table 6.1

	SO_2	O_2	SO_3
Initial amount/ mol			
Equilibrium amount/ mol			

[2]

	SO_2	O_2	SO_3
Initial amount/ mol	0.80	0.30	1.40
Equilibrium amount/ mol	0.43	0.30 – ½ (0.37) = 0.115	1.40 + 0.37 = 1.77

(ii) Write an expression for the equilibrium constant K_c.

[1]

$K_c = \frac{[SO_3]^2}{[SO_2]^2\,[O_2]}$

(iii) Calculate the value of K_c. State the units of K_c.

[2]

$K_c = \frac{(\frac{1.77}{2})^2}{(\frac{0.43}{2})^2\,(\frac{0.115}{2})} = \frac{0.7832}{0.002658} = 294.7 = 295$

Units for K_c: $mol^{-1}\ dm^3$

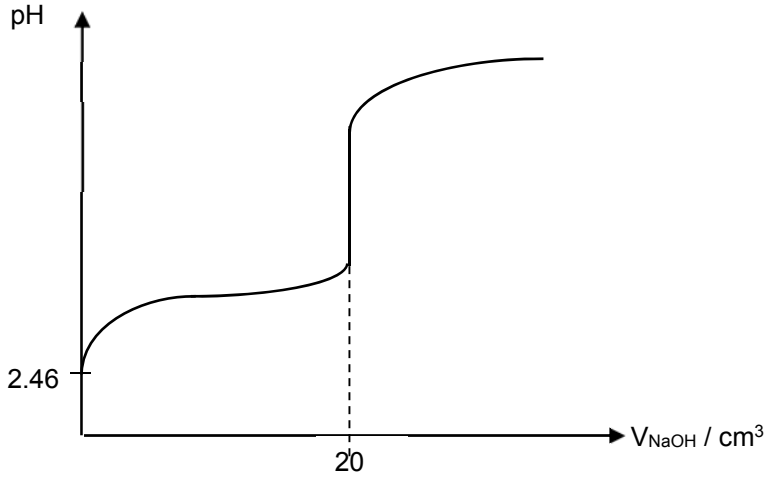
(c) **(i)** State the difference between a weak acid and a strong acid

……

…….. [1]

Weak acid undergoes **partially dissociation** in water to form H^+ ions whereas strong acid undergoes **complete dissociation** in water to form H^+ ions.

20.0 cm^3 of 0.01 mol dm^{-3} propanoic acid, CH_3CH_2COOH was titrated against 0.01 mol dm^{-3} aqueous sodium hydroxide.



The initial pH of propanoic acid is 2.46.

(ii) Calculate the initial concentration of hydrogen ions before the titration.

[1]

$[H^+] = 10^{-2.46}$
$= 3.47 \times 10^{-3}$ mol dm^{-3}

During the addition of the first 20 cm^3 of sodium hydroxide the mixture is behaving as a buffer.

(ii) Explain how the shape of the graph show this.

……

…….. [1]

The graph is **relatively flat/ gentle gradient** between 0 to 20 cm^3, indicating that **there is little change/increase in pH** during the addition of NaOH.

(iii) Identify the two species present in the mixture that constitutes to it behaving as a buffer.

…….. [1]

CH_3CH_2COOH and $CH_3CH_2COO^-$ / CH_3CH_2COONa

(d) Polyvinyl acetate, PVAc, is a useful adhesive for gluing together articles made from wood, paper or cardboard. The diagram shows a section (not a repeat unit) of the PVAc.

PVAc

(i) What type of polymerisation made this polymer?

…….. [1]
addition polymerisation

(ii) PVAc is made from monomer **X**. Draw the structure of the **X**.

[1]

(iii) PVAc can be converted to polyvinyl alcohol, PVA.

Draw a section of PVA containing at least 2 repeat units and suggest the reagents and conditions needed to make PVA from PVAc in the laboratory.

Section of PVA:

Reagents and conditions: ……..
[2]

NaOH(aq), heat or H_2SO_4(aq), heat

(e) The diagrams below are molecular representations of two types of plastics – thermoplastics and thermosets.

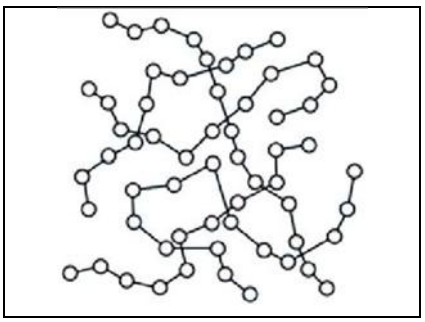


Diagram **A**

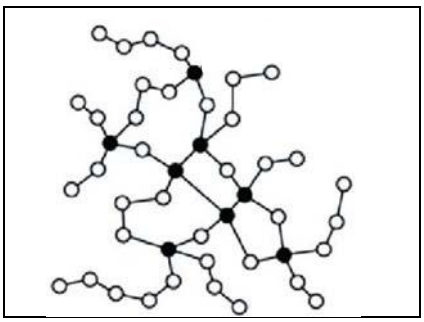


Diagram **B**

(i) State and explain which diagram could be the representation for thermosets.

……

…….. [1]

Diagram B. There is **extensive cross-linking** present between the polymer chains.

(ii) State a difference in physical properties between thermoplastics and thermosets.

……

…….. [1]

Thermoplastics **soften on heating** (and harden on cooling) whereas thermosets **cannot be soften on heating**.

[Total: 20m]

JURONG JUNIOR COLLEGE
2018 JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME	

CLASS	**18S24**	EXAM INDEX	

CHEMISTRY 8873/01

Higher 1

Paper 1 Multiple Choice **13 September 2018**

1 hour

Candidates answer on separate paper.

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and exam index number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** or **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **12** printed pages.

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1 When copper reacts with a 50% solution of nitric acid, nitrogen monoxide is evolved and a blue solution results.

The balanced equation for this reaction is shown.

$$p\text{Cu} + q\text{HNO}_3 \rightarrow r\text{Cu(NO}_3)_2 + s\text{H}_2\text{O} + t\text{NO}$$

What are the values of the integers *p, q, r, s* and *t*?

	p	*q*	*r*	*s*	*t*
A	1	4	1	2	2
B	2	6	2	3	2
C	2	8	2	4	4
D	3	8	3	4	2

2 A sample of silicon contains three naturally occurring isotopes, ^{28}Si, ^{29}Si and ^{30}Si.

The sample is made up of 92.23% ^{28}Si and the relative atomic mass of silicon in this sample is 28.10.

What is the percentage of the isotope ^{29}Si in the sample?

A 2.23% **B** 3.89% **C** 5.54% **D** 7.77%

3 The ^{68}Ge isotope is medically useful because it undergoes a natural radioactive process to give an isotope of a different element, ^{68}X, which can be used to detect tumours. This transformation of ^{68}Ge occurs when an electron enters the nucleus and changes a proton into a neutron.

Which statement about the composition of an atom of ^{68}X is correct?

A It has 4 electrons in its outer p orbitals.

B It has 13 electrons in its outer shell.

C It has 37 neutrons.

D Its proton number is 32.

4 Drinking water may contain dissolved calcium hydrogencarbonate, $Ca(HCO_3)_2$.

How many electrons are present in a hydrogencarbonate anion?

A 30 **B** 31

C 32 **D** 33

5 In which structure are there three atoms bonded together in a straight line?

A Poly(ethene), $-\left[CH_2-CH_2\right]_n-$

B Propane, C_3H_8

C Silicon tetrachloride, $SiCl_4$

D Sulfur hexafluoride, SF_6

6 At room temperature and pressure, H_2O is a liquid and H_2S is a gas.

What is the reason for this difference?

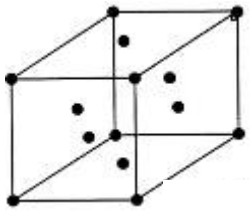
A O has higher first and second ionisation energies than S.

B The covalent bond between O and H is stronger than the covalent bond between S and H.

C There is significant hydrogen bonding between H_2O molecules but not between H_2S molecules.

D The instantaneous dipole-induced dipole forces between H_2O molecules are stronger than the instantaneous dipole-induced dipole forces between H_2S molecules.

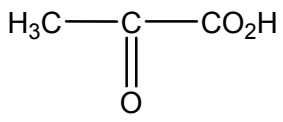
7 Copper and iodine are both shiny crystalline solids. The crystal structures of copper and iodine are both face-centred cubic. The diagram shows the arrangement of the particles in this type of crystal lattice.



What are the particles present in each lattice?

	Copper	iodine
A	atoms	anions
B	atoms	atoms
C	cations	atoms
D	cations	molecules

8 The diagram shows the structure of pyruvic acid.



pyruvic acid

Which set of bond angles in pyruvic acid would be predicted by Valence Shell Electron Pair Repulsion theory?

A 105°, 109°, 120°

B 105°, 120° only

C 109°, 120°, 180°

D 109°, 120° only

9 Which row describes and explains the trend in electronegativity from fluorine to iodine?

	trend in electronegativity	explanation
A	decreases	the bonding pair of electrons becomes further away from the nucleus and so is less attracted to it
B	decreases	ionisation energy decreases down the group because the outer electron is strongly attracted to the nucleus
C	increases	the bonding pair of electrons becomes further away from the nucleus and so is less attracted to it
D	increases	ionisation energy decreases down the group because the outer electron is strongly attracted to the nucleus

10 Which types of bond are broken and formed in the addition polymerisation of alkenes?

	Type of bond broken	Type of bond formed
A	π only	σ only
B	π only	σ and π
C	σ and π	σ only
D	σ and π	σ and π

11 All the reactants and products of an endothermic reaction are gaseous.

Which statements about this reaction is correct?

1 On the reaction pathway diagram, the energy of the products are lower than that of the reactants.

2 There is a net transfer of heat energy from the surroundings to the reacting system.

3 The total bond energy of the reactants is more than the total bond energy of the products.

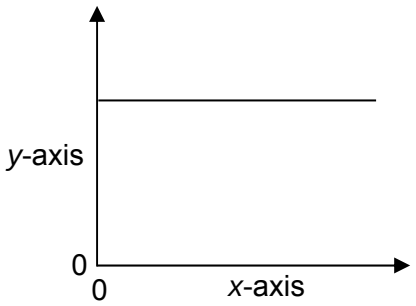
A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 3 only

12 The kinetics of the zero order reaction U → V were investigated under different conditions.
The table shows pairs of quantities that were plotted as graphs.
Which pairs gave the following graph?



	y-axis	*x*-axis
1	rate	time
2	rate constant	time
3	rate constant	temperature

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 1 and 3 only

13 Which statement about the effect of a catalyst on a reversible reaction is correct?

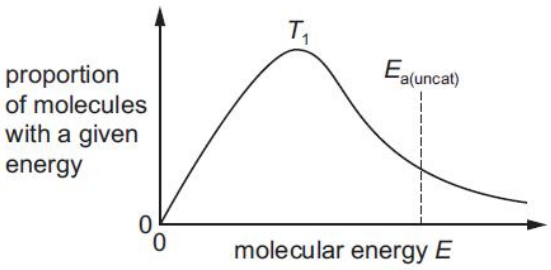
A The activation energy of the forward reaction stays the same.

B The composition of the equilibrium mixture stays the same.

C The rate of the backward reaction stays the same.

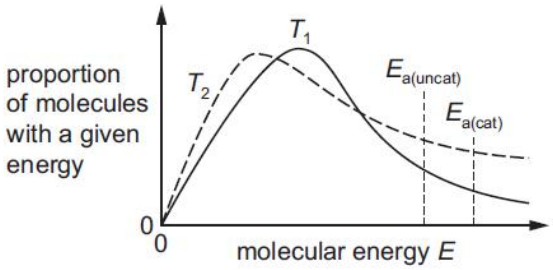
D The value of the equilibrium constant changes.

14 The diagram shows the distribution of molecular energies in a sample of gas at a temperature T_1. The activation energy for an uncatalysed reaction of this gas, $E_{a(uncat)}$, is shown.



Which diagram correctly shows the new distribution and new activation energy, $E_{a(cat)}$, when the temperature is increased to T_2, and a catalyst is used that increases the rate of reaction?

A



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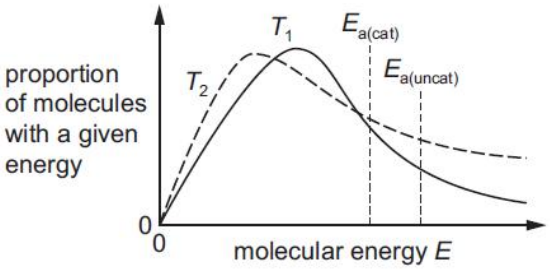

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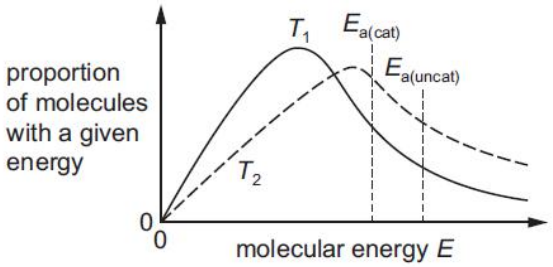
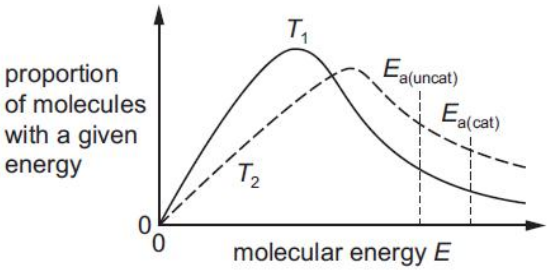


D



15 Nitrogen dioxide, NO_2, is a brown gas.
Dinitrogen tetroxide, N_2O_4, is a colourless gas.
An equilibrium is established between NO_2 and N_2O_4 in a closed vessel.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -57 \text{ kJ mol}^{-1}$$

brown colourless

Which row describes the effects of changing conditions on the colour of an equilibrium mixture of NO_2 and N_2O_4?

	Increasing the pressure	Increasing the temperature
A	Colour becomes darker	Colour becomes darker
B	Colour becomes darker	Colour becomes lighter
C	Colour becomes lighter	Colour becomes darker
D	Colour becomes lighter	Colour becomes lighter

16 The following equilibrium is an exothermic reaction in the forward direction.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

What happens when the concentration of $CrO_4^{2-}(aq)$ ions **increases and** the temperature **decreases**?

1 The concentration of $Cr_2O_7^{2-}(aq)$ increases.
2 The equilibrium constant for the forward reaction increases.
3 The rate constants for the forward and reverse reactions increase equally.

A 1, 2 and 3
B 1 and 2 only
C 2 and 3 only
D 1 only

17 The compound $(CH_3)_3NAlCl_3$ has a simple molecular structure.

Which statement about $(CH_3)_3NAlCl_3$ is correct?

A $(CH_3)_3NAlCl_3$ molecules attract each other by hydrogen bonds.
B The Al atom has an incomplete valence shell of electrons.
C The bonds around the Al atom are planar.
D The molecules contain coordinate and covalent bonding.

18 A solution was made by mixing 0.002 mol of H_2SO_4(aq) and 0.005 mol of KOH(aq). Water was added until the volume of the solution was 1 dm^3.

What is the pH of the solution?

A 11.0 **B** 11.5 **C** 11.7 **D** 12.0

19 Silver chloride and silver iodide form equilibria when added to water.

$$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq) \qquad K_c = K_1$$

$$AgI(s) \rightleftharpoons Ag^+(aq) + I^-(aq) \qquad K_c = K_2$$

Each equilibrium position lies well to the **left**.

Silver iodide will not dissolve in aqueous ammonia. Silver chloride will dissolve in aqueous ammonia. In both cases, adding aqueous ammonia will form the following equilibrium.

$$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+(aq) \qquad K_c = K_3$$

The position of this equilibrium lies to the **right**.

What is the order of magnitude for these three equilibrium constants?

A $K_2 > K_3 > K_1$

B $K_2 > K_1 > K_3$

C $K_3 > K_1 > K_2$

D $K_3 > K_2 > K_1$

20 An element **Y** reacts according to the following sequence.

$$\mathbf{Y} \xrightarrow{\text{burns in } O_2} \text{white solid} \xrightarrow{HCl\,(aq)} \text{solution} \xrightarrow{NaOH(aq)} \text{white precipitate} \xrightarrow{\text{an excess of } NaOH(aq)} \text{solution}$$

What could be element **Y**?

A Al **B** Ca **C** Mg **D** P

21 X_2, Y_2, Z_2 represent different halogens. The table shows the results of nine experiments in which aqueous solutions of X_2, Y_2 and Z_2 were separately added to separate aqueous solutions containing X^-, Y^- and Z^- ions.

	X^-(aq)	Y^-(aq)	Z^- (aq)
X_2(aq)	No reaction	No reaction	No reaction
Y_2(aq)	X_2 formed	No reaction	Z_2 formed
Z_2(aq)	X_2 formed	No reaction	No reaction

Which row of the following table contains the ions X^-, Y^- and Z^- in order of their decreasing strength as reducing agents?

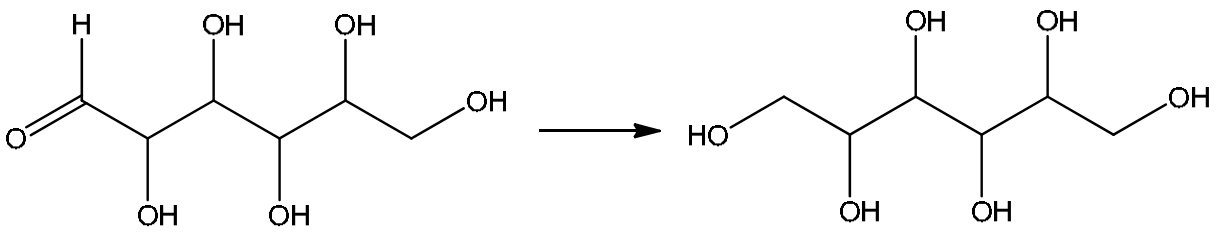
	strongest →		weakest
A	X^-	Y^-	Z^-
B	X^-	Z^-	Y^-
C	Y^-	Z^-	X^-
D	Z^-	X^-	Y^-

22 1-bromopropane undergoes a variety of reactions.

Which row is correct?

	Reagent added to 1-bromopropane	Products include
A	Hot NaOH(aq)	Propene
B	Cold NaOH(aq)	Prop-2-ene
C	Hot NaOH in ethanol	Propene
D	Hot NaOH in ethanol	Propan-1-ol

23 Glucose can be used to prepare sorbitol, a compound used as a sugar substitute.



glucose sorbitol

Which reagent may be used for this conversion?

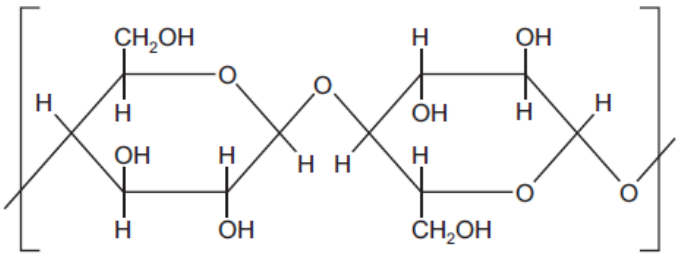
A Acidified potassium maganate(VII)

B Acidified potassium dichromate(VI)

C Sodium hydroxide

D Sodium borohydride

24 A cathedral in New Zealand has been constructed from cardboard. Cardboard contains polymer molecules. Part of one such polymer molecule is shown below.



Which statements about this polymer are correct?

1 The polymer molecules can form hydrogen bonds with each other.

2 The polymer can form intermolecular forces with water molecules.

3 The polymer will not burn easily because it is a secondary alcohol.

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 1 only

25 Graphene, graphite and the fullerene C_{60} are allotropes of carbon.

Which statements are correct for all three of these allotropes of carbon?

1 Delocalised electrons are present in the structure.

2 All bond angles are 120°.

3 It has a giant molecular crystalline lattice structure.

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 1 only

26 PVC, $\left[CH_2-CHCl \right]_n$ is difficult to dispose of.

Two possible methods are burying it in landfill sites and disposal by combustion.

Which row of the table is correct?

	Rate of biodegradation of PVC in landfill sites	Gases produced when PVC combusts
A	Fast	CO_2, H_2O, HCl
B	Fast	CO_2, H_2O, Cl_2
C	Slow	CO_2, H_2O, Cl_2
D	Slow	CO_2, H_2O, HCl

27 The gases butane, 2-methylpropane and propane are kept in a sealed container at atmospheric pressure and room temperature.

Which row represents the order in which these gases will liquefy as the pressure in the container is gradually increased?

	Increasing pressure		
	→		
A	butane	2-methylpropane	propane
B	2-methylpropane	butane	propane
C	propane	butane	2-methylpropane
D	propane	2-methylpropane	butane

28 Silver foil does not react when added to a beaker of dilute hydrochloric acid. However, silver nanoparticles do react with dilute hydrochloric acid.

$$2Ag + 2HCl \rightarrow 2AgCl + H_2$$

Which statement could explain why silver nanoparticles are more reactive than silver foil?

A They act as catalysts for the reaction.

B They contain a much greater concentration of silver.

C They do not have an unreactive oxide layer.

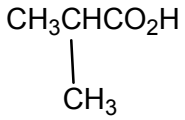
D They have a very high surface area to volume ratio.

29 Which molecular formula could represent molecules that exhibit *cis-trans* isomerism?

1	2	3	4
C_3H_6BrI	C_3H_5I	$C_3H_4I_2$	C_3H_4BrI

A 1, 2 and 3 **B** 2, 3 and 4 **C** 2 and 4 only **D** 3 and 4 only

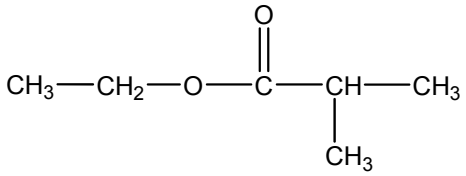
30 Ethyl propanoate is refluxed with aqueous sodium hydroxide. The alcohol produced is then reacted with methylpropanoic acid to make a second ester.



methylpropanoic acid

What is the structural formula of this second ester?

A



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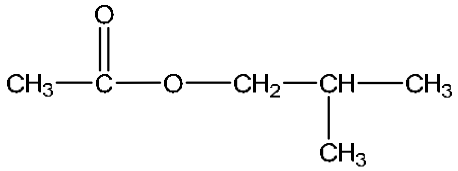
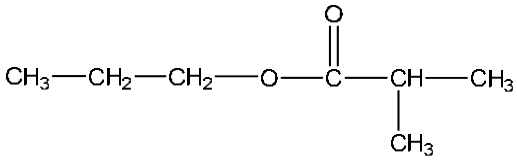
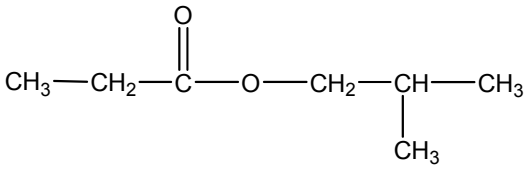


C



D



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JURONG JUNIOR COLLEGE
2018 JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME	

CLASS	**18S24**	EXAM INDEX	

CHEMISTRY 8873/02

Higher 1

Paper 2 Structured Questions **29 August 2018**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and exam index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in **Section A (60 marks)** in the space provided on the Question paper.
Answer **one** question in **Section B (20 marks)** in the space provided on the Question paper.
The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
Section B	
Lack **3sf** in final ans	**–1 / NA**
Missing/wrong **units** in final ans	**–1 / NA**
Total	

This document consists of **20** printed pages.

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Section A

Answer **all** the questions in this section, in the space provided.

For Examiner's Use

1 An experiment was carried out to determine the percentage of iron in a sample of iron wire.

(a) A 3.35 g piece of wire was reacted with dilute sulfuric acid, in the absence of air, so that all of the iron atoms were converted to iron(II) ions. The resulting solution was made up to 250 cm^3.

(i) Write a balanced equation for the reaction between the iron in the wire and the sulfuric acid.

……..…… [1]

A 25.0 cm^3 sample of this solution was acidified and titrated with 0.0250 mol dm^{-3} potassium manganate(VII). 32.0 cm^3 of the potassium manganate(VII) solution was required for complete reaction.

The relevant half-equations for the reaction are shown below.

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

$$Fe^{3+} + e^- \rightarrow Fe^{2+}$$

(ii) Use these two half-equations to construct an ionic equation for the reaction between manganate(VII) ions and iron(II) ions in acid solution.

……..……

……..……

……..…… [2]

(iii) Calculate the amount, in moles, of manganate(VII) ions used in the titration.

[1]

(iv) Calculate the total amount, in moles, of iron(II) ions in 250 cm^3 of the solution.

[2]

For Examiner's Use

1 **(a)** **(v)** Hence, calculate the percentage by mass of iron in the 3.35 g piece of wire.

[2]

(b) The electronegativity values of some elements are shown in the table below.

element	electronegativity
aluminium	1.5
chlorine	3.0
iron	1.8

(i) Use the data to suggest the nature of the bonding in iron(III) chloride. Explain your answer.

……

……

……

…… [2]

(ii) When a piece of universal indicator paper is dipped into a solution of iron(III) chloride, the indicator paper turns red.

Suggest an equation to account for the colour change in the indicator paper.

……

…… [1]

[Total: 11]

For Examiner's Use

2 **(a)** State the difference between a nanoparticle and a nanomaterial in terms of size.

……

…… [1]

(b) Many modern sunscreens contain nano-sized particles of titanium dioxide. This substance does **not** absorb ultraviolet radiation.

Suggest how these nano-particles are able to protect skin from ultraviolet radiation.

……

…… [1]

(c) The engines of modern motor cars have exhaust systems which are fitted with catalytic converters in order to reduce atmospheric pollution from substances such as nitrogen monoxide, NO. These substances are converted to less harmful gases on the catalyst surface before they are released into the atmosphere.

(i) One of the active materials present in the catalytic converter is platinum nanoparticles. Explain how the use of nanoparticles helps to increase the rate of gaseous reactions in the catalytic converter.

……

……

……

……

……

…… [2]

(ii) Give an equation for a reaction involved in the removal of nitrogen monoxide from the exhaust gases of the car, in the catalytic converter.

……

…… [1]

(iii) State one way in which nitrogen monoxide acts as air pollutant.

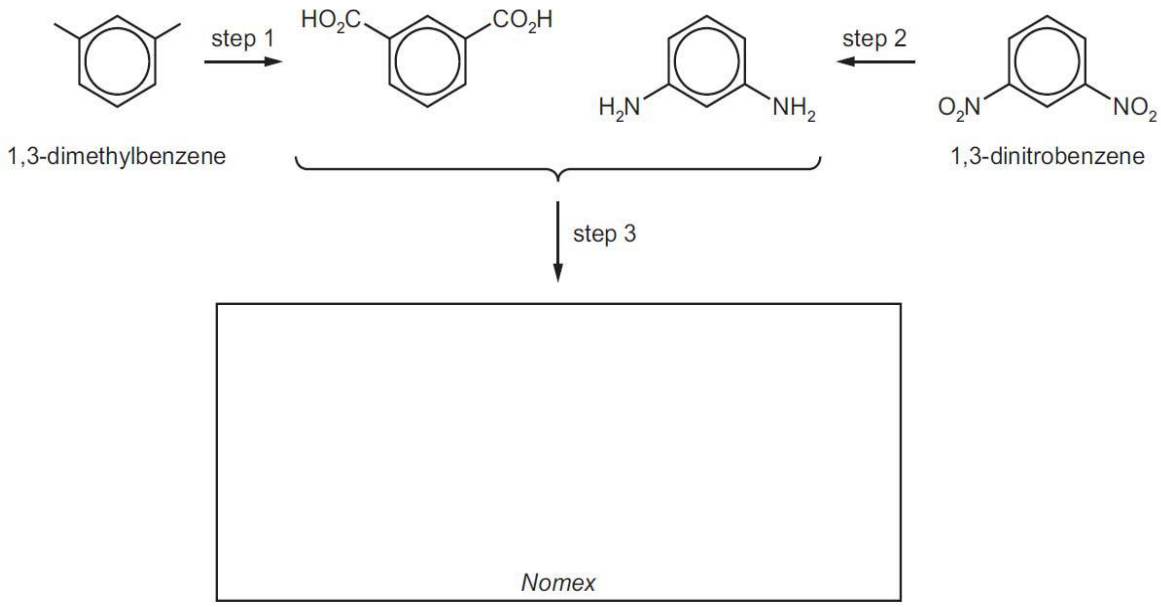
……

…… [1]

[Total: 6]

For Examiner's Use

3 1,3-dimethylbenzene is a starting material for the synthesis of the polymer *Nomex*, used in fireproof protective clothing worn by firefighters, military pilots and racing car drivers. The polymer is made from 1,3-dimethylbenzene and 1,3-dinitrobenzene by the following route.



(a) **(i)** Draw the structure of one repeat unit of *Nomex* in the box above. [1]

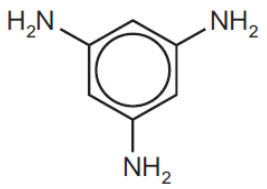
(ii) State the type of reaction that occurs in step 3.

..... [1]

(iii) Suggest the by-product formed in step 3.

[1]

(iv) Suggest how and why the properties of the polymer might change if some of the diamine monomer were replaced with 1,3,5-triaminobenzene.



1,3,5-triaminobenzene

.....

..... [1]

For Examiner's Use

3 **(b)** Similar to *Nomex*, Nylon is also a polyamide.

(i) State one use, with reason, of nylon.

……..……

……..…… [1]

(ii) Nylon is non-biodegradable. What does this mean?

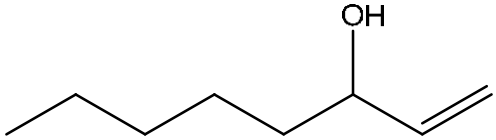
……..……

……..…… [1]

[Total: 6]

For Examiner's Use

4 1-octen-3-ol has the following structure.



This chemical is found in human sweat and breath, and is thought to attract biting insects such as mosquitoes. It is often used in combination with CO_2 in mosquito traps. It is also found in mushrooms, and sometimes called 'mushroom alcohol'.

(a) **(i)** State the type of reaction and what you would observe when 1-octen-3-ol reacts with a solution of bromine in tetrachloromethane (CCl_4).

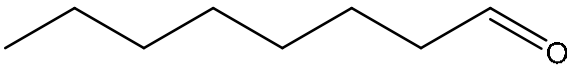
……..……

……..…… [2]

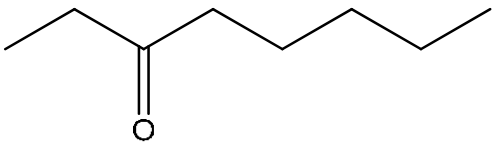
(ii) Draw the structure of the organic product formed when 1-octen-3-ol reacts with bromine in tetrachloromethane (CCl_4).

[1]

(b) Other examples of organic compounds containing eight carbon atoms are octanal and octan-3-one.



octanal



octan-3-one

(i) Octanal and octan-3-one can both be reduced using sodium borohydride, $NaBH_4$.

Draw the structural formula of the organic product obtained from the reduction of octanal and octan-3-one respectively.

Organic compound	Organic product obtained
Octanal	
Octan-3-one	

[2]

For Examiner's Use

4 (b) (ii) Octanal and octan-3-one were heated separately with acidified potassium dichromate(VI). Write an equation for any reaction that occurs.

……..……

……..…… [1]

(c) Oct-3-ene, C_8H_{16}, has two isomers with the same structural formula.

Draw the **displayed** formulae of the two isomers and label them clearly.

[2]

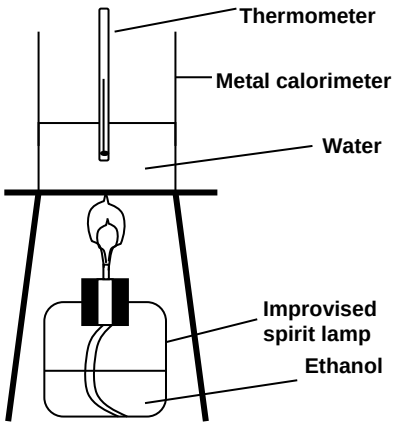
[Total: 8]

For Examiner's Use

5 Biofuels such as ethanol, methanol and methane have been investigated as possible alternative fuels for motor vehicles that currently uses petrol.

(a) The enthalpy change of combustion of ethanol can be determined in the laboratory using the apparatus shown in the diagram below.

The heat produced by the burning fuel warms a known mass of water.



The following results were obtained.

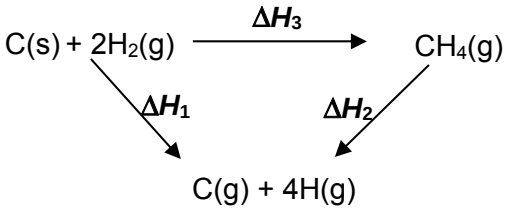
Mass of ethanol burnt (M_r = 46.0)	0.10 g
Initial temperature recorded	25.0 °C
Maximum temperature recorded	x °C
Enthalpy change of combustion of ethanol calculated	–840 kJmol^{-1}

Assume the total heat capacity of the calorimeter and its contents is 120 J K^{-1}, calculate the maximum temperature, x °C, recorded.

[3]

For Examiner's Use

5 **(b)** Consider the energy cycle below involving methane and the enthalpy changes, ΔH_1, ΔH_2 and ΔH_3.



(i) State *Hess's Law*.

……

……

…… [1]

(ii) Using the data given below, calculate ΔH_1.

$C(s) \rightarrow C(g)$ $\Delta H = +715$ kJ mol^{-1}

$H_2(g) \rightarrow 2H(g)$ $\Delta H = +436$ kJ mol^{-1}

[1]

(iii) What enthalpy change does ΔH_3 represent?

…… [1]

(iii) Using your answer to **(b)(ii)** and $\Delta H_3 = -75$ kJ mol^{-1}, calculate ΔH_2.

[1]

(iv) Write an equation to represent the average C−H bond energy in methane, CH_4.

…… [1]

(v) Hence, calculate the average C−H bond energy in methane.

[1]

5 (c) Methane and sulfur react to produce carbon disulfide (CS_2), a liquid often used in the production of cellophane.

$$2CH_4(g) + S_8(s) \rightarrow 2CS_2(l) + 4H_2S(g)$$

(i) Write an equation to represent the standard enthalpy change of combustion of liquid carbon disulfide.

……..…… [1]

The tables below contain values of standard enthalpy change of combustion, $\Delta H^{\ominus}_c$, and standard enthalpy change of formation, $\Delta H^{\ominus}_f$, of some substances.

Table (I)

	C(graphite)	S(s)
$\Delta H^{\ominus}_c$ / kJ mol^{-1}	–394	–297

Table (II)

	$CS_2(l)$	CO(g)
$\Delta H^{\ominus}_f$ / kJ mol^{-1}	+88	–111

Use of relevant data given in **Tables (I)** and **(II)** is required to solve **c(ii)** and **c(iii)** of this question.

(ii) Calculate the standard enthalpy change of combustion of $CS_2(l)$.

[2]

(iii)) Carbon disulfide reacts explosively with nitrogen monoxide (NO) according to the following equation.

$$CS_2(l) + 5NO(g) \rightarrow CO(g) + 2SO_2(g) + \frac{5}{2}N_2(g)$$

Given the enthalpy change of this reaction is –1243 kJ mol^{-1}, calculate the enthalpy change of formation of NO(g) in this reaction.

[2]

[Total: 14]

For Examiner's Use

6 Ammonium nitrate is an important fertiliser made by the acid-base reaction between ammonia and nitric acid.

(a) **(i)** Write an equation for the production of ammonium nitrate from ammonia and nitric acid.

…… [1]

(ii) Describe the meaning of the terms *Bronsted acid* and *Bronsted* base. Identify the acid and base for the reaction in **(a)(i)**, in terms of the Bronsted-Lowry theory.

……

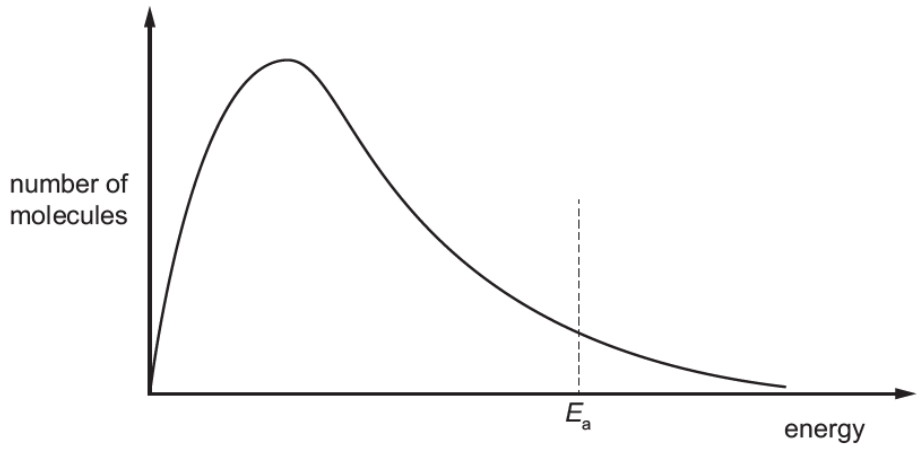
…… [2]

The ammonia for this reaction is produced by the Haber process and the nitric acid is produced by the oxidation of ammonia.

(b) The Haber process involves a reaction between nitrogen and hydrogen at a temperature of 450 °C and a pressure of 20 000 kPa.

$$N_2(g) + 3H_2(g) = 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

The diagram below shows the Boltzmann distribution curve for the uncatalysed reaction between nitrogen and hydrogen at 450 °C. The *activation energy* of the reaction is labelled as E_a.



(i) The Haber process is an example of a large-scale gaseous reaction that is catalysed. State the catalyst used.

…… [1]

(ii) Explain the meaning of the term *activation energy*.

……

……

…… [1]

(iii) On the energy axis of the graph above, clearly mark the position of the activation energy of the catalysed reaction between nitrogen and hydrogen with the letter **C**. [1]

For Examiner's Use

6 (b) (iv) At a higher reaction temperature, the rate of production of ammonia would be greater. Explain why a higher temperature is **not** used despite the fact that it would increase the rate of production of ammonia.

……

……

…… [2]

(c) The first stage in the production of nitric acid involves the reaction of ammonia with oxygen to form nitrogen monoxide, NO, and water.

Write an equation for this reaction and use oxidation numbers to show that it is a redox reaction.

……

……

……

…… [3]

(d) (i) Draw a dot-and-cross diagram of the ammonium ion. Show the outer electrons only.

[2]

(ii) State the shape of an ammonium ion and give the H–N–H bond angle.

shape……

bond angle…… [2]

[Total: 15]

Section B

Answer **one** question from this section, in the space provided.

For Examiner's Use

7 **(a)** Sodium, silicon and chlorine are all elements in Period 3 of the Periodic Table.

Describe the variation in atomic radius, melting point, electrical conductivity and bonding of sodium, silicon and chlorine.

……

……

……

……

……

……

……

……

……

……

[5]

(b) Three of the oxides of Period 3 elements are sodium oxide, phosphorus(V) oxide and sulfur trioxide.

(i) Write equations for the reactions of each of these oxides with water.

[3]

(ii) Write an equation for the reaction of each oxide with either sodium hydroxide or hydrochloric acid.

[3]

For Examiner's Use

7 **(b)** **(iii)** Describe the variation in behaviour shown by these oxides across Period 3 as shown in **(b)(ii)**.

……

…… [1]

(c) **(i)** Write a balanced equation to represent the lattice energy of sodium chloride.

…… [1]

(ii) Explain why the lattice energy of magnesium oxide is much more exothermic than that of sodium chloride.

……

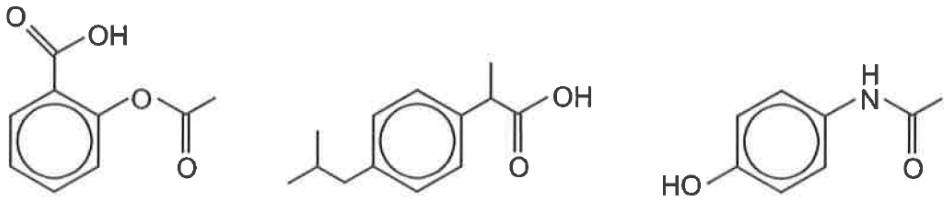
……

……

……

…… [2]

(d) The pharmaceuticals aspirin, ibuprofen and paracetamol are all painkillers.



aspirin ibuprofen paracetamol

Infra-red absorptions can be used to identify functional groups in organic compounds. For example, ethyl ethanoate shows absorptions at 1050–1330 cm^{-1} and 1710–1750 cm^{-1} as shown in the *Data Booklet*.

(i) Identify an infra-red absorption range that will be shown by aspirin and ibuprofen but **not** by paracetamol using the *Data Booklet*.

[1]

(ii) Identify two of the infra-red absorption range that will be shown by paracetamol but **not** by aspirin or ibuprofen using the *Data Booklet*.

[1]

7 **(d)** **(iii)** Identify a type of reaction which will occur with both paracetamol and aspirin but **not** with ibuprofen.

……..…… [1]

(iv) Write an equation for the reaction of ethanol with ethanoic acid. State the conditions required.

……..……

……..…… [2]

[Total: 20]

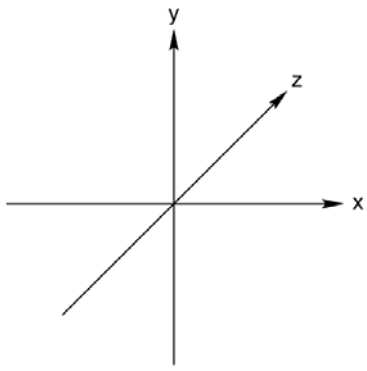
For Examiner's Use

8 This question is about phosphorus and its compounds.

(a) **(i)** State the full electronic configuration of phosphorus.

……..…… [1]

(ii) On the axes below, sketch the shape of the singly-occupied orbital in an atom of phosphorus at ground state.



[1]

(iii) The first ionisation energy of phosphorus is higher than that of sulfur. Explain why.

……..……

……..…… [1]

(b) The dissociation of phosphorus(V) chloride into phosphorus(III) chloride and chlorine gas is reversible:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

The reaction is an example of a *dynamic equilibrium*.

(i) Explain the meaning of the term *dynamic equilibrium*.

……..…… [1]

(ii) In an experiment, 1.00 mol of PCl_5 vapour was heated in a closed 5.00 dm^3 flask at 500 K until equilibrium had been established. When equilibrium is established, the percentage conversion of PCl_5 is found to be 51 %. Calculate the equilibrium constant, K_c, at this temperature and state its units.

[2]

For Examiner's Use

8 **(b)** **(iii)** State and explain what would happen to the equilibrium position if the initial concentration of chlorine was increased.

……

……

[1]

(iv) Draw and name the shapes of PCl_3 and PCl_5.

[2]

(v) Explain why PCl_5 sublimes at 160°C while PCl_3 boils at a lower temperature of 76.1°C.

……

……

……

……

[1]

(d) Phosphorus compounds are used in the pharmaceutical industries. For example, solutions containing hydrogen phosphates are used as buffers found in the hydrophilic gel used in skin patches. Write equations to show how the solution containing $H_2PO_4^-$/ HPO_4^{2-} can act as a buffer when H^+ and OH^- ions are added respectively to the solution.

……

……

……

……

[2]

For Examiner's Use

8 **(e)** Phosphine, PH_3, is a widely used fumigant. The thermal decomposition of phosphine into phosphorus and hydrogen is a *first-order reaction.*

$$4PH_3(g) \rightarrow P_4(g) + 6H_2(g)$$

(i) Explain the term in *italics*.

……..……

……..…… [1]

(ii) Sketch a graph of rate against concentration for the above decomposition reaction.

[1]

The half-life of the reaction is 35.0 seconds at 680 °C. Calculate

(iii) the rate constant for the reaction.

[1]

(iv) the time taken for 87.5% of the phosphine to decompose.

[1]

8 **(f)** Phosphorus compounds are also used in organic reactions, as shown in the following reactions. Suggest the type of reaction occurring in each case.

(i) Phosphoric(V) acid, H_3PO_4, is used as a catalyst in the reaction.

$$CH_2{=}CH_2 + H_2O \rightarrow CH_3CH_2OH$$

……..…… [1]

(ii) Phosphorus(V) chloride reacts with ethanol.

$$CH_3CH_2OH + PCl_5 \rightarrow CH_3CH_2OH + POCl_3 + HCl$$

……..…… [1]

(g) Describe, in terms of orbital overlap, the bonding of the two carbon atoms of the C=C bond in $CH_2{=}CH_2$. A clearly labelled diagram may clarify your answer.

[2]

[Total: 20]

JURONG JUNIOR COLLEGE
2018 JC 2 PRELIMINARY EXAMINATION
Paper 1 answers

1	**D**	11	**C**	21	**B**
2	**C**	12	**B**	22	**C**
3	**C**	13	**B**	23	**D**
4	**C**	14	**C**	24	**B**
5	**D**	15	**C**	25	**D**
6	**C**	16	**B**	26	**D**
7	**D**	17	**D**	27	**A**
8	**A**	18	**A**	28	**D**
9	**A**	19	**C**	29	**B**
10	**A**	20	**A**	30	**A**

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JURONG JUNIOR COLLEGE
2018 JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME	

CLASS	**18S24**	EXAM INDEX	

CHEMISTRY 8873/02

Higher 1

Paper 2 Structured Questions **29 August 2018**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and exam index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in **Section A (60 marks)** in the space provided on the Question paper.
Answer **one** question in **Section B (20 marks)** in the space provided on the Question paper.
The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
Section B	
Lack **3sf** in final ans	**–1 / NA**
Missing/wrong **units** in final ans	**–1 / NA**
Total	

This document consists of **20** printed pages and **1** blank page.

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Section A

Answer **all** the questions in this section, in the space provided.

For Examiner's Use

1 An experiment was carried out to determine the percentage of iron in a sample of iron wire.

(a) A 3.35 g piece of wire was reacted with dilute sulfuric acid, in the absence of air, so that all of the iron atoms were converted to iron(II) ions. The resulting solution was made up to 250 cm^3.

(i) Write a balanced equation for the reaction between the iron in the wire and the sulfuric acid.

$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$ ..... [1]

A 25.0 cm^3 sample of this solution was acidified and titrated with 0.0250 mol dm^{-3} potassium manganate(VII). 32.0 cm^3 of the potassium manganate(VII) solution was required for complete reaction.

The relevant half-equations for the reaction are shown below.

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

$$Fe^{3+} + e^- \rightarrow Fe^{2+}$$

(ii) Use these two half-equations to construct an ionic equation for the reaction between manganate(VII) ions and iron(II) ions in acid solution.

$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$ .....

.....

..... [2]

(iii) Calculate the amount, in moles, of manganate(VII) ions used in the titration.

Amount of MnO_4^- used = 32.0/1000 × 0.025 = **8.00×10^{-4} mol**

[1]

(iv) Calculate the total amount, in moles, of iron(II) ions in 250 cm^3 of the solution.

Amount of Fe^{2+} in 25.0 cm^3 = **$8.00 \times 10^{-4} \times 5$** = 4.00×10^{-3} mol

Amount of Fe^{2+} in 250 cm^3 = $4.00 \times 10^{-3} \times 250/25.0$ = **4.00×10^{-2} mol**

[2]

For Examiner's Use

1 **(a)** **(v)** Hence, calculate the percentage by mass of iron in the 3.35 g piece of wire.

Mass of Fe in wire = **$4.00 \times 10^{-2} \times 55.8$** = 2.23 g

% by mass of Fe in wire = 2.23/3.35 × 100 % = **66.6 %**

[2]

(b) The electronegativity values of some elements are shown in the table below.

element	electronegativity
aluminium	1.5
chlorine	3.0
iron	1.8

(i) Use the data to suggest the nature of the bonding in iron(III) chloride. Explain your answer.

Covalent. Smaller difference in electronegativity between Fe and C*l* compared to between A*l* and C*l*.

[2]

(ii) When a piece of universal indicator paper is dipped into a solution of iron(III) chloride, the indicator paper turns red.

Suggest an equation to account for the colour change in the indicator paper.

$[Fe(H_2O)_6]^{3+}(aq) = [Fe(H_2O)_5OH]^{2+}(aq) + H^+(aq)$

[1]

[Total: 11]

For Examiner's Use

2 **(a)** State the difference between a nanoparticle and a nanomaterial in terms of size.

Nanoparticles ALL dimensions 1–100nm/on the **nanoscale**
AND **nanomaterial (at least) one dimension 1–100nm**/on the **nanoscale** [1]

(b) Many modern sunscreens contain nano-sized particles of titanium dioxide. This substance does **not** absorb ultraviolet radiation.

Suggest how these nano-particles are able to protect skin from ultraviolet radiation.

The particles are **similar in size to the wavelength of uv light and deflect the harmful radiation** [1]

(c) The engines of modern motor cars have exhaust systems which are fitted with catalytic converters in order to reduce atmospheric pollution from substances such as nitrogen monoxide, NO. These substances are converted to less harmful gases on the catalyst surface before they are released into the atmosphere.

(i) One of the active materials present in the catalytic converter is platinum nanoparticles. Explain how the use of nanoparticles helps to increase the rate of gaseous reactions in the catalytic converter.

Pt nanoparticles are used due to the high **surface area to volume ratio**
Due to the **large surface area, more platinum atoms are exposed to the reactants**. Hence, the catalyst provides an alternative reaction pathway of lower activation energy.
the **greater the frequency of effective collisions** between the reactants and catalyst, the higher the reaction rate.
[2]

(ii) Give an equation for a reaction involved in the removal of nitrogen monoxide from the exhaust gases of the car, in the catalytic converter.

$2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g)$ [1]

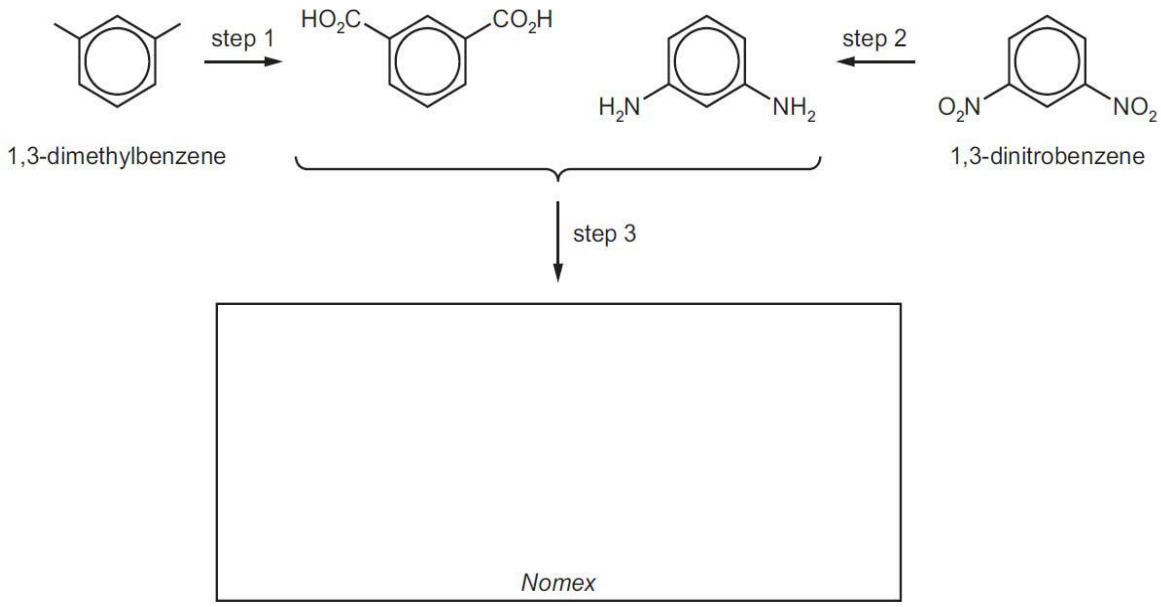
(iii) State one way in which nitrogen monoxide acts as air pollutant.

Formation of acid rain / causes smog [1]

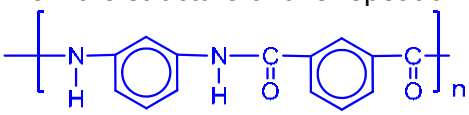
[Total: 6]

For Examiner's Use

3 1,3-dimethylbenzene is a starting material for the synthesis of the polymer *Nomex*, used in fireproof protective clothing worn by firefighters, military pilots and racing car drivers. The polymer is made from 1,3-dimethylbenzene and 1,3-dinitrobenzene by the following route.



(a) **(i)** Draw the structure of one repeat unit of *Nomex* in the box above.



[1]

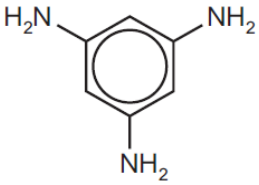
(ii) State the type of reaction that occurs in step 3.

condensation polymerisation ..... [1]

(iii) Suggest the by-product formed in step 3.

H_2O / water [1]

(iv) Suggest how and why the properties of the polymer might change if some of the diamine monomer were replaced with 1,3,5-triaminobenzene.



1,3,5-triaminobenzene

Harder/more dense/stronger/higher melting point/tougher/more rigid due to cross-linking/more hydrogen bonding between the chains

..... [1]

For Examiner's Use

3 **(b)** Similar to *Nomex*, Nylon is also a polyamide.

(i) State one use, with reason, of nylon.

rope as it is strong / fabric as it is lightweight……

…… [1]

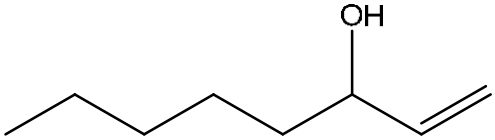
(ii) Nylon is non-biodegradable. What does this mean?

Cannot be broken down / changed to a harmless natural state by the action of bacteria / living organism

…… [1]

[Total: 6]

4 1-octen-3-ol has the following structure.



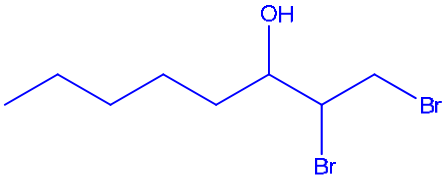
This chemical is found in human sweat and breath, and is thought to attract biting insects such as mosquito
mosquito traps. It is also found in mushrooms, and sometimes called 'mushroom alcoh

(a) **(i)** State the type of reaction and what you would observe when 1-octen-3-ol reacts with a solution o

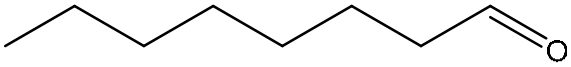
Electrophilic addition.....

Orange-red bromine decolourises.

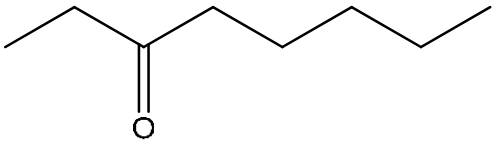
(ii) Draw the structure of the organic product formed when 1-octen-3-ol reacts with bromine in tetrach



(b) Other examples of organic compounds containing eight carbon atoms are octanal and octan-3-one.



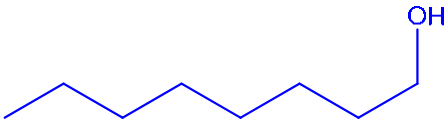
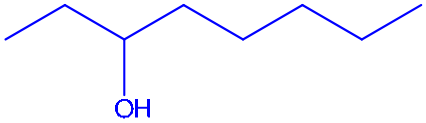
octanal



octan-3-one

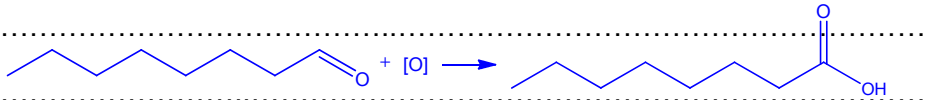
(i) Octanal and octan-3-one can both be reduced using sodium borohydride, $NaBH_4$.

Draw the structural formula of the organic product obtained from the reduction of octanal and oct

Organic compound	Organic product obtained
Octanal	
Octan-3-one	

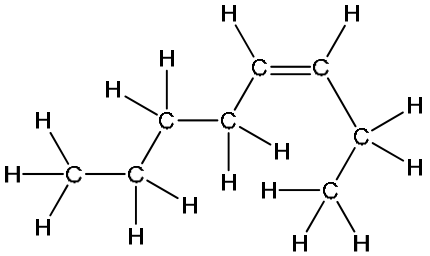
4 **(b)** **(ii)** Octanal and octan-3-one were heated separately with acidified potassium dichromate(VI). Write

.....

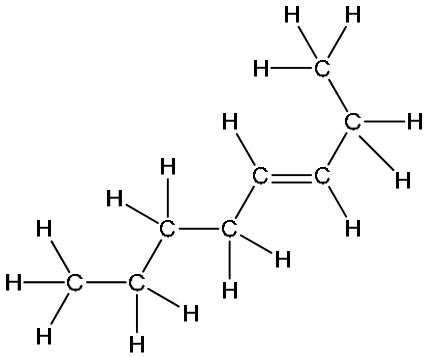


.....

(c) Oct-3-ene, C_8H_{16}, has two isomers with the same structural formula.
Draw the **displayed** formulae of the two isomers and label them clearly.



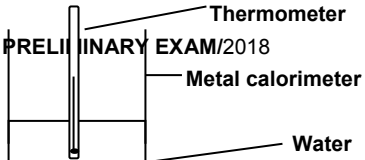
cis-oct-3-ene



trans-oct-3-ene

5 Biofuels such as ethanol, methanol and methane have been investigated as possible alternative fuels for m

(a) The enthalpy change of combustion of ethanol can be determined in the laboratory using the apparatus
The heat produced by the burning fuel warms a known mass of water.



The following results were obtained.

Mass of ethanol burnt (M_r = 46.0)	0.10 g
Initial temperature recorded	25.0 °C
Maximum temperature recorded	x °C
Enthalpy change of combustion of ethanol calculated	–840 kJmol^{-1}

Assume the total heat capacity of the calorimeter and its contents is 120 J K^{-1}, calculate the maximum

Amount of ethanol burnt in the experiment

$= \frac{\mathbf{0.10}}{\mathbf{46.0}} = 0.00217$ mol

Heat evolved by combustion of 0.10 g of ethanol

= Heat used to raise temp. of water

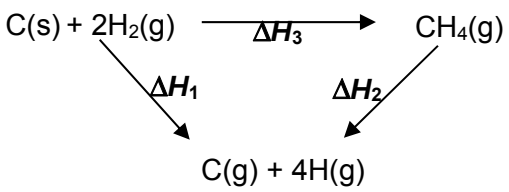
= **0.00217 × 840** = 1.82 kJ = **1820 J**

= **120 × ΔT**

ΔT = 15.2 K = 15.2 °C

Final max temp = 25.0 + 15.2 = **40.2 °C**

5 (b) Consider the energy cycle below involving methane and the enthalpy changes, ΔH_1, ΔH_2 and ΔH_3.



(i) State *Hess's Law*.

Hess' Law states that **the enthalpy change in a chemical reaction is constant and is independent of the reaction pathway between the initial and final states**.

.....

.....

.....

(ii) Using the data given below, calculate ΔH_1.

$C(s) \rightarrow C(g)$ $\Delta H = +715$ kJ mol^{-1}

$H_2(g) \rightarrow 2H(g)$ $\Delta H = +436$ kJ mol^{-1}

$\Delta H_1 = +715 + 2(+436) =$ **+1587 kJ mol^{-1}**

(iii) What enthalpy change does ΔH_3 represent?

Standard enthalpy change of formation of methane

(iii) Using your answer to **(b)(ii)** and $\Delta H_3 = -75$ kJ mol^{-1}, calculate ΔH_2.

$\Delta H_2 = \Delta H_1 - \Delta H_3$

$= +1587 - (-75)$

$= +1662$ kJ mol^{-1}

(iv) Write an equation to represent the average C−H bond energy in methane, CH_4.

$\frac{1}{4}CH_4(g) \rightarrow \frac{1}{4}C(g) + H(g)$

(v) Hence, calculate the average C−H bond energy in methane.

$\frac{1}{4} \times (+1662) =$ **+415.5 kJ mol^{-1}**

5 (c) Methane and sulfur react to produce carbon disulfide (CS_2), a liquid often used in the production of cell

$$2CH_4(g) + S_8(s) \rightarrow 2CS_2(l) + 4H_2S(g)$$

(i) Write an equation to represent the standard enthalpy change of combustion of liquid carbon disul

$CS_2(l) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$

The tables below contain values of standard enthalpy change of combustion, $\Delta H_c^\ominus$, and standard enth substances.

Table (I)

	C(graphite)	S(s)
$\Delta H^{\ominus}_c$ / kJ mol^{-1}	–394	–297

Table (II)

	$CS_2(l)$	CO(g)
$\Delta H^{\ominus}_f$ / kJ mol^{-1}	+88	–111

Use of relevant data given in **Tables (I)** and **(II)** is required to solve **c(ii)** and **c(iii)** of this question.

(ii) Calculate the standard enthalpy change of combustion of $CS_2(l)$.

$\Delta H^{\ominus}_r$ = Σm$\Delta H^{\ominus}_c$ (reactants) – Σn$\Delta H^{\ominus}_c$ (products)

$\Delta H^{\ominus}_f(CS_2) = \Delta H^{\ominus}_c(C) + 2\Delta H^{\ominus}_c(S) - \Delta H^{\ominus}_c(CS_2)$

$+88 = -394 + 2(-297) - \Delta H^{\ominus}_c(CS_2)$

$\Delta H^{\ominus}_c(CS_2)$ = **– 1076 kJ mol^{-1}**

(iii) Carbon disulfide reacts explosively with nitrogen monoxide (NO) according to the following equat

$$CS_2(l) + 5NO(g) \rightarrow CO(g) + 2SO_2(g) + \frac{5}{2}N_2(g)$$

Given the enthalpy change of this reaction is –1243 kJ mol^{-1}, calculate the enthalpy change of fo

$\Delta H^{\ominus}_r$ = Σn$\Delta H^{\ominus}_f$ (products) – Σm$\Delta H^{\ominus}_f$ (reactants)

$-1243 = \Delta H^{\ominus}_f(CO) + 2\Delta H^{\ominus}_f(SO_2) + 5/2(0) - [\Delta H^{\ominus}_f(CS_2)+5\Delta H^{\ominus}_f(NO)]$
$= -111 + 2(-297) - [(+88) + 5\Delta H^{\ominus}_f(NO)]$
$\Delta H^{\ominus}_f(NO)$ = **+90 kJ mol^{-1}**

6 Ammonium nitrate is an important fertiliser made by the acid-base reaction between ammonia and nitric aci

(a) **(i)** Write an equation for the production of ammonium nitrate from ammonia and nitric acid.

……
$NH_3(g) + HNO_3(l) \rightarrow NH_4NO_3(s)$

(ii) Describe the meaning of the terms *Bronsted acid* and *Bronsted* base. Identify the acid and b Bronsted-Lowry theory.

……
Bronsted acid is a proton donor and base is a proton acceptor
Acid – HNO_3, Base – NH_3

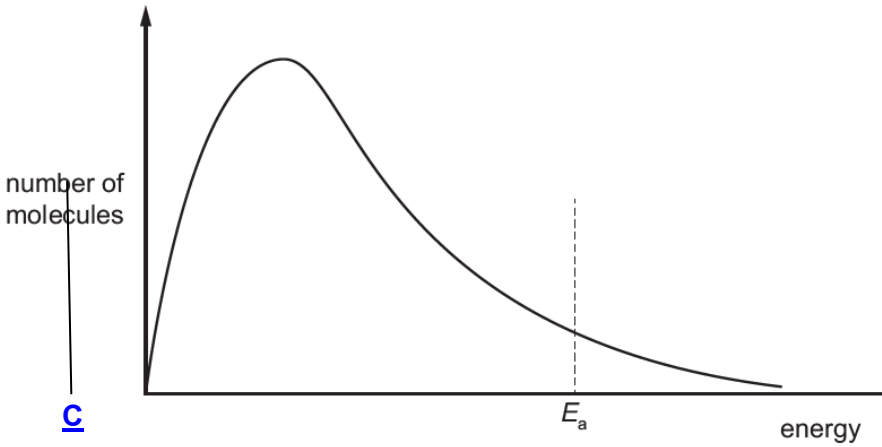
The ammonia for this reaction is produced by the Haber process and the nitric acid is produced by the oxida

(b) The Haber process involves a reaction between nitrogen and hydrogen at a temperature of 450 °C and

$$N_2(g) + 3H_2(g) = 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

The diagram below shows the Boltzmann distribution curve for the uncatalysed reaction between nitr

energy of the reaction is labelled as E_a.



(i) The Haber process is an example of a large-scale gaseous reaction that is catalysed. State the c

Iron / iron oxide

(ii) Explain the meaning of the term *activation energy*.

Activation energy (E_a) is **the minimum amount of energy that reactants must possess before a reaction can occur.**

(iii) On the energy axis of the graph above, clearly mark the position of the activation energy of hydrogen with the letter **C**.

6 (b) (iv) At a higher reaction temperature, the rate of production of ammonia would be greater. Explain the fact that it would increase the rate of production of ammonia.

Production of NH_3/forward reaction is exothermic

Position of equilibrium will shift left and yield would reduce at higher temperature.

(c) The first stage in the production of nitric acid involves the reaction of ammonia with oxygen to form nitr

Write an equation for this reaction and use oxidation numbers to show that it is a redox reaction.

$4NH_3(g) + 5O_2(g) \rightarrow 4NO + 6H_2O(l)$

The **oxidation number of N increases from -3 in NH_3 to +2 in NO.**

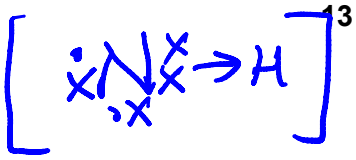
Hence, **oxidation** has taken place.

The **oxidation number of O decreases from 0 in O_2 to -2 in H_2O.**

Hence, **reduction** has taken place.

(d) (i) Draw a dot-and-cross diagram of the ammonium ion. Show the outer electrons only.

— ox f



(ii) State the shape of an ammonium ion and give the H–N–H bond angle.

shape……**tetrahedral**……

bond angle……**109/109.5°**……

Section B

Answer **one** question from this section, in the space provided.

For Examiner's Use

7 **(a)** Sodium, silicon and chlorine are all elements in Period 3 of the Periodic Table.

Describe the variation in atomic radius, melting point, electrical conductivity and bonding of sodium, silicon and chlorine.

Atomic radius:

Atomic radius decreases from Na to Si to C*l* due to increase in nuclear charge while the shielding effect by inner shell electrons remains almost constant across the period.

Melting point:

Na has a relatively **high melting point, Si** has the **highest melting point, C*l*$_2$** has the **lowest melting point**

Electrical conductivity:

Na is a good electrical conductor due to presence of mobile electrons in its metallic structure.

Si is a semi-conductor and **C*l* is a non-electrical conductor** due to absence of mobile charge carriers in its structure

Bonding:

Na has **strong electrostatic forces of attraction between the delocalised electrons and Na^+ ions.**

Si has strong covalent bonds between Si atoms.

C*l*$_2$ molecules consists of C*l* atoms are **bonded by strong covalent bonds**, **weak induced dipole-induced dipole interaction/attraction exist between C*l*$_2$ molecules**.

[5]

(b) Three of the oxides of Period 3 elements are sodium oxide, phosphorus(V) oxide and sulfur trioxide.

(i) Write equations for the reactions of each of these oxides with water.

$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$

$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$ or $P_2O_5(s) + 3H_2O(l) \rightarrow 2H_3PO_4(aq)$

$SO_3(l) + H_2O(l) \rightarrow H_2SO_4(aq)$

[3]

(ii) Write an equation for the reaction of each oxide with either sodium hydroxide or hydrochloric acid.

$Na_2O(s) + 2H^+(aq) \rightarrow 2Na^+(aq) + H_2O(l)$

$P_4O_{10}(s) + 12OH^-(aq) \rightarrow 4PO_4^{3-}(aq) + 6H_2O(l)$ Accept HPO_4^{2-} and $H_2PO_4^-$

$SO_3(l) + 2OH^-(aq) \rightarrow SO_4^{2-}(aq) + H_2O(l)$

[3]

7 **(b)** **(iii)** Describe the variation in behaviour shown by these oxides across Period 3 as shown in **(b)(ii)**.

For Examiner's Use

From basic in Na_2O to acidic in SO_3 and P_4O_{10}

[1]

(c) **(i)** Write a balanced equation to represent the lattice energy of sodium chloride.

$Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$ [1]

(ii) Explain why the lattice energy of magnesium oxide is much more exothermic than that of sodium chloride.

Ions in MgO are Mg^{2+} and O^{2-}

Ions in NaC*l* are Na^+ and Cl^-.

$$|L.E.| \propto \frac{q_+ q_-}{r_+ + r_-}$$

charge of Na^+ is smaller than that of Mg^{2+}

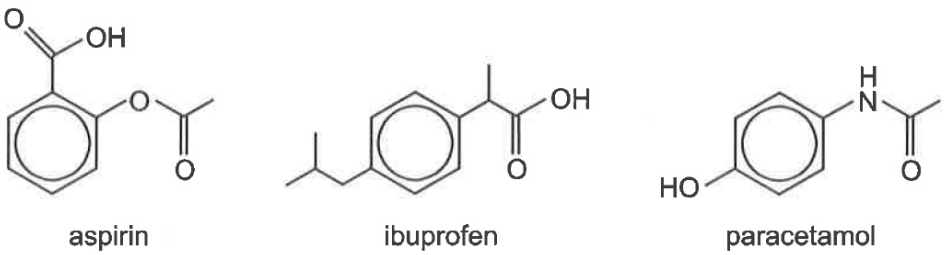
charge of Cl^- is smaller than that of O^{2-}

radius of Na^+ is greater than that of Mg^{2+}.

radius of Cl^- is greater than that of O^{2-}.

Therefore, the lattice energy of MgO is expected to be more exothermic. [2]

(d) The pharmaceuticals aspirin, ibuprofen and paracetamol are all painkillers.



Infra-red absorptions can be used to identify functional groups in organic compounds. For example, ethyl ethanoate shows absorptions at 1050–1330 cm^{-1} and 1710–1750 cm^{-1} as shown in the *Data Booklet*.

(i) Identify an infra-red absorption range that will be shown by aspirin and ibuprofen but **not** by paracetamol using the *Data Booklet*.

1680 – 1730 / 2500 – 3000 / 1210 – 1440 (cm^{-1})

[1]

(ii) Identify two of the infra-red absorption range that will be shown by paracetamol but **not** by aspirin or ibuprofen using the *Data Booklet*.

Any 2 from:

3300 – 3500 / 1640 – 1690 / 3200 – 3600 / 3580 – 3650 (cm^{-1})

[1]

7 (d) (iii) Identify a type of reaction which will occur with both paracetamol and aspirin but **not** with ibuprofen.

Hydrolysis

[1]

(iv) Write an equation for the reaction of ethanol with ethanoic acid. State the conditions required.

$CH_3CO_2H + CH_3CH_2OH \rightleftharpoons CH_3CO_2CH_2CH_3 + H_2O$

Conditions: conc H_2SO_4, heat under reflux

[2]

[Total: 20]

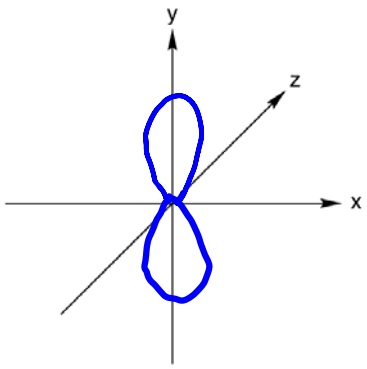
For Examiner's Use

8 This question is about phosphorus and its compounds.

(a) **(i)** State the full electronic configuration of phosphorus.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$ [1]

(ii) On the axes below, sketch the shape of the singly-occupied orbital in an atom of phosphorus at ground state.



[1]

(iii) The first ionisation energy of phosphorus is higher than that of sulfur. Explain why.

Mutual repulsion between the paired 3p electrons in sulfur makes it easier to remove the one of the paired **3p electrons from sulfur** than to remove the unpaired 3p electron from phosphorus which does not experience such repulsion. [1]

(b) The dissociation of phosphorus(V) chloride into phosphorus(III) chloride and chlorine gas is reversible:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

The reaction is an example of a *dynamic equilibrium*.

(i) Explain the meaning of the term *dynamic equilibrium*.

Rate of forward reaction equals to rate of backward reaction ..... [1]

(ii) In an experiment, 1.00 mol of PCl_5 vapour was heated in a closed 5.00 dm^3 flask at 500 K until equilibrium had been established. When equilibrium is established, the percentage conversion of PCl_5 is found to be 51 %. Calculate the equilibrium constant, K_c, at this temperature and state its units.

	$PCl_5(g)$	$\rightleftharpoons$	$PCl_3(g)$	+	$Cl_2(g)$
initial amount/mol	1.00		0		0
		– 1.00(0.51)	+ 0.51		+ 0.51
eqm amount/mol	**0.49**		**0.51**		**0.51**

$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{(\frac{0.51}{5})(\frac{0.51}{5})}{(\frac{0.49}{5})} = \mathbf{0.106\ mol\ dm^{-3}}$$

[2]

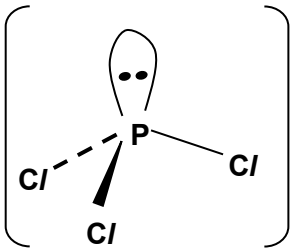
8 **(b)** **(iii)** State and explain what would happen to the equilibrium position if the initial concentration of chlorine was increased.

For Examiner's Use

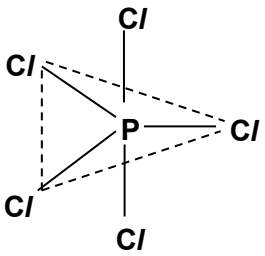
Equilibrium position **shift to the right to remove some of the Cl_2**

..... [1]

(iv) Draw and name the shapes of PCl_3 and PCl_5.



trigonal pyramidal



trigonal bipyramidal

[2]

(v) Explain why PCl_5 sublimes at 160°C while PCl_3 boils at a lower temperature of 76.1°C.

Both PCl_5 and PCl_3 have simple molecular structures.

Due to the **larger number of electrons in** the **PCl_5** molecule**/ larger electron cloud of PCl_5** molecule ..... [1]

more energy/ larger amount of energy is required to overcome/break the **stronger induced dipole-induced dipole interaction/attraction between PCl_5 molecules** than the **weaker permanent dipole-permanent dipole interaction/attraction between PCl_3 molecules**

.....

.....

(d) Phosphorus compounds are used in the pharmaceutical industries. For example, solutions containing hydrogen phosphates are used as buffers found in the hydrophilic gel used in skin patches. Write equations to show how the solution containing $H_2PO_4^-$/ HPO_4^{2-} can act as a buffer when H^+ and OH^- ions are added respectively to the solution.

On addition of H^+: **$HPO_4^{2-} + H^+ \rightarrow H_2PO_4^-$**

On addition of OH^-: **$H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_2O$**

.....

.....

.....

[2]

8 **(e)** Phosphine, PH_3, is a widely used fumigant. The thermal decomposition of phosphine into phosphorus and hydrogen is a *first-order reaction.*

For Examiner's Use

$$4PH_3(g) \rightarrow P_4(g) + 6H_2(g)$$

(i) Explain the term in *italics*.

A first-order reaction refers to one in which **the order of reaction with respect to the reactant is one in the rate equation**.

OR

In a first-order reaction, the **power** to which a **concentration of reactant** is raised in the **rate equation is one**.

OR

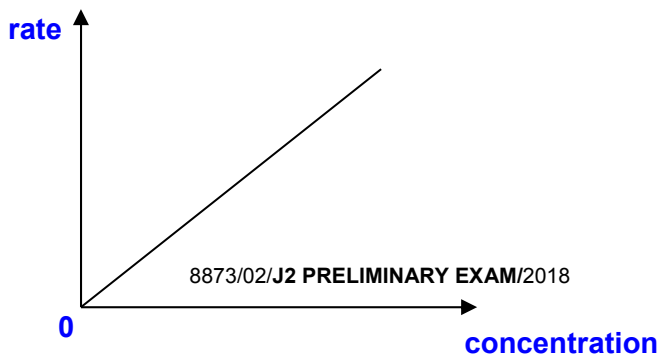
Consider an **experimentally determined rate equation**,

Rate = $k[A]^1$,

for a first-order reaction, **order of reaction with respect to A = 1**.

[1]

(ii) Sketch a graph of rate against concentration for the decomposition reaction.



[1]

The half-life of the reaction is 35.0 seconds at 680 °C. Calculate

(iii) the rate constant for the reaction.

$k = \ln 2/t_{1/2} = \ln 2/35.0 =$ **$0.0198\ s^{-1}$** [1]

(iv) the time taken for 87.5% of the phosphine to decompose.

100% → 50% → 25% → 12.5%

Time taken = 4 × 35.0 = **140 s** [1]

(f) Phosphorus compounds are also used in organic reactions, as shown in the following reactions. Suggest the type of reaction occurring in each case.

(i) Phosphoric(V) acid, H_3PO_4, is used as a catalyst in the reaction.

$$CH_2{=}CH_2 + H_2O \rightarrow CH_3CH_2OH$$

addition

(ii) Phosphorus(V) chloride reacts with ethanol.

$$CH_3CH_2OH + PCl_5 \rightarrow CH_3CH_2OH + POCl_3 + HCl$$

substitution [1]

(g) Describe, in terms of orbital overlap, the bonding of the two carbon atoms of the C=C bond in $CH_2{=}CH_2$. A clearly labelled diagram may clarify your answer.

In ethene, one *sp*^{2} orbital of C atom overlaps head-on with the *sp*^{2} orbital of another C atom, forming a C–C sigma bond.

The *unhybridised* 2p orbital of C atom overlaps side-way with the *unhybridised* 2p orbital of another C atom, forming a C–C π bond.

Or accept clearly labelled diagram [2]

[Total: 20]

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Class	Adm No

Candidate Name: _____

H

millennia institute

2018 End-of-Year Exams
Pre-University 2

H1 CHEMISTRY **8873/01**

Paper 1 Multiple Choice **13 Sept 2018**

1 hour

Additional materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so
Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and admission number in the spaces provided at the top of this page and on the Multiple Choice Answer Sheet provided.

There are thirty questions on this paper. Answer **ALL** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the Multiple Choice Answer Sheet provided.

Read the instructions on the Multiple Choice Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this question paper.
The use of an approved scientific calculator is expected, where appropriate.

FOR EXAMINER'S USE	
TOTAL (30 marks)	

This question paper consists of **13** printed pages and **1** blank page.

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 According to the equation below, how many moles of potassium chlorate, $KClO_3$, must be decomposed to generate 1000 cm^3 of O_2 gas at standard temperature and pressure?

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

A $\frac{2}{3}\left(\frac{1}{24}\right)$ mol

B $\frac{3}{2}\left(\frac{1}{24}\right)$ mol

C $\frac{2}{3}\left(\frac{1}{22.7}\right)$ mol

D $\frac{3}{2}\left(\frac{1}{22.7}\right)$ mol

2 *Use of the Data Booklet is relevant to this question.*

It is suggested that SO_2 which contributes to acid rain, could be removed from a stream of waste gases by bubbling the gases through 0.25 mol dm^{-3} KOH, thereby producing K_2SO_3. What is the maximum mass of SO_2 that could be removed by 1000 dm^3 of the KOH solution?

A 4.0 kg

B 8.0 kg

C 16.0 kg

D 20.0 kg

3 To determine the molar mass of a weak monoprotic acid, a student titrated 25.0 cm^3 of the acid with aqueous NaOH. Which of the following are appropriate indicators that could be used for the titration?

1 Phenolphthalein
2 Methyl Orange
3 Bromothymol blue

A 1 only
B 1 and 2 only
C 2 and 3 only
D 1, 2 and 3

4 A sample of 30.0 cm^3 of 0.050 mol dm^{-3} iron(II) sulfate is titrated against 0.025 mol dm^{-3} potassium manganate(VII) solution. It is found that 20.0 cm^3 of the manganate(VII) solution is required to reach end point.
What is the oxidation number of manganese at the end point?

A +2
B +3
C +4
D +5

5 The number of orbitals of a principal quantum number is dependent on the type of subshell. Which of the following statements about the s, p and d orbitals of principal quantum numbers 1, 2 and 3 are true?

1 Each s orbital can hold a minimum of two electrons.
2 There are 3 orbitals in a 2p subshell.
3 The s orbital has a lower energy than the p orbital with the same principal quantum number.

A 3 only
B 1 and 2 only
C 2 and 3 only
D 1, 2 and 3

6 In the equilibrium represented below, which of the following species act as bases?

$$HSO_4^- + H_2O \rightleftharpoons H_3O^+ + SO_4^{2-}$$

1 HSO_4^-
2 H_2O
3 SO_4^{2-}

A 3 only
B 1 and 2 only
C 2 and 3 only
D 1,2 and 3

7 Which of the following can be classified as a Lewis acid?

A An ion which accepts a pair of electrons to form a bond.
B A molecule which donates a pair of electrons to form a bond.
C A ion which accepts a proton from water.
D A molecule which donates a proton to water.

8 Which of the following is a non-polar molecule that contains polar bonds?

A F_2
B CHF_3
C CO_2
D NH_3

9 Which of the following species has a see-saw structure?

A BrF_4^+
B BrF_4^-
C IF_5
D SO_4^{2-}

10 The energy profile diagram for the reaction X + Y → Z is shown below.

Which of the indicated energy differences is affected by the addition of a catalyst?

A I only
B II only
C III only
D I and II only

11 Calcination is a process which converts sodium hydrogen carbonate, $NaHCO_3$, to sodium carbonate, water and carbon dioxide. The balanced equation for the reaction is given below.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

Standard enthalpy change of formation of $NaHCO_3(s)$ / kJ mol^{-1}	-951
Standard enthalpy change of formation of $Na_2CO_3(s)$ / kJ mol^{-1}	-1131
Standard enthalpy change of formation of $H_2O(l)$ / kJ mol^{-1}	-286
Standard enthalpy change of formation of $CO_2(g)$ / kJ mol^{-1}	-394

What is the standard enthalpy change for the calcination reaction?

A +860 kJ mol^{-1} **B** +91 kJ mol^{-1} **C** -91 kJ mol^{-1} **D** -860 kJ mol^{-1}

12 Which of the following is associated with a relatively slow rate of a chemical reaction?

A high temperature
B low activation energy
C strong bonds in reactant molecules
D high concentration of reactants

13 The radioactive decay of a sample of ^{131}I follows a first order kinetics. If a pure sample of ^{131}I undergoes radioactive decay and the half-life of the decay was found to be 10 days, what would be the half-life of the decay in a separate experiment where the initial concentration of the pure sample of ^{131}I was doubled?

A 2.5 days
B 5 days
C 10 days
D 20 days

14 The following table shows the results from a rate study of the reaction **X** + **Y** → **Z**.

Experiment	[X] / mol dm^{-3}	[Y] / mol dm^{-3}	Initial rate of formation of Z / mol dm^{-3} s^{-1}
1	0.40	0.10	R
2	0.20	0.20	?

Starting with known concentrations of **X** and **Y** in experiment **1**, the rate of formation of **Z** was measured. If the reaction was first order with respect to **X** and second order with respect to **Y**, what is the initial rate of formation of **Z** in experiment **2**?

A $\frac{R}{4}$

B $\frac{R}{2}$

C R

D 2R

15 Equal amounts of HC*l* and O_2 in a closed system are allowed to reach equilibrium as represented by the equation below. Which of the following must be true at equilibrium?

$$4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g)$$

1 [HC*l*] must be less than [Cl_2]

2 [O_2] must be greater than [HC*l*]

3 [Cl_2] must equal [H_2O]

A 3 only

B 1 and 2 only

C 2 and 3 only

D 1,2 and 3

16 Carbon dioxide dissolves in water sparingly to produce carbonic acid, H_2CO_3.

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

Carbonic acid further dissociates in water according to the two equations below.

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$$

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CO_3^{2-}(aq)$$

How would the addition of a small amount of NaOH(aq) affect $[CO_2]$, $[HCO_3^-]$ and $[CO_3^{2-}]$ when carbon dioxide dissolves in water?

	$[CO_2]$	**$[HCO_3^-]$**	**$[CO_3^{2-}]$**
A	decrease	decrease	increase
B	decrease	negligible change	increase
C	decrease	Increase	increase
D	increase	negligible change	decrease

17 Which of the following statements concerning the characteristics of halogens is **incorrect**?

A The fourth ionisation energies decrease as the atomic numbers of the halogens increase.

B Fluorine is the strongest oxidising agent.

C The ease of decomposition of hydrogen halides decreases down Group 17.

D The acid strength of an aqueous solution of the hydrogen halides increases from HC*l* to HI.

18 Which of the following elements from Period 3 (sodium to chlorine) in the Periodic Table forms an oxide which dissolves in water to form a solution of pH 13?

A Sodium

B Silicon

C Sulfur

D Chlorine

19 $[Al(H_2O)_6]^{3+}$ ion is hydrolysed in aqueous solution according to the equation below.

$$[Al(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H_3O^+(aq)$$

Which statements about this reaction are true?

1 $[Al(H_2O)_5(OH)]^{2+}$ is relatively less likely to undergo hydrolysis compared to $[Al(H_2O)_6]^{3+}$.
2 The aluminium undergoes a change in oxidation state from +3 to +2.
3 The hydrolysis is favoured by low pH.

A 1 only
B 1 and 2 only
C 2 and 3 only
D 1,2 and 3

20 **G**, **H** and **J** are three elements found in Period 3 of the Periodic Table.

Among the elements in Period 3,

- The melting point of **G** is the highest.
- The electrical conductivity of **H** is the highest.
- The melting point of the oxides of **J** is the highest.

Which of the following elements is **not** represented by **G**, **H** or **J**?

A Na
B Mg
C Al
D Si

21 Based on the concepts of polarity and hydrogen bonding, which of the following sequences correctly lists the compounds below in the order of **increasing** solubility in water?

CH_3-CH_2-CH_2-CH_2-CH_3	CH_3-CH_2-CH_2-CH_2-OH	HO-CH_2-CH_2-CH_2-OH
X	**Y**	**Z**

A **Z < Y < X**

B **Y < Z < X**

C **Y < X < Z**

D **X < Y < Z**

22 Which of the following is true when one mole of ethane is mixed in the dark at room temperature with six moles of chlorine gas?

A CCl_3CCl_3 and HCl are formed.

B CH_3CH_2Cl and HCl are formed.

C CH_3CCl_3 and HCl are formed.

D There is no reaction.

23 An amine is prepared in the following reaction.

$$C_2H_5I + 2NH_3 \rightarrow C_2H_5NH_2 + NH_4I$$

What is the type of reaction taking place?

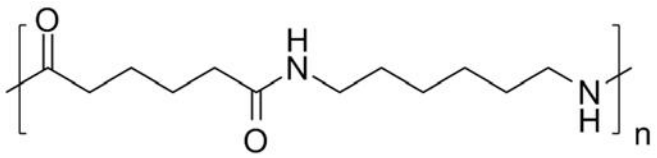
A addition

B substitution

C elimination

D redox

24 A repeat unit of nylon is shown below.



Nylon

Which of the following statements about nylon is correct?

A The monomers used are carboxylic acids and alcohols.

B It is formed via addition polymerisation.

C Water molecules are eliminated in the process of polymerisation.

D Hydrogen chloride molecules are eliminated in the process of polymerisation.

25 The mould *Phytophthora* damages many plants, destroying agricultural crops such as potatoes. A hormone-like compound called alpha 1 regulates the reproduction of all species of *Phytophthora*. The structure of alpha 1 is now known, giving scientists a key to the possible future eradication of the mould.

Which reagents will react with alpha 1?

1 Br_2(aq)

2 $SOCl_2$

3 $NaBH_4$

A 1 only

B 1 and 2 only

C 2 and 3 only

D 1,2 and 3

26 Which one of the following compounds will react with its own oxidation product to give a fruity smelling liquid?

A ethene
B propane
C propan-1-ol
D propan-2-ol

27 Which of the following has hydrogen bonds between its polymer chains?

A poly(propene)
B polyamide
C poly(phenylethene)
D polyester

28 Which option best defines the size of nanoparticles?

A between 100 to 1000 nm
B between 0.1 to 10 nm
C between 1 to 100 nm
D between 0.01 to 1 nm

29 Carbon nanotubes usually form in bundles.

Which of the statements best describes the bundle seen it the figure above?

A The tubes are connected together by covalent C-C bonds.

B The tubes are randomly organised, with the axes of the tubes lying in random directions.

C The tubes are aligned, axes parallel, with dispersion forces operating between adjacent tubes.

D The bundles are of discrete sizes, and permanent dipoles hold the tubes together.

30 Which of the following pair of compounds show one compound which can be oxidised by acidified potassium dichromate(VI) and the other be reduced by sodium borohydride, $NaBH_4$?

$C_3H_7CH(OH)C_3H_7$	C_6H_5CHO	$C_3H_7COC_3H_7$	$(C_3H_7)_3COH$
I	**II**	**III**	**IV**

	Can be oxidised	Can be reduced
A	**I**	**II**
B	**II**	**IV**
C	**III**	**I**
D	**IV**	**III**

END OF PAPER 1

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Class	Adm No

Candidate Name: _____

2018 End-of-Year Exams
Pre-University 2

H1 CHEMISTRY **8873 / 02**

Paper 2 Structured Questions **11 Sept 2018**

2 hours

Candidates answer on the Question paper.

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write your name, class and admission number on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

Question	1	2	3	4	5	Section B	Total
Marks	15	10	15	9	11	20	80

This question paper consists of **17** printed pages and **1** blank page.

For Examiners' Use

Section A
Answer all questions in the spaces provided.

1 In acidic solution, bromate(V) ions, BrO_3^-, oxidises bromide ions to bromine. The progress of the reaction may be followed by adding a fixed amount of phenol (an aromatic alcohol) together with methyl red indicator.

The bromine produced during the reaction reacts very rapidly with phenol. When all the phenol is consumed, any excess bromine bleaches the indicator immediately. The initial rate of formation of Br_2 is indicated by the time taken for the bromine to bleach the indicator.

(a) An experiment was carried out four times at room temperature. The total volume of the reaction mixture is the same in all four experiments and the following data were obtained.

Experiment	$[BrO_3^-]$ / mol dm^{-3}	$[Br^-]$ / mol dm^{-3}	Initial rate of formation of Br_2 / mol dm^{-3} s^{-1}
1	0.10	0.10	8×10^{-2}
2	0.10	0.05	4×10^{-2}
3	0.05	0.05	2×10^{-2}
4	0.05	0.10	4×10^{-2}

(i) Determine the order of the reaction with respect to each of the following reactants, showing your working clearly.

I. BrO_3^-

II. Br^-

[3]

(ii) Based on your answer in **(a)(i)**, sketch a concentration-time graph for BrO_3^-.

[1]

For Examiners' Use

(iii) Describe, and explain in molecular terms, how the rate of reaction is affected by an increase in temperature. You should make reference to the Boltzmann distribution in your answer.

.....

.....

.....

.....[3]

(b) **(i)** State the oxidation number of the **Br atom** in each of the following substances:

I. BrO_3^- Oxidation number of the Br atom: _____

II. bromide, Oxidation number of the Br atom: _____

III. bromine Oxidation number of the Br atom: _____ [3]

(ii) In a separate experiment, 20.0 cm^3 of 0.0200 mol dm^{-3} BrO_3^- was found to react completely with 80.0 cm^3 of 0.0100 mol dm^{-3} hydroxylamine, NH_2OH. BrO_3^- ions were reduced as shown in the ion-electron equation below.

$$BrO_3^- + 6e^- + 6H^+ \rightarrow Br^- + 3H_2O$$

Given that the original oxidation number of N in NH_2OH was -1, calculate the final oxidation number of N.

[4]

For Examiners' Use

(iii) Based on your answer in **(b)(ii)**, suggest a possible product for the oxidation of hydroxylamine.

.....[1]

[Total: 15]

2 Magnesium and aluminium are elements in Period 3 of the Periodic Table.

(a) State and explain **two** factors that lead to aluminium having a higher melting point than magnesium.

.....

.....

.....[2]

(b) MgO and Al_2O_3 have giant ionic lattice structures.
Explain why the melting point of Al_2O_3 is lower than MgO.

.....

.....

.....[2]

(c) Explain the following observations when separate samples of MgO and Al_2O_3 were added to water. Write suitable equation(s) were appropriate.

I. MgO dissolves slightly in water to give a weakly alkaline solution

II. Al_2O_3 did not dissolve when added to water.

.....

.....

.....

.....

.....[2]

For Examiners' Use

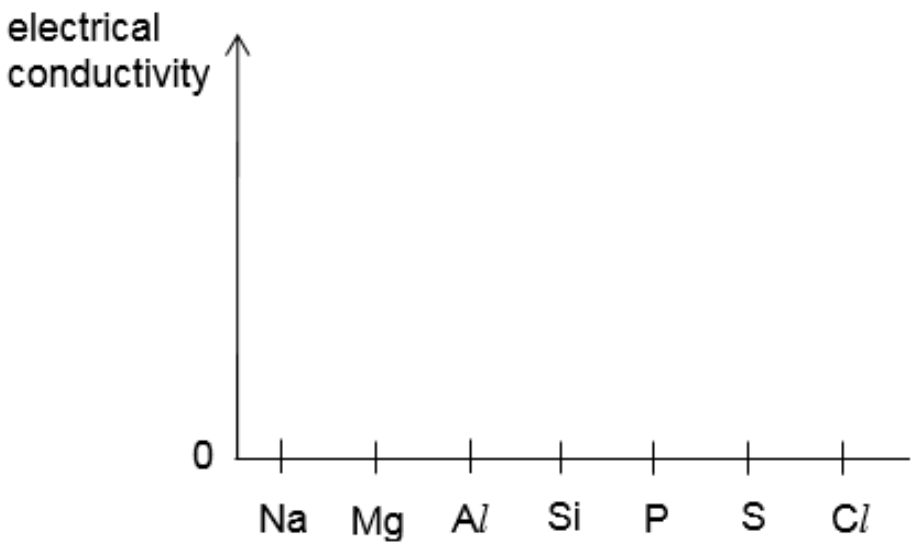
(d) Unlike $MgCl_2$, $AlCl_3$ has the tendency to dimerise to form Al_2Cl_6.
Draw the 'dot-and-cross' diagram of Al_2Cl_6 and explain how the dimer was formed.

…….....

…….....

…….....[3]

(e) Using the axes below, sketch the graph to show the electrical conductivity of the Period 3 elements from Na to Cl.



[1]

[Total: 10]

For Examiners' Use

3 The following abstract is taken from an article from the popular online site '*Chemistry World*'.

Mazda Motor Corporation has unveiled a new generation of catalytic converters that uses 70% to 90% less of the precious metals to purify exhaust emissions. The converters rely on nanoparticles of the catalytic metal, each less than five nanometres across, studded onto the surface of tiny ceramic spheres. The Japanese firm claims this is the first time a catalyst material has been achieved that features single, nanosized precious metal particles embedded in fixed positions.

Automotive catalysts use platinum, rhodium and palladium nanoparticles instead of other larger particles to speed up chemical reactions of pollutants such as nitrogen oxide, carbon monoxide and hydrocarbons, to create non-toxic emissions. Unfortunately, using platinum and palladium nanoparticles can result in negative impacts on human health. Ongoing research suggests that emissions of platinum-group metals from catalytic converters along US highways might be a root cause of an alarming rise in allergies and asthma.

Adapted from ''Catalytic Converters Go Nano' ~ Ned Stafford

(a) **(i)** By writing a chemical equation, illustrate how automotive catalyst convert pollutants into non-toxic emissions.

…….....[1]

(ii) Suggest why automotive catalysts use nanoparticles instead of larger particles.

…….....

…….....

…….....[2]

(iii) Explain why having platinum or palladium in catalysts can translate into health risks.

…….....

…….....[1]

For Examiners' Use

(b) Gas chromatography (GC) is a type of chromatography used in analytical Chemistry for separating and analysing compounds that can be vaporised without decomposing. The composition of the pollutants in petrol in vehicles can be determined using GC. The exhaust gases are passed through a separating column and the gaseous compounds are being analysed by their interactions with the walls of the column which is coated with a stationary phase (usually a large polymer). These interactions cause the gaseous compounds to be extracted at different timings, known as the retention time of the compounds. If the polarity of the gases and the stationary phase are similar, then there is likely to be a greater interaction between the two. In other words, the retention time will be longer for polar compounds on polar stationary phases and shorter on non-polar stationary phases. Boiling point is another property that affects retention times. If a component has a low boiling point, it is likely to spend more time in the gas phase in the column instead of interacting with the walls of the column. The comparison of retention times gives GC its analytical usefulness.

The following table gives the retention timings of some pollutants.

Compound	**Retention time/ min**
Hydrogen (H_2)	3.0
Carbon monoxide (CO)	14.5
Nitrogen Oxide (NO)	18.8

(i) Account for the difference in retention times for CO and NO.

…….....

…….....

…….....

…….....[2]

(ii) Carbon monoxide can be oxidised to CO_2.

Draw a dot-and-cross diagram to illustrate the bonding in CO_2. State its shape and bond angle.

Shape: …… Bond Angle: …… [2]

For Examiners' Use

(c) Under room conditions and in the presence of a platinum catalyst, one mole of compound **A**, with molecular formula, C_5H_{10}, requires an equal amount of hydrogen gas for reduction.

(i) Identify the functional group present in compound **A**.

…….....[1]

(ii) Identify the number of sigma and pi bonds in compound **A**.

…….....[2]

(iii) Draw **and** name any **three** possible structures of **A**.

[3]

(iv) Compound **B** can be synthesised from **A**. Given that **B** is a ketone with a relative molecular mass of 58.0 and contains 3 carbon atoms, draw the structure of **B**.

[1]

[Total: 15]

For Examiners' Use

4 But-1-ene, $CH_3CH_2CH{=}CH_2$, is an important raw material for the production of synthetic rubber. The enthalpy change of combustion, ΔH_c, of but-1-ene can be determined using bond energy values.

(a) **(i)** Define the term *bond energy*.

…….....

…….....[1]

(ii) The bond energy of the C-C bond in butane is 350 kJ mol^{-1}. It was expected that the bond energy of the C=C bond in but-1-ene to be twice that of the C-C bond in butane. However, actual bond energy of the C=C bond in but-1-ene is only 610 kJ mol^{-1}. Account for the difference.

…….....

…….....

…….....[2]

(b) **(i)** Write an equation to represent the standard enthalpy change of combustion of gaseous but-1-ene.

…….....[1]

(ii) Hence, use the bond energies in the *Data Booklet* to calculate the standard enthalpy change of combustion of gaseous but-1-ene.

[3]

For Examiners' Use

(iii) In the theoretical calculations in **(b)(ii)**, the physical state of water was assumed to be gaseous. However, in practice, **water vapour condenses into a liquid at room temperature**. State and explain how this would affect the magnitude of your answer in **(b)(ii)**.

…….....

…….....

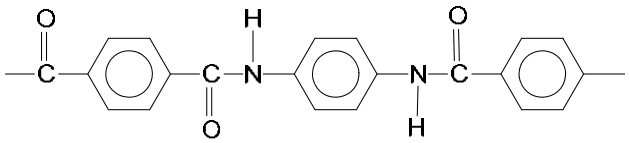
…….....

…….....[2]

[Total: 9]

5 **(a)** Kevlar is a heat-resistant and strong synthetic fibre used in many applications from bicycle tyres to bulletproof vests because of its high tensile strength-to-weight ratio.

Part of the structure of the polymer Kevlar is shown below.



Kevlar

(i) Draw the monomer(s) involved in the formation of Kevlar.

[2]

(ii) State the functional group present in Kevlar and state whether Kevlar is an addition or condensation polymer.

…….....[2]

(iii) Explain the high tensile strength of Kevlar in terms of its structure and bonding.

…….....

…….....[1]

For Examiners' Use

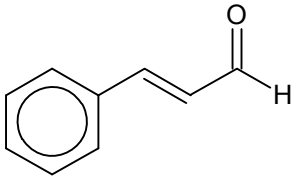
(iv) Explain why a bullet proof vest made of Kevlar should be stored away from concentrated acids.

…….....

…….....[1]

(b) The benzene ring is an important functional group for many naturally occurring aromatic compounds. The term 'aromatic' was used to describe a group of compounds, many of which have aromas.

The compound that gives cinnamon its characteristic smell is cinnamaldehyde



cinnamaldehyde

Draw the organic product obtained when cinnamaldehyde is treated with the following reagents. For each reagent, state the type of reaction that has occurred and record any observations.

I. $LiAlH_4$ in dry ether

Type of reaction and / or observations: …….

……..

II. $K_2Cr_2O_7(aq)$, $H_2SO_4(aq)$, heat

Type of reaction and / or observations: …….

……..…[5]

[Total: 11]

End of Section A

Section B

Answer any <u>one</u> of the two questions.

For Examiners' Use

1 **(a)** Geckos are a type of reptiles that possess the ability to adhere to almost any surface. As such, research is undergoing to develop synthetic material that resembles the feet of geckos. The main reason why geckos can adhere to any surfaces is due to the nanostructures found on their feet.

(i) State what is the nanostructure found on geckos' feet.

…….....[1]

(ii) Explain how these nanostructures help geckos to stick to most surfaces.

…….....

…….....

…….....

…….....

…….....[3]

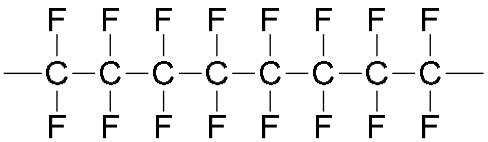
(b) One type of materials that some geckos are unable to adhere to is polytetrafluoroethylene (PTFE). PTFE is used in making non-stick pans and other cookwares.

(i) Define *polymers*.

…….....

…….....[1]

(ii) The structure of PTFE is given below.



Draw the repeat unit that make up PTFE.

[1]

For Examiners' Use

(iii) Thermoplastic and thermosetting polymers differ in their structure and bonding. Explain the differences in the rigidity and strength of thermoplastic and thermosetting polymers.

.....

.....

.....

.....

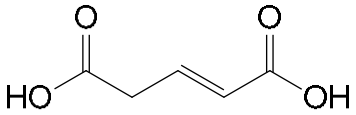
.....

.....[3]

(iv) Hence or otherwise, suggest if PTFE is a thermoplastic or thermosetting polymer.

.....[1]

(c) Glutaconic acid is a product of hydrolysis of proteins in the human body. Excessive levels of glutaconic acid can lead to brain damage.

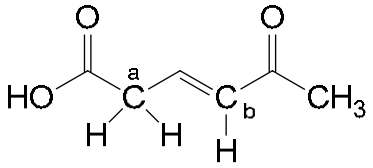


Glutaconic acid

(i) State the IUPAC name for glutaconic acid.

.....[1]

(ii) State the bond angle and shape around the carbon labelled as C_a and C_b.

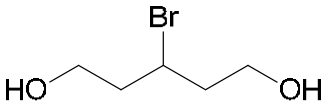


C_a: .....

C_b: ..... [2]

For Examiners' Use

(iii) Draw the synthetic route and suggest reagents and conditions for each step to show how glutaconic acid can be synthesised from 3-bromopenta-1,5-diol. You are required to draw the structures of all intermediates.



3-bromopenta-1,5-diol

[3]

(iv) Describe a distinguishing test between glutaconic acid and 3-bromopenta-1,5-diol. State the observations, if any.

…….....

…….....[2]

(v) Glutaconic acid is soluble in water. Explain, in terms of structure and bonding, why this happens.

…….....

…….....[2]

[Total: 20]

For Examiners' Use

2 **(a)** Transition metals are very useful in the chemical industries as they can act as catalysts. Vanadium, iron and chromium are commonly used as catalysts for various common reactions.

(i) Write the electronic configuration of the following particles.

V^{6+}: ……

Cr^{6+}:……...[2]

(ii) Draw the shapes of the orbitals in which the valence electrons of V^{6+} occupy.

[2]

(iii) Define the sixth ionisation energy of vanadium.

…….....

…….....[1]

(iv) State whether the 6th ionisation energy of vanadium is higher or lower than that of chromium. Explain your answer.

…….....

…….....

…….....

…….....[3]

(v) Niobium (Nb) and tantalum (Ta) are elements below that of vanadium in the periodic table. State and explain the trend in atomic radii among the three elements.

…….....

…….....

…….....[2]

For Examiners' Use

(b) Haber process is a very important industrial process as it is the main process involved in making of fertilisers. A similar industrial process is the Contact process, which is the process of making sulfuric acid from sulfur. The main reaction is given below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197 \text{ kJ mol}^{-1}$$

(i) State what is meant by Le Chatelier's Principle.

…….....

…….....[1]

(ii) The reaction is carried out at 450 °C and 1.5 atm. Suggest, using Le Chatelier's Principle, why this may not be the ideal condition.

…….....

…….....[2]

(iii) An equilibrium was established at 700 °C in a 10 dm^3 vessel. The equilibrium amounts of sulfur dioxide, oxygen and sulfur trioxide were 10.0 mol, 4.0 mol and 25.1 mol.

Calculate K_c and state its units.

[3]

(iv) State the effect on the K_c calculated in **(b)(iii)** if the contact process is carried out at 450 °C instead of 700 °C.

…….....[1]

(c) **(i)** Many of the food consumed commonly contain acids. One of them is citric acid, found in citrus fruits. The dissociation of citric acid is given below.

$$H_3C_6H_5O_7\,(aq) + H_2O\,(l) \rightleftharpoons H_2C_6H_5O_7^-\,(aq) + H_3O^+\,(aq)$$

Write the K_a expression for the dissociation of citric acid.

…….....[1]

For Examiners' Use

(ii) A sample of citric acid with the concentration of 0.01 mol dm^{-3} was obtained. The pH of the solution was measured and found to be 2.54. Calculate the concentration of H_3O^+ ions present in the solution.

[1]

(iii) Hence, deduce if citric acid is a strong or weak acid. Explain your answer.

…….....

…….....[1]

[Total: 20]

End of Section B

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Class	Adm No

Candidate Name: _____

H

millennia institute

2018 End-of-Year Exams
Pre-University 2

H1 CHEMISTRY **8873/01**

Paper 1 Multiple Choice **13 Sept 2018**

1 hour

Additional materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so
Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and admission number in the spaces provided at the top of this page and on the Multiple Choice Answer Sheet provided.

There are thirty questions on this paper. Answer **ALL** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the Multiple Choice Answer Sheet provided.

Read the instructions on the Multiple Choice Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this question paper.
The use of an approved scientific calculator is expected, where appropriate.

FOR EXAMINER'S USE	
TOTAL (30 marks)	

This question paper consists of **13** printed pages and **1** blank page.

Section A

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 According to the equation below, how many moles of potassium chlorate, $KClO_3$, must be decomposed to generate 1000 cm^3 of O_2 gas at standard temperature and pressure?

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

A $\frac{2}{3}\left(\frac{1}{24}\right)$ mol

B $\frac{3}{2}\left(\frac{1}{24}\right)$ mol

C $\frac{2}{3}\left(\frac{1}{22.7}\right)$ mol

D $\frac{3}{2}\left(\frac{1}{22.7}\right)$ mol

2 *Use of the Data Booklet is relevant to this question.*

It is suggested that SO_2 which contributes to acid rain, could be removed from a stream of waste gases by bubbling the gases through 0.25 mol dm^{-3} KOH, thereby producing K_2SO_3. What is the maximum mass of SO_2 that could be removed by 1000 dm^3 of the KOH solution?

A 4.0 kg

B 8.0 kg

C 16.0 kg

D 20.0 kg

3 To determine the molar mass of a weak monoprotic acid, a student titrated 25.0 cm^3 of the acid with aqueous NaOH. Which of the following are appropriate indicators that could be used for the titration?

1 Phenolphthalein
2 Methyl Orange
3 Bromothymol blue

A 1 only
B 1 and 2 only
C 2 and 3 only
D 1, 2 and 3

4 A sample of 30.0 cm^3 of 0.050 mol dm^{-3} iron(II) sulfate is titrated against 0.025 mol dm^{-3} potassium manganate(VII) solution. It is found that 20.0 cm^3 of the manganate(VII) solution is required to reach end point.
What is the oxidation number of manganese at the end point?

A +2
B +3
C +4
D +5

5 The number of orbitals of a principal quantum number is dependent on the type of subshell. Which of the following statements about the s, p and d orbitals of principal quantum numbers 1, 2 and 3 are true?

1 Each s orbital can hold a minimum of two electrons.
2 There are 3 orbitals in a 2p subshell.
3 The s orbital has a lower energy than the p orbital with the same principal quantum number.

A 3 only
B 1 and 2 only
C 2 and 3 only
D 1, 2 and 3

6 In the equilibrium represented below, which of the following species act as bases?

$$HSO_4^- + H_2O \rightleftharpoons H_3O^+ + SO_4^{2-}$$

1 HSO_4^-
2 H_2O
3 SO_4^{2-}

A 3 only
B 1 and 2 only
C 2 and 3 only
D 1,2 and 3

7 Which of the following can be classified as a Lewis acid?

A An ion which accepts a pair of electrons to form a bond.
B A molecule which donates a pair of electrons to form a bond.
C A ion which accepts a proton from water.
D A molecule which donates a proton to water.

8 Which of the following is a non-polar molecule that contains polar bonds?

A F_2
B CHF_3
C CO_2
D NH_3

9 Which of the following species has a see-saw structure?

A BrF_4^+
B BrF_4^-
C IF_5
D SO_4^{2-}

10 The energy profile diagram for the reaction X + Y → Z is shown below.

Which of the indicated energy differences is affected by the addition of a catalyst?

A I only
B II only
C III only
D I and II only

11 Calcination is a process which converts sodium hydrogen carbonate, $NaHCO_3$, to sodium carbonate, water and carbon dioxide. The balanced equation for the reaction is given below.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

Standard enthalpy change of formation of $NaHCO_3(s)$ / kJ mol^{-1}	-951
Standard enthalpy change of formation of $Na_2CO_3(s)$ / kJ mol^{-1}	-1131
Standard enthalpy change of formation of $H_2O(l)$ / kJ mol^{-1}	-286
Standard enthalpy change of formation of $CO_2(g)$ / kJ mol^{-1}	-394

What is the standard enthalpy change for the calcination reaction?

A +860 kJ mol^{-1} **B** +91 kJ mol^{-1} **C** -91 kJ mol^{-1} **D** -860 kJ mol^{-1}

12 Which of the following is associated with a relatively slow rate of a chemical reaction?

A high temperature
B low activation energy
C strong bonds in reactant molecules
D high concentration of reactants

13 The radioactive decay of a sample of ^{131}I follows a first order kinetics. If a pure sample of ^{131}I undergoes radioactive decay and the half-life of the decay was found to be 10 days, what would be the half-life of the decay in a separate experiment where the initial concentration of the pure sample of ^{131}I was doubled?

A 2.5 days
B 5 days
C 10 days
D 20 days

14 The following table shows the results from a rate study of the reaction **X** + **Y** → **Z**.

Experiment	[X] / mol dm^{-3}	[Y] / mol dm^{-3}	Initial rate of formation of Z / mol dm^{-3} s^{-1}
1	0.40	0.10	R
2	0.20	0.20	?

Starting with known concentrations of **X** and **Y** in experiment **1**, the rate of formation of **Z** was measured. If the reaction was first order with respect to **X** and second order with respect to **Y**, what is the initial rate of formation of **Z** in experiment **2**?

A $\frac{R}{4}$

B $\frac{R}{2}$

C R

D 2R

15 Equal amounts of HC*l* and O_2 in a closed system are allowed to reach equilibrium as represented by the equation below. Which of the following must be true at equilibrium?

$$4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g)$$

1 [HC*l*] must be less than [Cl_2]

2 [O_2] must be greater than [HC*l*]

3 [Cl_2] must equal [H_2O]

A 3 only

B 1 and 2 only

C 2 and 3 only

D 1,2 and 3

16 Carbon dioxide dissolves in water sparingly to produce carbonic acid, H_2CO_3.

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

Carbonic acid further dissociates in water according to the two equations below.

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$$

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CO_3^{2-}(aq)$$

How would the addition of a small amount of NaOH(aq) affect $[CO_2]$, $[HCO_3^-]$ and $[CO_3^{2-}]$ when carbon dioxide dissolves in water?

	$[CO_2]$	**$[HCO_3^-]$**	**$[CO_3^{2-}]$**
A	decrease	decrease	increase
B	decrease	negligible change	increase
C	decrease	Increase	increase
D	increase	negligible change	decrease

17 Which of the following statements concerning the characteristics of halogens is **incorrect**?

A The fourth ionisation energies decrease as the atomic numbers of the halogens increase.

B Fluorine is the strongest oxidising agent.

C The ease of decomposition of hydrogen halides decreases down Group 17.

D The acid strength of an aqueous solution of the hydrogen halides increases from HC*l* to HI.

18 Which of the following elements from Period 3 (sodium to chlorine) in the Periodic Table forms an oxide which dissolves in water to form a solution of pH 13?

A Sodium

B Silicon

C Sulfur

D Chlorine

19 $[Al(H_2O)_6]^{3+}$ ion is hydrolysed in aqueous solution according to the equation below.

$$[Al(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H_3O^+(aq)$$

Which statements about this reaction are true?

1 $[Al(H_2O)_5(OH)]^{2+}$ is relatively less likely to undergo hydrolysis compared to $[Al(H_2O)_6]^{3+}$.
2 The aluminium undergoes a change in oxidation state from +3 to +2.
3 The hydrolysis is favoured by low pH.

A 1 only
B 1 and 2 only
C 2 and 3 only
D 1,2 and 3

20 **G**, **H** and **J** are three elements found in Period 3 of the Periodic Table.

Among the elements in Period 3,

- The melting point of **G** is the highest.
- The electrical conductivity of **H** is the highest.
- The melting point of the oxides of **J** is the highest.

Which of the following elements is **not** represented by **G**, **H** or **J**?

A Na
B Mg
C Al
D Si

21 Based on the concepts of polarity and hydrogen bonding, which of the following sequences correctly lists the compounds below in the order of **increasing** solubility in water?

CH_3-CH_2-CH_2-CH_2-CH_3	CH_3-CH_2-CH_2-CH_2-OH	HO-CH_2-CH_2-CH_2-OH
X	**Y**	**Z**

A **Z < Y < X**

B **Y < Z < X**

C **Y < X < Z**

D **X < Y < Z**

22 Which of the following is true when one mole of ethane is mixed in the dark at room temperature with six moles of chlorine gas?

A CCl_3CCl_3 and HCl are formed.

B CH_3CH_2Cl and HCl are formed.

C CH_3CCl_3 and HCl are formed.

D There is no reaction.

23 An amine is prepared in the following reaction.

$$C_2H_5I + 2NH_3 \rightarrow C_2H_5NH_2 + NH_4I$$

What is the type of reaction taking place?

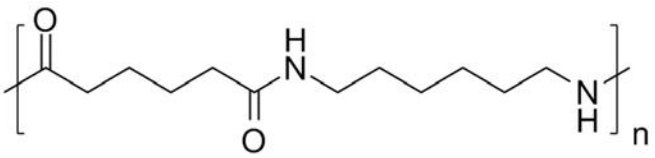
A addition

B substitution

C elimination

D redox

24 A repeat unit of nylon is shown below.



Nylon

Which of the following statements about nylon is correct?

A The monomers used are carboxylic acids and alcohols.

B It is formed via addition polymerisation.

C Water molecules are eliminated in the process of polymerisation.

D Hydrogen chloride molecules are eliminated in the process of polymerisation.

25 The mould *Phytophthora* damages many plants, destroying agricultural crops such as potatoes. A hormone-like compound called alpha 1 regulates the reproduction of all species of *Phytophthora*. The structure of alpha 1 is now known, giving scientists a key to the possible future eradication of the mould.

Which reagents will react with alpha 1?

1 Br_2(aq)

2 $SOCl_2$

3 $NaBH_4$

A 1 only

B 1 and 2 only

C 2 and 3 only

D 1,2 and 3

26 Which one of the following compounds will react with its own oxidation product to give a fruity smelling liquid?

A ethene
B propane
C propan-1-ol
D propan-2-ol

27 Which of the following has hydrogen bonds between its polymer chains?

A poly(propene)
B polyamide
C poly(phenylethene)
D polyester

28 Which option best defines the size of nanoparticles?

A between 100 to 1000 nm
B between 0.1 to 10 nm
C between 1 to 100 nm
D between 0.01 to 1 nm

29 Carbon nanotubes usually form in bundles.

Which of the statements best describes the bundle seen in the figure above?

A The tubes are connected together by covalent C-C bonds.

B The tubes are randomly organised, with the axes of the tubes lying in random directions.

C The tubes are aligned, axes parallel, with dispersion forces operating between adjacent tubes.

D The bundles are of discrete sizes, and permanent dipoles hold the tubes together.

30 Which of the following pair of compounds show one compound which can be oxidised by acidified potassium dichromate(VI) and the other be reduced by sodium borohydride, $NaBH_4$?

$C_3H_7CH(OH)C_3H_7$	C_6H_5CHO	$C_3H_7COC_3H_7$	$(C_3H_7)_3COH$
I	**II**	**III**	**IV**

	Can be oxidised	Can be reduced
A	**I**	**II**
B	**II**	**IV**
C	**III**	**I**
D	**IV**	**III**

END OF PAPER 1

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Class	Adm No

Candidate Name: _____

H

millennia institute

2018 End-of-Year Exams
Pre-University 2

H1 CHEMISTRY **8873 / 02**

Paper 2 Structured Questions **11 Sep 2018**

2 hours

Candidates answer on the Question paper.

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write your name, class and admission number on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

Question	1	2	3	4	5	Section B	Total
Marks	15	10	15	9	11	20	80

This question paper consists of xx printed pages and x blank page.

For Examiners' Use

Section A
Answer all questions in the spaces provided.

1 In acidic solution, bromate(V) ions, BrO_3^-, oxidises bromide ions to bromine. The progress of the reaction may be followed by adding a fixed amount of phenol (an aromatic alcohol) together with methyl red indicator.

The bromine produced during the reaction reacts very rapidly with phenol. When all the phenol is consumed, any excess bromine bleaches the indicator immediately. The initial rate of formation of Br_2 is indicated by the time taken for the bromine to bleach the indicator.

(a) An experiment was carried out four times at room temperature. The total volume of the reaction mixture is the same in all four experiments and the following data were obtained.

Experiment	$[BrO_3^-]$ / mol dm^{-3}	$[Br^-]$ / mol dm^{-3}	Initial rate of formation of Br_2 / mol dm^{-3} s^{-1}
1	0.10	0.10	8×10^{-2}
2	0.10	0.05	4×10^{-2}
3	0.05	0.05	2×10^{-2}
4	0.05	0.10	4×10^{-2}

(i) Determine the order of the reaction with respect to each of the following reactants, showing your working clearly.

I. BrO_3^-

II. Br^- [3]

Comparing Expt 1 & 2,

when $[Br^-]$ increases by 2 times, rate increases by 2 times $\left(\frac{8\times10^{-2}}{4\times10^{-2}}\right)$. [1]

⇒ rate is directly proportional to $[Br^-]$

⇒ reaction is 1st order with respect to Br^- [1]

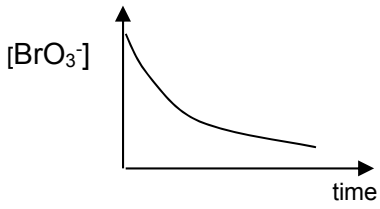
Comparing Expt 2 & 3,

when $[BrO_3^-]$ increases by 2 times, rate increases by 2 times $\left(\frac{4\times10^{-2}}{2\times10^{-2}}\right)$.

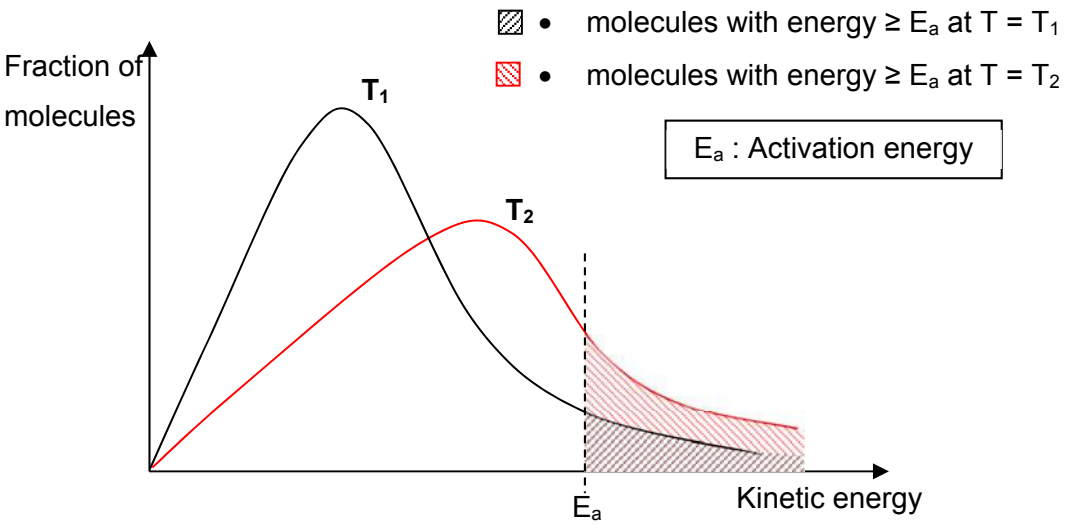
⇒ rate is directly proportional to $[BrO_3^-]$

⇒ reaction is 1st order with respect to BrO_3^- [1]

(ii) Based on your answer in **(a)(i)**, sketch a concentration-time graph for BrO_3^-. [1]



(iii) Describe, and explain in molecular terms, how the rate of reaction is affected by an increase in temperature. You should make reference to the Boltzmann distribution in your answer. [3]



When temperature increases, the average kinetic energies of the reactant molecules increase.
Thus, the number of reactant molecules with energy greater or equal to the activation energy will increase. This results in an increase in the frequency of effective collisions.
Hence, the rate of reaction increases.

(b) **(i)** State the oxidation number of the Br atom in each of the following substances:

I. BrO_3^-,

II. bromide,

III. bromine [3]

+5, -1, 0

(ii) In a separate experiment, 20.0 cm^3 of 0.0200 mol dm^{-3} BrO_3^- was found to react completely with 80.0 cm^3 of 0.0100 mol dm^{-3} hydroxylamine, NH_2OH. BrO_3^- ions were reduced as shown in the ion-electron equation below.

$$BrO_3^- + 6e^- + 6H^+ \rightarrow Br^- + 3H_2O$$

Given that the original oxidation number of N in NH_2OH was -1, calculate the final oxidation number of N. [4]

Amount of BrO_3^- = 20/1000 x 0.0200 = 0.0004 mol

Amounf of NH_2OH = 80/1000 x 0.01 = 0.0008 mol ;

Amount of e gained by BrO_3^- = 0.0004 x 6 = 0.0024 mol ;

Mole ratio of NH_2OH: electrons = 0.0008:0.0024 = 1:3 ;

Final oxidation number of N = -1 – (-3) = +2 ;

(iii) Based on your answer in **(b)(ii)**, suggest a possible product for the oxidation of hydroxylamine. [1]

NO
(ecf based on (b)(ii))

[Total: 15]

2 Magnesium and aluminium are elements from Period 3 of the Periodic Table.

(a) State and explain **two** factors that leads to aluminium having a higher melting point than magnesium. [2]

From Mg to Al, the number of delocalised electrons and charge density of metal cation increases, thus the strength of metallic bond also increases from. Hence there is an increase in melting point from Mg to Al

(b) MgO and Al_2O_3 have giant ionic lattice structures.

Explain why the melting point of Al_2O_3 is lower than MgO. [2]

The melting point of Al_2O_3 is lower than MgO due to Al_2O_3 being an ionic compound with partial covalent character. This occurs as the Al^{3+} cation has a high charge density and can strongly polarise/distort the electron cloud of the O^{2-} anion.

(c) Explain the following observations when separate samples of MgO and Al_2O_3 were added to water. Write suitable equation(s) were appropriate.

I. MgO dissolves slightly in water to give a weakly alkaline solution

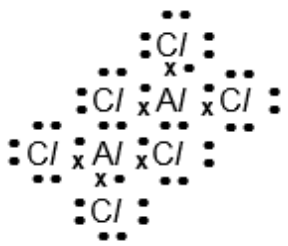
II. Al_2O_3 did not dissolve when added to water. [2]

$MgO\ (s) + H_2O\ (l) \rightleftharpoons Mg(OH)_2\ (aq)$

Al_2O_3 has high lattice energy.

(d) Unlike $MgCl_2$, $AlCl_3$ has the tendency to dimerise to form Al_2Cl_6.

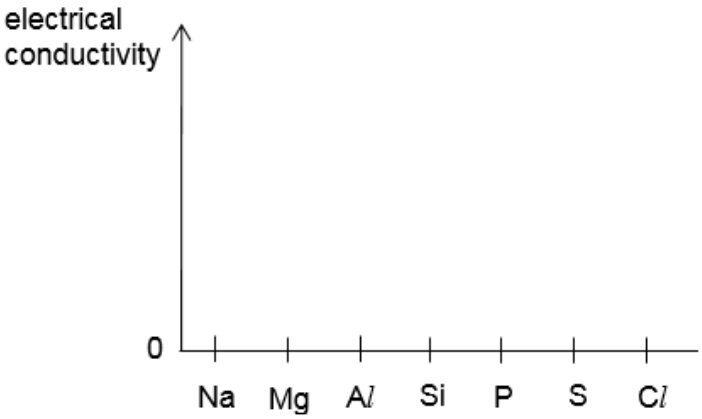
Draw the 'dot-and-cross' diagram of Al_2Cl_6 and explain how the dimer was formed. [3]

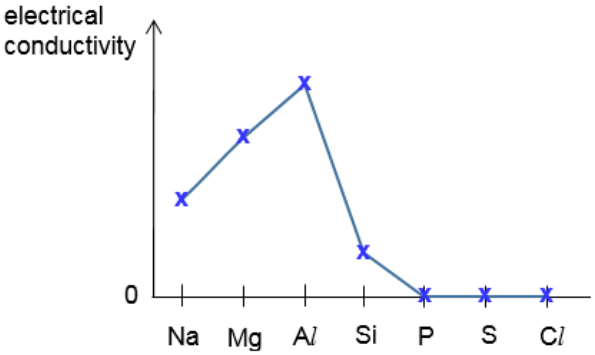


Chlorine atom possess a lone pair of electrons in its valence quantum shell.

Aluminium has energetically-accessible vacant orbitals in its valence quantum shell to accommodate the lone pair of electrons from chlorine to form a dative covalent bond.

(e) Using the axes below, sketch the graph to show the electrical conductivity of the Period 3 elements from Na to *Cl*. [1]





[Total: 10]

3 The following abstract is taken from an article from the popular online site '*Chemistry World*'.

Mazda Motor Corporation has unveiled a new generation of catalytic converters that use 70% to 90% less of the precious metals which help to purify exhaust emissions. The converters rely on nanoparticles of the catalytic metal, each less than five nanometres across, studded onto the surface of tiny ceramic spheres. The Japanese firm claims this is the first time a catalyst material has been achieved that features single, nanosized precious metal particles embedded in fixed positions.

Automotive catalysts use platinum, rhodium and palladium nanoparticles instead of other larger particles to speed up chemical reactions of pollutants such as nitrogen oxide, carbon monoxide and hydrocarbons, to create non-toxic emissions. Unfortunately, using platinum and palladium nanoparticles can result in negative impacts on human health. Ongoing research suggests that emissions of platinum-group metals from catalytic converters along US highways might be a root cause of an alarming rise in allergies and asthma.

Adapted from ''Catalytic Converters Go Nano' ~ Ned Stafford

(a) **(i)** By writing a chemical equation, illustrate how automotive catalyst convert pollutants into non-toxic emissions. [1]

$2CO + O_2 \rightarrow 2CO_2$

(ii) Suggest why automotive catalysts use nanoparticles instead of larger particles. [2]

The higher surface area to volume ratio of platinum nanoparticles increases catalytic efficiency in catalytic converters. There are more collisions between the reactants and catalyst, increasing the frequency of effective collisions, thus speeding up the chemical reactions.

(iii) Explain why having platinum and palladium in catalysts can translate into health risks.[1]

The small size of nanoparticles means that nanoparticles can be easily inhaled and absorbed by the lungs and subsequently absorbed into the blood steam. This can lead to health risks such as asthma, poisoning of the blood.

(b) Gas chromatography (GC) is a type of chromatography used in analytical Chemistry for separating and analysing compounds that can be vaporised without decomposing. The composition of the pollutants in petrol in vehicles can be determined using GC. The exhaust gases are passed through a separating column and the gaseous compounds are being analysed by their interactions with the walls of the column which is coated with a stationary phase (usually a large polymer). These interactions cause the gaseous compounds to be extracted at different timings, known as the retention time of the compounds. If the polarity of the gases and the stationary phase are similar, then there is likely to be a greater interaction between the two. In other words, the retention time will be longer for polar compounds on polar stationary phases and shorter on non-polar stationary phases. Boiling points is another property that affects retention times If a component has a low boiling point, it is likely to spend more time in the gas phase in the column instead of interacting with the walls of the column. The comparison of retention times gives GC its analytical usefulness.

The following table gives the retention timings of some pollutants.

Compound	**Retention time / min**
Hydrogen (H_2)	3.0
Carbon monoxide (CO)	14.5
Nitrogen Oxide (NO)	18.8

(i) Account for the difference in retention times for CO and NO. [2]

Both CO and NO are simple covalent molecules. Both CO and NO has pd-pd forces of attraction between its molecules. However, NO has a larger size of electron cloud, thus more thermal energy is required to overcome the stronger pd-pd forces of attraction in NO, thus NO has a higher boiling point and a longer retention time.

(ii) Draw a dot-and-cross diagram to illustrate the bonding in CO_2.

State its shape and bond angle. [2]

O==C=O, linear, 180°

(c) Under room conditions and in the presence of a platinum catalyst, one mole of compound **A**, with molecular formula, C_5H_{10}, requires an equal amount of hydrogen gas for reduction.

(i) Identify the functional group present in compound **A**. [1]

Alkene

(ii) Identify the number of sigma and pi bonds in compound **A**. [2]

14 sigma, 1 pi

(iii) Draw **and** name any **three** possible structures of **A**. [3]

Pent-2-ene / pentene / 3-methyl butene

(iv) Compound **B** can be synthesised from **A**. Given that **B** is a ketone with a relative molecular mass of 58.0 and contains 3 carbon atoms, draw the structure of **B**. [1]

CH_3COCH_3

[Total: 15]

4 But-1-ene, $CH_3CH_2CH{=}CH_2$, is an important raw material for the production of synthetic rubber. The enthalpy change of combustion, ΔH_c, of but-1-ene can be determined using bond energy values.

(a) **(i)** Explain the term *bond energy*. [1]

The energy required to break one mole of a covalent bond between two atoms of a molecule in gaseous state, under standard conditions of 298 K, 1 bar.

(ii) The bond energy of the C-C bond in butane is 350 kJ mol^{-1}. It was expected that the bond energy of the C=C bond in but-1-ene to be twice that of the C-C bond in butane. However, actual bond energy of the C=C bond in but-1-ene is only 610 kJ mol^{-1}. Account for the difference. [2]

The C-C bond in the butane consists of 1 sigma bond. The C=C in but-1-ene consists of 1 sigma and 1 pi bond.

A pi bond is weaker than a sigma bond due to less effective overlap, hence C=C bond is less than twice of C-C bond.

(b) **(i)** Write an equation to represent the standard enthalpy change of combustion of gaseous but-1-ene. [1]

$CH_3CH_2CH{=}CH_2 + 6O_2 \rightarrow 4CO_2\,(g) + 4H_2O$

(ii) Hence, use the bond energies in the *Data Booklet* to calculate the standard enthalpy change of combustion of gaseous but-1-ene. [3]

$\Delta H = [2\times BE(C\text{-}C) + BE(C{=}C) + 8\times BE(C\text{-}H) + 6\times BE(O{=}O)] - [8\times BE(C{=}O) + 8\times BE(O\text{-}H)]$
$= (2\times 350 + 610 + 8\times 410 + 6\times 496) - (8\times 740 + 8\times 460)$
$= 7566 - 9600$
$= -2034 \approx -2030$ kJ mol^{-1}

(iii) In the theoretical calculations in **(b)(ii)**, the physical state of water was assumed to be gaseous. However, in practice, **water vapour condenses into a liquid at room temperature**. State and explain how this would affect the magnitude of your answer in **(b)(ii)**. [2]

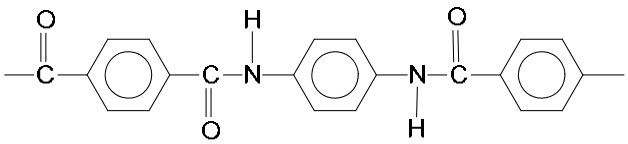
The magnitude will be larger.

When water condenses into liquid, addition energy is released.

[Total: 9]

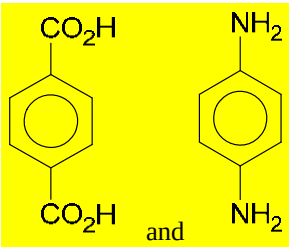
5 Kevlar is a heat-resistant and strong synthetic fibre used in many applications from bicycle tyres to bulletproof vests because of its high tensile strength-to-weight ratio.

(a) **(i)** Part of the structure of the polymer Kevlar is shown below.



Kevlar

Draw the monomer(s) involved in the formation of Kevlar. [2]



(ii) State the functional group present in Kevlar and state whether Kevlar is an addition or condensation polymer. [2]

Amide

Condensation polymer.

(iii) Explain the high tensile strength of Kevlar in terms of its structure and bonding. [1]

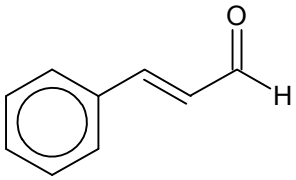
When the polymer chains are aligned, the molecules are held together by strong hydrogen bonds. / id-id

(iv) Explain why a bullet-proof vest made of Kevlar should be stored away from concentrated acids. [1]

In the presence of acids, the amide linkages holding the monomers can be hydrolysed, thus disrupting the structure of Kevlar.

(b) The benzene ring is an important functional group for many naturally aromatic compounds. The term was used to describe a group of compounds, many of which have aromas.

The compound that gives cinnamon its characteristic smell is cinnamaldehyde

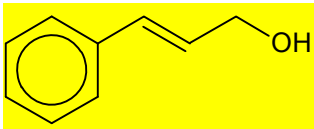


cinnamaldehyde

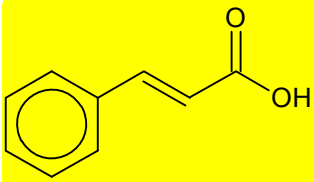
Draw the organic product obtained when cinnamaldehyde is treated with the following reagents:

I. $LiAlH_4$ in dry ether
II. $K_2Cr_2O_7$(aq), H_2SO_4(aq), heat

For each reagent, state the type of reaction that has occurred and record any observations observed. [5]



reduction



oxidation; $K_2Cr_2O_7$ solution changed from orange to green.

[Total: 11]

End of Section A

Section B

Answer any one of the two questions.

For Examiners' Use

1 **(a)** Geckos are a type of reptiles that possess the ability to adhere to almost any surface. As such, research is undergoing to develop synthetic material that resembles the feet of geckos. The main reason why geckos can adhere to any surfaces is due to the nanostructures found on their feet.

(i) State what is the nanostructure found on geckos' feet.

[1]

Spatulae

(ii) Explain how these nanostructures help geckos to stick to most surfaces.

[3]

Spatulae forms instantaneous-dipole induced-dipole interactions with the surface. As the spatulae have high surface area to volume ratio, there is a huge cumulative surface area of contact between the gecko's feet and the surface. As such, there is a strong collective adhesive force that allows the gecko to stick on the surface.

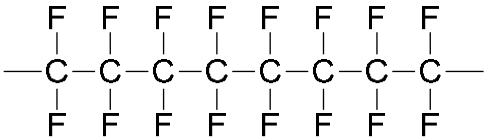
(b) One type of materials that some geckos are unable to adhere to is polytetrafluoroethylene (PTFE). PTFE is used in making non-stick pans and other cookwares.

(i) Define *polymers*.

[1]

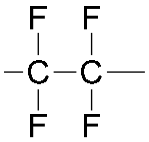
macromolecules built up from monomers, with average molar mass of at least 1000 or at least 100 repeat units.

(ii) The structure of PTFE is given below.



Draw the repeat unit that make up PTFE.

[1]



(iii) Thermoplastic and thermosetting polymers differ in their structure and bonding. Explain the differences in the rigidity and strength of thermoplastic and thermosetting polymers.

[3]

Thermoplastics are made of linear polymers whereas thermosets are made of polymers with crosslinks.

The branches of LDPE prevent maximum surface area of contact between the polymeric molecules. As a result, the instantaneous dipole-induced dipole (i.d.-i.d.) between the molecules are not extensive, less energy is required to break the i.d.-i.d. between molecules, leading to lower melting point and also greater distance of separation between the molecules. The greater distance of separation results in lower density as the mass per unit volume is smaller. The lower tensile strength arises because of the weak i.d.-i.d. too.

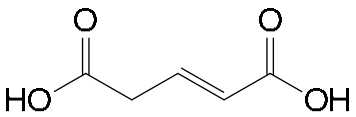
In general, branched-chain polymers would have a lower melting point, density and tensile strength than linear chain polymers of the same type.

(iv) Hence or otherwise, suggest if PTFE is a thermoplastic or thermosetting polymer. [1]

PTFE is a thermoplastic as it is a linear polymer.

For Examiners' Use

(c) Glutaconic acid is a product of hydrolysis of proteins in the human body. Excessive levels of glutaconic acid can lead to brain damage.



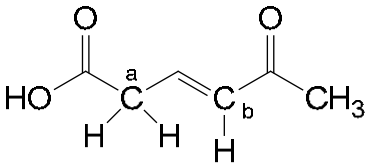
Glutaconic acid

(i) State the IUPAC name for glutaconic acid.

[1]

pent-2-ene-1,5-dioic acid / 2-pentene-1,5-dioic acid

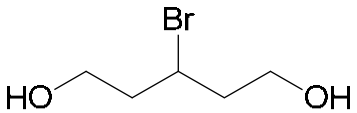
(ii) State the bond angle and shape of the carbon stated.



[2]

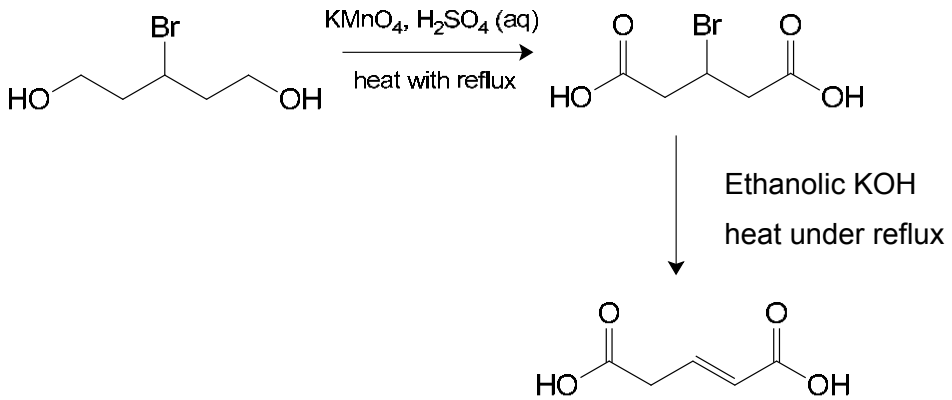
Cα: 109.5°, tetrahedral
Cβ: 120°, trigonal planar

(iii) Draw the synthetic route and suggest reagents and conditions for each step to show how glutaconic acid can be synthesised from 3-bromopenta-1,5-diol. You are required to draw the structures of all intermediates.



3-bromopenta-1,5-diol

[3]



(iv) Describe a distinguishing test between glutaconic acid and 3-bromopenta-1,5-diol. State the observations, if any.

[2]

Aqueous bromine. For 3-bromo-penta-1,5-diol, the orange aq. bromine will remain whereas for glutaconic acid orange aq bromine decolourises.

(v) Glutaconic acid is soluble in water. Explain, in terms of structure and bonding, why this happens.

[2]

Glutaconic acid is a simple covalent molecule held together by hydrogen bonds. energy evolved from the formation of hydrogen bonds with water is sufficient enough to overcome the hydrogen bonds between the glutaconic acid molecules.

[Total: 20]

2 **(a)** Transition metals are very useful in the chemical industries as they can act as catalysts. Vanadium, iron and nickel are commonly used as catalysts for various common reactions.

For Examiners' Use

(i) Write out the electronic configuration of the following particles.

V^{6+}: .....

Cr^{6+}: .....

[2]

V^{6+}: $1s^2 2s^2 2p^6 3s^2 3p^5$

Cr^{6+}: $1s^2 2s^2 2p^6 3s^2 3p^6$

(ii) Draw the shapes of the orbitals in which the valence electrons of V^{6+} occupy. [2]

(iii) Define the sixth ionisation energy of vanadium. [1]

(iv) State whether the 6th ionisation energy of vanadium is higher or lower than that of chromium. Explain your answer. [3]

It will be higher for vanadium.

V^{5+}: $1s^2 2s^2 2p^6 3s^2 \underline{3p^6}$

Cr^{5+}: $1s^2 2s^2 2p^6 3s^2 3p^6 \underline{3d^1}$

More energy is needed to remove the electron from the 3p orbital of V^{5+} as compared to the 3d orbital of Cr^{5+} as the 3p orbital is nearer to the nucleus and hence experiences weaker screening.

(v) Niobium (Nb) and tantalum (Ta) are elements below that of vanadium in the periodic table. State and explain the trend in atomic radii between the three elements.

[2]

The atomic radii increase in this manner: V > Nb > Ta.

Down the group, the number of principle quantum shells increases, hence the distance between the valence electrons and nucleus increases. As such, strength of electrostatic attraction decreases and atomic radius decrease down the group.

(b) Haber process is a very important industrial process as it is the main process involved in making of fertilisers. A similar industrial process is the Contact process, which is the process of making sulfuric acid from sulfur. The main reaction is given below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197 \text{ kJ mol}^{-1}$$

(i) State what is meant by Le Chatelier's Principle.

[1]

Le Chatelier's Principle states that when a system in equilibrium is disturbed, the position of the equilibrium will shift in a direction that tends to reduce that change so as to re-establish the equilibrium.

(ii) The reaction is carried out at 450 °C and 1.5 atm. Suggest, using Le Chatelier's Principle, why this may not be the ideal condition.

[2]

The pressure is lower / close to the atmospheric pressure. If the pressure is higher, by LCP, the equilibrium position will shift towards the right so as to where there is lesser number of gaseous molecules which will help to improve the yield.

(iii) An equilibrium was established at 700 °C in a 10 dm^3 vessel. The equilibrium amounts of sulfur dioxide, oxygen and sulfur trioxide were 10.0 mol, 4.0 mol and 25.1 mol.

Calculate K_c and state its units.

[3]

$$K_c = \frac{[SO_3]^2}{[O_2][SO_2]^2}$$

$$K_c = \frac{\left[\frac{25.1}{10}\right]^2}{\left[\frac{4.0}{10}\right]\left[\frac{10.0}{10}\right]^2} = \underline{\mathbf{15.8\ mol^{-1}dm^3}}$$

(iv) State the effect on the K_c calculated in **(b)(iii)** if the contact process is carried out at 450 °C instead of 700°C.

[1]

K_c will increase

(c) **(i)** Many of the food consumed commonly contain acids. One of them is citric acid, found in citrus fruits. The dissociation of citric acid is given below.

$$H_3C_6H_5O_7\ (aq) + H_2O\ (l) \rightleftharpoons H_2C_6H_5O_7^-\ (aq) + H_3O^+\ (aq)$$

Write the K_a expression for the dissociation of citric acid. [1]

$$K_a = \frac{[H_3O^+][H_2C_6H_5O_7^-]}{[H_3C_6H_5O_7]}$$

(ii) A sample of citric acid with the concentration of 0.01 mol dm^{-3} was obtained. The pH of the solution was measured and found to be 2.54. Calculate the concentration of H_3O^+ ions present in the solution.

[1]

$[H_3O^+] = 10^{-2.54} = 2.88 \times 10^{-3}$ mol dm^{-3}

(iii) Hence, deduce if citric acid is a strong or weak acid. Explain your answer.

[1]

Citric acid is a weak acid as $[H_3O^+]$ is smaller than that of [citric acid].

[Total: 20]

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Class	Reg Number
17	

Name _____

Calculator Model / No.

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 1

Chemistry 8873/01

Paper 1 **21 September 2018**
1 hour

Additional Material: *Data Booklet*
OMS

READ THESE INSTRUCTIONS FIRST

Write your name, class and register number in the spaces provided at the top of this page.

There are **thirty** questions in this paper. Answer **all** questions. For each question, there are four possible answers labelled **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the OMR answer sheet.

Read very carefully the instructions on the use of OMR answer sheet.

You are advised to fill in the OMR Answer Sheet as you go along; no additional time will be given for the transfer of answers once the examination has ended.

Use of OMR Answer Sheet

Ensure you have written your name, class register number and class on the OMR Answer Sheet.

Use a **2B** pencil to shade your answers on the OMR sheet; erase any mistakes cleanly. Multiple shaded answers to a question will not be accepted.

For shading of class register number on the ***OMR sheet***, please follow the given examples:
If your register number is **1**, then shade **01** in the index number column.
If your register number is **21**, then shade **21** in the index number column.

This document consists of **12** printed pages (including this cover page)

Answer all questions.

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 Zinc ethanoate, $(CH_3CO_2)_2Zn$ (M_r = 183.4) may be taken as a dietary supplement to prevent zinc deficiency.

What is the total number of ions present in a 5 cm^3 solution of aqueous zinc ethanoate given that the solution has a concentration of 10.64 g dm^{-3}?

A 1.7×10^{19} **B** 5.2×10^{20} **C** 3.5×10^{22} **D** 1.0×10^{23}

2 Gases given off during volcanic eruptions include H_2S and CS_2.

A 40 cm^3 gaseous sample of H_2S and CS_2, present in a 3 : 1 ratio respectively, was analysed by combustion using 100 cm^3 of oxygen. After measuring the volume of gas remaining, the product was treated with an excess of aqueous sodium hydroxide and the volume of gas measured again.

Any sulfur present is converted to SO_2 after combustion.

Given that all volume measurements were made under room conditions, what were the measured volumes?

	volume of gaseous mixture after burning / cm^3	volume of gaseous mixture after adding NaOH (aq) / cm^3
A	60	0
B	60	50
C	85	25
D	85	75

3 Na_3NO_4 is very sensitive to water vapour and carbon dioxide in the air and it reacts with both of them to produce equimolar amounts of $NaNO_3$, $NaHCO_3$ and compound **E**.

What is compound **E**?

A NaH **B** Na_2O

C NaOH **D** $NaNO_2$

4 Which of the following contains more than one type of chemical bond?

1 barium carbonate

2 graphene

3 water

A **1**, **2** and **3**

B **1** and **2** only

C **1** and **3** only

D **1** only

5 Consider the following reactions:

Reaction 1 $F_2 + Cl_2 \longrightarrow 2\ ClF$

Reaction 2 $3\ F_2 + 4\ NH_3 \longrightarrow 3\ NH_4F + NF_3$

Reaction 3 $3\ Cl_2 + 8\ NH_3 \longrightarrow 6\ NH_4Cl + N_2$

Which of the following correctly shows the increasing order of reducing strength of the three species, Cl_2, F_2 and NH_3?

A $F_2 < Cl_2 < NH_3$

B $Cl_2 < F_2 < NH_3$

C $NH_3 < F_2 < Cl_2$

D $NH_3 < Cl_2 < F_2$

6 Which of the following statements about A*l* is correct?

1 It has high electrical conductivity due to the ability of its ions to carry the current.

2 It has high melting point due to strong attraction between the delocalised electrons and residual cations.

3 It has stronger metallic bonding than Na.

A **1**, **2** and **3**

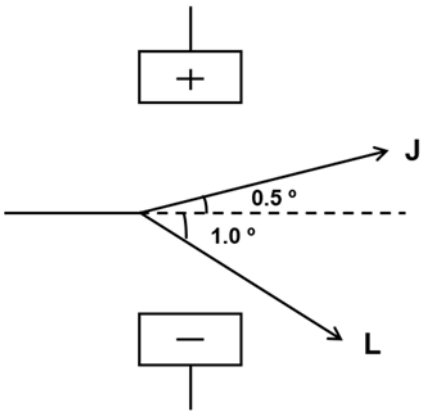
B **1** and **2** only

C **1** only

D **2** and **3** only

7 In the presence of an electric field, which of the following pair of ions will demonstrate deflection pathways as shown in the diagram below?

In this particular experimental setup, protons are deflected through an angle of 7.0º.



	J	L
A	$^{14}N^{-}$	$^{7}Li^{+}$
B	$^{18}O^{-}$	$^{27}Al^{3+}$
C	$^{16}O^{+}$	$^{32}S^{2-}$
D	$^{28}Si^{2+}$	$^{28}Si^{4-}$

8 A comparison is made of four different organic compounds with the same molar mass.

$CH_3CH_2CH_2CH_2CH_3$	$CH_3C(CH_3)_3$	$CH_3CH_2CH_2CHO$	$CH_2{=}CHCOOH$
W	**X**	**Y**	**Z**

Which of the following shows the boiling points of these compounds in the correct sequence?

	highest			lowest
A	**W**	**X**	**Y**	**Z**
B	**Y**	**Z**	**W**	**X**
C	**Z**	**Y**	**W**	**X**
D	**Z**	**Y**	**X**	**W**

9 *Use of the Data Booklet is relevant to this question.*

Bismuth–212 is an unstable isotope of bismuth with a half–life of around 60 min.

The radioactive decay of bismuth–212 follows the following scheme, giving rise to two particles, **R** and **T**:

$$^{212}_{83}\text{Bi} \longrightarrow {}^{\mathbf{a}}_{\mathbf{b}}\mathbf{R} + {}^{4}_{2}\text{He}$$

$$^{\mathbf{a}}_{\mathbf{b}}\mathbf{R} \longrightarrow {}^{\mathbf{c}}_{\mathbf{d}}\mathbf{T} + {}^{0}_{-1}\text{e}$$

Which are the likely formulae of the chlorides formed by particles, **R** and **T**?

	chloride of **R**	chloride of **T**
A	**R**Cl_2	**T**Cl_2
B	**R**Cl_2	**T**Cl_3
C	**R**Cl_3	**T**Cl_2
D	**R**Cl_3	**T**Cl_3

10 A 25 cm^3 of solution containing 0.010 mol dm^{-3} of an ion $\mathbf{G}^{4+}$ (aq) was reduced by excess zinc. After the unreacted zinc was removed, the resultant solution required 20.0 cm^3 of 0.0050 mol dm^{-3} potassium manganate(VII) to oxidise **G** back to its original +4 oxidation state.

MnO_4^- is reduced according to the equation:

$$MnO_4^- + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O$$

To what oxidation state was $\mathbf{G}^{4+}$ reduced by zinc?

A +3 **B** +2 **C** +1 **D** 0

11 The hydrolysis of the anticancer drug *cis–platin* in water follows a first–order kinetics with a rate constant of 0.09 h^{-1} at 25 °C.

How long will it take for the concentration of a freshly prepared aqueous solution of *cis–platin* to decrease to 18% of its original concentration?

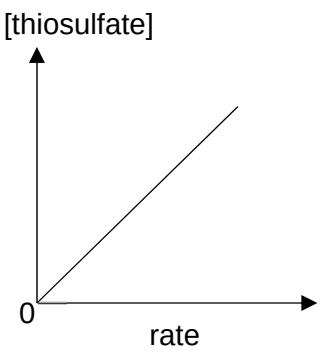
A 7.7 h **B** 15.4 h

C 19.0 h **D** 42.8 h

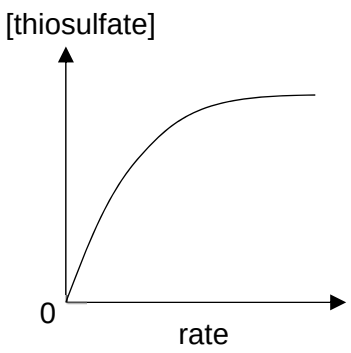
12 In the reaction between aqueous sodium thiosulfate and dilute acid, the reaction is found to be first order with respect to thiosulfate.

Which graph represents the experimental results?

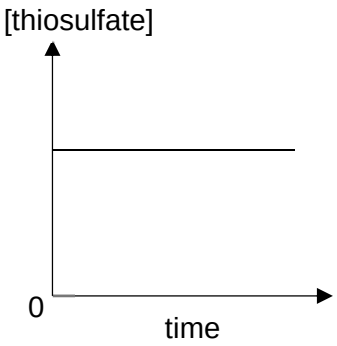
A



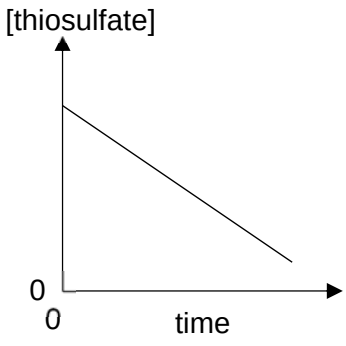
B



C



D



13 Which statement **best** defines the term *bond energy* for HF?

A Energy released when one mole of HF is formed from its gaseous ions.

B Energy released when one mole of HF is formed from its gaseous atoms.

C Energy required when one molecule of HF is broken into its gaseous atoms.

D Energy required when one mole of HF is broken into its gaseous atoms.

14 The values for the standard enthalpy changes of formation of iron(II) oxide, FeO (s), and aluminium oxide, Al_2O_3 (s) are –266 kJ mol^{-1} and –1676 kJ mol^{-1} respectively.

$$3FeO\ (s) + 2Al\ (s) \longrightarrow 3Fe\ (s) + Al_2O_3\ (s)$$

What is the standard enthalpy change for the above reaction?

A +878 kJ mol^{-1}

B –878 kJ mol^{-1}

C +1410 kJ mol^{-1}

D –1410 kJ mol^{-1}

15 Which of the following enthalpy changes is always exothermic?

1 standard enthalpy change of formation

2 standard enthalpy change of combustion

3 standard enthalpy change of neutralisation

4 standard enthalpy change of reaction

A **1**, **2**, **3** and **4**

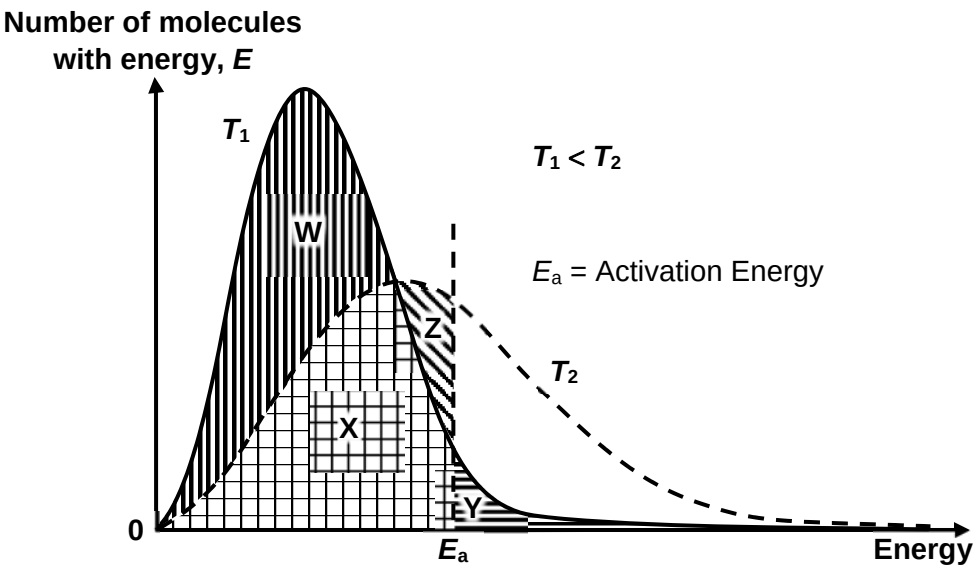
B **1** and **2** only

C **2** and **4** only

D **2** and **3** only

16 The distribution of the fraction of molecules with energy for two temperatures, T_1 and T_2 are shown in the diagram below.

W, **X**, **Y** and **Z** refer to the different shaded areas under the two graphs.



Which of the following expressions gives the **increase** in fraction of molecules having at least the activation energy at higher temperature, T_2?

A $\dfrac{\mathbf{Y}}{\mathbf{X+Y+Z}}$

B $\dfrac{\mathbf{Z}}{\mathbf{X+Y+Z}}$

C $\dfrac{\mathbf{X-Z}}{\mathbf{W+X+Y}}$

D $\dfrac{\mathbf{W-Z}}{\mathbf{W+X+Y}}$

17 Which of the following statements about a catalyst is correct?

1 A catalyst increases both the rate of the forward and backward reaction.

2 A catalyst increases the rate of reaction through affecting the rate constant.

3 A catalyst increases the rate of reaction through decreasing the enthalpy change of the reaction, ΔH.

4 A catalyst increases the rate of reaction through increasing the average kinetic energy of the reactant particles.

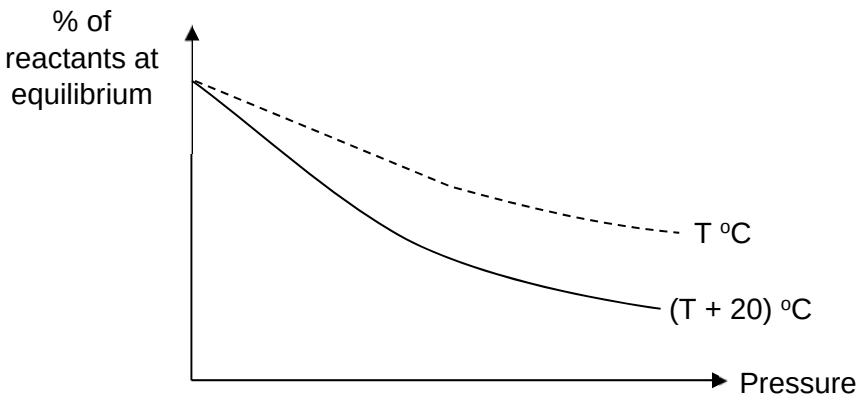
A **1**, **2** and **4** only

B **1** and **2** only

C **2** and **3** only

D **2** and **4** only

18 The graphs below show the variation of the percentage of gaseous reactants present at equilibrium, with temperature and pressure.



Which of the following systems could the graphs represent?

A $2N_2(g) + O_2(g) \rightleftharpoons 2N_2O(g)$ $\Delta H = +82$ kJ mol^{-1}

B $CO_2(g) + C(s) \rightleftharpoons 2CO(g)$ $\Delta H = +173$ kJ mol^{-1}

C $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -92$ kJ mol^{-1}

D $3O_2(g) + 4NH_3(g) \rightleftharpoons 2N_2(g) + 6H_2O(g)$ $\Delta H = -1248$ kJ mol^{-1}

19 Platinum and rhodium nanoparticles are used in catalytic converters of motor cars.

Which reaction in the catalytic converter does **not** remove hazardous and polluting gases from the exhaust fumes?

These equations are qualitative and unbalanced.
[HC = unburnt hydrocarbon; NO_x = oxides of nitrogen]

A $HC + NO_x \longrightarrow H_2O + CO + N_2$

B $CO + NO_x \longrightarrow CO_2 + N_2$

C $HC + NO_x \longrightarrow H_2O + CO_2 + N_2$

D $CO + O_2 \longrightarrow CO_2$

20 What is the volume of deionised water that needs to be added to a 10 cm^3 of 0.0100 mol dm^{-3} calcium hydroxide to have a resultant solution with pH of 11.5?

A 21.6 cm^3 **B** 31.6 cm^3

C 53.2 cm^3 **D** 63.2 cm^3

21 The table shows some data of two acid–base indicators.

indicator	approximate pH range of colour change	colour change	
		acid	alkali
bromophenol–blue	3.0 – 4.6	yellow	purple
phenol–red	6.8 – 8.5	yellow	red

Which conclusion can be drawn about a solution when it turns bromophenol–blue purple and phenol–red yellow?

A The solution is strongly acidic.

B The solution is weakly acidic.

C The solution is strongly alkaline.

D The solution is weakly alkaline.

22 Which of the following is correctly arranged in order of **decreasing** values?

A atomic radius of P, S, C*l*

B melting point of P, S, C*l*

C first ionisation energy of Na, Mg, A*l*

D electrical conductivity of Na, Mg, A*l*

23 The properties of the oxides of four elements in Period 3, **E, F, G** and **H** are given below.

1	The oxide of **E** is amphoteric.
2	The oxide of **F** dissolves in water to form a strongly alkaline solution.
3	The oxide of **G** reacts with dilute sodium hydroxide at room temperature.
4	The oxide of **H** is insoluble in water but is soluble in concentrated sodium hydroxide.

Which of the following shows the correct sequence of the four elements in order of increasing proton number?

A **F**, **E**, **G**, **H**

B **F**, **E**, **H**, **G**

C **G**, **F**, **E**, **H**

D **G**, **F**, **H**, **E**

24 Which of the following statements explains the trend in thermal stability of hydrogen halides down the group?

A Hydrogen halide bond becomes less polar down the group.

B Electron cloud size of hydrogen halide molecules increases down the group.

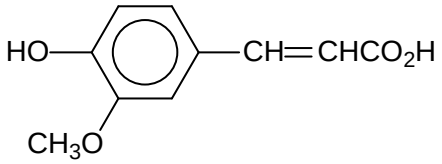
C Bond energy of hydrogen halide decreases more than the bond energy of the halogens.

D Less energy is required to break the permanent dipole – permanent dipole attractive forces in the hydrogen halides down the group.

25 How many isomers (including both constitutional and cis–trans isomers) are possible for C_4H_7Cl?

A 9 **B** 10 **C** 11 **D** 12

26 Ferulic acid is an antioxidant that occurs widely in plants.

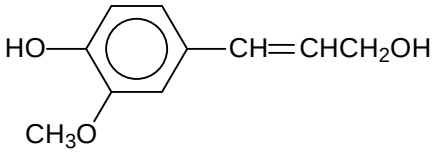


ferulic acid

Which of the following statements is true about ferulic acid?

1 It decolourises aqueous bromine.

2 It is not very soluble in water but dissolves in aqueous NaOH.

3 It can be prepared from 

using hot acidified $K_2Cr_2O_7$.

A **1**, **2** and **3**

B **1** and **2** only

C **1** only

D **2** and **3** only

27 Compound **T** can be converted to a compound **U** as shown below.

$$\underset{\textbf{T}}{CH_3COCH_2COOH} \xrightarrow{\textbf{I}} CH_3CH(OH)CH_2COOH \xrightarrow{\textbf{II}} \underset{\textbf{U}}{CH_3CH(OH)CH_2CONHCH_3}$$

Which of the following statements is **incorrect** with regards to the given reaction scheme?

A Stage **I** may involve the use of sodium borohydride.

B Stage **I** may involve the use of lithium aluminium hydride.

C Stage **II** may involve the use of DCC and methylamine.

D Stage **II** may involve the use of $CH_3CH(OH)CH_2COCl$ and methylamine.

28 Which of the following compounds are formed when $CH_3CO_2CH_2NHCOCH_3$ is heated under reflux with excess aqueous sodium hydroxide?

A $CH_3CO_2CH_2NH_2$ and CH_3COOH

B $CH_3CO_2CH_2NH_2$ and CH_3COONa

C CH_3COOH and $HOCH_2NH_2$

D CH_3COONa and $HOCH_2NH_2$

29 A section of nylon–6,6 is shown below.

$$–CO(CH_2)_4CONH(CH_2)_6NHCO(CH_2)_4CONH(CH_2)_6NH–$$

Which monomers could form this polymer?

A $NH_2(CH_2)_6NH_2$ and $CH_3(CH_2)_3CO_2H$

B $NH_2(CH_2)_6NHCO_2H$ and $CH_3(CH_2)_3CO_2H$

C $NH_2(CH_2)_6NH_2$ and $HO_2C(CH_2)_4CO_2H$

D $CH_3(CH_2)_5NH_2$ and $HO_2C(CH_2)_4CONH_2$

30 LDPE is used to make plastic bags while and HDPE is used to make milk jug.

Which of the following statements is true about these substances?

1 LDPE is flexible and HPDE is rigid.

2 LDPE comprises of shorter branched polymer chains while HPDE comprises of longer linear polymer chains.

3 LDPE and HDPE can be generated from propene using appropriate catalysts and reaction conditions.

A **1**, **2** and **3**

B **1** and **2** only

C **1** only

D **1** and **3** only

END OF PAPER

Class	Reg Number
17	

Name _____

Calculator Model / No.

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 1

Chemistry 8873/02

Paper 2 **13 September 2018**
2 hours

Additional Material: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

Write your name, class and register number in the spaces at the top of this page.

This booklet contains Section **A** and Section **B**.

Section A (60 marks): Page 2 to 15
Answer **all** questions in the spaces provided. You are advised to spend about **1 h 30 min** on Section **A**.

Section B (20 marks): Page 16 to 24
Answer **one** question in Section **B** in the spaces provided You are advised to spend about **30 min** on Section **B**.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question.

Examiner's Use		
Paper 1	MCQ	/ 30
		/ 33 %
Paper 2 Section A	Q1	/ 15
	Q2	/ 17
	Q3	/ 16
	Q4	/ 12
Paper 2 Section B		/ 20
Paper 2 Total		/ 80
		/ 67 %
Grand Total		/ 100 %
Grade		

This document consists of **24** printed pages. (inclusive of this cover page)

Section A

Answer **all** questions in this section, in the spaces provided.

1 Chemists have long studied the trend of elements, and the Periodic Table was celebrated as an effective way to arrange the elements while reflecting some of the most well-known trends in their physical and chemical properties.

(a) Using structure and bonding, describe and explain the variation in melting points for elements aluminium to phosphorous.

[4]

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(b) **(i)** The ionisation energies of Period 3 elements from sodium to argon generally increases, with the exception of two decreases: from Mg to A*l*, and from P to S.

Explain these two anomalies in the trend.

[2]

From Mg to A*l*

.....

.....

.....

From P to S

.....

.....

.....

(ii) An element from Period 3 was found to have the following successive ionisation energy values. Deduce the identity of this element.

Ionisation Energy	1st	2nd	3rd	4th	5th	6th	7th	8th
Value / kJ mol^{-1}	790	1600	3200	4400	16000	20000	24000	29000

[1]

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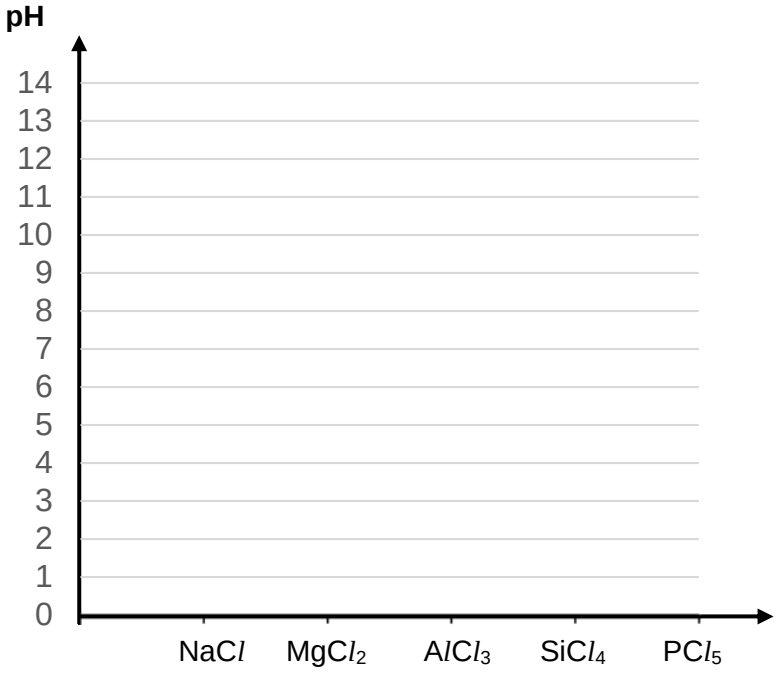
(c) Chlorides of Period 3 elements display a wide range of properties.

(i) The pH of the resultant solution when Period 3 chlorides dissolves in or react with water shows a periodic trend. Sketch the pH trend from NaC*l* to PCl_5.

[1]



(ii) Write an equation for the reaction of PCl_5 with water.

[1]

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(iii) One of the Period 3 chlorides and $BeCl_2$ have similar reaction with water. Identify this Period 3 chloride and explain why these two chlorides have similar chemical reactivity.

[1]

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(d) Describe and explain the relative reactivity of elements of Group 17 as oxidising agents.

[2]

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(e) At the nanoscale, new properties may emerge in certain compounds.

For example, graphene is known to have very high tensile strength and high electrical conductivity. Describe the structure of graphene and explain how its structure relates to these two properties.

[3]

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[Total: 15]

2(a) Nearly all petrol and diesel vehicles have some kind of catalytic converter fitted to the exhaust to reduce the amount of pollutants emitted into the environment. The catalytic converter usually contains palladium nanoparticles which act as catalyst.

(i) Define the term nanoparticles.

[1]

(ii) Explain why palladium used is in the form of nanoparticles instead of its bulk form.

[2]

(iii) The palladium catalyst helps to remove carbon monoxide from the exhaust. For example,

$$CO + \frac{1}{2} O_2 \longrightarrow CO_2$$

State the **type** of catalyst and outline the mode of action of catalyst in this reaction.

[2]

(b) Carbon monoxide, water and propene can be used to produce butanoic acid according to the following equation:

$$CO + H_2O + CH_3CH{=}CH_2 \xrightarrow{\text{metal catalyst}} CH_3CH_2CH_2CO_2H$$

Draw the structure of the product formed when 2-methylpropene is used in the above reaction.

[1]

(c) Propene can be converted to propanone by the following route.

$$CH_3CH{=}CH_2 \xrightarrow{\mathbf{I}} CH_3CHC\mathit{l}CH_3 \xrightarrow{\mathbf{II}} CH_3CH(OH)CH_3 \xrightarrow{\mathbf{III}} CH_3COCH_3$$

(i) Suggest the types of reaction for steps **I** and **III**.

[2]

	step **I**	step **III**
type of reaction		

(ii) State the reagent and conditions for step **II**.

[1]

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(iii) State and explain how the rate of reaction for step **II** changes when 2-chloropropane is replaced by 2-iodopropane

[2]

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(d) The kinetics of the acid-catalysed reaction of propanone with iodine

$$CH_3COCH_3(aq) + I_2(aq) \xrightarrow{H^+(aq)} CH_2ICOCH_3(aq) + HI\ (aq)$$

can be investigated experimentally by varying the concentrations of the three substances involved and determining the time for the colour of the iodine to disappear.

In this method the rate of the reaction is measured in terms of the rate at which the iodine changes, i.e.

$$\text{rate} \propto \frac{\text{volume of aqueous iodine used}}{\text{time for the colour of iodine to disappear}}$$

The following results were obtained in such an investigation.

Expt	Volume of CH_3COCH_3 / cm^3	Volume of I_2 / cm^3	Volume of H^+ / cm^3	Volume of H_2O / cm^3	Relative time for the colour of iodine to disappear
1	8	4	8	0	1
2	8	4	4	4	2
3	4	4	8	4	2
4	8	2	8	2	0.5

(i) Deduce the order of reaction with respect to propanone, iodine and hydrogen ions.

[3]

propanone

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iodine

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hydrogen ions

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(ii) Hence write the rate equation for this reaction.

[1]

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(iii) Another experiment, with 0.80 mol dm^{-3} propanone, 0.0010 mol dm^{-3} iodine and 0.20 mol dm^{-3} hydrochloric acid, is carried out at the same temperature.

Calculate the value of the rate constant if the rate is 4.2×10^{-6} mol dm^{-3} s^{-1}. Give the units of the rate constant.

[2]

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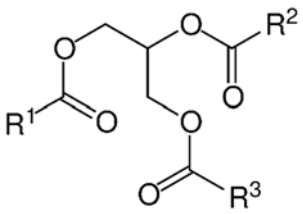
[Total: 17]

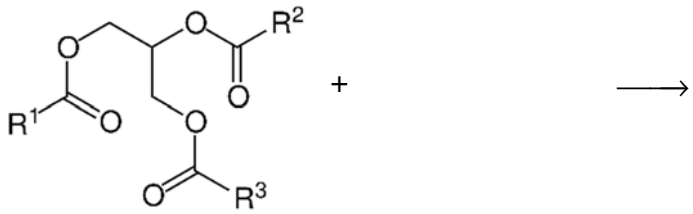
3(a) Limited scientific evidence suggests that eating two tablespoons of olive oil daily may reduce the risk of coronary heart disease. Olive oil comprises mainly of the mixed triglyceride esters of oleic acid, palmitic acid and other fatty acids. The general chemical structure of olive oil is shown below where R^1, R^2 and R^3 are alkyl groups or alkenyl groups.



Olive oil undergoes rancidification when exposed to moisture, resulting in an unpleasant taste and odour. The products formed in the reaction are propane-1,2,3-triol and fatty acids.

Complete the equation to illustrate the rancidification reaction of olive oil.

[1]



(b) Oleic acid has the structure shown.

$$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$$

(i) Describe the bonding in C=C in terms of orbital overlap. Draw a diagram to illustrate your answer.

[2]

(ii) Oleic acid exists as a pair of isomers.

Draw and label the structural formulae of the two isomers.

[2]

(iii) Describe a chemical test that would distinguish oleic acid from ethanoic acid.

[2]

(c) **Fig. 3.1** shows a bomb calorimeter, inside a controlled temperature water jacket, which is used to find an accurate value of standard enthalpy change of combustion of oleic acid.

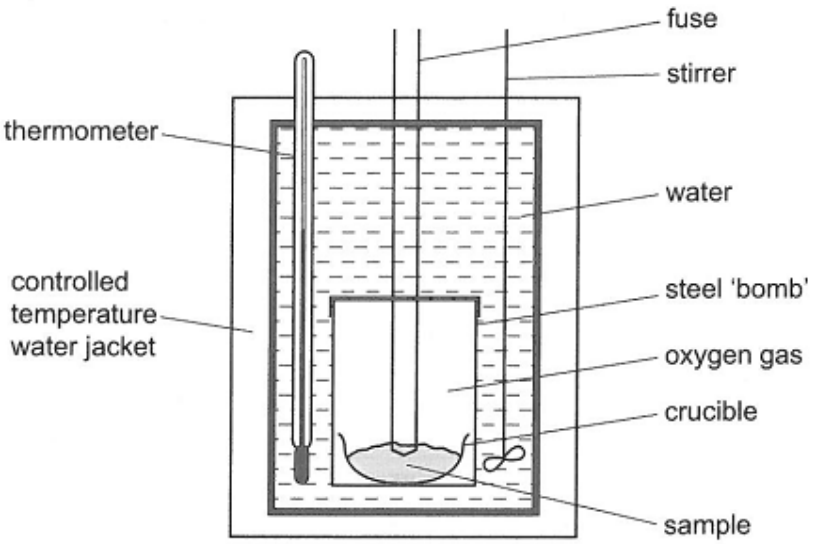


Fig. 3.1

(i) What is meant by the *standard enthalpy change of combustion* of oleic acid?

[1]

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(ii) Explain why the steel 'bomb' is flushed with a high pressure of oxygen at the start of the experiment.

[1]

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(iii) There is no heat lost from the calorimeter because of the controlled temperature water jacket.

Suggest how the controlled temperature water jacket achieves this.

[1]

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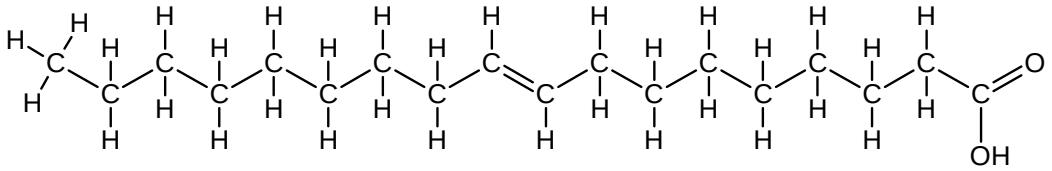
(iv) A 2.98 g sample of oleic acid ($C_{18}H_{34}O_2$) is burned in a bomb calorimeter with a heat capacity of 1.98 kJ K^{-1}. The temperature of the calorimeter increases by 59.3 ^{o}C.

Calculate the standard enthalpy change of combustion of oleic acid.

[2]

(v) Use the bond energies given in the *Data Booklet* to calculate another value for the standard enthalpy change of combustion of oleic acid.



oleic acid

You may find the following information useful in your calculation.
An oleic acid ($C_{18}H_{34}O_2$) molecule contains 33 C–H bonds,16 C–C bonds and other bonds.

[3]

(vi) Suggest a reason for the discrepancy between the value in **(c)(iv)** and that in **(c)(v).**

[1]

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[Total: 16]

4(a) There are two types of polymerisation, addition and condensation

Account for the differences between these two types of polymerisation.

[2]

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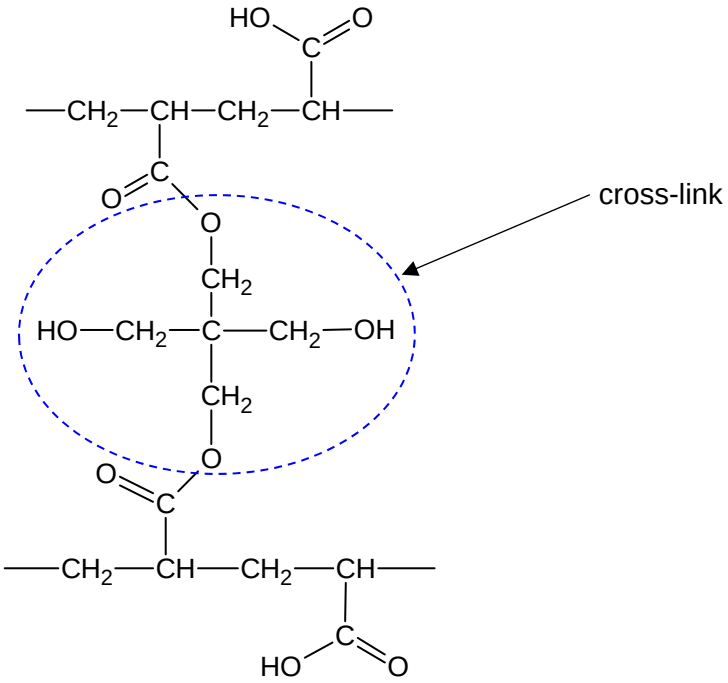
(b) Super-absorbent polymers have the ability to absorb 200 – 300 times their own mass of water. They are classified as hydrogels and are widely used in personal disposable hygiene products such as diapers. However, these synthetically made hydrogels are usually non-biodegradable.

The diagram below shows part of the structure of a hydrogel.



The hydrogel is formed from chains of one polymer which are then cross-linked using another molecule.

(i) State the type of polymerisation used to form these polymer chains.

[1]

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(ii) Draw the **displayed** structural formula of the monomer used.

[1]

(iii) Draw the structure of the molecule used to cross-link the polymer chains.

[1]

(iv) Once a hydrogel has absorbed water, it can be dried and re-used many times. Explain why this is possible, referring to the structure.

[1]

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(v) The amount of cross-linking has little effect on the ability of the gel to absorb water. Suggest why this is the case.

[1]

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(vi) Suggest one property of the hydrogel that will change if more cross-linking takes place. Explain how the increased cross-linking brings about this change.

[2]

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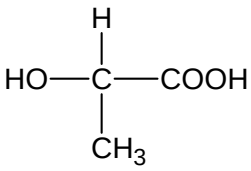
(c) Unlike hydrogel, the polymer, 'polyactide' or PLA is biodegradable. The monomer required to produce PLA is *lactic acid*, 2-hydroxypropanoic acid.

The structure of *lactic acid* is as shown.



(i) Draw the structure of the polymer PLA, showing **two** repeat units.

[1]

One of the reasons PLA has attracted so much attention is that it is biodegradable. This does, however restrict some potential uses. The polymer has a melting point of around 175 °C , but soften between 60 – 80°C. However, its properties enable it to have a range of uses in food packaging and in fibres.

(ii) Explain why PLA would not be a suitable packaging materials for food pickled in vinegar.

[1]

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(iii) Suggest why PLA containers are not usually used to hold hot drinks.

[1]

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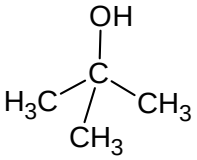
[Total: 12]

END OF SECTION A

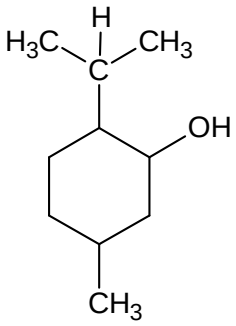
Section B

Answer **one** question from this section, in the spaces provided.

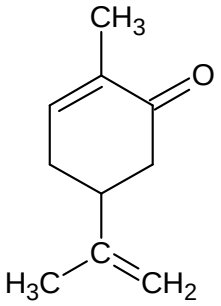
5(a) Three natural–occurring compounds used commercially are shown below:



2 methylpropan–2–ol



Menthol

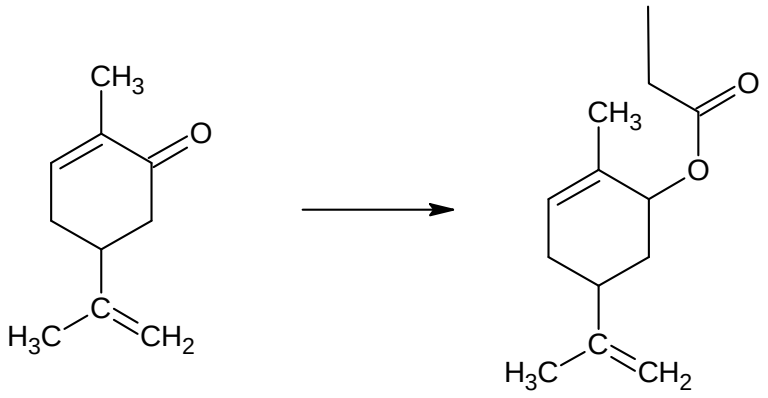


Carvone

(i) Describe a set of two chemical tests that can be used to distinguish the above three compounds. Write an equation for each reaction that takes place.

[5]

(ii) Carvone can be converted to organic compound **D** in two steps.



Carvone Compound **D**

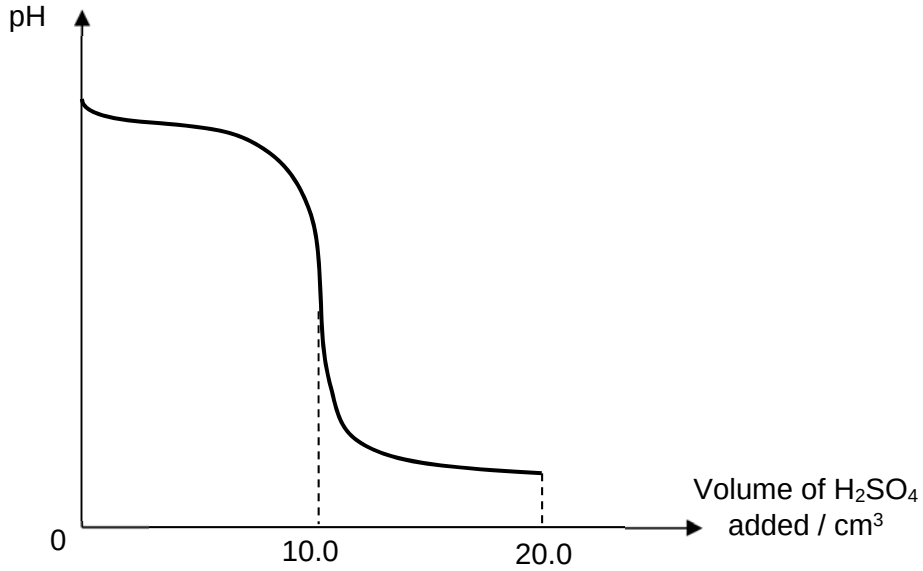
State the reagents and conditions necessary for each step. Give the structure of the intermediate involved in the conversion.

[3]

(b) Ammonia was used in smelling salts to treat fainting. Modern smelling salt solution may contain other products such as lavender oil to act in conjunction with aqueous ammonia.

When 40 cm^3 of aqueous ammonia was titrated against 0.200 mol dm^{-3} sulfuric acid, H_2SO_4 using a pH meter, the following graph was obtained.

$$2NH_3\,(aq) + H_2SO_4\,(aq) \longrightarrow (NH_4)_2SO_4\,(aq)$$



(i) Explain what is meant by the terms *Bronsted–Lowry base* and *conjugate acid–base pair*. Illustrate your explanation using ammonia in the above reaction with sulfuric acid.

Explain why the *Arrhenius* definition of base does not apply for ammonia in the above reaction.

[3]

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(ii) Write an expression for the base dissociation constant, K_b, of ammonia.

[1]

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(iii) Using the titration curve provided, state the volume of sulfuric acid needed for the exact neutralisation of 40 cm^3 of aqueous ammonia. Hence, calculate the initial concentration of aqueous ammonia.

[2]

(iv) The resultant solution at the end of the titration can be considered as a sulfuric acid solution of concentration 0.0333 mol dm^{-3}. Calculate the pH of this resultant solution to 2 decimal place.

[1]

(v) Suggest an appropriate indicator for the titration, giving a reason for your choice.

[1]

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(vi) Explain what do you understand by the term *buffer solution*.

[1]

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(vii) The *Henderson–Hasselbalch* equation is useful for the estimation of the pH of a buffer solution. An alternative form of the equation is shown below which can be used to determine the pOH of a basic buffer solution.

$$pOH = pK_b + \log_{10}\frac{[BH^+]}{[B]}$$

Calculate the pH of a basic buffer solution, if the solution contains NH_4^+ and NH_3 in a 2 : 1 ratio, given that the base dissociation constant, K_b of ammonia, NH_3 is 1.78×10^{-5} mol dm^{-3}.

[2]

(viii) The enthalpy changes of neutralisation involving sulfuric acid with two bases are shown below.

sodium hydroxide, NaOH	– 57.3 kJ mol^{-1}
ethylamine, $CH_3CH_2NH_2$	– 51.5 kJ mol^{-1}

Comment and explain for the above observation as fully as you can.

[1]

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[Total: 20]

6(a) Hydroxylamine, NH_2OH is commonly used in photography developing solution. Prolonged exposure to hydroxylamine by photography developers might cause irritation to their respiratory tract. To minimise the health hazard on these developers, the safety limit of the concentration of hydroxylamine is capped at below 0.00200 mol dm^{-3}.

A scientist performed the following experiment to determine if a sample of photography developing solution was within the safety limit.

100 cm^3 of NH_2OH solution was added to 40 cm^3 of 0.015 mol dm^{-3} acidified I_2 (aq) solution. In this reaction, iodine is used in excess and NH_2OH is oxidised to form dinitrogen monoxide, N_2O.

(i) Using half-equations, write a balanced equation for the reaction between NH_2OH (aq) and I_2 (aq) in an acidic medium.

[2]

Reduction: _____

Oxidation: _____

Overall: _____

A 25.0 cm^3 aliquot of the resultant reaction mixture was then titrated with a standard solution of 0.00500 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$ (aq).

$$I_2\ (aq) + 2\ S_2O_3^{2-}\ (aq) \longrightarrow 2I^-\ (aq) + S_4O_6^{2-}\ (aq)$$

Starch solution was added as indicator for this titration to enhance the contrast of the colour change at the end-point of the titration. 22.50 cm^3 of $Na_2S_2O_3$ (aq) was required.

(ii) State the expected colour change at the end-point of the titration.

[1]

_____

(iii) Calculate the amount of I_2 remaining in the reaction mixture.

[2]

(iv) Calculate the concentration of NH_2OH in 100 cm^3 sample of the photography developing solution. Hence conclude whether the solution is within the safety limit.

[2]

(v) Iodate(V) ion, IO_3^- was used to generate iodine required for the reaction with NH_2OH.

In this IO_3^- ion, the central iodine atom can expand its octet structure. Draw the dot-and-cross diagram of IO_3^- ion.

[1]

(vi) From your answer in **(a)(v)**, state the bond angle around the central iodine atom and account for the shape of IO_3^- ion.

[2]

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(b) In an industrial process, 5 mol of dinitrogen tetroxide, N_2O_4 and 7 mol of nitrogen monoxide, NO was heated in a 2.0 dm^3 vessel. The temperature is kept at 500 °C. The two gases react slowly to form blue dinitrogen trioxide, N_2O_3 according to the following equation. It was found that the equilibrium mixture contains 2.3 mol of NO.

$$N_2O_4\,(g) + 2NO\,(g) \rightleftharpoons 2N_2O_3\,(g) \qquad \Delta H = -30.5\ kJmol^{-1}$$

(i) Write an expression for the equilibrium constant, K_c for the reaction, stating the units.

[1]

(ii) Determine the equilibrium concentrations of the three gases. Hence, calculate the value of K_c.

[2]

(iii) Predict and explain the effect of increasing temperature on the equilibrium position and equilibrium composition.

[2]

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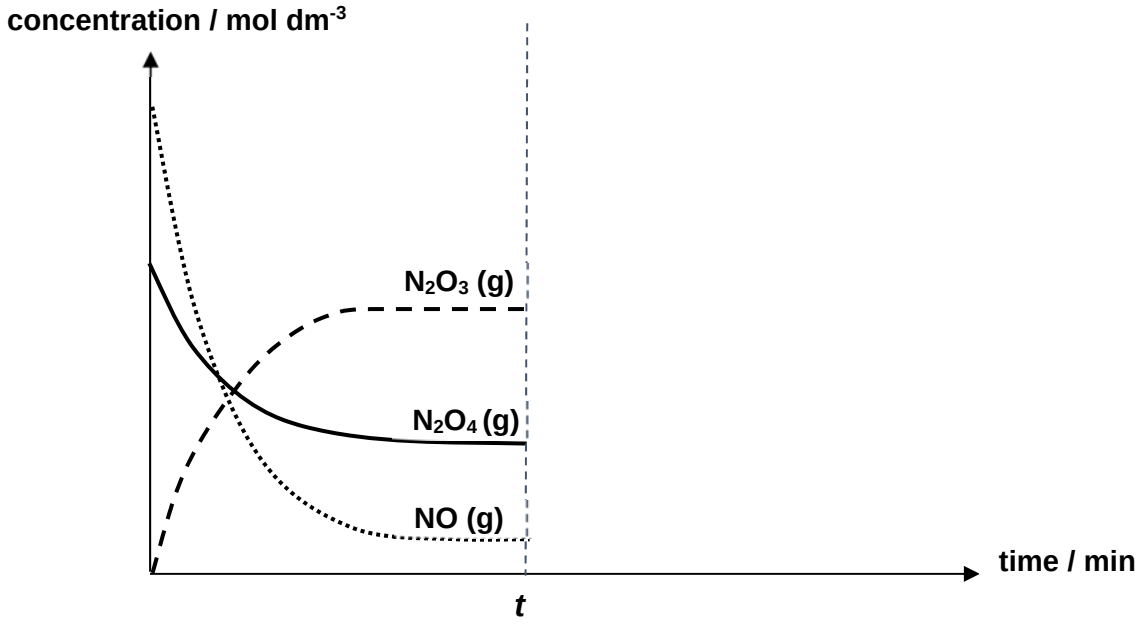
(iv) Sketch on the same axes, how the concentration of the three gases will change when temperature was increased at ***t***.

[2]



(v) State the operating pressure and temperature (high or low) required to obtain a high yield of N_2O_3. Explain your answer.

[2]

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(vi) Hence, suggest why the operating temperature is fixed at a moderately high temperature of 500 °C.

[1]

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[Total: 20]

END OF PAPER

Name **Suggested Solutions**

Class	Reg Number
17	

Calculator Model / No.

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 1

Chemistry 8873/01

Paper 1 **21 September 2018**
1 hour

Additional Material: *Data Booklet*
OMS

READ THESE INSTRUCTIONS FIRST

Write your name, class and register number in the spaces provided at the top of this page.

There are **thirty** questions in this paper. Answer **all** questions. For each question, there are four possible answers labelled **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the OMR answer sheet.

Read very carefully the instructions on the use of OMR answer sheet.

You are advised to fill in the OMR Answer Sheet as you go along; no additional time will be given for the transfer of answers once the examination has ended.

Use of OMR Answer Sheet

Ensure you have written your name, class register number and class on the OMR Answer Sheet.

Use a **2B** pencil to shade your answers on the OMR sheet; erase any mistakes cleanly. Multiple shaded answers to a question will not be accepted.

For shading of class register number on the ***OMR sheet***, please follow the given examples:
If your register number is **1**, then shade **01** in the index number column.
If your register number is **21**, then shade **21** in the index number column.

This document consists of **13** printed pages (including this cover page)

Qn	Ans
1	B
2	C
3	C
4	D
5	A
6	D
7	A
8	C
9	C
10	B

Qn	Ans
11	C
12	A
13	D
14	B
15	D
16	D
17	B
18	A
19	A
20	C

Qn	Ans
21	B
22	A
23	B
24	C
25	C
26	A
27	B
28	D
29	C
30	B

1 **Answer: B**

Explanation:

$[(CH_3CO_2)_2Zn] = \frac{10.64}{183.4} = 0.0580$ mol dm^{-3}

Amount of $(CH_3CO_2)_2Zn = \frac{5}{1000} \times 0.0580 = 2.90 \times 10^{-4}$ mol

$(CH_3CO_2)_2Zn \equiv 2CH_3CO_2^- \equiv Zn^{2+}$

Total amount of ions = $3 \times 2.90 \times 10^{-4} = 8.70 \times 10^{-4}$ mol

Total number of ions = $8.70 \times 10^{-4} \times 6.02 \times 10^{23}$ = 5.2×10^{20} ions

2 **Answer: C**

Volume of H_2S = $\frac{3}{4} \times 40$ **= 30 cm³ and volume of CS_2 =** $\frac{1}{4} \times 40$ **= 10 cm³**

Combustion equations:

$H_2S\,(g) + \frac{3}{2}O_2\,(g) \rightarrow SO_2\,(g) + H_2O\,(l)$ and

30 cm³ 45 cm³ 30 cm³

$CS_2\,(g) + 3O_2\,(g) \rightarrow CO_2\,(g) + 2SO_2$

10 cm³ 30 cm³ 10 cm³ 20 cm³

Total volume of SO_2 formed = 30 + 20 = **50 cm³**

Volume of CO_2 formed = **10 cm³**

volume of O_2 remaining = 100 – (45 + 30) = **25 cm³**

Volume of gaseous mixture after burning = 50 + 10 + 25 = **85 cm³**

Since CO_2 and SO_2 are acidic gases, they will be removed by NaOH (aq)

therefore, **Volume of gaseous mixture after adding NaOH (aq)** = 85 – 60 = **25 cm³**

3 **Answer: C**

By conservation of mass,

$Na_3NO_4 + H_2O + CO_2 \longrightarrow NaNO_3 + NaHCO_3 + NaOH$

4 **Answer: D**

Option 1 Bonding in barium carbonate: ionic between Ba^{2+} and CO_3^{2-}, covalent within CO_3^{2-}

Option 2 Bonding in graphene: covalent only between C atoms

Option 3 Bonding in water: covalent only between H and O atoms

5 **Answer: A**

By considering change in oxidation number of element:

Reaction 1 $F_2 + Cl_2 \longrightarrow 2ClF$

0 0 +1 –1

Cl_2 acts as reducing agent hence it is a stronger reducing agent than F_2.

Reaction 2 $3F_2 + 4NH_3 \longrightarrow 3NH_4F + NF_3$

0 –3 –1 +3

NH_3 acts as reducing agent hence it is a stronger reducing agent than F_2.

Reaction 3 $3Cl_2 + 8NH_3 \longrightarrow 6NH_4Cl + N_2$

0 –3 –1 0

NH_3 acts as reducing agent hence it is a stronger reducing agent than Cl_2.

NH_3 is the **strongest reducing agent** whereas **F_2** is the **weakest reducing agent**.

6 **Answer: D**

Statement **1** is incorrect as electrical conductivity in metals is due to the delocalised electrons, not mobile ions.

Statement **2** is correct as melting involves overcoming of the strong metallic bonds arising from the strong electrostatic forces attraction between the delocalised electrons and the residual metallic cations.

Statement **3** is correct as A*l* contribute more delocalised electrons than Na and this contributes to stronger metallic bonds.

7 **Answer: A**

J must be an **anion** (deflected towards positive terminal) while **L** is a **cation** (deflected towards negative plate). Options **C** and **D** are incorrect.

$\frac{q}{m}$ ratio for proton ($^{1}H^{+}$ nuclei) = $\frac{1}{1}$ ➔ **7.0°** **(deflected towards negative plate)**

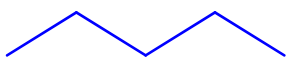
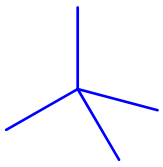
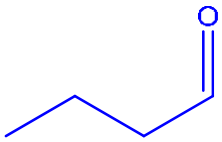
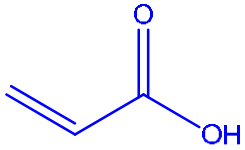
$\frac{q}{m}$ ratio for $^{14}N^{-}$ = $-\frac{1}{14}$ hence angle of deflection of $^{14}N^{-}$ = $-\frac{1}{14} \times 7.0°$ = **– 0.5°** **(deflected towards positive plate)**

$\frac{q}{m}$ ratio for $^{7}Li^{+}$ = $+\frac{1}{7}$ hence angle of deflection of $^{7}Li^{+}$ = $+\frac{1}{7} \times 7.0°$ = **+1.0°** **(deflected towards negative plate)**

$\frac{q}{m}$ ratio for $^{18}O^{-}$ = $-\frac{1}{18}$ hence angle of deflection of $^{18}O^{-}$ = $-\frac{1}{18} \times 7.0°$ = –0.4° (deflected towards positive plate)

$\frac{q}{m}$ ratio for $^{27}Al^{3+}$ = $+\frac{3}{27}$ hence angle of deflection of $^{27}Al^{3+}$ =$+\frac{3}{27} \times 7.0°$ = +0.8° (deflected towards negative plate)

8 **Answer: C**

W	X	Y	Z
$CH_3CH_2CH_2CH_2CH_3$	$CH_3C(CH_3)_3$	$CH_3CH_2CH_2CHO$	$CH_2{=}CHCOOH$
 non–polar, straight chain	 non–polar, spherical	 polar (no hydrogen bonding between molecules)	 polar (hydrogen bonding present between molecules)
id–id	id–id (less extensive)	pd–pd	Hydrogen bonds
b.p. 36.1 °C	b.p. 10 °C	b.p. 74.8 °C	b.p. 141 °C

9 **Answer: C**

$^{212}_{83}Bi \rightarrow {}^{208}_{81}\mathbf{Tl} + {}^{4}_{2}He$

$^{208}_{81}\mathbf{Tl} \rightarrow {}^{208}_{82}\mathbf{Pb} + {}^{0}_{-1}e$

R is T*l* and **T** is Pb. Since T*l* and Pb belong to Group 13 and 14 respectively, the likely formulae of chlorides formed with T*l* and Pb in this context are T*l*C*l*$_3$ (**RC*l*$_3$**) and PbC*l*$_2$ (**TC*l*$_2$**) respectively.

10 **Answer: B**

Initial amount of $\mathbf{G}^{4+}$ = $\frac{25}{1000}$ x 0.010 = 2.50 x 10^{-4} mol

Let the product formed be G^{n+}

Amount of G^{n+} in resultant solution = 2.50 x 10^{-4} mol

Amount of MnO_4^- reacted = $\frac{20}{1000}$ x 0.0050 = 1.00 x 10^{-4} mol

$MnO_4^- + 8H^+ \longrightarrow Mn^{2+} + 4H_2O + 5e$

$MnO_4^- \equiv 5e$

Amount of electrons lost = 5.00 x 10^{-4} mol

2.50 x 10^{-4} mol of G^{n+} gained 5.00 x 10^{-4} mol of electrons.

$G^{n+} \equiv 2e$

Hence the oxidation state of G in G^{n+} <u>increases by 2</u> to +4 in G^{4+}

Therefore, G^n is G^{2+}.

11 **Answer: C**

Half–life, $t_{\frac{1}{2}} = \frac{\ln 2}{k} = \frac{\ln 2}{0.09} = 7.7$ h

$$\frac{C_t}{C_o} = \left(\frac{1}{2}\right)^n$$

$$\frac{18}{100} = \left(\frac{1}{2}\right)^n \Rightarrow n = 2.47$$

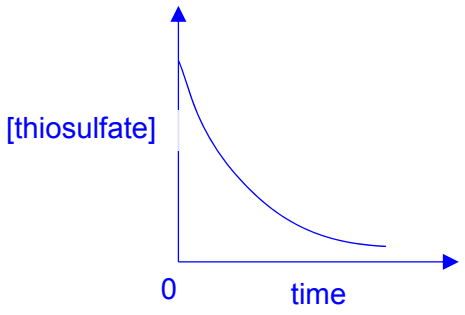
Time taken = half–life × n = 7.7 × n = **<u>19.0 h</u>**

12 **Answer: A**

Since order of reaction w.r.t. thiosulfate is 1 ⇒ Rate = k'[thiosulfate], where $k' = k[\text{acid}]^n$

Graph **A** shows the relationship where [thiosulfate] ∝ rate, while graph **B** shows a second order relationship.

Graph **C** and **D** are both incorrect as the graph of concentration against time should be



13 **Answer: D**

Bond energy of X–Y bond is the average energy ***absorbed*** to **break one mole of covalent bond in the gas phase** into **constituent gaseous atoms under standard conditions.**

Equation: X–Y (g) → X (g) + Y (g)

Option **A** is incorrect because one mole of HF is broken into gaseous atoms and not formed from its gaseous ions.

Option **B** is incorrect because energy is not released, but absorbed when one mole of HF is broken into its gaseous atoms.

Option **C** is incorrect because the quantity in the definition of bond energy is stated as one mole of covalent bond and not one molecule.

Hence, only Option **D** best defines the term *bond energy* for a diatomic gaseous molecule.

14 **Answer: B**

$\Delta H^{\ominus}_{rxn} = \sum \Delta H^{\theta}_f(\text{products}) - \sum \Delta H^{\theta}_f(\text{reactants})$

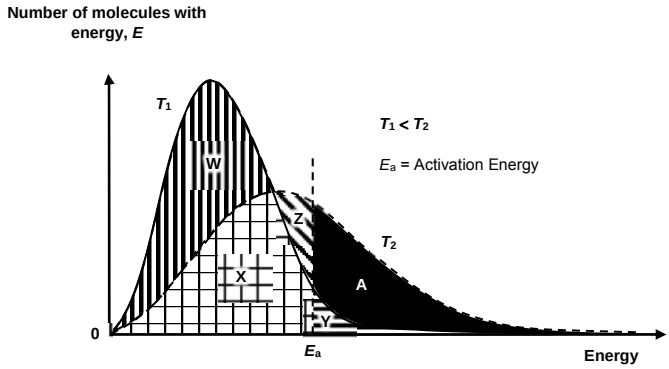
$= 3\,\Delta H^{\ominus}_f(Fe\ (s)) + \Delta H^{\ominus}_f(Al_2O_3\ (s)) - 3\,\Delta H^{\ominus}_f(FeO\ (s)) - 2\,\Delta H^{\ominus}_f(Al\ (s))$

$= (-1676) - 3(-266)$ = **– 878 kJ mol^{-1}**

15 **Answer: D**

Enthalpy change of combustion / neutralisation are always exothermic as heat is released with these reactions.

16 **Answer: D**



Explanation:

The black area (**A**) gives the **increase** in *number of molecules* with energy ≥ E_a

The *total number of molecules* is given by the area under each graph:

Total area under the graph
= W + X + Y = X + Y + Z + A

So, **W = Z + A** or **A = W – Z**

$$\text{Fraction of molecules} = \frac{\mathbf{A}}{\mathbf{W+X+Y}} = \frac{\mathbf{W-Z}}{\mathbf{W+X+Y}}$$

17 **Answer: B**

Option 1 is correct.
A catalyst provides an alternative reaction pathway with lower activation energy. Hence, a catalyst increases the both the rate of the forward and reverse reaction.

Option 2 is correct.
A catalyst provides an alternative reaction pathway with lower activation energy. Hence, a catalyst increases the rate of reaction through affecting the rate constant, *k*. (Arrhenius Equation).

Option 3 is wrong.
A catalyst does not alter the ΔH of the reaction.

Option 4 is wrong.
A catalyst does not increase the average kinetic energy of the reactant particles. Temperature does.

18 **Answer: A**

From the graph, the % gaseous reactants present at equilibrium decreases with an increase in pressure and temperature.

➔ % product present at equilibrium increases with an increase in pressure and temperature.

This shows that equilibrium position shifts right with an increase in temperature and pressure. This implies that forward reaction is endothermic and there are more moles of gaseous reactants than products.

19 **Answer: A**

Toxic CO gas is produced in A.

20 **Answer: C**

pH = 11.5 ➔ pOH = 14 – 11.5 = 2.5

$[OH^-] = 10^{-2.5} = 3.16 \times 10^{-3}$ mol dm^{-3}

$Ca(OH)_2 \equiv 2\ OH^-$

$[Ca(OH)_2]_{diluted} = ½ \times 3.16 \times 10^{-3} = 1.08 \times 10^{-3}$ mol dm^{-3}

Let x be the final volume of the diluted solution in cm^3

Apply $c_1v_1 = c_2v_2$ ➔ $(0.0100)\left(\frac{10}{1000}\right) = (1.08 \times 10^{-3})\left(\frac{x}{1000}\right)$

x = 63.24 cm^3

Volume of deionised water required = 63.24 – 10.0 = 53.2 cm^3

21 **Answer: B**

Bromophenol–blue appears purple (**pH > 4.6)** ⇒ Option **A** is **incorrect**

Phenol–red appears yellow (**pH < 6.8)** ⇒ Options **C and D** are **incorrect**.

The solution must be **weakly acidic and with 4.6 < pH < 6.8**.

22 **Answer: A**

- Atomic radius decreases from P to S to C*l*.
- Melting point of S_8 is the highest among the 3 elements.
- First ionisation energy increases across the period. However 1st I.E of Mg > 1st I.E of A*l* as 3p valence electron of A*l* is further away from nucleus than 3s valence electron of Mg.
- Electrical conductivity increases with more valence electrons available for metals.

23 **Answer: B**

1 The oxide of **E** is amphoteric.	**E** is **aluminum**.
2 The oxide of **F** dissolves in water to form a strongly alkaline solution.	**F** is **sodium**.
3 The oxide of **G** reacts with dilute sodium hydroxide at room temperature.	**G** could either be **phosphorus or sulfur**.
4 The oxide of **H** is insoluble in water but is soluble in concentrated sodium hydroxide.	**H** is **silicon**.

In **increasing proton number**,
sodium, aluminium, silicon, phosphorus/sulfur

Option **B**: **F, E, H, G**

24 **Answer: C**

Thermal decomposition: $H–X \longrightarrow H_2 + X_2$

A is incorrect as polarity of the H–X bond does not affect thermal stability.

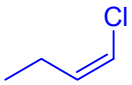
B is incorrect as the size of the H–X molecules relates to the extent of electron cloud distortion and intermolecular forces of attraction; this does not affect the H – X bond strength.

C is correct as thermal decomposition of H–X is more predominantly affected by energy required to break the H – X bond in the reactant compared with the energy released in forming the X–X bond in the product.

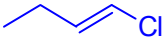
D is incorrect as thermal decomposition involves breaking the H–X bond, not the intermolecular forces of attraction between the H–X molecules.

25 **Answer: C**

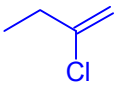
C_4H_7Cl



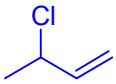
cis–1–chlorobut–1–ene



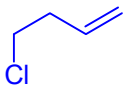
trans–1–chlorobut–1–ene



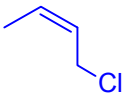
2–chlorobut–1–ene



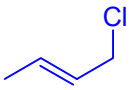
3–chlorobut–1–ene



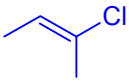
4–chlorobut–1–ene



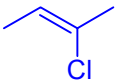
cis–1–chlorobut–2–ene



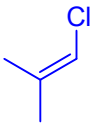
trans–1–chlorobut–2–ene



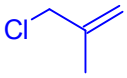
cis–2–chlorobut–2–ene



trans–2–chlorobut–2–ene



1–chloro–2–methylpropene



3–chloro–2–methylpropene

26 **Answer: A**

1 The alkene functional group in ferulic acid undergoes addition with aqueous bromine.

2 It is insoluble in water due to the hydrophobic benzene ring.
It undergoes neutralisation with NaOH(aq) to form sodium carboxylate salt (ionic compound) which is then soluble in water due to the formation of more favourable ion–dipole interactions.

3 Primary alcohol in ferulic acid undergoes oxidation with hot acidified $K_2Cr_2O_7$ to form carboxylic acid.

27 **Answer: B**

Lithium aluminium hydride will reduce both ketone and carboxylic acid to alcohols**,** which is **not** what happened in stage **I** (reduction of ketone to form secondary alcohol)

28 **Answer: D**

Ester and amide undergo basic hydrolysis simultaneously to form CH_3COONa and $HOCH_2NH_2$.

29 **Answer: C**

The repeat unit of nylon–6,6 is $–CO(CH_2)_4CONH(CH_2)_6NH–$
and the 3 amide linkages undergo hydrolysis to form two monomers $HO_2C(CH_2)_4CO_2H$ and $NH_2(CH_2)_6NH_2$.

30 **Answer: B**

Statement **1** is correct. (infer from the given products).

Statement **2** is correct.
HDPE is a linear chain polymer and has little branching as the polymer chains lie close to each other and are packed regularly. The better packing in HDPE means a decrease in distance between HDPE polymer chains and hence a higher density is observed. On the other hand, LDPE has a lot of branching and this increases the distance between polymer chain molecules due to irregular packing.

Statement **3** is incorrect as the monomer is ethene not propene.

END OF PAPER

Name SUGGESTED SOLUTIONS

Class	Reg Number
17	

Calculator Model / No.

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 1

Chemistry 8873/02

Paper 2 **13 September 2018**
2 hours

Additional Material: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

Write your name, class and register number in the spaces at the top of this page.

This booklet contains Section **A** and Section **B**.

Section A (60 marks) : Page 2 to 15
Answer **all** questions in the spaces provided. You are advised to spend about **1 h 30 min** on Section **A**.

Section B (20 marks): Page 16 to 24
Answer **one** question in Section **B** in the spaces provided. You are advised to spend about **30 min** on Section **B**.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question.

Examiner's Use		
Paper 1	MCQ	/ 30
		/ 33 %
Paper 2 Section A	Q1	/ 15
	Q2	/ 17
	Q3	/ 16
	Q4	/ 12
Paper 2 Section B		/ 20
Paper 2 Total		/ 80
		/ 67 %
Grand Total		/ 100 %
Grade		

This document consists of **24** printed pages.

Section A

Answer **all** questions in this section, in the spaces provided.

1 Chemists have long studied the trend of elements, and the Periodic Table was celebrated as an effective way to arrange the elements while reflecting some of the most well-known trends in their physical and chemical properties.

(a) Using structure and bonding, describe and explain the variation in melting points for elements aluminium to phosphorous.

[4]

The melting point increases from aluminium (A*l*) to silicon (Si), then decrease to phosphorous (P_4)

Aluminium: giant metallic lattice structure
Large amount of energy needed to overcome strong electrostatic forces of attraction between the cations and the sea of delocalised electrons.

Silicon: giant molecular structure
Larger amount of energy to overcome the strong and extensive covalent bonds between Si atoms in the giant 3–dimensional molecular structure.

Phosphorous: simple molecular structure
Small amount of energy to overcome the weak intermolecular instantaneous dipole–induced dipole forces of attraction between P_4 molecules.

(b) **(i)** The ionisation energies of Period 3 elements from sodium to argon generally increases, with the exception of two decreases: from Mg to A*l*, and from P to S.

Explain these two anomalies in the trend.

[2]

From Mg to A*l*
A*l* has a lower 1st I.E as compared to Mg. The 3p electron in A*l* is further away from the nucleus compared to 3s electron in Mg. Hence, the 3p electron in A*l* experience weaker electrostatic attraction with the nucleus and hence require less energy to remove.

From P to S.
S has a lower 1st I.E as compared to P. Inter–electron repulsion is present in the doubly–filled 3p orbital of S atom. Hence, it is easier to remove the valence electron in the doubly-filled 3p orbital of S atom.

(ii) An element from Period 3 was found to have the following successive ionisation energy values. Deduce the identity of this element.

Ionisation Energy	1st	2nd	3rd	4th	5th	6th	7th	8th
Value / kJ mol^{-1}	790	1600	3200	4400	16000	20000	24000	29000

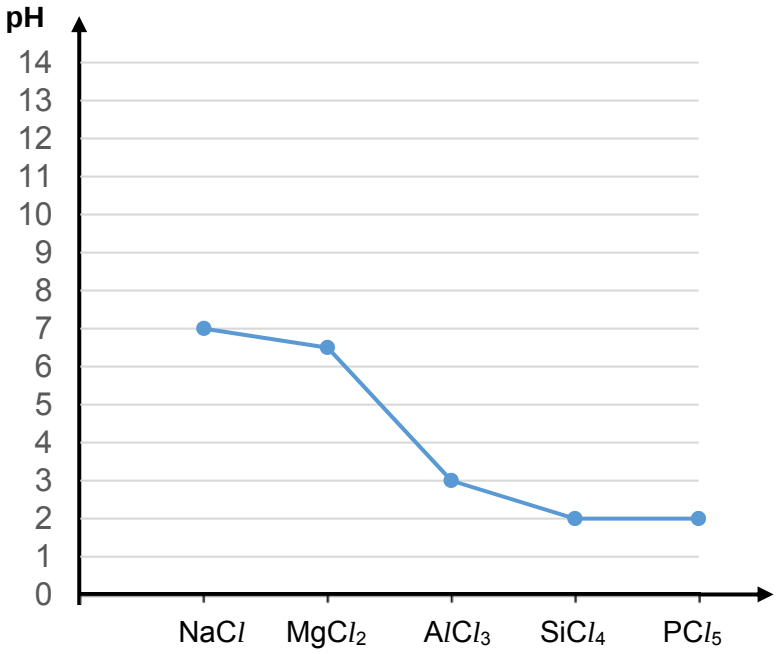
[1]

The element is silicon because there was a large increase from 4th to 5th ionisation energy. This indicates that the removal of the 5th electron was from the inner quantum shell and the element has 4 valence electrons.

(c) Chlorides of Period 3 elements display a wide range of properties.

(i) The pH of the resultant solution when Period 3 chlorides dissolves in or react with water shows a periodic trend. Sketch the pH trend from $NaCl$ to PCl_5.

[1]



(ii) Write an equation for the reaction of PCl_5 with water.

[1]

$PCl_5 + 4H_2O \longrightarrow H_3PO_4 + 5HCl$

(iii) One of the Period 3 chlorides and $BeCl_2$ have similar reaction with water. Identify this Period 3 chloride and explain why these two chlorides have similar chemical reactivity.

[1]

Period 3 chloride: $AlCl_3$
Be^{2+} and Al^{3+} have similar charge density
OR Be and Al have same atomic radius and electronegativity.

(d) Describe and explain the relative reactivity of elements of Group 17 as oxidising agents.

[2]

Down the group,

- atomic radius increases.
- tendency for X_2 to accept electrons decreases.
- tendency for X_2 to be reduced to X^- decreases.
- oxidising power of X_2 decreases.

(e) At the nanoscale, new properties may emerge in certain compounds.

For example, graphene is known to have very high tensile strength and high electrical conductivity. Describe the structure of graphene and explain how its structure relates to these two properties.

[3]

Graphene is a single layer of carbon atoms arranged in hexagons as they are in graphite (or a single layer of graphite). Each carbon atom in the layer is covalently bonded with 3 other carbon atoms resulting in a hexagonal lattice structure. Graphene has high tensile strength because of the strong covalent bonds between carbon atoms.

Each carbon atom has a 2p orbital that has a single electron that is not involved in bonding. This p orbital overlap sideways with its neighbouring carbon atom, resulting in an extended π-electron cloud of delocalised electrons above and below the plane. Graphene is an excellent conductor of electricity because it has delocalised mobile electrons over the layer which serves as charge carriers and can carry an electric current.

[Total: 15]

2(a) Nearly all petrol and diesel vehicles have some kind of catalytic converter fitted to the exhaust to reduce the amount of pollutants emitted into the environment. The catalytic converter usually contains palladium nanoparticles which act as catalyst.

(i) Define the term nanoparticles.

[1]

Nanoparticles are defined as particles with all dimensions between 1–100 nm on the nanoscale.

(ii) Explain why palladium used is in the form of nanoparticles instead of its bulk form.

[2]

Nanoparticles has high surface area per unit volume, i.e. the proportion of atoms on the surface of the nanoparticles is larger. As reaction occur on the surface of materials, chemical reaction often proceed more quickly OR rate of reaction increases.

(iii) The palladium catalyst helps to remove carbon monoxide from the exhaust. For example,

$$CO + \frac{1}{2} O_2 \longrightarrow CO_2$$

State the **type** of catalyst and outline the mode of action of catalyst in this reaction.

[2]

Heterogeneous catalyst

Adsorption: Reactant molecules are adsorbed onto the nanoparticle catalyst surface through the formation of *temporary bonds*.

Activation: This adsorption increases the surface concentration of the reactants and weakens the covalent bonds within the reactant molecules, thereby lowering the activation energy. Reactant molecules are brought closer together and reaction can take place between the reactants molecules more easily.

Desorption: Products diffuse away formed from the surface of the catalyst

(b) Carbon monoxide, water and propene can be used to produce butanoic acid according to the following equation:

$$CO + H_2O + CH_3CH{=}CH_2 \xrightarrow{\text{metal catalyst}} CH_3CH_2CH_2CO_2H$$

Draw the structure of the product formed when 2-methylpropene is used in the above reaction.

[1]

$CO + H_2O + (CH_3)_2C{=}CH_2 \longrightarrow (CH_3)_2CHCH_2CO_2H$ **[1]**

(c) Propene can be converted to propanone by the following route.

$$CH_3CH{=}CH_2 \xrightarrow{\mathbf{I}} CH_3CHCl/CH_3 \xrightarrow{\mathbf{II}} CH_3CH(OH)CH_3 \xrightarrow{\mathbf{III}} CH_3COCH_3$$

(i) Suggest the types of reaction for steps **I** and **III**.

[2]

	step **I**	step **III**
type of reaction	addition	oxidation

(ii) State the reagent and conditions for step **II**.

[1]

aqueous NaOH, heat

(iii) State and explain how the rate of reaction for step **II** changes when 2-chloropropane is replaced by 2-iodopropae.

[2]

Relative reactivity of halogenoalkanes depends on the C-X bond strength.
C–I covalent bond is weaker than C–Cl
Relative ease of breaking C–I bond is greater than C–Cl
Hence rate of reaction increases when 2-chloropropane is replaced by 2-iodopropane.

(d) The kinetics of the acid-catalysed reaction of propanone with iodine

$$CH_3COCH_3(aq) + I_2(aq) \xrightarrow{H^+(aq)} CH_2ICOCH_3(aq) + HI\,(aq)$$

can be investigated experimentally by varying the concentrations of the three substances involved and determining the time for the colour of the iodine to disappear.

In this method the rate of the reaction is measured in terms of the rate at which the iodine changes, i.e.

$$\text{rate} \propto \frac{\text{volume of aqueous iodine used}}{\text{time for the colour of iodine to disappear}}$$

The following results were obtained in such an investigation.

Expt	Volume of CH_3COCH_3 / cm^3	Volume of I_2 / cm^3	Volume of H^+ / cm^3	Volume of H_2O / cm^3	Relative time for the colour of iodine to disappear
1	8	4	8	0	1
2	8	4	4	4	2
3	4	4	8	4	2
4	8	2	8	2	0.5

(i) Deduce the order of reaction with respect to propanone, iodine and hydrogen ions.

[3]

propanone

Comparing experiment 1 and 3, when conc. of propanone is halved while keeping the conc. of other reactants constant, rate is halved. Hence order of reaction w.r.t. propanone is 1

iodine

Comparing experiment 1 and 4, when conc. of iodine is halved while keeping the conc. of other reactants constant, rate does not change. Hence order of reaction w.r.t. iodine is 0.

hydrogen ions

Comparing experiment 1 and 2, when conc. of H^+ is halved while keeping the conc. of other reactants constant, rate is halved. Hence order of reaction w.r.t. H^+ is 1.

(ii) Hence write the rate equation for this reaction.

[1]

rate = $k\,[CH_3COCH_3]\,[H^+]$

(iii) Another experiment, with 0.80 mol dm^{-3} propanone, 0.0010 mol dm^{-3} iodine and 0.20 mol dm^{-3} hydrochloric acid, is carried out at the same temperature.

Calculate the value of the rate constant if the rate is 4.2×10^{-6} mol dm^{-3} s^{-1}. Give the units of the rate constant.

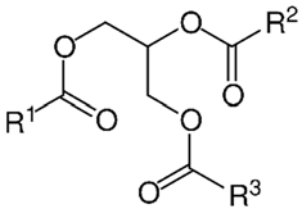
[2]

$4.2 \times 10^{-6} = k(0.80)(0.2)$

$k = 2.6 \times 10^{-5}$ units: $mol^{-1}\ dm^3\ s^{-1}$

[Total: 17]

3(a) Limited scientific evidence suggests that eating two tablespoons of olive oil daily may reduce the risk of coronary heart disease. Olive oil comprises mainly of the mixed triglyceride esters of oleic acid, palmitic acid and other fatty acids. The general chemical structure of olive oil is shown below where R^1, R^2 and R^3 are alkyl groups or alkenyl groups.



Olive oil undergoes rancidification when exposed to moisture, resulting in an unpleasant taste and odour. The products formed in the reaction are propane-1,2,3-triol and fatty acids.

Complete the equation to illustrate the rancidification reaction of olive oil.

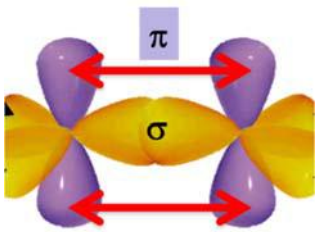
[2]

(b) Oleic acid has the structure shown.

$$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$$

(i) Describe the bonding in C=C in terms of orbital overlap. Draw a diagram to illustrate your answer.

[2]



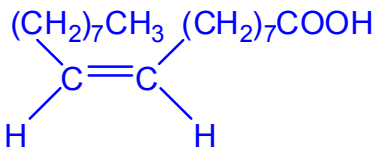
The C=C double bond consists of 1 σ bond and 1 π bond.
The C−C σ bond is formed by the head-on overlap between one orbital of the carbon atom and one orbital of another carbon atom.

The C−C π bond is formed by the sideway overlap between the 2*p* orbital of the carbon atom and 2*p* orbital of another carbon atom.

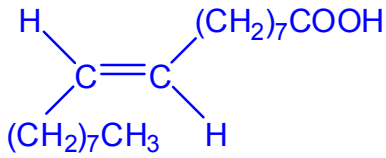
(ii) Oleic acid exists as a pair of isomers.

Draw and label the structural formulae of the two isomers.

[2]



cis isomer



trans isomer

(iii) Describe a chemical test that would distinguish oleic acid from ethanoic acid.

[2]

Add Br_2 in CCl_4 to each compound in the dark at r.t.p.
Oleic acid: Orange-red bromine solution is decolourised.
Ethanoic acid: Orange-red bromine solution is NOT decolourised.

(c) Fig. 3.1 shows a bomb calorimeter, inside a controlled temperature water jacket, which is used to find an accurate value of standard enthalpy change of combustion of oleic acid.

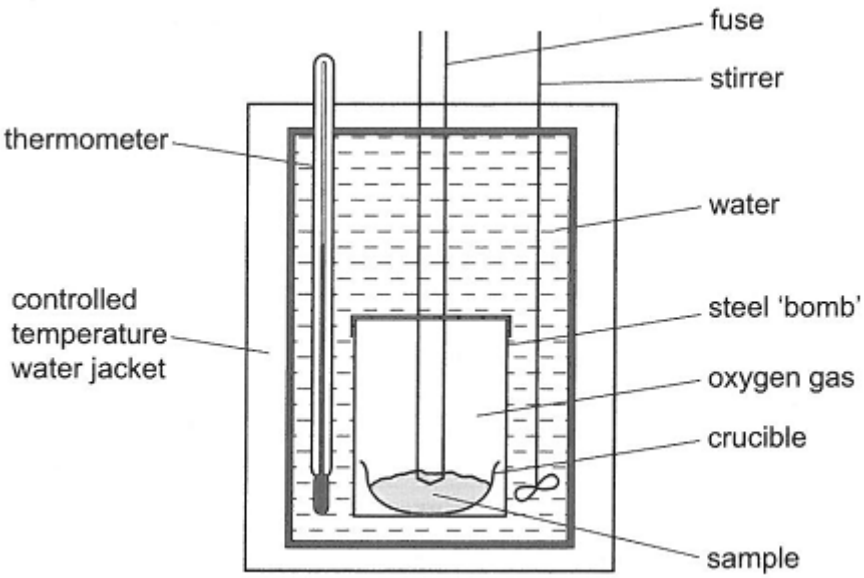


Fig. 3.1

(i) What is meant by the *standard enthalpy change of combustion* of oleic acid?

[1]

It is the energy released when 1 mole of oleic acid is completely burned in (excess) oxygen under standard conditions (298 k and 1 bar).

(ii) Explain why the steel 'bomb' is flushed with a high pressure of oxygen at the start of the experiment.

[1]

It is to ensure that there is sufficient O_2 present in the steel bomb for complete combustion.

(iii) There is no heat lost from the calorimeter because of the controlled temperature water jacket. Suggest how the controlled temperature water jacket achieves this.

[1]

The temperature of water in the jacket is raised with an electric heater so that it just matches the average temperature of the calorimeter.

(iv) A 2.98 g sample of oleic acid ($C_{18}H_{34}O_2$) is burned in a bomb calorimeter with a heat capacity of 1.98 kJ K^{-1}. The temperature of the calorimeter increases by 59.3 °C.

Calculate the standard enthalpy change of combustion of oleic acid.

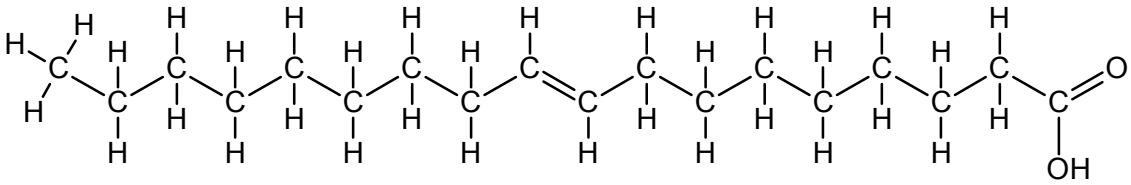
[2]

Heat absorbed by calorimeter = 1.98 × 59.3 = 117 kJ

Amount of oleic acid used = $\frac{2.98}{282.0}$ = 0.0106 mol

$\Delta H_c^{\ominus}$(oleic acid) = $-\frac{117}{0.0106}$ = – 11000 kJ mol^{-1}

(v) Use the bond energies given in the *Data Booklet* to calculate another value for the standard enthalpy change of combustion of oleic acid.



oleic acid

You may find the following information useful in your calculation.
An oleic acid ($C_{18}H_{34}O_2$) molecule contains 33 C–H bonds,16 C–C bonds and other bonds.

[3]

$$C_{18}H_{34}O_2\ (l) + \frac{51}{2}O_2\ (g) \rightarrow 18\ CO_2\ (g) + 17\ H_2O\ (l)$$

Bond breaking (endothermic) ➔ energy absorbed		Bonds forming (exothermic ➔ energy released	
33 C-H bonds	33 (410)	36 C=O bonds in CO_2	36 (805)
16 C-C bonds	16 (350)	34 O-H bonds	34 (460)
1 C=C bond	610		
1 C=O bond	740		
1 C-O bond	360		
1 O-H bond	460		
$\frac{51}{2}$ O=O bonds	$\frac{51}{2}$ (496)		
Total	33948 kJ mol^{-1}	Total	44620 kJ mol^{-1}

$\Delta H_c^{\ominus}$(oleic acid) = 33948 – 44620 = – 10672 = – 10700 kJ mol^{-1}

(vi) Suggest a reason for the discrepancy between the value in **(c)(iv)** and that in **(c)(v).**

[1]

Bond energy values of polyatomic molecules in the *Data Booklet* are average values.
OR
Oleic acid is not in gaseous state**.**

[Total: 16]

4(a) There are two types of polymerisation, addition and condensation

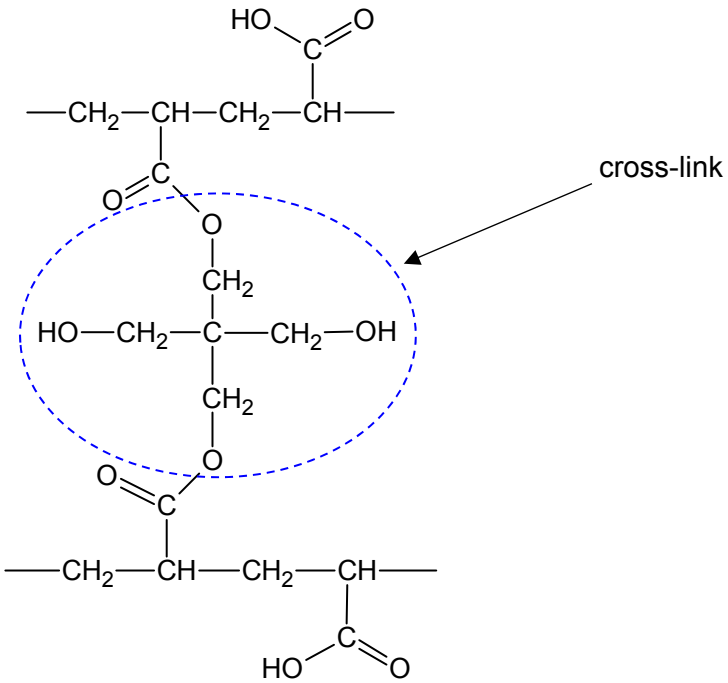
Account for the differences between these two types of polymerisation.

[2]

	Addition Polymerisation	**Condensation Polymerisation**
Type of monomers	Involves monomers containing double or triple bonds (unsaturated compounds)	Involves monomers containing alcohol, carboxylic acid or amino ($-NH_2$) functional groups.
By-products during polymerisation	No loss of molecules and the polymer is the only product.	Involves elimination of small molecules e.g. H_2O or HC*l*.
Empirical formula of polymer as compared to its monomers	Addition polymers have the same empirical formula as their monomers.	Empirical formula of the condensation polymer is not the same as that of the monomer.

(b) Super-absorbent polymers have the ability to absorb 200 – 300 times their own mass of water. They are classified as hydrogels and are widely used in personal disposable hygiene products such as diapers. However, these synthetically made hydrogels are usually non-biodegradable.

The diagram below shows part of the structure of a hydrogel.



The hydrogel is formed from chains of one polymer which are then cross-linked using another molecule.

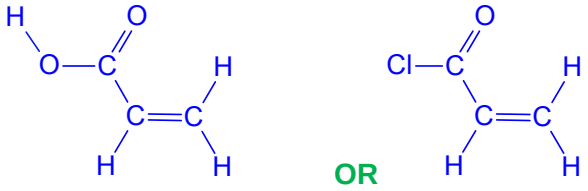
(i) State the type of polymerisation used to form these polymer chains.

[1]

Addition polymerisation

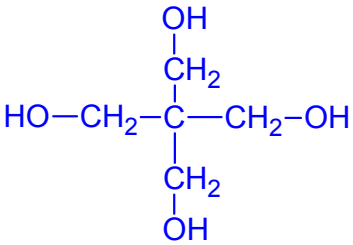
(ii) Draw the **displayed** structural formula of the monomer used.

[1]



(iii) Draw the structure of the molecule used to cross-link the polymer chains.

[1]



(iv) Once a hydrogel has absorbed water, it can be dried and re-used many times. Explain why this is possible, referring to the structure.

[1]

Water is held to the hydrogel by hydrogen bonds formed between water molecules and –COOH of the chain or –OH of the cross-link. These hydrogen bonds can be easily broken to release the held water molecules during drying.

(v) The amount of cross-linking has little effect on the ability of the gel to absorb water. Suggest why this is the case.

[1]

The amount of cross-linking does not affect the number of O-H groups available for hydrogen bonding.

(v) Suggest one property of the hydrogel that will change if more cross-linking takes place. Explain how the increased cross-linking brings about this change.

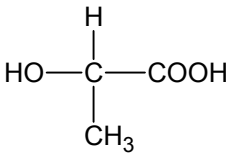
[2]

Hydrogel becomes harder / more rigid / less flexible / more brittle.

The strong cross-link covalent bonds between chains cannot be easily overcome. More cross–links hold the chains more tightly and strongly OR decreases the freedom of movement of individual chains

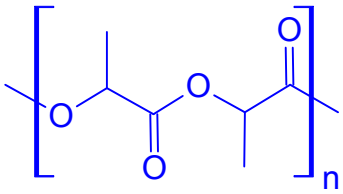
(c) Unlike hydrogel, the polymer, 'polyactide' or PLA is biodegradable. The monomer required to produce PLA is *lactic acid*, 2-hydroxypropanoic acid.

The structure of *lactic acid* is as shown.



(i) Draw the structure of the polymer PLA, showing two repeat units.

[1]



One of the reasons PLA has attracted so much attention is that it is biodegradable. This does, however restrict some potential uses. The polymer has a melting point of around 175 °C , but soften between 60 – 80°C. However, its properties enable it to have a range of uses in food packaging and in fibres.

(ii) Explain why PLA would not be a suitable packaging materials for food pickled in vinegar.

[1]

PLA contains ester linkages in the polymer which can be hydrolysed by the acid present in vinegar e.g. CH_3COOH (aq), under prolonged exposure.

(iii) Suggest why PLA containers are not usually used to hold hot drinks.

[1]

PLA is a thermoplastic polymer. PLA softens when heated and hence the PLA container changes shape easily as weak van der Waals' forces of attractions between chains are easily overcome and the chains are able to slide past each other.

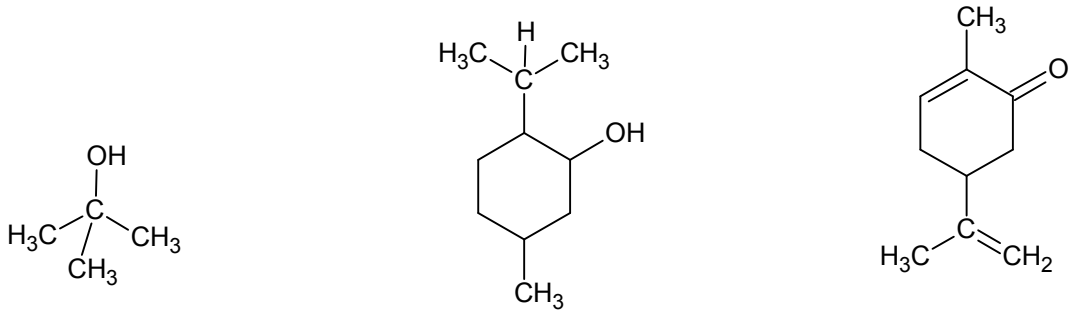
[Total: 12]

END OF SECTION A

Section B

Answer **one** question from this section, in the spaces provided.

5(a) Three natural–occurring compounds used commercially are shown below:



2 methylpropan–2–ol Menthol Carvone

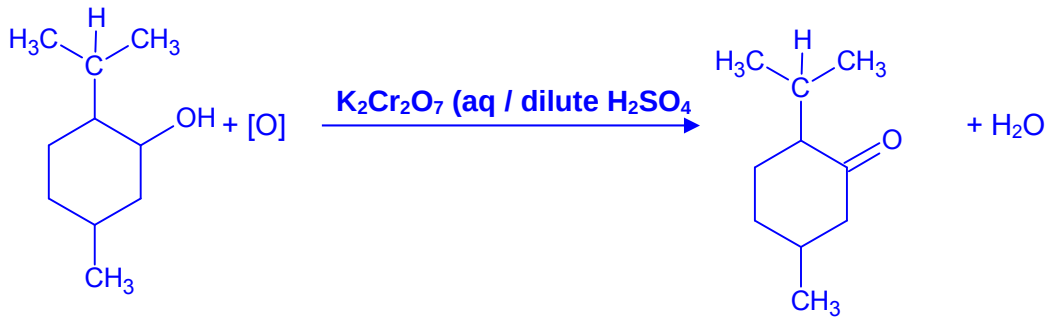
(i) Describe a set of two chemical tests that can be used to distinguish the above three compounds. Write an equation for each reaction that takes place.

[5]

Test: Add $K_2Cr_2O_7$ (aq), H_2SO_4 (aq) to each compound separately and heat.

Observations:

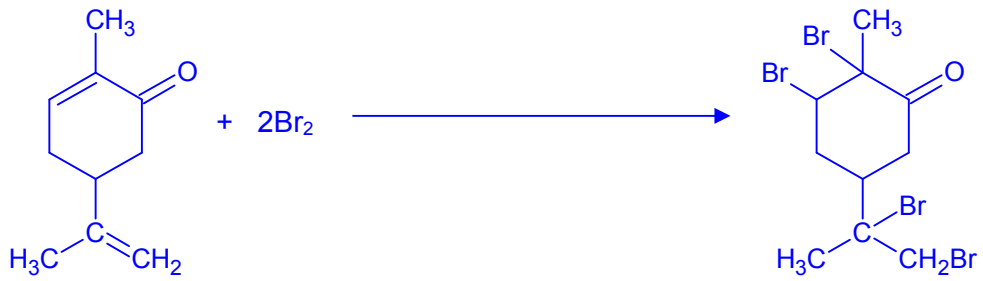
- 2 methylpropan–2–ol: Orange acidified $K_2Cr_2O_7$ remains.
- Menthol : Orange acidified $K_2Cr_2O_7$ turns green.
- Carvone: Orange acidified $K_2Cr_2O_7$ remains.



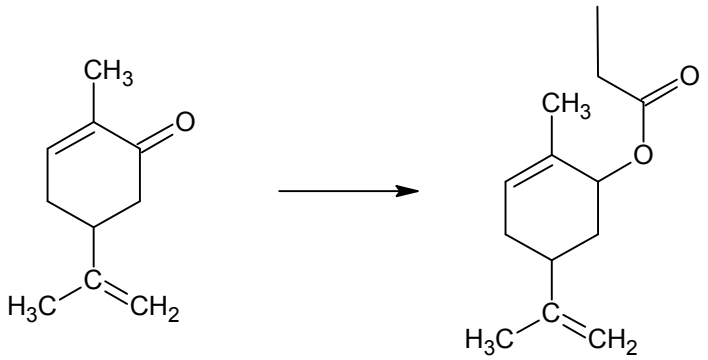
Test: Add Br_2 (CCl_4) / Br_2 (aq) to remaining compounds in the dark separately at r.t.p.

Observations:

- 2 methylpropan–2–ol: No decolourisation of orange–red Br_2 (CCl_4)
- Carvone: Decolourisation of orange–red Br_2(CCl_4)



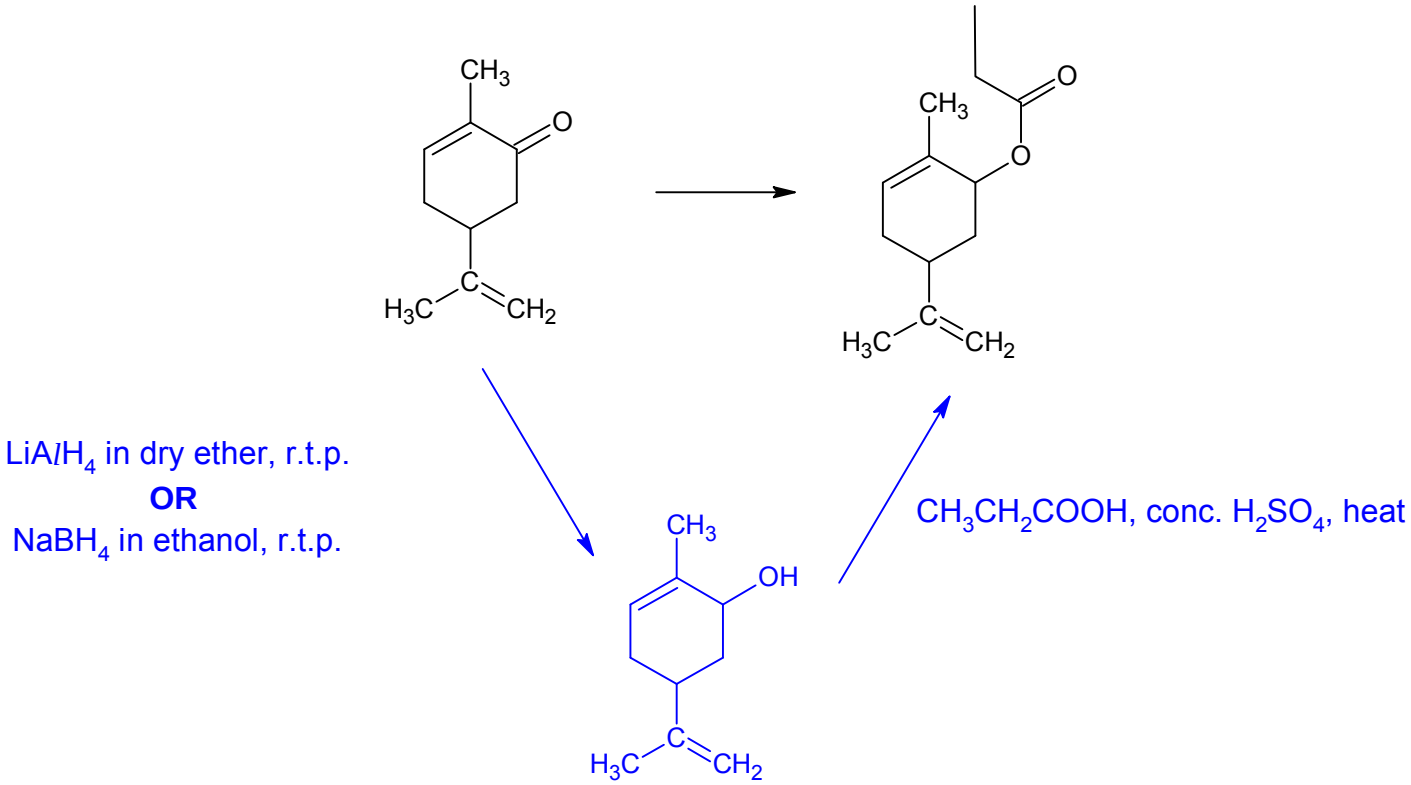
(ii) Carvone can be converted to organic compound D in two steps.



Carvone Compound D

State the reagents and conditions necessary for each step. Give the structure of the intermediate involved in the conversion.

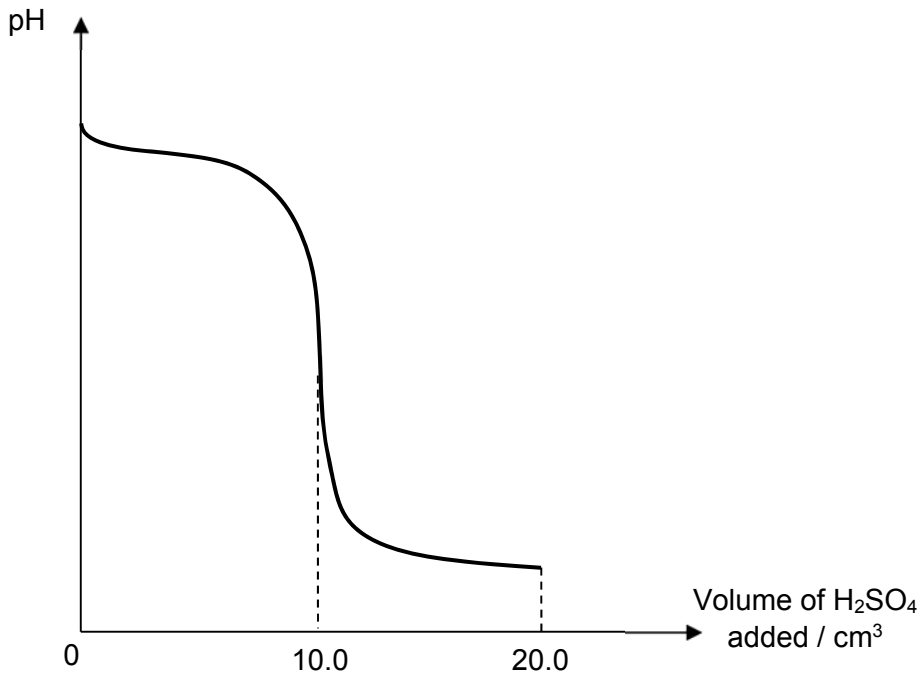
[3]



(b) Ammonia was used in smelling salts to treat fainting. Modern smelling salt solution may contain other products such as lavender oil to act in conjunction with aqueous ammonia.

When 40 cm^3 of aqueous ammonia was titrated against 0.200 mol dm^{-3} sulfuric acid, H_2SO_4 using a pH meter, the following graph was obtained.

$$2NH_3\ (aq) + H_2SO_4\ (aq) \longrightarrow (NH_4)_2SO_4\ (aq)$$



The base dissociation constant for ammonia, K_b is 1.78 x 10^{-5} mol dm^{-3}.

(i) Explain what is meant by the terms *Bronsted–Lowry base* and *conjugate acid–base pair*. Illustrate your explanation using ammonia in the above reaction with sulfuric acid.

Explain why the *Arrhenius* definition of base does not apply for ammonia in the above reaction.

[3]

A Bronsted–Lowry base is a proton acceptor.
A conjugate acid–base pair is a pair of species that differs from each other by a proton.

$NH_3\ (aq)$ + $H^+\ (aq)$ $\longrightarrow$ $NH_4^+\ (aq)$

proton acceptor — base; proton from H_2SO_4; conjugate acid

An Arrhenius base is a substance that has OH in its formula and releases OH^- when dissolved in water. This definition does not explain basic property of ammonia that does not contain the OH group.

(ii) Write an expression for the base dissociation constant, K_b, of ammonia.

[1]

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ $\qquad K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$

(iii) Using the titration curve provided, state the volume of sulfuric acid needed for the exact neutralisation of 40 cm^3 of aqueous ammonia. Calculate the initial concentration of aqueous ammonia.

[2]

From the graph, the equivalence volume is 10.0 cm^3.

Amount of H_2SO_4 in 10.0 cm^3 = $\frac{10}{1000} \times 0.200$ = 0.00200 mol

Mole ratio: $2NH_3 \equiv H_2SO_4$
Amount of NH_3 in 40.0 cm^3 solution = 0.00400 mol
Initial concentration of ammonia in 40.0 cm^3 = $\frac{0.00400}{\left(\frac{40.0}{1000}\right)}$ = 0.100 mol dm^{-3}

(iv) The resultant solution at the end of the titration can be considered as a sulfuric acid solution of concentration 0.0333 mol dm^{-3}. Calculate the pH of this resultant solution to 2 decimal place.

[1]

$[H_2SO_4]$ = 0.0333 mol dm^{-3}

Since H_2SO_4 is a strong diprotic acid,

$[H^+]$ = 2 x 0.0333 = 0.0666 mol dm^{-3}

pH = - lg $[H^+]$ = - lg (0.0666) = 1.18 (2 d.p.)

(v) Suggest an appropriate indicator for the titration, giving a reason for your choice.

[1]

Methyl orange / methyl red may be used for this strong acid–weak base titration.

The pH transition range of the indicator (around 3.0 – 4.5) lies within the region of the rapid pH change (around 3 – 7) over the equivalence point.

(vi) Explain what do you understand by the term *buffer solution*.

[1]

A buffer solution is one which is capable of maintaining a fairly constant pH when small amounts of acid or base are added to it.

(vii) The *Henderson–Hasselbalch* equation is useful for the estimation of the pH of a buffer solution.

An alternative form of the equation is shown below which can be used to determine the pOH of a basic buffer solution.

$$\text{pOH} = \text{p}K_b + \log_{10}\frac{[BH^+]}{[B]}$$

Calculate the pH of a basic buffer solution, if the solution contains NH_4^+ and NH_3 in a 2 : 1 ratio. given that the base dissociation constant, K_b of ammonia, NH_3 is 1.78×10^{-5} mol dm^{-3}.

[2]

$$\text{pOH} = \text{p}K_b + \log_{10}\frac{[NH_4^+]}{[NH_3]}$$

$$\text{pOH} = -\log(1.78 \times 10^{-5}) + \log_{10}\left(\frac{2}{1}\right)$$

$$\text{pOH} = 5.05$$

$$\text{pOH} = 14 - \text{pH} = 14 - 5.05 = 8.95$$

(viii) The enthalpy changes of neutralisation involving sulfuric acid with two bases are shown below.

sodium hydroxide, NaOH	– 57.3 kJ mol^{-1}
ethylamine, $CH_3CH_2NH_2$	– 51.5 kJ mol^{-1}

Comment and explain for the above observation as fully as you can.

[1]

Ethylamine is a weak base. $CH_3CH_2NH_2$ is only slightly dissociated in aqueous solution.

$$CH_3CH_2NH_2 + H_2O \rightleftharpoons CH_3CH_2NH_3^+ + OH^-$$

Some of the energy evolved from the neutralisation process is used to further dissociate the weak base completely.

Hence, the enthalpy change of neutralisation involving $CH_3CH_2NH_2$ is less exothermic.

[Total: 20]

6(a) Hydroxylamine, NH_2OH is commonly used in photography developing solution. Prolonged exposure to hydroxylamine by photography developers might cause irritation to their respiratory tract. To minimise the health hazard on these developers, the safety limit of the concentration of hydroxylamine is capped at below 0.00200 mol dm^{-3}.

A scientist performed the following experiment to determine if a sample of photography developing solution was within the safety limit.

100 cm^3 of NH_2OH solution was added to 40 cm^3 of 0.015 mol dm^{-3} acidified I_2 (aq) solution. In this reaction, iodine is used in excess and NH_2OH is oxidised to form dinitrogen monoxide, N_2O.

(i) Using half-equations, write a balanced equation for the reaction between NH_2OH (aq) and I_2 (aq) in an acidic medium.

[2]

Reduction: $I_2 + 2e \longrightarrow 2I^-$

Oxidation: $2NH_2OH \longrightarrow N_2O + H_2O + 4H^+ + 4e$

Overall: $2NH_2OH + 2I_2 \longrightarrow N_2O + H_2O + 4I^- + 4H^+$

A 25.0 cm^3 aliquot of the resultant reaction mixture was then titrated with a standard solution of 0.00500 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$ (aq).

$$I_2\,(aq) + 2\,S_2O_3^{2-}\,(aq) \longrightarrow 2I^-\,(aq) + S_4O_6^{2-}\,(aq)$$

Starch solution was added as indicator for this titration to enhance the contrast of the colour change at the end-point of the titration. 22.50 cm^3 of $Na_2S_2O_3$ (aq) was required.

(ii) State the expected colour change at the end-point of the titration.

[1]

Blue-black to colourless.

(iii) Calculate the amount of I_2 remaining in the reaction mixture.

[2]

Amount of $Na_2S_2O_3$ required = $\frac{22.50}{1000} \times 0.00500$ = 1.125 x 10^{-4} mol

$2S_2O_3^{2-} \equiv I_2$

Amount of I_2 remaining in 25 cm^3 of the reaction mixture $= \frac{1}{2} \times 1.125 \times 10^{-4}$

= 5.625 x 10^{-5} mol

Amount of I_2 remaining in reaction mixture (140 cm^3) $= \frac{140}{25.0} \times 5.625 \times 10^{-5}$

= 3.15 x 10^{-4} mol

(iv) Calculate the concentration of NH_2OH in 100 cm^3 sample of the photography developing solution. Hence conclude whether the solution is within the safety limit.

[2]

Amount of I_2 reacted with NH_2OH $= \left(\frac{40.0}{1000} \times 0.015\right)$ mol – 3.15 x 10^{-4} mol

= 2.85 x 10^{-4} mol

$NH_2OH \equiv I_2$

Amount of NH_2OH present in 100 cm^3 = 2.85 x 10^{-4} mol

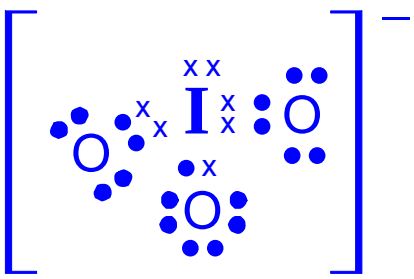
$[NH_2OH]$ = 2.85 x 10^{-4} mol / (100/1000) = 0.00285 mol dm^{-3}

Solution is > 0.00200 mol dm^{-3}, hence it is NOT within the safety limit.

(v) Iodate(V) ion, IO_3^- was used to generate iodine required for the reaction with NH_2OH.

In this IO_3^- ion, the central iodine atom can expand its octet structure. Draw the dot-and-cross diagram of IO_3^- ion.

[1]



(vi) From your answer in **(a)(v)**, state the bond angle around the central iodine atom and account for the shape of IO_3^- ion.

[2]

IO_3^- have 3 bond pairs and 1 lone pair around the central I atom.

To minimise repulsion and maximise stability, the 4 electron pairs are directed toward the corners of a regular tetrahedron.

Lone pair – bond pair repulsion > bond pair – bond pair repulsion

IO_3^- is trigonal pyramidal, with a bond angle of 107°

(b) In an industrial process, 5 mol of dinitrogen tetroxide, N_2O_4 and 7 mol of nitrogen monoxide, NO was heated in a 2.0 dm^3 vessel. The temperature is kept at 500 °C. The two gases react slowly to form blue dinitrogen trioxide, N_2O_3 according to the following equation. It was found that the equilibrium mixture contains 2.3 mol of NO.

$$N_2O_4\ (g) + 2NO\ (g) \rightleftharpoons 2N_2O_3\ (g) \qquad \Delta H = -30.5\ kJmol^{-1}$$

(i) Write an expression for the equilibrium constant, K_c for the reaction, stating the units.

[1]

$$K_c = \frac{[N_2O_3]^2}{[N_2O_4]\,[NO]^2} \quad mol^{-1}\ dm^3$$

(ii) Determine the equilibrium concentrations of the three gases. Hence, calculate the value of K_c.

[2]

	N_2O_4 (g) +	2NO (g) $\rightleftharpoons$	$2N_2O_3$ (g)
Initial amount / mol	5	7	0
Change in amount/ mol	- ½ (4.7) = - 2.35	- 4.7	+4.7
Equilibrium amount / mol	2.65	2.3	+4.7

$$K_c = \frac{[N_2O_3]^2}{[N_2O_4][NO]^2}$$

$$K_c = \frac{\left(\frac{4.70}{2.0}\right)^2}{\left(\frac{2.65}{2.0}\right)\left(\frac{2.30}{2.0}\right)^2}$$

K_c = 3.15 $mol^{-1}\ dm^3$

(iii) Predict and explain the effect of increasing temperature on the equilibrium position and equilibrium composition.

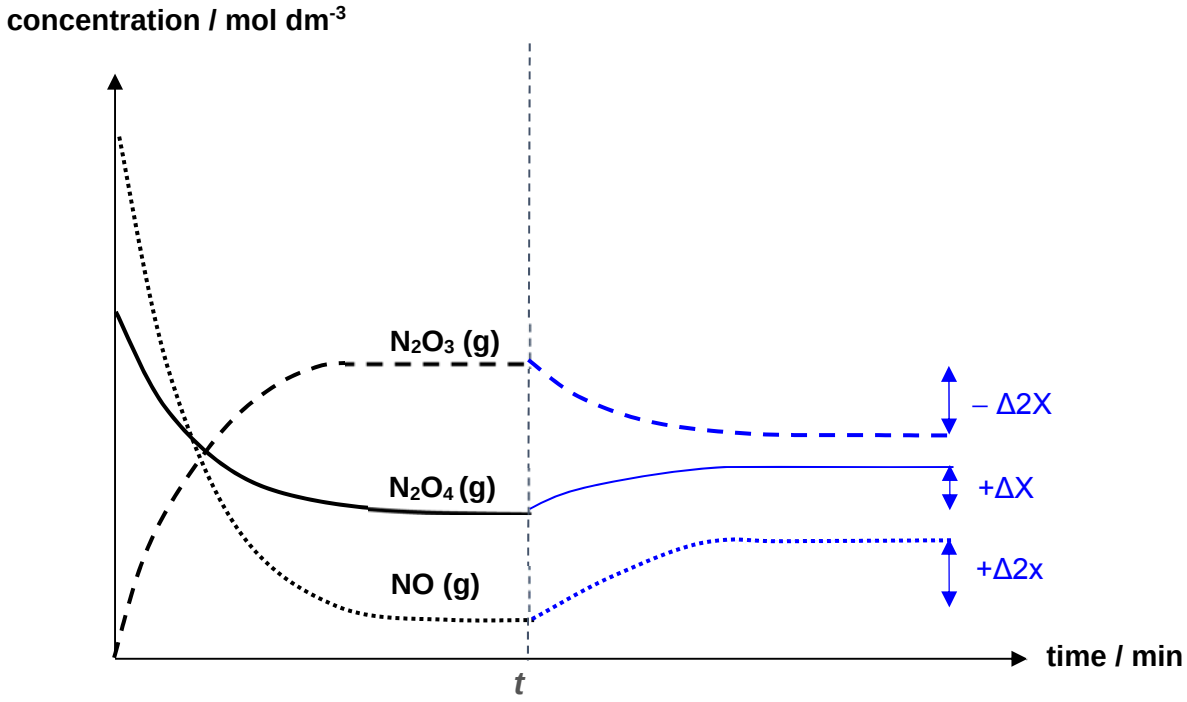
[2]

As temperature increases, the system will try to remove the heat added. By Le Chatelier's Principle, the equilibrium position will shift left towards the endothermic reaction to absorb heat.

The new equilibrium mixture contains less product, N_2O_3 and more reactants N_2O_4 and NO.

(iv) Sketch on the same axes, how the concentration of the three gases will change when temperature was increased at ***t***.

[2]



(v) State the operating pressure and temperature (high or low) required to obtain a high yield of N_2O_3. Explain your answer.

[2]

To obtain a high yield of N_2O_3, a high pressure and low temperature should be used instead.

At high pressure, the system will try to reduce the pressure
By Le Chatelier's Principle, the equilibrium position shifts right to decrease the number of moles of gases to decrease pressure. [N_2O_3] increases, resulting in a higher yield.

To obtain a high yield of N_2O_3, a low temperature should be used instead.
At low temperature, the system will try to produce heat. By Le Chatelier's Principle, the equilibrium position will shift right towards the exothermic reaction to release heat. [N_2O_3] increases, resulting in a higher yield.

(vi) Hence, suggest why the operating temperature is fixed at a moderately high temperature of 500 °C.

[1]

If the temperature is too low, the rate of reaction will be too slow. Hence, a moderately high temperature is chosen as a compromise between the conflicting demands of rate and yield of the reaction.

[Total: 20]

END OF PAPER

NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY **8873/01**
Paper 1 Multiple Choice **Thur 13 September 2018**
Additional Materials: Optical Answer Sheet **1 hour**
Data Booklet

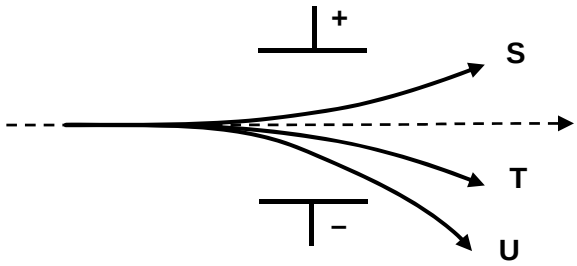
READ THESE INSTRUCTIONS FIRST
Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, subject class and registration number on the Answer Sheet in the spaces provided unless this has been done for you.
There are **30** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.
Read the instructions on the Answer Sheet very carefully.
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This paper consists of **14** printed pages

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 *Use of the Data Booklet is relevant to this question.*

The following are flight paths of charged particles when accelerated in an electric field.



Which of the following correctly identifies **S**, **T** and **U**?

	S	T	U
A	$^{15}O^{+}$	$^{14}C^{+}$	$^{14}N^{+}$
B	$^{15}O^{-}$	$^{15}O^{+}$	$^{28}Si^{+}$
C	$^{14}N^{-}$	$^{28}Si^{2+}$	$^{14}C^{2+}$
D	$^{14}N^{-}$	$^{14}C^{+}$	$^{28}Si^{2+}$

2 An element **L** can exist in a few oxidation states. 0.1 mol of $\mathbf{L}^{2+}$ requires 0.04 mol of acidified $KMnO_4$ for complete reaction.

The half equation for reduction of MnO_4^- is

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

What is the final oxidation state of **L**?

A +4 **B** +3 **C** 0 **D** −1

3 *Use of Data Booklet is relevant to this question.*

Nickel makes up 20% of the total mass of a coin. The coin has a mass of 10.0 g.

How many nickel atoms are in the coin?

A 2.05×10^{22} **B** 4.30×10^{22} **C** 1.03×10^{23} **D** 1.20×10^{24}

4 Which compound has an unpaired electron in its structure?

A N_2O_4 **B** BCl_3 **C** NO **D** NP_3

5 In which sequence is the molecules listed in the order of increasing dipole moment?

A CH_4, CO, HF

B H_2O, H_2S, HBr

C SO_3, CO_2, $AlCl_3$

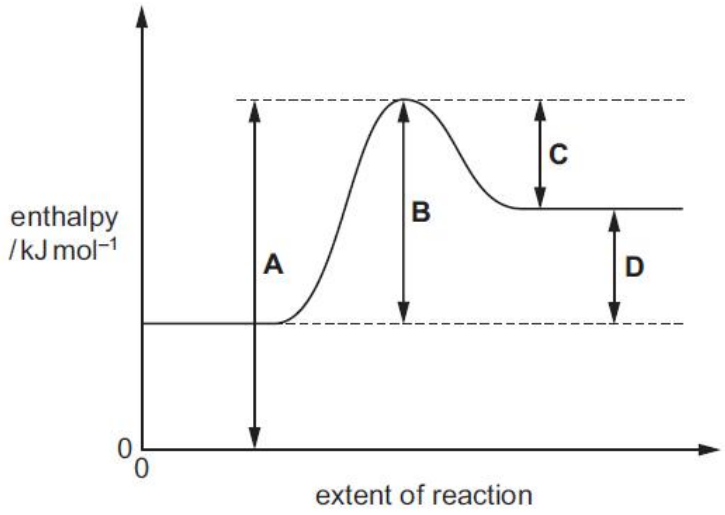
D NH_3, HF, $BeCl_2$

6 The C_2H_2 molecule is linear.

What can be deduced from this about the numbers of σ and π bonds present in the molecule?

	σ	π
A	2	2
B	2	3
C	3	1
D	3	2

7 The diagram shows a reaction pathway for an endothermic reaction.



Which arrow represents the activation energy for the forward reaction?

8 The standard enthalpy changes of combustion of carbon are as follows.

C(graphite) = – 393 kJ mol^{-1}
C(diamond) = – 395 kJ mol^{-1}

Which deductions can be made from the data above?

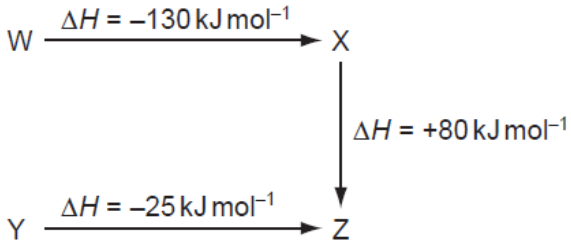
1 Graphite is more stable than diamond.

2 Graphite has a higher energy content than diamond.

3 Graphite is formed endothermically from diamond.

A 1, 2 and 3 **B** 2, and 3 **C** 1 and 3 only **D** 1 only

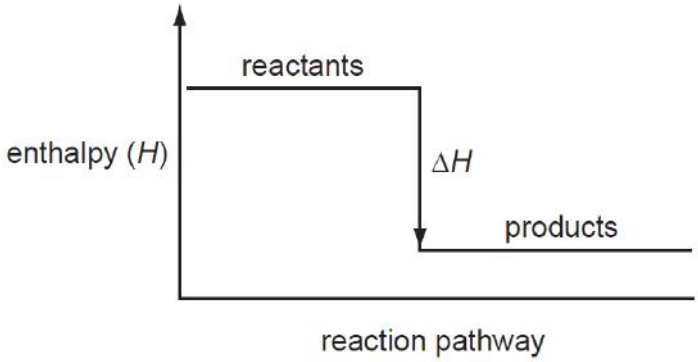
9 The diagram represents the energy changes for some reactions.



What are the natures of the conversions W → Y, Y → X and Z → W?

	W → Y	Y → X	Z → W
A	exothermic	endothermic	endothermic
B	exothermic	exothermic	endothermic
C	endothermic	exothermic	exothermic
D	endothermic	endothermic	exothermic

10 Which enthalpy change could **not** be correctly represented by the enthalpy diagram shown?



A standard enthalpy change of atomisation

B standard enthalpy change of combustion

C standard enthalpy change of hydration

D standard enthalpy change of neutralisation

11 Azomethane decomposes when heated according to the following equation.

$$CH_3N{=}NCH_3(g) \rightarrow CH_3CH_3(g) + N_2(g)$$

This reaction is first order with respect to azomethane.

In experiment I, 160 cm^3 of azomethane took 20 min to decompose to 10% of its original volume measured at constant temperature and pressure.

In experiment II, 320 cm^3 of azomethane was allowed to decompose to 10% of its original volume at the same temperature and pressure as experiment I.

What is the time taken for 320 cm^3 of azomethane to decompose to 10% of its original volume?

A 10 min

B 20 min

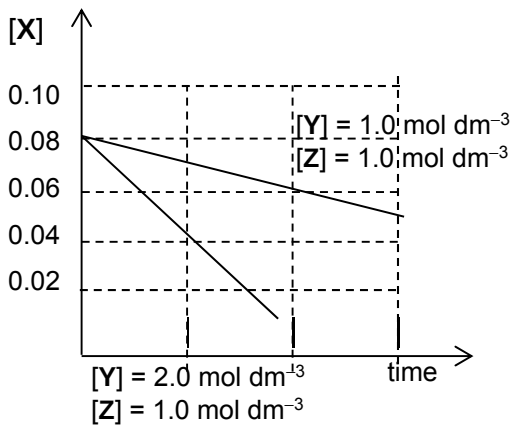
C 30 min

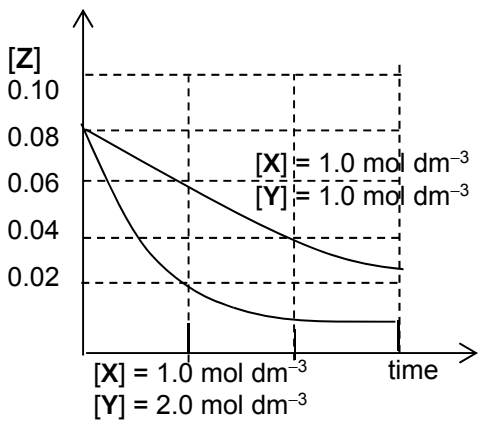
D 40 min

12 Substances **X**, **Y** and **Z** react according to the following equation:

$$\mathbf{X}(aq) + 2\mathbf{Y}(aq) + \mathbf{Z}(aq) \rightarrow 2\mathbf{W}(aq) + \mathbf{U}(aq)$$

To find the rate equation for the above reaction, two sets of separate experiments were performed, in which the initial concentrations of each of the reactants **X**, **Y** and **Z** were varied while the other two were kept constant. The results are shown below.





Which rate equations represent the experimental results?

A rate = k[**Y**]^2

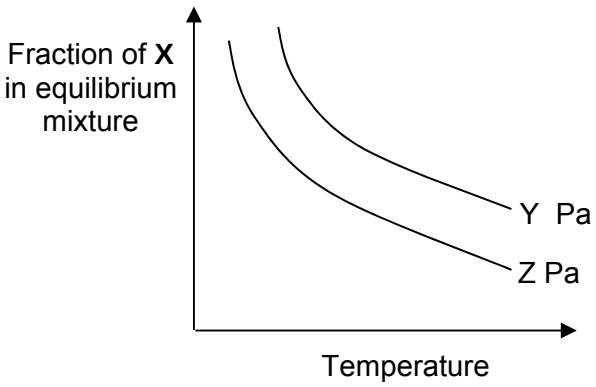
B rate = k[**Y**][**Z**]

C rate = k[**Y**]^2[**Z**]

D rate = k[**X**][**Y**][**Z**]

13 The graph below shows how the fraction of **X**, which represents one of the following compounds in the equilibrium mixture shown below, varies with temperature at pressures of Y Pa and Z Pa.

$$4NH_3(g) + 3O_2(g) \rightleftharpoons 2N_2(g) + 6H_2O(g) \quad \Delta H = -1267 \text{ kJ mol}^{-1}$$



Identify **X** and the correct relative magnitudes of Y and Z.

	X	**Pressure**
A	N_2	Z > Y
B	O_2	Y > Z
C	H_2O	Y > Z
D	NH_3	Z > Y

14 One of the key production stages in the Contact Process is the production of sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H < 0$$

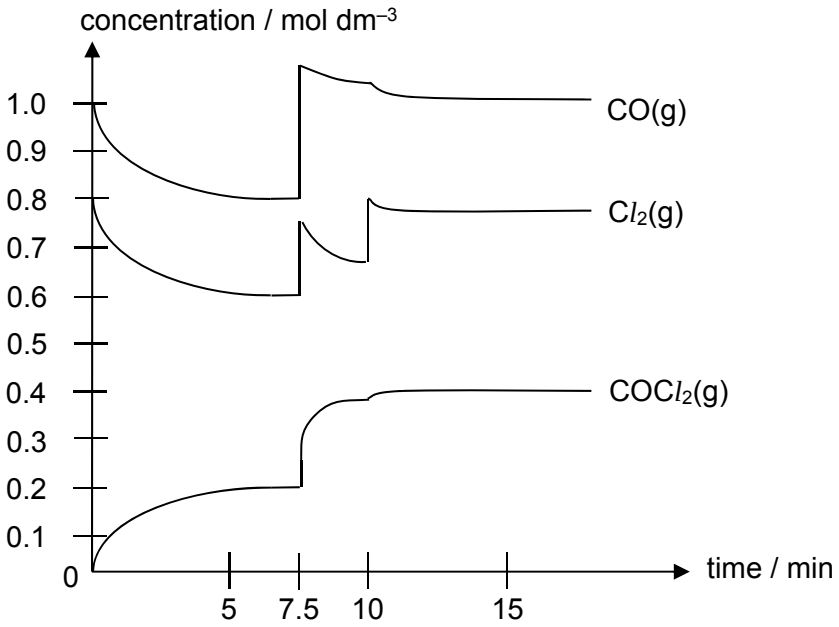
The rate constants of the forward and backward reactions are given as k_1 and k_{-1} respectively.

What happens to k_1, k_{-1} and K_c if the temperature of the reaction is increased?

	k_1	k_{-1}	K_c
A	increase	increase	no change
B	increase	decrease	increase
C	decrease	increase	decrease
D	increase	increase	decrease

15 The reaction between carbon monoxide and chlorine was studied in an experiment by mixing the two gases and changing the reaction conditions inside the reaction vessel at different times during the experiment. The concentrations of the gases in the vessel were followed with time, and the following graph is obtained.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g) \qquad \Delta H^{\ominus} = -113.4 \text{ kJ mol}^{-1}$$



Which conclusion deduced from the graph is **incorrect**?

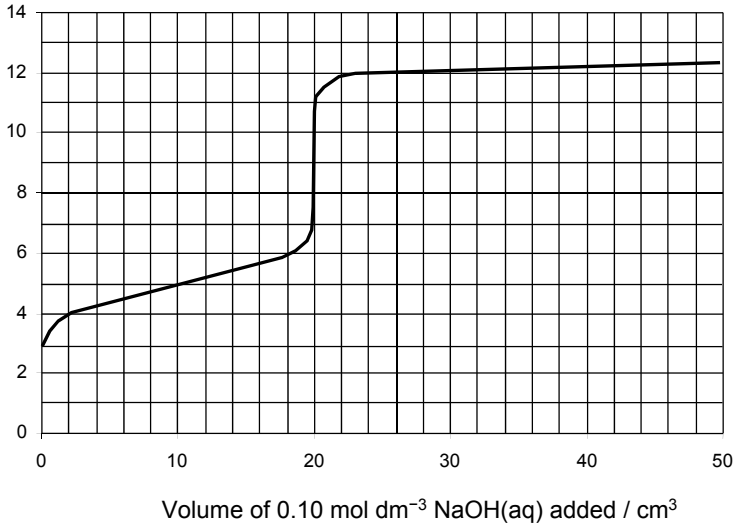
A The rate of forward reaction equals the rate of backward reaction at 7 min.

B The equilibrium constant, K_c, for the system when determined at 7 min is 2.4 mol^{-1} dm^3.

C The change in concentration from 7.5 min to 10 min was produced by an decrease in volume at constant temperature.

D The change in concentration from 10 min to 15 min was produced by the addition of more chlorine.

16 The titration curve below shows the reaction between 20.0 cm^3 of **HX**, and aqueous sodium hydroxide.



Given the following data:

Indicator	Colour change (acidic to basic medium)	pH range in which colour change occurs
Methyl red	red to yellow	4.2 – 6.3
Bromothylmol blue	yellow to blue	6.0 – 7.6
Thymolpthalein	colourless to blue	8.3 – 10.5

What statements are correct?

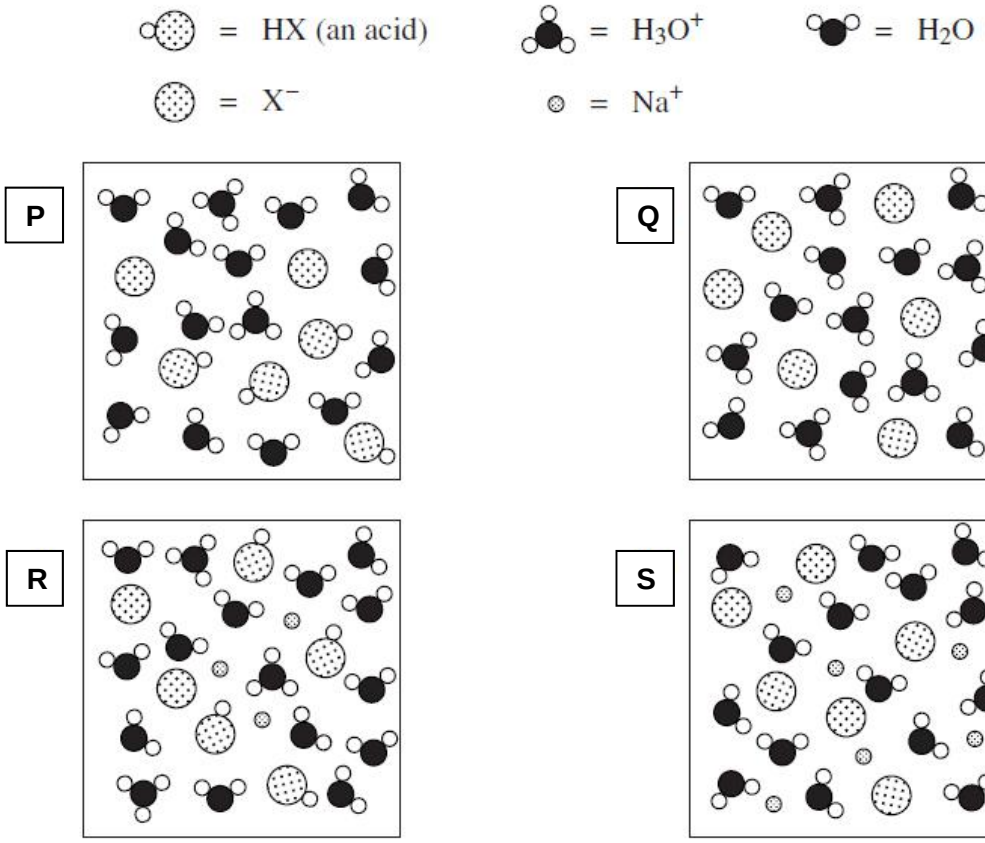
1 Methyl red is the most suitable indicator to be used for this titration.

2 Initial concentration of HX is 0.10 mol dm^{-3}.

3 When 10.0 cm^3 of NaOH is added, $[H^+]$ in the mixture is 1.00×10^{-5} mol dm^{-3}.

A 1, 2 and 3 **B** 2, and 3 **C** 1 and 3 only **D** 3 only

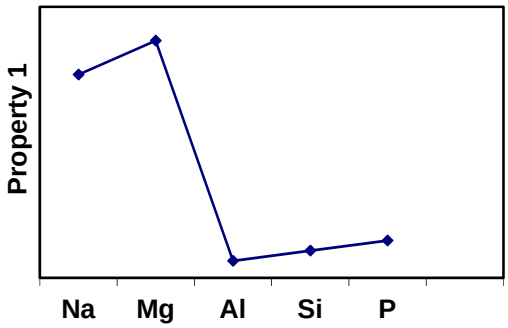
17 The diagrams represent some dilute aqueous solutions.
In all cases, only a few of the large numbers of water molecules are shown.

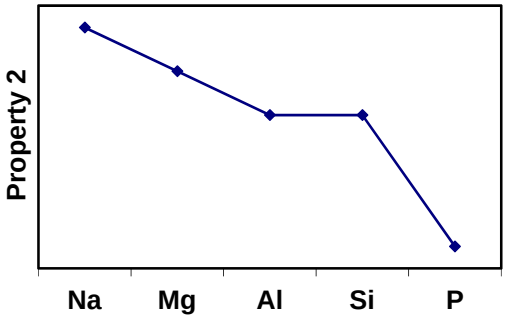


Which option correctly describes the solutions represented by the diagrams?

	P	Q	R	S
A	a strong acid	a weak acid	a salt formed by neutralising a strong acid with sodium hydroxide	weak acid partially neutralised by sodium hydroxide
B	a weak acid	a strong acid	a salt formed by neutralising a strong acid with sodium hydroxide	weak acid partially neutralised by sodium hydroxide
C	a strong acid	a weak acid	weak acid partially neutralised by sodium hydroxide	a salt formed by neutralising a strong acid with sodium hydroxide
D	a weak acid	a strong acid	weak acid partially neutralised by sodium hydroxide	a salt formed by neutralising a strong acid with sodium hydroxide

18 The graphs below show the variation of two properties of some period 3 elements and/or their compounds.





Which correctly describes properties 1 and 2?

	Property 1	Property 2
A	atomic radius of the elements	electrical conductivity of the elements
B	boiling point of the highest oxidation state chlorides	pH of the highest oxidation state oxides when added to water
C	melting point of the highest oxidation state oxides	first ionisation energies of the elements
D	electrical conductivity of elements	pH of the highest oxidation state chlorides when added to water

19 Element **H** is in Period 3 of the Periodic Table. The following four statements were made about the properties of element **J** or its compounds.

Three statements are correct descriptions and one is false.

Which statement does **not** fit with the other three?

A Adding NaOH(aq) to the solution resulting from the reaction of a chloride of **J** with water produces a white precipitate which is soluble in an excess of NaOH(aq).

B Element **H** is a solid at room temperature.

C Element **H** has the highest melting point among the period 3 elements.

D The oxide of element **H** is soluble in hydrochloric acid.

20 **J**, **K** and **L** are elements in Period 3 of the Periodic Table.

A mixture containing the oxides of **J**, **K** and **L** was dissolved in excess dilute sulfuric acid and filtered. The oxide of **L** was collected as a residue. When excess dilute sodium hydroxide was added to the filtrate, only a white precipitate of the hydroxide of **K** was formed.

What are the possible identities of **J**, **K** and **L**?

	J	**K**	**L**
A	Mg	A*l*	P
B	A*l*	Mg	P
C	Mg	A*l*	Si
D	A*l*	Mg	Si

21 Which are the principal factors which cause the properties of nanomaterials to differ significantly from other materials?

1 Size distribution

2 Specific surface feature

3 Very high surface area to volume ratio

A **1**, **2** and **3** **B** **1** and **2**

C **2** and **3** **D** **1** only

22 The size of nanoparticles is between _____ m.

A 10^{-8} to 10^{-7} **B** 10^{-10} to 10^{-8} **C** 10^{-9} to 10^{-7} **D** 10^{-11} to 10^{-9}

23 How many structural isomers can C_4H_9Cl form?

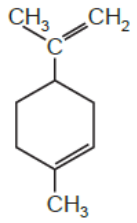
A 3 **B** 4 **C** 5 **D** 6

24 Compound **G** has the following structure: $(CH_3)_2C{=}CHCH_2CH(OH)CH_2CH{=}CH(CH_3)$

How many cis-trans isomers does Compound **G** have?

A 0 **B** 2 **C** 3 **D** 4

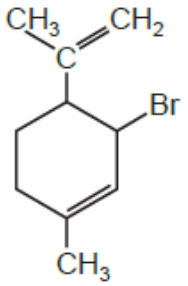
25 Limonene is an oil formed in the peel of citrus fruits.



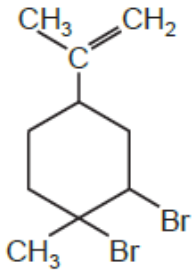
limonene

Which product is formed when an excess of bromine, $Br_2(l)$ reacts with limonene at room temperature in the dark?

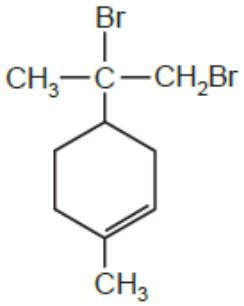
A



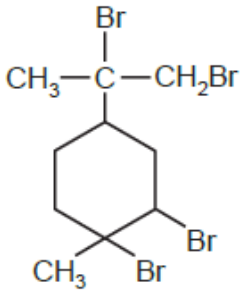
B



C



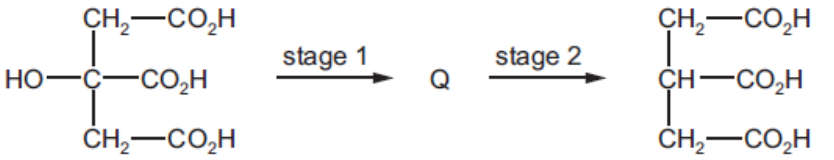
D



26 Which compound is a product of the hydrolysis of $CH_3CO_2CH_2CH_2CH_3$ by boiling aqueous sodium hydroxide?

A CH_3OH **B** C_3H_7OH **C** $C_3H_7CO_2H$ **D** $C_3H_7CO_2^-Na^+$

27 Citric acid can be converted into tricarballylic acid in two stages. An intermediate, Q, is formed.



citric acid tricarballylic acid

Which reagents are needed for each stage?

	stage 1	stage 2
A	Concentrated H_2SO_4	$H_2(g)$ and Ni
B	Concentrated H_2SO_4	$LiAlH_4$
C	$LiAlH_4$	$H_2SO_4(aq)$
D	NaOH(aq)	$H_2(g)$ and Ni

28 Which statements are correct for monomers and polymers involved in addition polymerization?

1 The monomers contain at least one unsaturated bond.

2 Empirical formula of the addition polymer is the same as that of its monomer.

3 Poly(vinyl alcohol) is formed via addition polymerization and can form hydrogen bonds between its adjacent molecules.

4 Low density poly(ethene) (LDPE) and high density poly(ethene) (HDPE) are addition polymers but differ in their monomers.

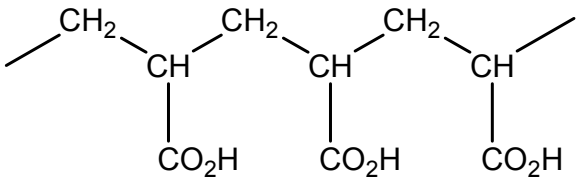
A All correct.

B 1, 2 and 3

C 1 and 2

D 1, 2 and 4

29 The absorbent material in babies' disposable nappies is made from the polymer



From which monomer could this polymer be obtained?

A $ClCH_2CH_2CO_2H$

B $HOCH_2CH_2CO_2H$

C $H_2C{=}CHCO_2H$

D $HO_2CCH{=}CHCO_2H$

30 Chlorofluorocarbons (CFCs) are commonly used as aerosols, propellants and refrigerants. However in the stratosphere, CFCs can damage the ozone layer through a radical chain reaction.

In which sequence are the following compounds listed in increasing order of their ability to destroy ozone?

A	$CHClFCClF_2$	<	CCl_2FCCl_2F	<	$CHClF_2$
B	CCl_2FCCl_2F	<	$CHClF_2$	<	$CHClFCClF_2$
C	$CHClF_2$	<	CCl_2FCCl_2F	<	$CHClFCClF_2$
D	$CHClF_2$	<	$CHClFCClF_2$	<	CCl_2FCCl_2F

End of Paper

NATIONAL JUNIOR COLLEGE
SH 2 PRELIMINARY EXAMINATION

Higher 1

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY

8873/02

Paper 2 Structured Questions

Tues 21 Aug 2018
2 hours

Candidates answer **all** questions on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid/tape.

Section **A**
Answer **all** the questions.

Section **B**
Answer **only one** question.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use			
1	/5		
2	/10		
3	/7		
4	/12		
5	/16		
6	/8		
7	/5		
8 OR 9	/20		
Penalty units			
Penalty sf			
Paper 2	/83		

Answer <u>ALL</u> questions on the space provided.
This paper consists of **20** printed pages.

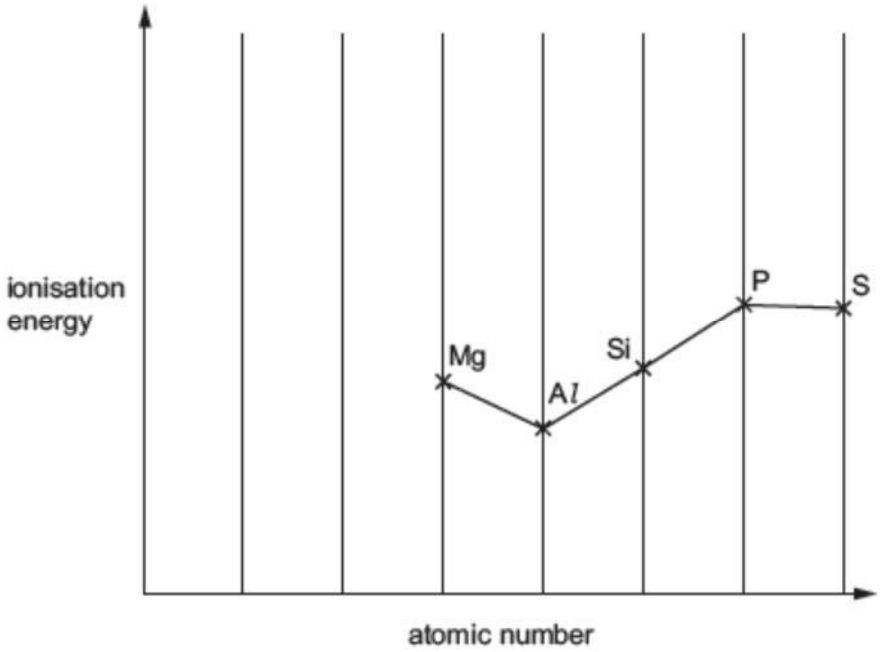
Section A

Answer **all** the questions in this section, in the spaces provided.

1 The properties of elements and their compounds show similarities, differences and trends depending on the positions of the elements.

(a) The elements in the third period, and their compounds, show trends in their physical and chemical properties.

A sketch graph of the first ionisation energies of five successive elements in the third period is shown.



(i) Sketch on the graph, the position of the ionisation energy of the two elements that come before Mg in this sequence.

[1]

(ii) Explain, with reference to electronic arrangements, the decreases in first ionisation energy between Mg and A*l* and between P and S.

Mg and A*l*: .....

.....

.....

P and S: .....

.....

.....

[2]

(b) The chlorides of the elements in the third period behave in different ways when added to water, depending on their structure and bonding.

L is a chloride of an element in Period 3. A student investigated **L** and the results are as given below.

- **L** is a white crystalline solid with a melting point of 987 K.
- **L** dissolves in water to form a weakly acidic solution.
- Addition of NaOH(aq) to an aqueous solution of **L** produces a white precipitate.

(i) Identify **L.**

L: …… [1]

(ii) Write an equation to illustrate the formation of the weakly acidic solution.

…… [1]

[Total: 5]

2 Nanomaterials research takes a materials science-based approach to nanotechnology, leveraging advances in materials metrology and synthesis which have been developed in support of microfabrication research. Materials with structures at the nanoscale often have unique optical, electronic, or mechanical properties as compared to its corresponding bulk materials.

Graphene is a nanomaterials which is an allotrope of carbon such as graphite and diamond. It has many uncommon properties. Graphene is the strongest material ever tested, efficiently conducts heat and electricity, and is nearly transparent.

Because nanotechnology is a recent development, the health and safety effects of exposures to nanomaterials and nanoparticles, and what levels of exposure may be acceptable, are subjects to ongoing research.

(a) State the difference between a nanoparticle and a nanomaterials in terms of size.

……

……

[1]

(b) Describe the property of nanomaterials. Explain how this property enables it to be used in the following application:

1 Catalysis

.....

.....

.....

2 Climbing ability of geckos

.....

.....

.....[4]

(c) With the aid of a labelled diagram, describe the structure of graphene. Explain how this structure gives graphene the properties of high electrical conductivity and high tensile strength.

.....

.....

.....

.....

.....[3]

(d) Cerium oxide is being used in electronics, biomedical supplies, energy and fuel additives.
Predict how nanoparticles of cerium oxide could present a risk to human health **and** the environment.

.....

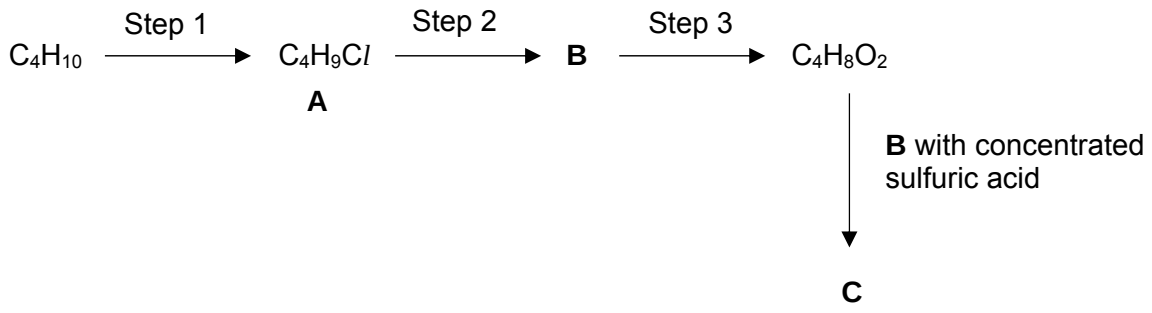
.....

.....

.....[2]

[Total: 10]

3 Student **M** suggested a 2-step process as shown, to synthesise **B** from a suitable butane.



(a) Identify the structures of compounds **B** and **C**. Suggest reagents and conditions for each of the steps.

Structure of **B**	Structure of **C**

Step 1: .....

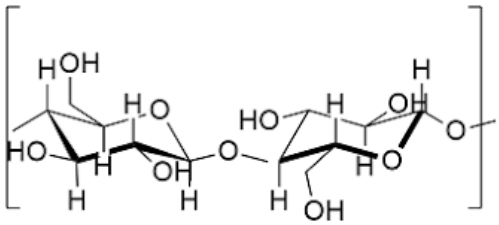
Step 2: .....

Step 3: ..... [5]

(b) Compound **D,** an isomer of compound **A**, is formed after **step 1.**
Suggest the structure of compound **D**. Hence, state the approximate ratio in which compounds **A** and **D** are formed.

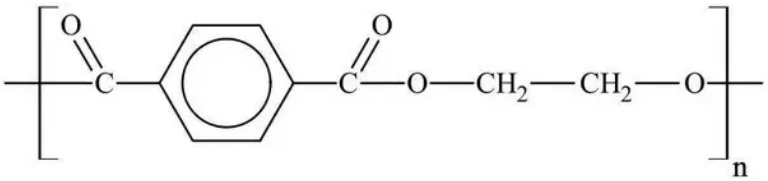
[2]
[Total:7]

4 In the past, football shirts were made from cotton, or even wool. These cotton or wool shirts trapped heat and readily soaked up any sweat produced, making them rather uncomfortable to wear.



Repeating unit of cotton

Nowadays, polyethylene terephthalate (PET) and spandex are used in manufacture of football shirts. Cotton can absorb 7% of its weight in water, whereas polyester only absorbs about 0.4% of its weight. PET also does not crease easily.



Repeating unit of PET

(a) **(i)** Suggest why cotton can absorb more water than PET.

……

……

[1]

(ii) Explain why PET does not crease easily with respect to its **structure.**

……

……

[1]

(b) **(i)** Calculate the percentage of mass of carbon in PET.

[2]

(ii) Identify the type of polymerisation in the formation of PET and provide **two** reasons to explain your answer.

Type of polymer .....

Reason 1.....

.....

Reason 2.....

.....
[3]

(iii) Explain why a PET fabric dissolves slowly when placed in aqueous alkali.

……..……

……..……..……..……..…
[1]

(iv) Write an equation for **one repeat unit** of PET reacting with aqueous sodium hydroxide.

[1]

(c) PET is a thermoplastic. With respect to the structure and interactions of polymer chains, explain

(i) the difference between thermoplastics and thermosets.

……..……

……..……..……..…….
[1]

(ii) why PET can be used as a fabric.

……..……

……..……

……..……..……..…….
[2]

[Total: 12]

5 On 11 May 2018, Mount Merapi on Central Java, Indonesia erupted, causing the local airport to be closed. The eruption was reported to be caused by accumulation of volcanic gases. The volcanic ash and gases spewed can be dangerous to planes passing through the plume. The most abundant volcanic gas is harmless water vapour. However, significant amounts of carbon dioxide, sulfur dioxide, hydrogen sulfide and hydrogen halides are also emitted.

When carbon dioxide is emitted from volcanoes, it typically becomes diluted to low concentrations very quickly and is not life threatening. However, cold carbon dioxide gas can flow into low-lying areas where it can reach much higher concentrations. Breathing air with more than 3% CO_2 can quickly lead to headaches, dizziness, increased heart rate and difficulty breathing. At about 15%, unconsciousness and death can result quickly.

Table 1: Volcanic gas composition in area **A**

Gas	Volume Percentage
Water vapour, H_2O	87.1
Carbon dioxide, CO_2	unknown
Sulfur dioxide, SO_2	0.5
Hydrogen, H_2	0.7
Carbon monoxide, CO	0.01
Hydrogen sulfide, H_2S	0.23
Hydrogen halides	unknown

Composition of the volcanic gases are typically expressed in terms of volume percentage, which can be calculated as follows

$$\text{volume percentage} = \frac{\text{volume of gas}}{\text{total volume}} \times 100\%$$

(a) **(i)** Draw the dot-and-cross diagram of H_2S.

[1]

(ii) State and explain whether H_2S or H_2O has a larger bond angle with respect to its central atom.

.....

.....

.....

.....

[2]

(iii) Suggest a reason why at low temperature, carbon dioxide would sink rapidly and accumulate to high concentrations.

……...

……...

……...
[2]

(iv) People living in area **A** were evacuated as the level of carbon dioxide was increasing rapidly. Given that 0.3 g of CO_2 was present in 1 dm^3 of gas mixture at r.t.p, determine the volume percentage of carbon dioxide present.

Hence comment on the possible danger if people remained in the area.

Volume percentage of carbon dioxide = ……

……...

……...
[2]

(b) Hydrogen sulfide can react with methane in the following equation.

$$CH_4(g) + 2\,H_2S(g) \rightleftharpoons CS_2(g) + 4H_2(g)$$

1 mol of CH_4, 2 mol of H_2S, 1 mol of CS_2 and 1 mol of H_2 were allowed to reach equilibrium in a 2 dm^3 container at a constant temperature and pressure.

(i) State the oxidation state of carbon in each carbon-containing compound.

CH_4 : ……... CS_2: …… [1]

(ii) Hence comment on the role of H_2S in the reaction.

……..…….
. [1]

(iii) Given that CS_2 was found to be 1.2 mol at equilibrium, determine the value of K_c, giving its units.

[2]

(iv) Using the *Data Booklet,* calculate the enthalpy change of the above reaction. Assume bond energy of C-S bond is 272 kJ mol^{-1}.

[2]

(v) Hence state and explain the effect of increasing the temperature of the system on

- position of the equilibrium
- rate of the reaction.

.....

.....

.....

.....

.....

[3]

[Total: 16]

6 1–chloro–1–phenylethane undergoes hydrolysis with hydroxide ions to produce 1–phenylethanol, as shown in the equation below.

$$C_6H_5CHClCH_3 + OH^- \rightarrow C_6H_5CH(OH)CH_3 + Cl^-$$

1-chloro-1-phenylethane 1-phenylethanol

The rate of this reaction can be studied by measuring the amount of hydroxide ions that remain in the solution at a given time after the reaction has been quenched.

(a) Suggest a suitable quenching agent that can be used to slow down the rate of the reaction effectively.

.....
[1]

(b) The rate of this reaction was measured using different initial concentrations of the two reagents and the results are shown below.

Experiment	$[C_6H_5CHClCH_3]$ / mol dm^{-3}	$[OH^-]$ / mol dm^{-3}	Relative rate
1	0.05	0.10	1.0
2	0.10	0.20	2.0
3	0.15	0.10	3.0

(i) Deduce the order of reaction with respect to each of the reagents. Explain your reasoning.

Order with respect to $C_6H_5CHClCH_3$ = ...

Order with respect to OH^- = ...
[2]

(ii) Write the rate equation for this reaction, stating the units of the rate constant, *k*.

rate = ... mol dm^{-3} s^{-1}

units of *k* = ...
[2]
[Total: 5]

7 Lithium is a scavenger for hydrogen, hence able to prevent the reaction between hydrogen and copper during pure copper casting. Reaction with hydrogen makes the copper brittle, causing it to fall apart under very light stress.

Table 2

	Enthalpy / kJ mol^{-1}
Enthalpy change of formation of $LiAlH_4(l)$	–152.5
Enthalpy change of formation of $LiAlH_6(s)$	–454

(a) Heating lithium in a stream of hydrogen gas produces white, crystalline, ionic lithium hydride, LiH.

(i) By quoting relevant data from the *Data Booklet*, suggest and explain how the magnitude of the lattice energy of LiC*l* would compare to that of LiH.

.....

.....

.....
[2]

(b) When lithium hydride is heated with anhydrous aluminium chloride, lithium aluminium hydride, $LiAlH_4$ and lithium chloride are produced.

Balance the equation for the above reaction.

…….. LiH + …… $AlCl_3$ → …….. $LiAlH_4$ + …….LiC*l*
[1]

(c) Just above its melting point, $LiAlH_4$ decomposes according to the following equation.

$$3\ LiAlH_4\ (l) \rightarrow LiAlH_6(s) + 2Al(s) + 3H_2(g)$$

Using **Table 2**, calculate the standard enthalpy change of this reaction.

[2]
[Total: 5]

Section B

Answer only **one** question from this section, in the spaces provided.

8(a) With the aid of a Boltzman distribution curve, explain how the presence of a catalyst increase the rate of a reaction.

.....

.....

.....

[3]

(b) The melting points of some compounds are given.

Substance	Octan-1-ol	Iodine	Fullerene	Graphite
Formula	$CH_3(CH_2)_9OH$	I_2	C_{60}	C
Melting point/ K	277	286	873	>3000

(i) Explain why the melting points of octan-1-ol and iodine are comparable.

.....

.....

.....

.....

[2]

(ii) Explain why the melting point of graphite is higher than that of fullerene.

.....

.....

.....

[2]

(iii) By quoting relevant data from the *Data Booklet*, account for the trend in the thermal stabilities from HC*l* to HI.

.....

.....

.....
[2]

(iv) Arrange the pH of HC*l* to HI in aqueous solution in ascending order.
Explain the variation you have outlined.

.....

.....

.....
[2]

(c) Compound **X** has the molecular formula $C_4H_8O_2$.

(i) Treatment of **X** with acidified potassium dichromate(VII) produces a green solution.
What could be the functional groups present in **X**?

.....

.....

[1]

(ii) There is no reaction when **X** is treated with aqueous sodium carbonate, Na_2CO_3.
What could be the functional groups absent in **X**?

.....

.....

[1]

(iii) When **X** is shaken with aqueous bromine, the orange colour disappears.
What could be the functional groups present in **X**?

.....

.....

[1]

(iv) The molecule of **X** has the following features.

- The carbon chain is unbranched and the molecule is not cyclic.
- No oxygen atom is attached to any carbon atom which is involved in π bonding.
- No carbon atom has more than one oxygen atom joined to it.

There are four possible isomers of **X** which fit these data.

Draw displayed formulae of **all** possible isomers and state which type of isomerism they show.

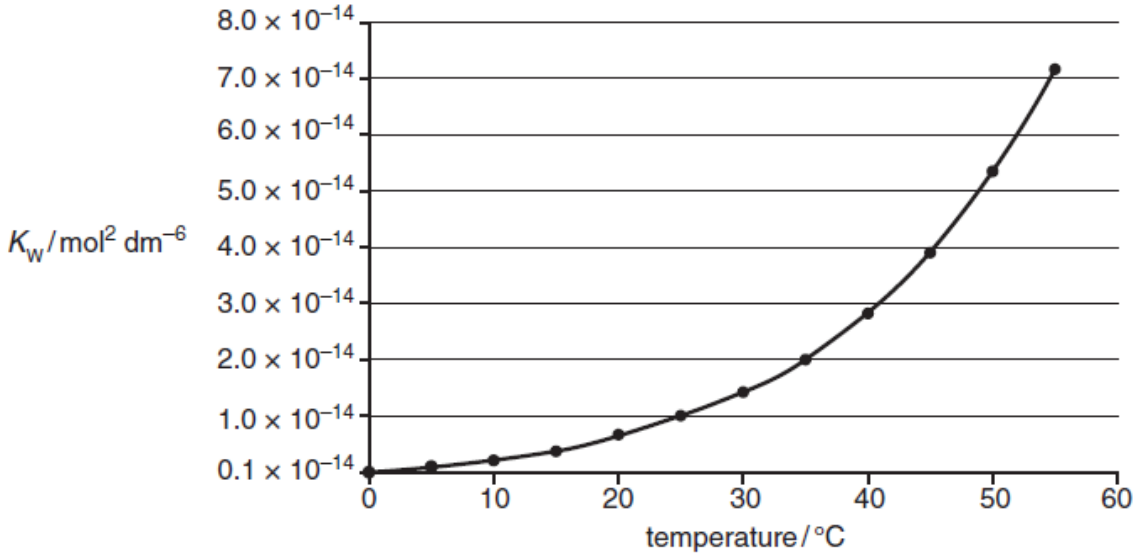
[6]
[Total: 20]

9 (a) The dissociation of water is a reversible reaction.

$$H_2O\ (l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The ionic product of water, K_w, measures the extent of dissociation of water. K_w varies with temperature. It is always important to quote the temperature at which measurements are being taken.

The graph below shows the variation of K_w. between 0 °C and 60 °C.



(i) Write the expression for K_w.

.....

[1]

(ii) Calculate the concentration of hydroxide ions, $[OH^-]$, in an aqueous solution of hydrochloric acid at pH of 4.37 at 25 °C.

[2]

(iii) Using the graph, explain whether the dissociation of water is an exothermic or endothermic process.

.....

.....

.....

.....

[2]

(iv) Using the graph, determine the pH of pure water at body temperature, at 37 ^{o}C.

[3]

(v) Given the following data:

Indicator	Colour change (acidic to basic medium)	pH range in which colour change occurs
Bromothylmol blue	yellow to blue	6.0 – 7.6

State the colour observed when a few drops of bromothylmol blue is added to a sample of pure water at body temperature, at 37 ^{o}C.

.....

[1]

(vi) Buffer solutions are important in biological systems and in industry to maintain almost constant pH values

In the human body, one important buffer system in blood involves the hydrogencarbonate ion, HCO_3^- and carbonic acid, H_2CO_3, which is formed when carbon dioxide dissolves in water.

Use the following equation to explain how this buffer maintains a constant pH of 7.41 even if a small amount of acid enters the bloodstream.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

.....

.....

.....

.....

.....

[2]

(b) The hydrocarbons **A**, C_4H_{10}, and **B**, C_4H_8, are both unbranched.
A does **not** decolourise bromine.
B decolourises bromine and shows cis-trans isomerism.

(i) Draw the skeletal formula of **A**.

[1]

(ii) The hydrocarbon **A**, C_4H_{10}, has a branched isomer.
Suggest why unbranched **A** has a higher boiling point than its branched isomer.

.....

.....

.....

.....

[2]

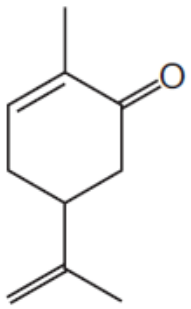
(iii) Draw the structure of the product obtained from the reaction between **B** and bromine. State the type of reaction that occurred.

Type of reaction: …….

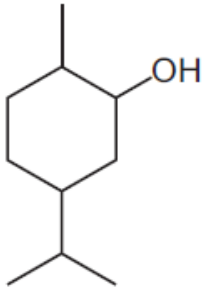
Product:

[2]

(c) Carvone occurs in spearmint and can be converted to compound **M**.



carvone



M

(i) State the reagent and conditions for the conversion of carvone to compound **M**.

name of reagent…..……..……

conditions…..……..……..
[1]

(ii) Draw the structure of the product when **M** is treated with excess concentrated sulfuric acid at 170 °C.

[1]

(d) Write an equation for the reaction that occurs when silicon tetrachloride is added to water. Predict the pH of the resulting solution.

……

……
[2]

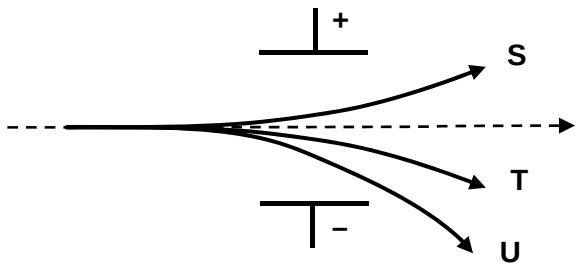
[Total: 20]

End of Paper

NJC 2018 SH2 H1 Chemistry Paper 1 Solutions:

1 *Use of the Data Booklet is relevant to this question.*

The following are flight paths of charged particles when accelerated in an electric field.



Which correctly identifies **S**, **T** and **U**?

	S	T	U
A	$^{15}O^{+}$	$^{14}C^{+}$	$^{14}N^{+}$
B	$^{15}O^{-}$	$^{15}O^{+}$	$^{28}Si^{+}$
C	$^{14}N^{-}$	$^{28}Si^{2+}$	$^{14}C^{2+}$
D	$^{14}N^{-}$	$^{14}C^{+}$	$^{28}Si^{2+}$

C: Negatively charged ions (T and U) attracted to positive plate, positive ions (S) to negative plate.

particles	$^{14}N^{-}$	$^{14}C^{2+}$	$^{14}C^{+}$	$^{28}Si^{2+}$	$^{15}O^{-}$
Charge /mass	1/14	2/14 = 1/7	1/14	2/28 = 1/14	1/15

Since angle of deflection is charge/mass ratio, **S** and **T** have roughly the same angle of deflection but different polarity, while **U** has almost double the angle of deflection as **T**.

2 An element **L** can exist in a few oxidation states. 0.1 mol of $\mathbf{L}^{2+}$ requires 0.04 mol of acidified $KMnO_4$ for complete reaction.

The half equation for reduction of MnO_4^- is

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

What is the final oxidation state of **L**?

A +4 **B** +3 **C** 0 **D** −1

0.1 mol of $\mathbf{L}^{2+}$ loses 0.04(5) = 0.20 mol of electrons.
Imply 1 mol of $\mathbf{L}^{2+}$ loses 2 mol of electrons.

Oxidation state of **L** increases from + 2 to +4.

3 *Use of Data Booklet is relevant to this question.*

Nickel makes up 20% of the total mass of a coin. The coin has a mass of 10.0 g.

How many nickel atoms are in the coin?

A 2.05×10^{22} **B** 4.30×10^{22} **C** 1.03×10^{23} **D** 1.20×10^{24}

2.0 g Ni = 0.03407 mol of Ni

No. of Ni atoms = 0.03407(6.02×10^{23}) = 2.05×10^{22}

4 Which compound has an unpaired electron in its structure?

A N_2O_4 **B** BCl_3 **C** NO **D** NP_3

2 In which sequence is the molecules listed in the order of increasing dipole moment?

A CF_4, CO, HF

CF_4 is non-polar, dipole moments cancel out due to tetrahedral shape of molecule.
CO and HF are linear. HF is more polar than CO, as electronegativity difference is greater between H and F than between C and O.

B H_2O, H_2S, HBr

H_2O and H_2S have bent shape. **H_2O is more polar than H_2S** as O is more electronegative than S.

C SO_3, CO_2, $AlCl_3$

All non-polar. Dipole moments cancel out due to shape of molecule.

D NH_3, HF, $BeCl_2$

NH_3 and HF are polar but $BeCl_2$ is non-polar, dipole moments cancel out due to linear shape of molecule.

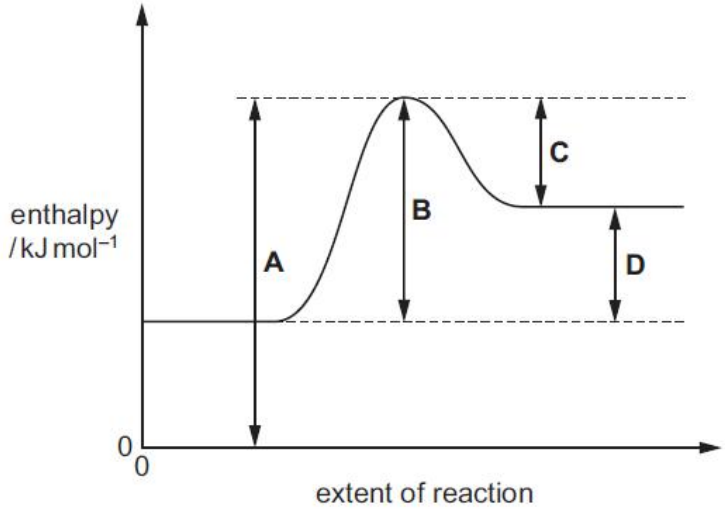
6 The C_2H_2 molecule is linear.

What can be deduced from this about the numbers of σ and π bonds present in the molecule?

	σ	π
A	2	2
B	2	3
C	3	1
D	3	2

C_2H_2 has structure H–C≡C–H.

7 The diagram shows a reaction pathway for an endothermic reaction.



Which arrow represents the activation energy for the forward reaction?

B is activation energy for the forward reaction. C is activation energy for the backward reaction.

8 The standard enthalpy changes of combustion of carbon are as follows.

C(graphite) = – 393 kJ mol^{-1}
C(diamond) = – 395 kJ mol^{-1}

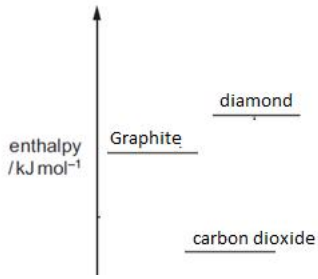
Which deductions can be made from the data above?

1 Graphite is more stable than diamond.

2 Graphite has a higher energy content than diamond.

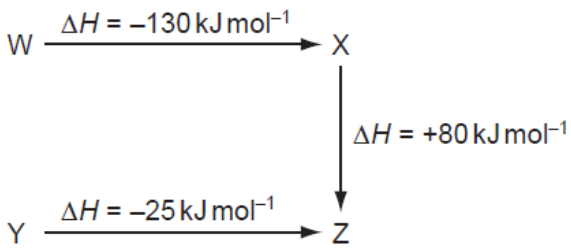
3 Graphite is formed endothermically from diamond.

A 1, 2 and 3 **B** 2, and 3 **C** 1 and 3 only **D** 1 only



From diagram, graphite is more stable than diamond, i.e. lower energy content from diamond and is formed exothermically from diamond.

9 The diagram represents the energy changes for some reactions.

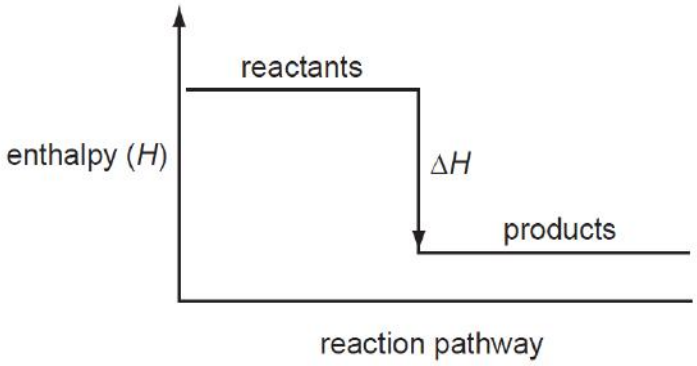


What are the natures of the conversions W → Y, Y → X and Z → W?

	W → Y	Y → X	Z → W
A	exothermic	endothermic	endothermic
B	exothermic	exothermic	endothermic
C	endothermic	exothermic	exothermic
D	endothermic	endothermic	exothermic

	W → Y	Y → X	Z → W
	–130 + 80 + 25 = –25	–25 – 80 = –105	–80 + 130 = +50

10 Which enthalpy change could **not** be correctly represented by the enthalpy diagram shown?



A standard enthalpy change of atomisation

B standard enthalpy change of combustion

C standard enthalpy change of hydration

D standard enthalpy change of neutralisation

Atomisation is endothermic (breaking of bonds to form gaseous atoms), while combustion, hydration and neutralisation are exothermic.

11 Azomethane decomposes when heated according to the following equation.

$$CH_3N{=}NCH_3(g) \rightarrow CH_3CH_3(g) + N_2(g)$$

This reaction is first order with respect to azomethane.

In experiment I, 160 cm^3 of azomethane took 20 min to decompose to 10% of its original volume measured at constant temperature and pressure.

In experiment II, 320 cm^3 of azomethane was allowed to decompose to 10% of its original volume at the same temperature and pressure as experiment I.

What is the time taken for 320 cm^3 of azomethane to decompose to 10% of its original volume?

A 10 min

B 20 min

C 30 min

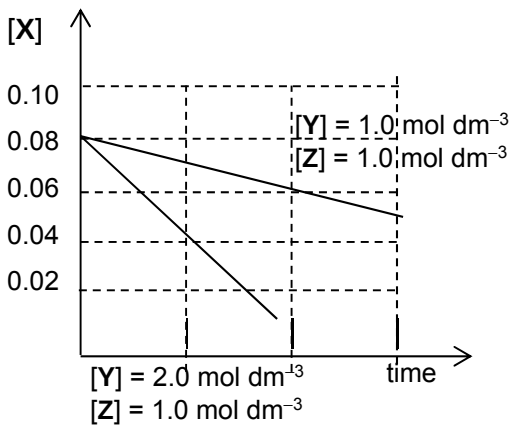
D 40 min

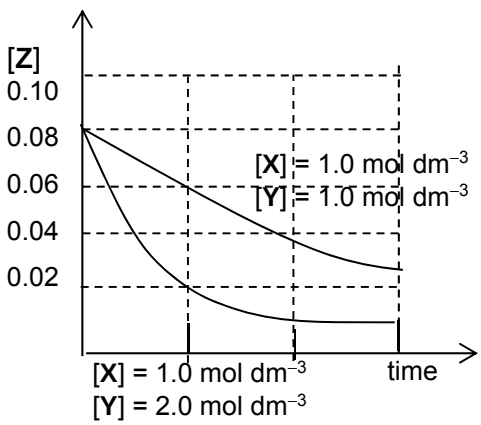
This reaction is first order with respect to azomethane. i.e. constant half-life at constant temperature. Hence same amount of time for azomethane to decrease to 10% of its of its original volume regardless of initial volume.

12 Substances **X**, **Y** and **Z** react according to the following equation:

$$\mathbf{X}(aq) + 2\mathbf{Y}(aq) + \mathbf{Z}(aq) \rightarrow 2\mathbf{W}(aq) + \mathbf{U}(aq)$$

To find the rate equation for the above reaction, two sets of separate experiments were performed, in which the initial concentrations of each of the reactants **X**, **Y** and **Z** were varied while the other two were kept constant. The results are shown below.





Which rate equations represent the experimental results?

A rate = k[**Y**]^2

B rate = k[**Y**][**Z**]

C rate = k[**Y**]^2[**Z**] **D** rate = k[**X**][**Y**][**Z**]

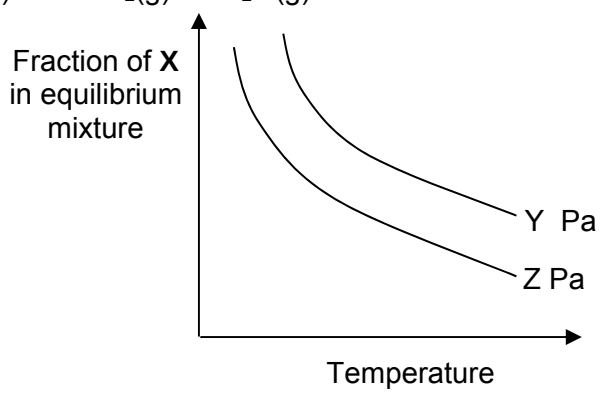
From the [X] versus time graph, a straight line indicates that the rate is constant with respect to any changes in [X]. Therefore order of reaction with respect to X is zero.

From the [Z] versus time graph, a constant half-time is obtained which indicates that the reaction is first order with respect to Z.

From the [Z] versus time graph, the time taken when [Y]= 2.0 mol dm^{-3} is $\frac{1}{4}$ of the time taken when [Y]=1.0 mol dm^{-3} for [Z] to drop from 0.08 mol dm^{-3} to 0.04 mol dm^{-3}.
Therefore order of reaction with respect to Y is 2.

13 The graph below shows how the fraction of **X**, which represents one of the following compounds in the given equilibrium mixture, varies with temperature at pressures of Y Pa and Z Pa.

$4NH_3(g) + 3O_2(g) \rightleftharpoons 2N_2(g) + 6H_2O(g)$ $\Delta H = -1267$ kJ mol^{-1}



Identify **X** and the correct relative magnitudes of Y and Z.

	X	**Pressure**
A	N_2	Z > Y
B	O_2	Y > Z
C	H_2O	Y > Z
D	NH_3	Z > Y

Shape of graph:

(i) As temperature increase, fraction of **X** decrease.

(ii) As temperature increase, as forward reaction is exothermic, eqm shifts left to partially absorb some heat. Fraction of product should decrease.

Matching (i) and (ii): **X** should be the product of the reaction => either N_2 or H_2O.

Comparison of the two graphs:

(i) From eqm equation: 7 mol of gaseous reactants vs 8 mol of gaseous products => decrease pressure will favour the forward reaction, to partially increase pressure.

(ii) Decrease pressure increase the fraction of **X** (since **X** is the product)

Matching (i) and (ii): Fraction of **X** is higher for Y Pa than Z Pa (Y Pa < Z Pa)

14 One of the key production stages in the Contact Process is the production of sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H < 0$$

The rate constants of the forward and backward reactions are given as k_1 and k_{-1} respectively.

What happens to k_1, k_{-1} and K_c if the temperature of the reaction is increased?

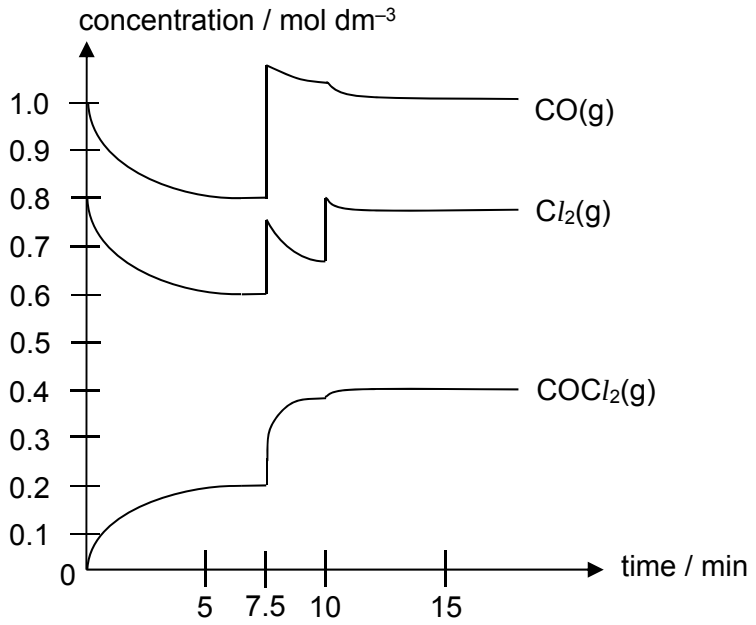
	k_1	k_{-1}	K_c
A	increase	increase	increase
B	increase	decrease	increase
C	decrease	increase	decrease
D	increase	increase	decrease

When temperature increases, no of molecules with energy greater than activation energy increases, frequency of effective collisions increases, **rates of reaction for forward and backward reactions increase. Rate constant for forward and backward reactions increase**. k_1 and k_{-1} increase.

As reaction is exothermic, as temperature increases, equilibrium shifts backward to partially absorb the excess heat. Hence, K_c decreases as [product]/[reactant] decrease.

15 The reaction between carbon monoxide and chlorine was studied in an experiment by mixing the two gases and changing the reaction conditions inside the reaction vessel at different times during the experiment. The concentrations of the gases in the vessel were followed with time, and the following graph is obtained.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g) \qquad \Delta H^{\ominus} = -113.4 \text{ kJ mol}^{-1}$$



Which conclusion deduced from the graph is **incorrect**?

A The rate of forward reaction equals the rate of backward reaction at 7 min.

Correct: At 7 min, the system is in dynamic equilibrium (illustrated by constant concentrations/ plateaus) and hence the rate of forward reaction is equal to the rate of backward reaction.

B The change in concentration from 7.5 min to 10 min was produced by an increase in volume at constant temperature.

Incorrect: Increase in volume at constant temperature will cause all concentrations to decrease instanteously, not increased.

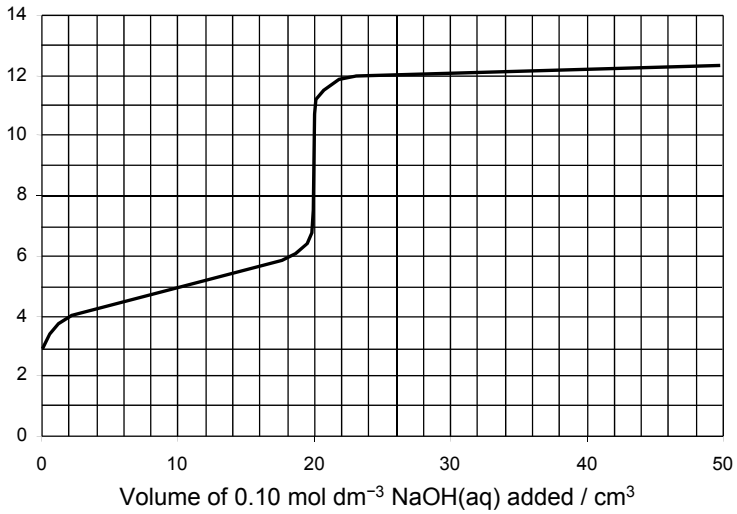
C The equilibrium constant, K_c, for the system when determined at 7 min is 0.417 $mol^{-1}\ dm^3$.

Correct: Using $K_c = \frac{[COCl_2]}{[CO][Cl_2]}$ and calculate.

D The change in concentration from 10 min to 15 min was produced by the addition of more chlorine.

Correct: When chlorine is added, the concentration of chlorine increases instantaneously as shown in the graph and then eqm shifts forward to partially reduce some chlorine.

16 The titration curve below shows the reaction between 20.0 cm^3 of **HX**, and aqueous sodium hydroxide.



Given the following data:

Indicator	Colour change (acidic to basic medium)	pH range in which colour change occurs
Methyl red	red to yellow	4.2 – 6.3
Bromothylmol blue	yellow to blue	6.0 – 7.6
Thymolpthalein	colourless to blue	8.3 – 10.5

What statements are correct?

1 Methyl red is the most suitable indicator to be used for this titration.

Incorrect. Equivalence point occurs around pH 9 which coincides/falls within working pH range of thymolpthalein. Thymolpthalein is the most suitable indicator, not methyl red.

2 Initial concentration of HX is 0.10 mol dm^{-3}.
Correct. 20.0 cm^3 of **HX** requires 20.0 cm^3 of 0.10 mol dm^{-3} NaOH(aq) for complete neutralisation. Hence initial concentration of HX is 0.10 mol dm^{-3}.

3 When 10.0 cm^3 of NaOH is added, $[H^+]$ in the mixture is 1.00×10^{-5} mol dm^{-3}.

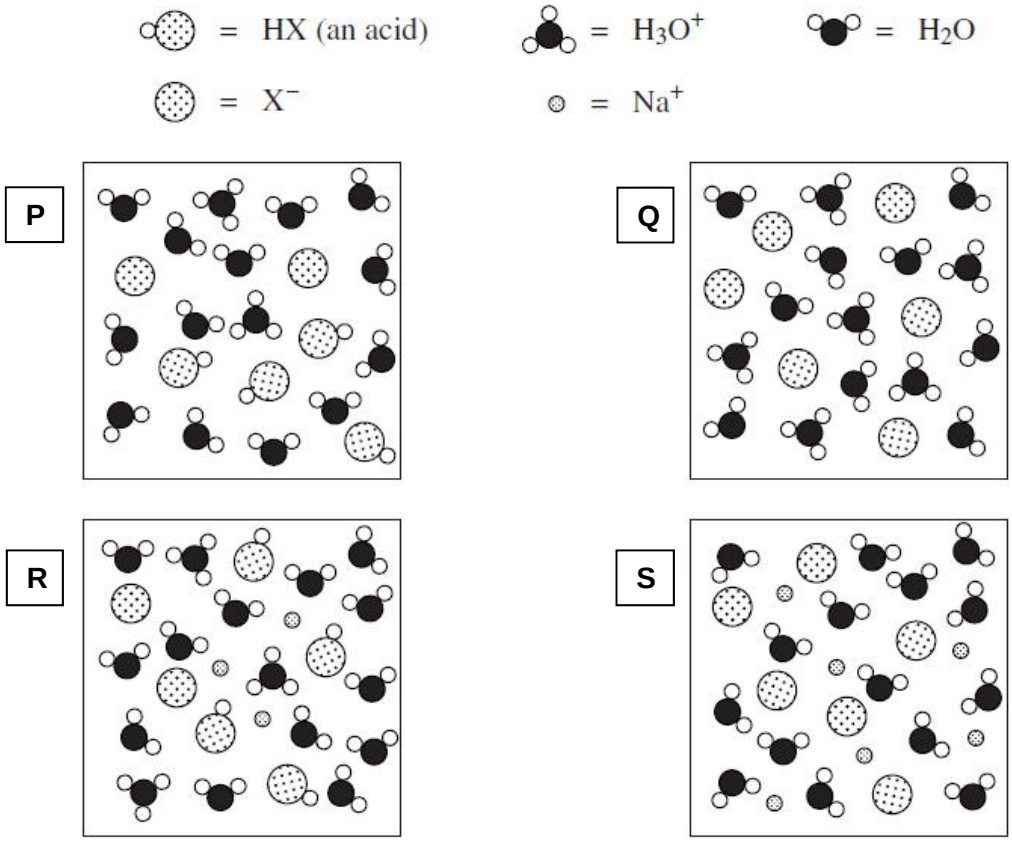
When 10.0 cm^3 of 0.10 mol dm^{-3} NaOH(aq) is added, pH = 5 from graph.

pH = -lg $[H^+]$ = 5

$[H^+] = 1.00 \times 10^{-5}$ mol dm^{-3}

A 1, 2 and 3 **B** 2, and 3 **C** 1 and 3 only **D** 3 only

17 The diagrams represent some dilute aqueous solutions.
In all cases, only a few of the large numbers of water molecules are shown.

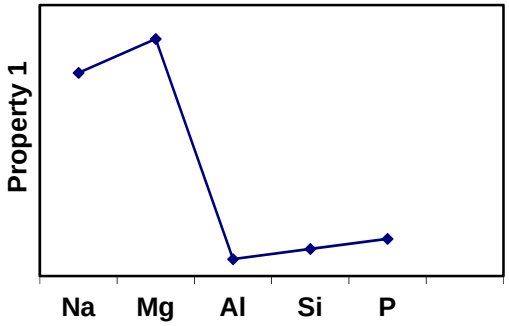


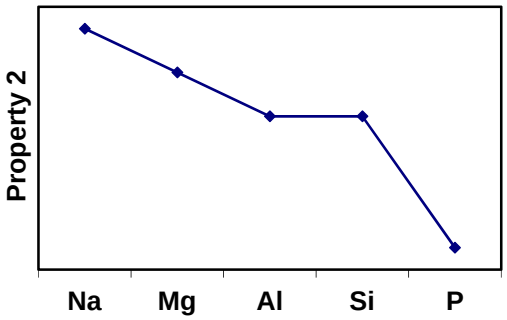
Which option correctly describes the solutions represented by the diagrams?

	P	Q	R	S
A	a strong acid	a weak acid	a salt formed by neutralising a strong acid with sodium hydroxide	weak acid partially neutralised by sodium hydroxide

B	a weak acid	a strong acid	a salt formed by neutralising a strong acid with sodium hydroxide	weak acid partially neutralised by sodium hydroxide
C	a strong acid	a weak acid	weak acid partially neutralised by sodium hydroxide	a salt formed by neutralising a strong acid with sodium hydroxide
D	a weak acid	a strong acid	weak acid partially neutralised by sodium hydroxide	a salt formed by neutralising a strong acid with sodium hydroxide
	Partial dissociation: mixture of HX, X^-, H_3O^+, H_2O	Full dissociation of HX: mixture of X^- and H_3O^+	weak acid partially neutralised, ie. HX and NaX present. mixture of HX, X^-, Na^+, H_2O	Salt from strong acid with NaOH. Hence only salt NaX and water present: X^-, Na^+, H_2O

18 The graphs below show the variation of two properties of some period 3 elements and/or their compounds.





Which correctly describes properties 1 and 2?

	Property 1	Property 2
A	atomic radius of the elements	electrical conductivity of the elements
B	boiling point of the highest oxidation state chlorides	pH of the highest oxidation state oxides when added to water
C	melting point of oxides	first ionisation energies of the elements
D	electrical conductivity of elements	pH of the highest oxidation state chlorides when added to water

Property 1	Property 2
For option A Atomic radii is a continuous decrease across the period. There is an increase in nuclear attraction for the outermost electrons because of increase in nuclear charge but constant shielding	Electrical conductivity increases from Mg to Al due to increase in no. of mobile charged carriers (more electrons in the sea of delocalised electrons). Electrical conductivity is very low for Si while P exhibit zero electrical conductivity.

caused by the same number of inner electrons. Hence graph cannot be atomic radii.	Hence graph cannot be electrical conductivity.
For option B Boiling points of chloride compounds decrease from NaCl to $AlCl_3$. Less energy is required to overcome the weak temporary dipole induced dipole interactions between $AlCl_3$ molecules compared to the strong ionic bonds in giant ionic lattice of NaCl and $MgCl_2$. $AlCl_3$ to PCl_5 are simple covalent molecules with Mr of $AlCl_3$ (133.5) < $SiCl_4$ (170.1) < PCl_5 (208.5). B.pt increases with increasing ease of distortion of the electron clouds of the chloride compound, tdid interactions increase. Hence graph shows the correct trend in the b.pt of chlorides across period 3 element.	**Acid base property of oxide** depends on the **nature of bonds present in the oxide**. Ionic oxides tend to be basic and covalent oxides are usually acidic; ionic oxides with significant covalent character are amphoteric, this is usually observed when cation has high charge/size ratio. **pH of oxides in aqueous medium** depends on the nature of the bonds and **solubility.** Na_2O is **basic and fully soluble** in water, therefore pH is very high (highly alkaline). Solubility of MgO is less than Na_2O but more soluble than Al_2O_3, hence pH of MgO > Al_2O_3. Al_2O_3 is an amphoteric oxide while SiO_2 is an acidic oxide. **pH of Al_2O_3 and SiO_2 are 7 because both are insoluble in water.** Oxides of P dissolve in water to give phosphoric acid, therefore pH is very low. Hence graph shows the correct trend for pH of aqueous oxides across period 3.
For option C Melting points of oxides across the period peak at SiO_2 since SiO_2 has a very strong giant covalent lattice. Phosphoric oxide is a simple covalent molecule, therefore drastic drop of m.pt from SiO_2 to P_4O_{10}. Hence graph cannot be m.pt of oxides across period 3 elements.	First ionisation energy of elements across period has a general increasing trend. There is an increase in nuclear attraction for the most loosely held electron because of increase in nuclear charge but constant shielding caused by the same number of inner electrons. Hence graph cannot be first ionisation energy.
For option D Electrical conductivity increases from Mg to Al due to increase in no. of mobile charged carriers (more electrons in the sea of delocalised electrons). Electrical conductivity is very low for Si while P exhibit zero electrical conductivity. Hence graph cannot be electrical conductivity.	Chlorides across period 3 are all soluble in aqueous medium. For chlorides that dissociates into ions in aq medium, cation hydrolysis gives rise to acidic solution. Extent of cation hydrolysis increases with charge/size ratio of the cation. Hence $AlCl_3$ (aq) is more acidic than $MgCl_2$(aq) while NaCl is neutral (pH =7) Covalent chlorides react with water to form HCl, therefore the pH value is low for both $SiCl_4$ and PCl_5. Hence graph cannot be pH trend of aqueous chlorides across the period.

19 Element **H** is in Period 3 of the Periodic Table. The following four statements were made about the properties of element **J** or its compounds.

Three statements are correct descriptions and one is false.

Which statement does **not** fit with the other three?

A Adding NaOH(aq) to the solution resulting from the reaction of a chloride of **J** with water produces a white precipitate which is soluble in an excess of NaOH(aq).

From Data Booklet, cation that gives white precipitate with NaOH and soluble in an excess of NaOH(aq) is Al^{3+} and Zn^{2+}. Only Al^{3+} is in period 3.

B Element **H** is a solid at room temperature.

can be Na, Mg, Al, Si, S_8, P_4 from Period 3.

C Element **H** has the highest melting point among the period 3 elements.

must be Si if highest melting point.

D The oxide of element **H** is soluble in hydrochloric acid.

Al_2O_3 reacts with acid, henceis soluble in acid. SiO_2 is not soluble in HCl. SiO_2 is acidic, no reaction with HCl,

20 **J**, **K** and **L** are elements in Period 3 of the Periodic Table.

A mixture containing the oxides of **J**, **K** and **L** was dissolved in excess dilute sulfuric acid and filtered. The oxide of **L** was collected as a residue. When excess dilute sodium hydroxide was added to the filtrate, only a white precipitate of the hydroxide of **K** was formed.

What are the possible identities of **J**, **K** and **L**?

	J	**K**	**L**
A	Mg	A*l*	P
B	A*l*	Mg	P
C	Mg	A*l*	Si
D	A*l*	Mg	Si

L: SiO_2 is not soluble in HCl. SiO_2 is acidic, no reaction with HCl.

J: Al^{3+} gives white precipitate with NaOH and soluble in an excess of NaOH(aq).

K: Mg^{2+} gives white precipitate with NaOH and insoluble in an excess of NaOH(aq).

21 Which are the principal factors which cause the properties of nanomaterials to differ

significantly from other materials?

1 Size distribution (the size of the material can also influence its properties of a material at nanoscale)

2 Specific surface feature (Reactions and interactions occur on the surface of materials)

3 Very high surface area to volume ratio (proportion of atoms on the surface of the nanomaterials is large)

A **1**, **2** and **3** **B** **1** and **2**

C **2** and **3** **D** **1** only

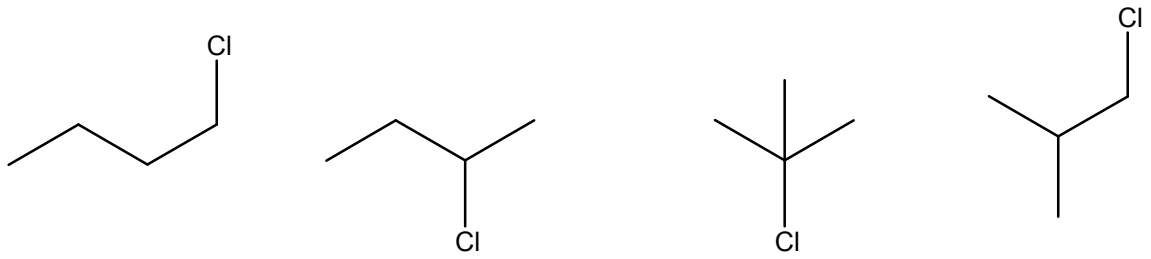
22 The size of nanoparticles is between _____ m.

A 10^{-8} to 10^{-7} **B** 10^{-10} to 10^{-8} **C** 10^{-9} to 10^{-7} **D** 10^{-11} to 10^{-9}

A material with all dimensions to be in the nanoscale (1- 100 nm)

23 How many structural isomers can C_4H_9Cl form?

A 3 **B** 4 **C** 5 **D** 6



24 Compound **G** has the following structure: $(CH_3)_2C{=}CHCH_2CH(OH)CH_2CH{=}CH(CH_3)$

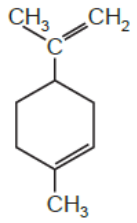
How many cis-trans isomers does Compound **G** have?

A 0 **B** 2 **C** 3 **D** 4

$(CH_3)_2C{=}CHCH_2CH(OH)CH_2CH{=}CH(CH_3)$

There must be different groups bonded to each C of the restricted bond rotation. Only the highlighted C=C bond exhibits cis-trans isomerism.

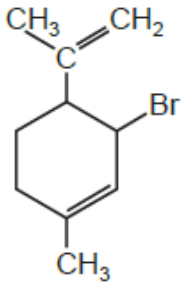
25 Limonene is an oil formed in the peel of citrus fruits.



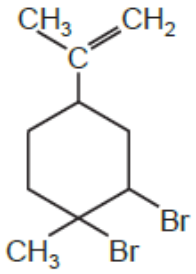
limonene

Which product is formed when an excess of bromine, $Br_2(l)$ reacts with limonene at room temperature in the dark?

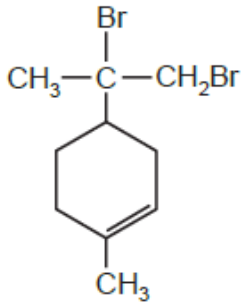
A



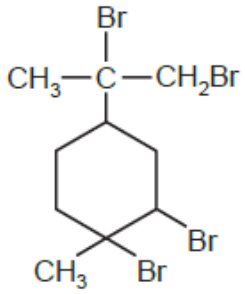
B



C



D



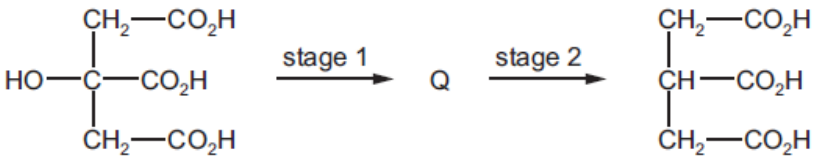
Answer: D. Bromine adds across both C=C bonds.

26 Which compound is a product of the hydrolysis of $CH_3CO_2CH_2CH_2CH_3$ by boiling aqueous sodium hydroxide?

A CH_3OH **B** C_3H_7OH **C** $C_3H_7CO_2H$ **D** $C_3H_7CO_2^-Na^+$

$CH_3CO_2CH_2CH_2CH_3 + NaOH \rightarrow CH_3CO_2Na + CH_3CH_2CH_2OH$

27 Citric acid can be converted into tricarballylic acid in two stages. An intermediate, Q, is formed.



citric acid tricarballylic acid

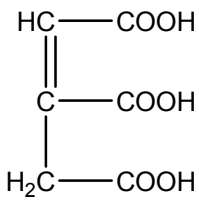
Which reagents are needed for each stage?

	stage 1	stage 2
A	Concentrated H_2SO_4	$H_2(g)$ and Ni

B Concentrated H_2SO_4 $LiAlH_4$

C $LiAlH_4$ $H_2SO_4(aq)$

D NaOH(aq) $H_2(g)$ and Ni



Q

Stage 1 is elimination of water, ie. Excess concentrated H_2SO_4 , heat
Stage 2 is reduction of C=C bond. You can only use $H_2(g)$ and Ni, heat.
If $LiAlH_4$, dry ether is used, C=C bond is not reduced while COOH group is reduced instead.

28 Which statements are correct for monomers and polymers involved in addition polymerization?

1 The monomers contain at least one unsaturated bond.

2 Empirical formula of the addition polymer is the same as that of its monomer.

3 Poly(vinyl alcohol) is formed via addition polymerization and can form hydrogen bonds between its adjacent molecules.

4 Low density poly(ethene) (LDPE) and high density poly(ethene) (HDPE) are addition polymers but differ in their monomers.

A All correct.

B 1, 2 and 3

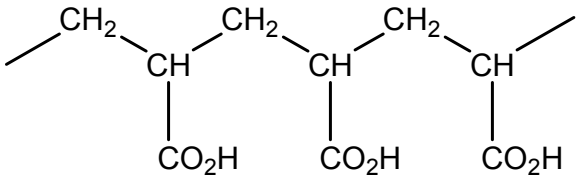
C 1 and 2

D 1, 2 and 4

Statements 1-3 are true.

Statement 4: LDPE and HDPE are addition polymers of ethene.

29 The absorbent material in babies' disposable nappies is made from the polymer



From which monomer could this polymer be obtained?

A $ClCH_2CH_2CO_2H$

B $HOCH_2CH_2CO_2H$

C $H_2C{=}CHCO_2H$

D $HO_2CCH{=}CHCO_2H$

Above polymer is an addition polymer. Monomer contains C=C and a single COOH group.

30 Chlorofluorocarbons (CFCs) are commonly used as aerosols, propellants and refrigerants. However in the stratosphere, CFCs can damage the ozone layer through a radical chain reaction.

In which sequence are the following compounds listed in increasing order of their ability to destroy ozone?

A $CHClFCClF_2$ < CCl_2FCCl_2F < $CHClF_2$

B CCl_2FCCl_2F < $CHClF_2$ < $CHClFCClF_2$

C $CHClF_2$ < CCl_2FCCl_2F < $CHClFCClF_2$

D $CHClF_2$ < $CHClFCClF_2$ < CCl_2FCCl_2F

C-F bond is much stronger than C-Cl, C-F bond does not break easily to form F radicals => does not damage ozone layer.
All four options (A), (B), (C) and (D) comprise of molecules containing C-F and C-Cl bonds. The molecule with more C-Cl bonds will have higher ability to destroy ozone due to more Cl radicals produced. Hence, answer is (D).

END of PAPER

1	C	11	B	21	A
2	A	12	C	22	C
3	A	13	A	23	B
4	C	14	D	24	B
5	A	15	B	25	D
6	D	16	B	26	B
7	B	17	D	27	A
8	D	18	B	28	B
9	B	19	C	29	C
10	A	20	D	30	D

NATIONAL JUNIOR COLLEGE
SH 2 PRELIMINARY EXAMINATION

Higher 1

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY

8873/02

Paper 2 Structured Questions

Tues 21 Aug 2018
2 hours

Candidates answer **all** questions on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid/tape.

Section **A**
Answer **all** the questions.

Section **B**
Answer **only one** question.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use			
1	/5		
2	/10		
3	/7		
4	/12		
5	/16		
6	/5		
7	/5		
8 OR 9	/20		
Penalty units			
Penalty sf			
Paper 2	/80		

Answer <u>ALL</u> questions on the space provided.
This paper consists of **20** printed pages.

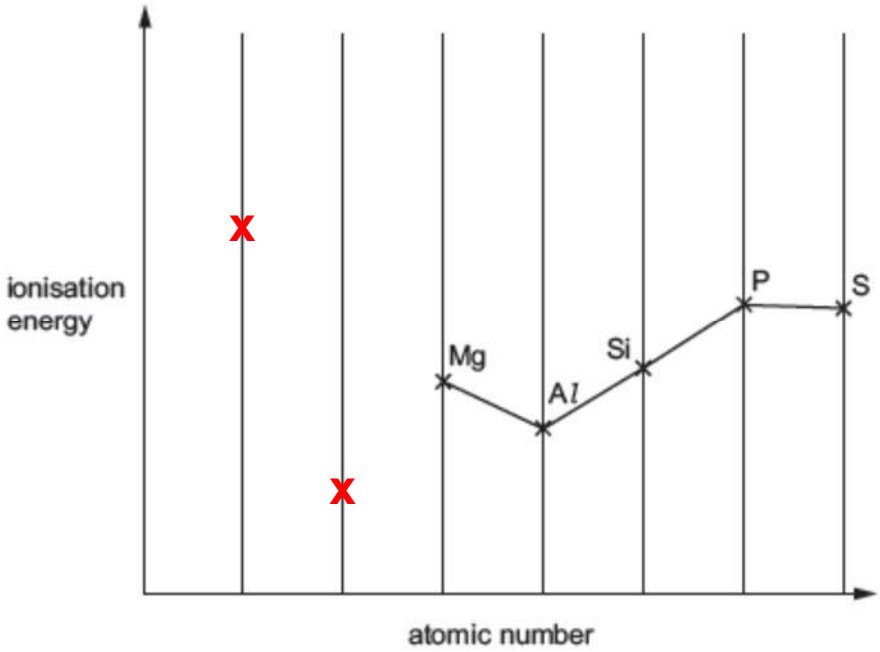
Section A

Answer **all** the questions in this section, in the spaces provided.

1 The properties of elements and their compounds show similarities, differences and trends depending on the positions of the elements.

(a) The elements in the third period, and their compounds, show trends in their physical and chemical properties.

A sketch graph of the first ionisation energies of five successive elements in the third period is shown.



(i) Sketch on the graph, the position of the ionisation energy of the two elements that come before Mg in this sequence.

[1]

Cross shown on first vertical line from the y-axis (group 0/Ne) is clearly higher than all shown.
Cross shown on second vertical line from the y-axis (group 1/Na) is clearly lower than all shown.

[1]

(ii) Explain, with reference to electronic arrangements, the decreases in first ionisation energy between Mg and A*l* and between P and S.

Mg and A*l*: The most loosely held electron in A*l* is in the **higher energy 3p subshell** while that of Mg is in the **lower energy 3s subshell.**
This **outweighs the effect of the increase in nuclear charge** from Mg to A*l*.
Hence **nuclear attraction for the most loosely held electron in A*l* is weaker**, i.e. A*l* has a lower 1st IE. [1]

P and S: The most loosely held electron in S is one of the **paired electrons in 3p** orbital while that of P is in the **singly filled 3p** orbital.
Inter-electronic repulsion between the paired electrons in the same p orbital **outweighs the effect of an increase in nuclear charge**.
Hence, **nuclear attraction for the most loosely held electrons is weaker in**

S, i.e. S has a lower first IE. [1]

[2]

(b) The chlorides of the elements in the third period behave in different ways when added to water, depending on their structure and bonding.

L is a chloride of an element in Period 3. A student investigated **L** and the results are as given below.

- **L** is a white crystalline solid with a melting point of 987 K.
- **L** dissolves in water to form a weakly acidic solution.
- Addition of NaOH(aq) to an aqueous solution of **L** produces a white precipitate.

(i) Identify **L.**

L: $MgCl_2$ [1]

(ii) Write an equation to illustrate the formation of the weakly acidic solution.

$[Mg(H_2O)_6]^{2+}(aq) + H_2O(l) \rightleftharpoons [Mg(H_2O)_5(OH)]^{+}(aq) + H_3O^{+}(aq)$ [1]
(state symbols not necessary)

[Total: 5]

2 Nanomaterials research takes a materials science-based approach to nanotechnology, leveraging advances in materials metrology and synthesis which have been developed in support of microfabrication research. Materials with structures at the nanoscale often have unique optical, electronic, or mechanical properties as compared to its corresponding bulk materials.

Graphene is a nanomaterials which is an allotrope of carbon such as graphite and diamond. It has many uncommon properties. Graphene is the strongest material ever tested, efficiently conducts heat and electricity, and is nearly transparent.

Because nanotechnology is a recent development, the health and safety effects of exposures to nanomaterials and nanoparticles, and what levels of exposure may be acceptable, are subjects to ongoing research.

(a) State the difference between a nanoparticle and a nanomaterials in terms of size.

Nanomaterials: A material with at least one dimension to be in the nanoscale (1 – 100 nm)

Nanoparticles: A material with all dimensions to be in the nanoscale (1- 100 nm)

[1]

(b) Describe the property of nanomaterials. Explain how this property enables it to be used in the following application:

1 Catalysis

By using nanoparticles of the precious metals instead of larger particles, less metal is needed to produce the same surface area over the ceramic base of the catalyst

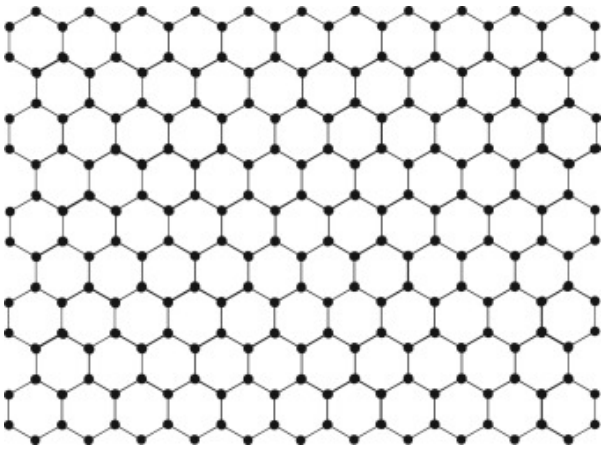
2 Climbing ability of geckos

The spatula-shaped setae arranged in lamellae on gecko footpads enable attractive van der Waals' forces between spatulae structures and the surface.

Use of small van der Waals attraction force requires very large surface areas.

[4]

(c) With the aid of a labelled diagram, describe the structure of graphene. Explain how this structure gives graphene the properties of high electrical conductivity and high tensile strength.



One p electrons per C atom delocalised so high electrical conductivity

Each C attached to 3 others by a network of strong covalent bonds so high strength.

[3]

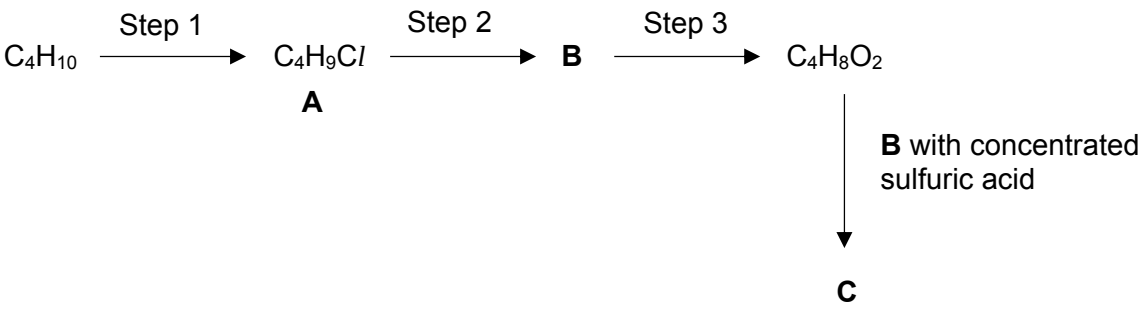
(d) Cerium oxide is being used in electronics, biomedical supplies, energy and fuel additives.
Predict how nanoparticles of cerium oxide could present a risk to human health **and** the environment.

Small enough to go through the pores AND can get into the blood and affects organs

High energy requirements for synthesizing nanoparticles causing high energy demand./Dissemination of toxic, persistent nanosubstances originating environmental harm/ Lower recovery and recycling rates

[2]
[Total: 10]

3 Student **M** suggested a 2-step process as shown, to synthesise **B** from a suitable butane.



(a) Identify the structures of compounds **B** and **C**. Suggest reagents and conditions for each of the steps.

$CH_3CH_2CH_2CH_2OH$ Structure of **B**	$CH_3CH_2CH_2CH_2OCOCH_2CH_2CH_3$ Structure of **C**

Step 1: Cl_2 (g), uv light/ heat

Step 2: KOH(aq), heat or NaOH(aq), heat

Step 3: $KMnO_4$, H_2SO_4(aq), heat or $K_2Cr_2O_7$, H_2SO_4(aq), heat under reflux

[5]

(b) Compound **D,** an isomer of compound **A**, is formed after **step 1.**
Suggest the structure of compound **D**. Hence, state the approximate ratio in which compounds **A** and **D** are formed.

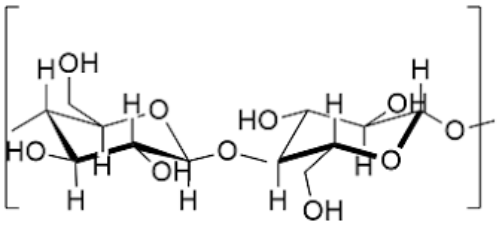
Compound A: $CH_3CH_2CH_2CH_2Cl$, 1-chlorobutane

Compound D: $CH_3CH_2CHClCH_3$, 2-chlorobutane

approximate ratio for **A**: **D**
3: 2

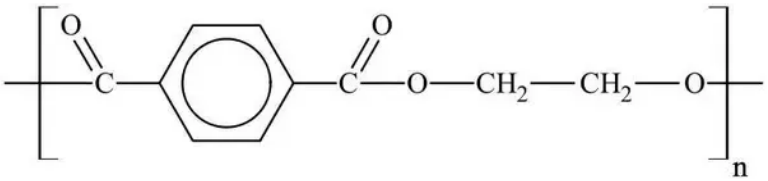
[2]
[Total:7]

4 In the past, football shirts were made from cotton, or even wool. These cotton or wool shirts trapped heat and readily soaked up any sweat produced, making them rather uncomfortable to wear.



Repeating unit of cotton

Nowadays, polyethylene terephthalate (PET) and spandex are used in manufacture of football shirts. Cotton can absorb 7% of its weight in water, whereas polyester only absorbs about 0.4% of its weight. PET also does not crease easily.



Repeating unit of PET

(a) **(i)** Suggest why cotton can absorb more water than PET.

Cotton has many hydroxyl groups (OH groups), thus able to form more extensive hydrogen bonds with water molecules, trapping water. PET form less extensive hydrogen bonding with water.

[1]

(ii) Explain why PET does not crease easily with respect to its **structure.**

The aromatic benzene ring adds rigidity to PET's structure and prevents polyester from deforming easily. OR

There is <u>restricted rotation of bonds due to the presence of double bonds in the benzene rings</u> or due to the presence of the COO group which is planar, this prevents polyester from deforming easily.

[1]

(b) **(i)** Calculate the percentage of mass of carbon in PET.

Formula of repeating unit: $C_{10}H_8O_4$
Mr of repeating unit = 10(12) + 8(1) + 4(16) = 192
Percentage of mass of carbon = $\frac{10(12)}{192} \times 100\%$ = 62.5%

[2]

(ii) Identify the type of polymerisation in the formation of PET and provide **two** reasons to explain your answer.

Type of polymerisation : Condensation polymerisation [1]

Reason 1: PET is formed when 2 different types of monomers (with different functional groups) reacted to form a long chain polymer molecule [1]

Reason 2: a small molecule is are eliminated during the reaction [1]

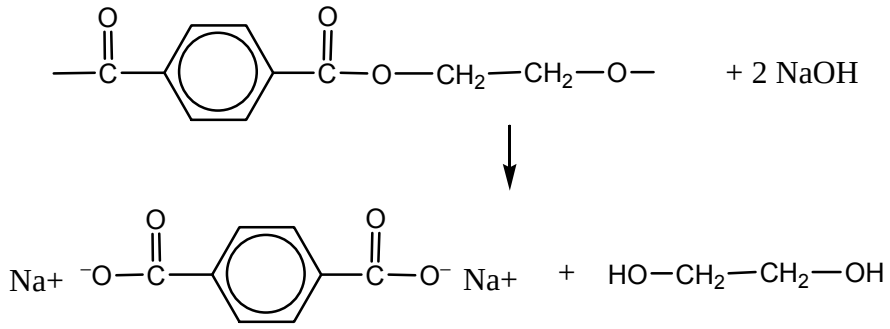
[3]

(iii) Explain why a PET fabric dissolves slowly when placed in aqueous alkali.

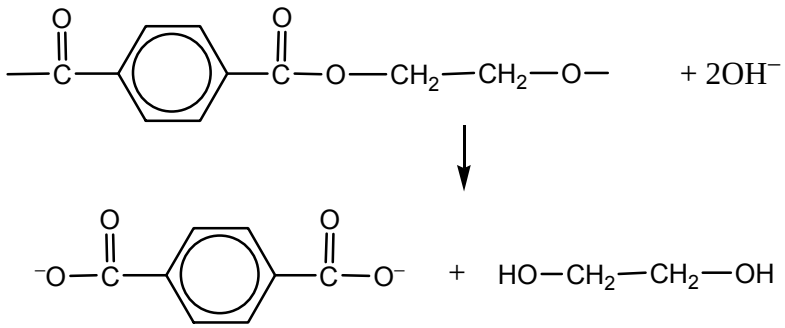
PET undergoes hydrolysis when exposed to alkali, causing the ester linkages to break.

[1]

(iv) Write an equation for **one repeat unit** of PET reacting with aqueous sodium hydroxide.



OR



[1]

(c) PET is a thermoplastic. With respect to the structure and interactions of polymer chains, explain

(i) the difference between thermoplastics and thermosets.

Thermoplastics have no cross links between the chains. Thermoset have cross links between the chains.

[1]

(ii) why PET can be used as a fabric.

In PET, there are **weak permanent dipole-permanent dipole interactions** between the side groups of neighbouring polymer chains, hence allowing the chains to side over each other, giving the flexibility/ fluidity as a fabric.

[2]

[Total: 12]

5 On 11 May 2018, Mount Merapi on Central Java, Indonesia erupted, causing the local airport to be closed. The eruption was reported to be caused by accumulation of volcanic gases. The volcanic ash and gases spewed can be dangerous to planes passing through the plume. The most abundant volcanic gas is harmless water vapour. However, significant amounts of carbon dioxide, sulfur dioxide, hydrogen sulfide and hydrogen halides are also emitted.

When carbon dioxide is emitted from volcanoes, it typically becomes diluted to low concentrations very quickly and is not life threatening. However, cold carbon dioxide gas can flow into low-lying areas where it can reach much higher concentrations. Breathing air with more than 3% CO_2 can quickly lead to headaches, dizziness, increased heart rate and difficulty breathing. At about 15%, unconsciousness and death can result quickly.

Table 1: Volcanic gas composition in area **A**

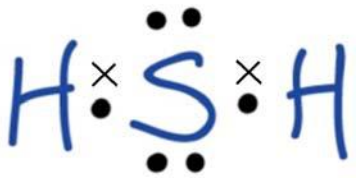
Gas	Volume Percentage
Water vapour, H_2O	87.1
Carbon dioxide, CO_2	unknown
Sulfur dioxide, SO_2	0.5
Hydrogen, H_2	0.7
Carbon monoxide, CO	0.01
Hydrogen sulfide, H_2S	0.23
Hydrogen halides	unknown

Composition of the volcanic gases are typically expressed in terms of volume percentage, which can be calculated as follows

$$\text{volume percentage} = \frac{\text{volume of gas}}{\text{total volume}} \times 100\%$$

(a) **(i)** Draw the dot-and-cross diagram of H_2S.

[1]



(ii) State and explain whether H_2S or H_2O has a larger bond angle with respect to its central atom.

H_2S and H_2O are bent as there are 2 bond pairs and 2 lone pairs around each central atom.

H_2O has a larger bond angle than H_2S as

1) O is more electronegative than S, O pulls electron density of bond pairs more towards itself, leading to greater bond-pair bond-pair repulsion.
   OR
2) O has a smaller lone pair region than S (O is above S in group 16). Lone-pair bond-pair repulsion is smaller, leading to a larger bond angle.

(iii) Suggest a reason why at low temperature, carbon dioxide would sink rapidly and accumulate to high concentrations.

At low temperatures, there is insufficient energy to overcome the strong temporary dipole induced dipole (tdid) interactions between CO_2 molecules. Hence CO_2 would aggregate together/ more CO_2 molecules in a smaller volume and have a higher density thus sink down.

[2]

(iv) People living in area **A** were evacuated as the level of carbon dioxide was increasing rapidly. Given that 0.3 g of CO_2 was present in 1 dm^3 of gas mixture at r.t.p, determine the volume percentage of carbon dioxide present.

Hence comment on the possible danger if people remained in the area.

Amt of CO_2 = $\frac{0.30}{44.0} = 0.006818\ mol$

Vol of CO_2 = $0.006818\ (24.0) = 0.1636\ dm^3$

volume percentage of CO_2= $\frac{0.1636}{1} \times 100\%$ = 16.4%

Ans: 16.4% unconsciousness and death can result quickly

[2]

(b) Hydrogen sulfide can react with methane in the following equation.

$$CH_4(g) + 2\,H_2S(g) \rightleftharpoons CS_2(g) + 4H_2(g)$$

1 mol of CH_4, 2 mol of H_2S, 1 mol of CS_2 and 1 mol of H_2 were allowed to reach equilibrium in a 2 dm^3 container at a constant temperature and pressure.

(i) State the oxidation state of carbon in each carbon-containing compound.

CH_4 : –4 CS_2: +4 [1]

(ii) Hence comment on the role of H_2S in the reaction.

H_2S is an oxidising agent.

. [1]

(iii) Given that CS_2 was found to be 1.2 mol at equilibrium, determine the value of K_c, giving its units.

[2]

	$CH_4(g)$	$+ 2\,H_2S(g)$	$\rightleftharpoons$	$CS_2(g)$	$+ 4\,H_2(g)$
Initial/ mol	1	2		1	1
Eqm/ mol	1-x	2-2x		1 + x	1 + 4 x
	=0.8	= 1.6		=1.2	=1.8
Eqm / mol dm^{-3}	0.8/ 2 = 0.4	1.6/2 = 0.8		1.2/ 2 = 0.6	1.8/ 2 = 0.9

1 + x = 1.2
x = 0.2

Volume is 2 dm^3 container

$$K_c = \frac{(H_2)^4.CS_2}{CH_4.(H_2S)^2}$$

$$K_c = \frac{(0.9)^4(0.6)}{(0.4).(0.8)^2} = 1.537 = 1.54 \text{ mol}^2\,\text{dm}^{-6}$$

(iv) Using the *Data Booklet,* calculate the enthalpy change of the above reaction. Assume bond energy of C-S bond is 272 kJ mol^{-1}.

Bond break / kJ mol^{-1}	Bond form kJ mol^{-1}
4 C–H = 4(410)	2 C–S = 2(272)
4 S–H = 4(347)	4 H–H = 4(436)
3028	2288

ΔH reaction = bond breaking – bond forming
= + 3028 – 2288
= + 740 kJ mol^{-1}

[2]

(v) Hence state and explain the effect of increasing the temperature of the system on

- position of the equilibrium
- rate of the reaction.

Increasing the temperature **shifts eqm to the right** to favour the forward endothermic reaction as to partially absorb some heat.

Rate of reaction increases. Increasing the temperature increases energy of particles. There is a **greater proportion of particles with energy greater than activation energy**, hence frequency of effective collisions increases, leading to increase rate of reaction.

[3]

[Total: 16]

6 1–chloro–1–phenylethane undergoes hydrolysis with hydroxide ions to produce 1–phenylethanol, as shown in the equation below.

$$C_6H_5CHClCH_3 + OH^- \rightarrow C_6H_5CH(OH)CH_3 + Cl^-$$

1-chloro-1-phenylethane 1-phenylethanol

The rate of this reaction can be studied by measuring the amount of hydroxide ions that remain in the solution at a given time after the reaction has been quenched.

(a) Suggest a suitable quenching agent that can be used to slow down the rate of the reaction effectively.

cold water

[1]

.

[1]

(b) The rate of this reaction was measured using different initial concentrations of the two reagents and the results are shown below.

Experiment	$[C_6H_5CHClCH_3]$ / mol dm^{-3}	$[OH^-]$ / mol dm^{-3}	Relative rate
1	0.05	0.10	1.0
2	0.10	0.20	2.0
3	0.15	0.10	3.0

(i) Deduce the order of reaction with respect to each of the reagents. Explain your reasoning.

Comparing experiment 1 & 3, when $[OH^-]$ is constant, $[C_6H_5CHClCH_3]$ is tripled, relative rate is tripled. Hence, reaction is 1st order with respect to $C_6H_5CHClCH_3$. [1]

Comparing experiment 1 & 2, when both $[OH^-]$ and $[C_6H_5CHClCH_3]$ are doubled, relative rate is doubled. Since reaction is 1st order with respect to $C_6H_5CHClCH_3$, the doubling of $[OH^-]$ has no effect on rate, so reaction is zero order with respect to OH^-. [1]

* Accept if student write conc / rate <u>increases by</u> 3 times.

Order with respect to $C_6H_5CHClCH_3$ = **first order**

Order with respect to OH^- = **zero order**

[2]

(ii) Write the rate equation for this reaction, stating the units of the rate constant, *k*.

rate = $k[C_6H_5CHClCH_3]$ mol dm^{-3} s^{-1}

units of *k* = s^{-1}

[2]
[Total: 5]

7 Lithium is a scavenger for hydrogen, hence able to prevent the reaction between hydrogen and copper during pure copper casting. Reaction with hydrogen makes the copper brittle, causing it to fall apart under very light stress.

Table 2

	Enthalpy / kJ mol^{-1}
Enthalpy change of formation of $LiAlH_4(l)$	–152.5
Enthalpy change of formation of $LiAlH_6(s)$	–454

(a) Heating lithium in a stream of hydrogen gas produces white, crystalline, ionic lithium hydride, LiH.

(i) By quoting relevant data from the *Data Booklet*, suggest and explain how the magnitude of the lattice energy of LiC*l* would compare to that of LiH.

$$|LE| = \left|\frac{q^+q^-}{r^+ + r^-}\right|$$

Ionic radii of Cl^- = 0.181, ionic radii of H^- = 0.208nm
They have the same product but LiH has a larger interionic distance than LiC*l*, therefore LE magnitude of LiH is smaller.

[2]

(b) When lithium hydride is heated with anhydrous aluminium chloride, lithium aluminium hydride, $LiAlH_4$ and lithium chloride are produced.

Balance the equation for the above reaction.

……4…….. LiH + ……1…… $AlCl_3$ → …1…….. $LiAlH_4$ + ……3….LiC*l*

[1]

(c) Just above its melting point, $LiAlH_4$ decomposes according to the following equation.

$$3\ LiAlH_4\ (l) \rightarrow LiAlH_6(s) + 2Al(s) + 3H_2(g)$$

Using **Table 2**, calculate the standard enthalpy change of this reaction.

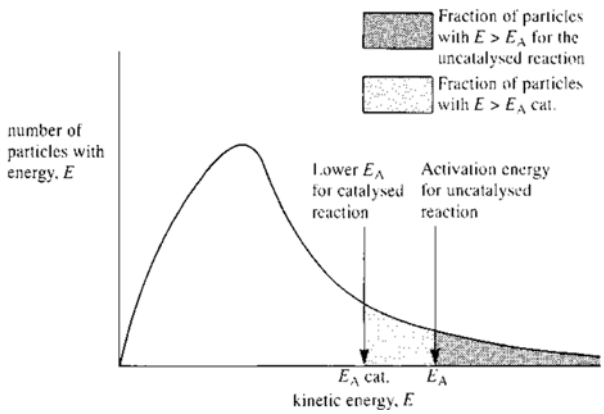
$\Delta H_{reaction}$ = $\Sigma n\Delta Hf$(products) - $\Sigma n\Delta Hf$(reactants)
= –454 – 3(–152.5)
= +3.5 $kJmol^{-1}$

[2]
[Total: 5]

Section B

Answer only **one** question from this section, in the spaces provided.

8(a) With the aid of a Boltzman distribution curve, explain how the presence of a catalyst increase the rate of a reaction.



A catalyst provides an alternative pathway for the reaction, **lowering the activation energy** required. Hence there is **a greater proportion of particles with energy greater than activation energy** as reflected by the shaded region in the diagram above. Frequency of effective collisions increases, leading to increase rate of reaction.

[3]

(b) The melting points of some compounds are given.

Substance	Octan-1-ol	Iodine	Fullerene	Graphite
Formula	$CH_3(CH_2)_9OH$	I_2	C_{60}	C
Melting point/ K	277	286	873	>3000

(i) Explain why the melting points of octan-1-ol and iodine are comparable.

Both octan-1-ol and iodine have simple covalent structure.
Strength of Td-Id in iodine due to its large electron cloud size is comparable to the stronger hydrogen bonding between octan-1-ol molecules.

[2]

(ii) Explain why the melting point of graphite is higher than that of fullerene.

Graphite has a giant molecular structure with strong covalent bonds between carbon atoms to be overcome during melting.
Fullerene has a simple covalent structure with weaker td-id interactions between fullerene molecules to be overcome during melting.
Hence, more energy is required to melt graphite and a higher temperature is required.
.

[2]

(iii) By quoting relevant data from the *Data Booklet*, account for the trend in the thermal

stabilities from HC*l* to HI.

Bond energy/ kJ mol^{-1} : H–C*l* = 431, H–Br = 366 , H–I = 299

Down the group, less energy is needed to break the weaker H–X bond, resulting in decreasing thermal stability of HX.

[2]

(iv) Arrange the pH of HC*l* to HI in aqueous solution in ascending order.

Explain the variation you have outlined.

pH decreases from HCl to HI as the it is easier to break the H-X bond from H-Cl to H-I to donate a proton.

[2]

(c) Compound **X** has the molecular formula $C_4H_8O_2$.

(i) Treatment of **X** with acidified potassium dichromate(VII) produces a green solution.

What could be the functional groups present in **X**?

Alcohol

[1]

(ii) There is no reaction when **X** is treated with aqueous sodium carbonate, Na_2CO_3.
What could be the functional groups absent in **X**?

Carboxylic acid

[1]

(iii) When **X** is shaken with aqueous bromine, the orange colour disappears.
What could be the functional groups present in **X**?
Alkene

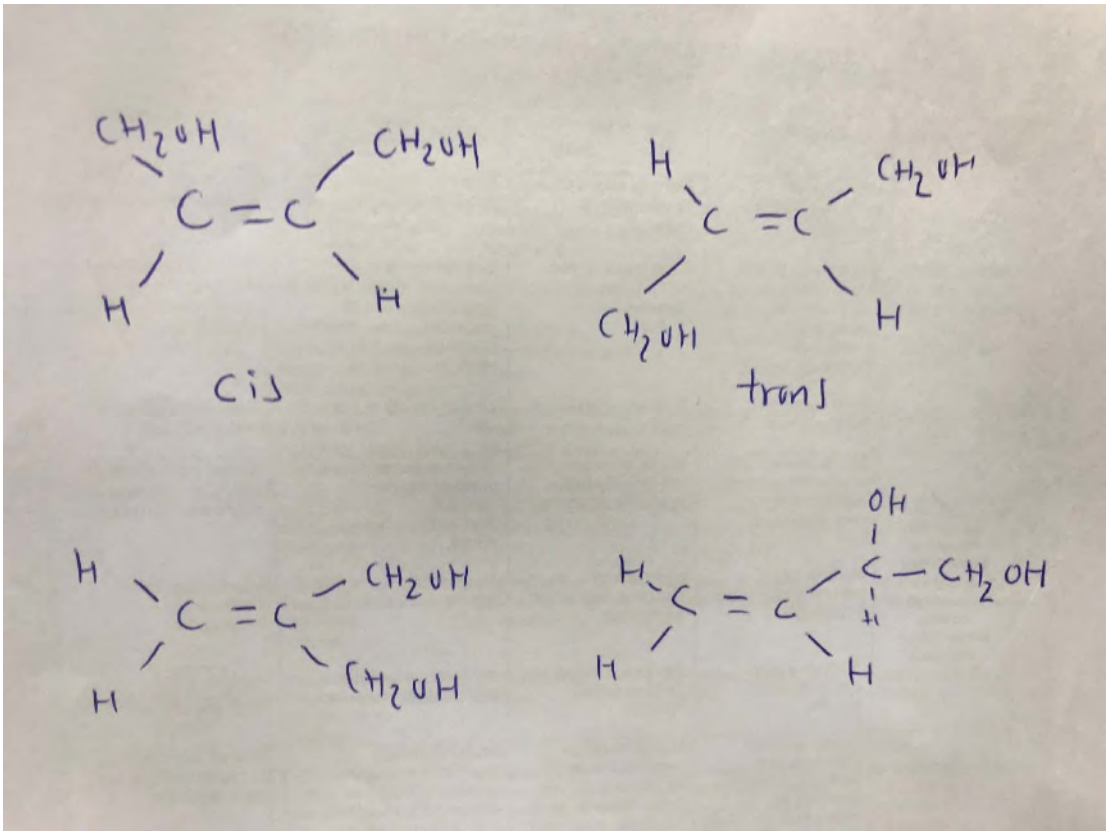
[1]

(iv) The molecule of **X** has the following features.

- The carbon chain is unbranched and the molecule is not cyclic.
- No oxygen atom is attached to any carbon atom which is involved in π bonding.
- No carbon atom has more than one oxygen atom joined to it.

There are four possible isomers of **X** which fit these data.

Draw displayed formulae of **all** possible isomers and state which type of isomerism they show.


CH2OH
CH2OH
C=C
H
H
cis
H
CH2OH
C=C
CH2OH
H
trans
H
CH2OH
C=C
H
CH2OH
OH
H
C=C
C
CH2OH
H
H

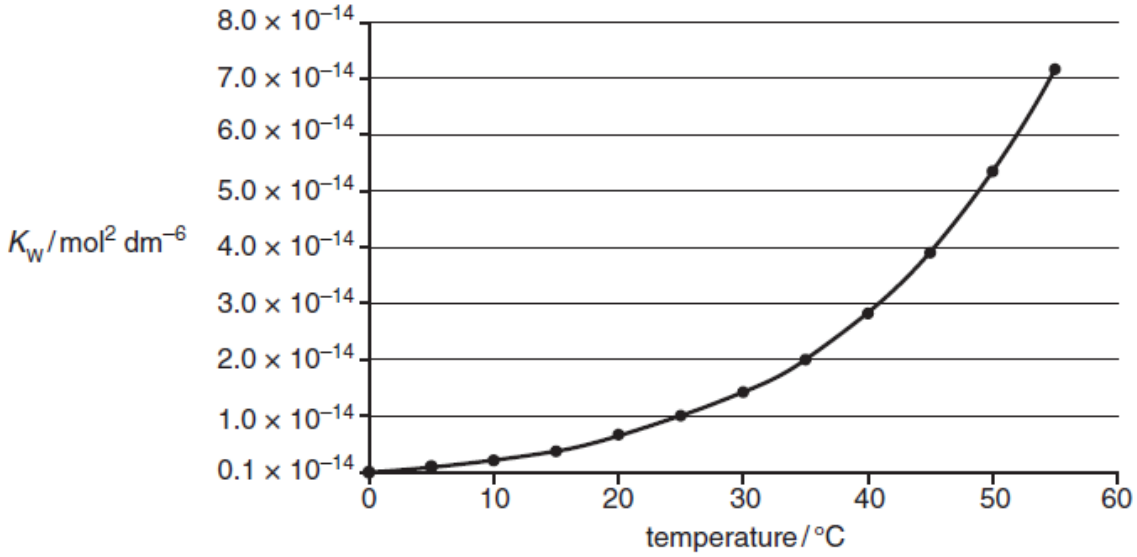
[6]
[Total: 20]

9 (a) The dissociation of water is a reversible reaction.

$$H_2O\ (l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The ionic product of water, K_w, measures the extent of dissociation of water. K_w varies with temperature. It is always important to quote the temperature at which measurements are being taken.

The graph below shows the variation of K_w. between 0 °C and 60 °C.



(i) Write the expression for K_w.

$K_w = [H^+][OH^-]$

.....

[1]

(ii) Calculate the concentration of hydroxide ions, $[OH^-]$, in an aqueous solution of hydrochloric acid at pH of 4.37 at 25 °C.

Method 1

pH = 4.37

$-\lg [H^+] = 4.37$

$[H^+] = 10^{-4.37} = 4.265 \times 10^{-5}$ mol dm^{-3}

$[OH^-] = 1 \times 10^{-14} \div 4.265 \times 10^{-5} = 2.34 \times 10^{-10}$ mol dm^{-3}

Method 1

pH + pOH = 14

pOH = 14 - 4.37 = 9.63

$[OH^-] = 10^{-9.63} = 2.34 \times 10^{-10}$ mol dm^{-3}

[2]

(iii) Using the graph, explain whether the dissociation of water is an exothermic or endothermic process.

As K_w increases with temperature; the forward reaction is favoured by higher temperature. By Le Chatelier's Principle, as temperature increases, the position of equilibrium shifts to favour the endothermic reaction to partially remove some heat.

Thus dissociation of water (forward reaction) is endothermic.

[2]

(iv) Using the graph, determine the pH of pure water at body temperature, at 37 °C.

At 37 °C, $K_w = 2.5 \times 10^{-14}$ mol dm^{-3}

$[H^+] = \sqrt{K_w} = 1.58 \times 10^{-7}$ mol dm^{-3}

pH = 6.80

[3]

(v) Given the following data:

Indicator	Colour change (acidic to basic medium)	pH range in which colour change occurs
Bromothylmol blue	yellow to blue	6.0 – 7.6

State the colour observed when a few drops of bromothylmol blue is added to a sample of pure water at body temperature, at 37 °C.

Green (due to mixture of yellow and blue)

[1]

(vi) Buffer solutions are important in biological systems and in industry to maintain almost constant pH values

In the human body, one important buffer system in blood involves the hydrogencarbonate ion, HCO_3^- and carbonic acid, H_2CO_3, which is formed when carbon dioxide dissolves in water.

Use the following equation to explain how this buffer maintains a constant pH of 7.41 even if a small amount of acid enters the bloodstream.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

When a small amount of acid enters bloodstream, HCO_3^- will remove the acid to form H_2CO_3/ eqm (above) shifts to the left.

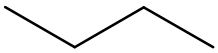
The excess H_2CO_3 produced is then removed by an increase in the rate of respiration and the rapid expulsion of CO_2 from the lungs. Eqm (2) shifts to the left.

$$H_2CO_3 \rightleftharpoons CO_2 + H_2O$$

[2]

(b) The hydrocarbons **A**, C_4H_{10}, and **B**, C_4H_8, are both unbranched.
A does **not** decolourise bromine.
B decolourises bromine and shows cis-trans isomerism.

(i) Draw the skeletal formula of **A**.



[1]

(ii) The hydrocarbon **A**, C_4H_{10}, has a branched isomer.
Suggest why unbranched **A** has a higher boiling point than its branched isomer.

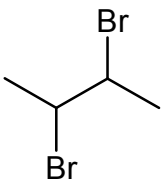
Straight chain A/ unbranched A has greater surface area of contact between molecules compared to branched isomer. Hence temporary dipole-induced dipole (tdid) interactions are more easily induced between molecules of A. More energy is required to stronger tdid interactions in A, hence higher bp.

[2]

(iii) Draw the structure of the product obtained from the reaction between **B** and bromine. State the type of reaction that occurred.

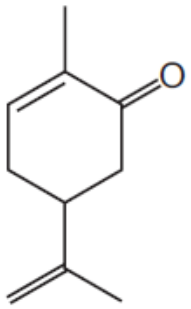
Type of reaction: …**addition** …….

Product:

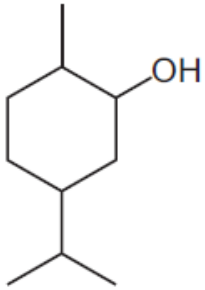


[2]

(c) Carvone occurs in spearmint and can be converted to compound **M**.



carvone



M

(i) State the reagent and conditions for the conversion of carvone to compound **M**.

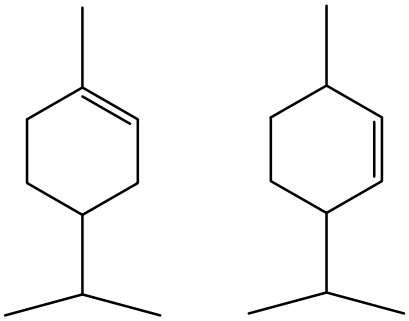
name of reagent: **H_2**

conditions: **Ni, heat / Pt**

[1]

(ii) Draw the structure of the product when **M** is treated with excess concentrated sulfuric acid at 170 °C.

Either structures



[1]

(d) Write an equation for the reaction that occurs when silicon tetrachloride is added to water. Predict the pH of the resulting solution.

$SiCl_4 + 4H_2O \rightarrow SiO_2.\ 2H_2O + 4\ HCl$ or
$SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4\ HCl$ or

$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4\ HCl$

pH = 2 or 1 [2]

[Total: 20]

End of Paper

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CHEMISTRY 8873/01

Paper 1 Multiple Choice **24 September 2018**

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and tutor's name on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **14** printed pages.

[Turn over

For each question there are four possible answers, **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.

1 In the discovery of an element, **A**, scientists found that it consists of 3 isotopes, ^{140}**A**, ^{142}**A** and ^{144}**A** in the ratio of 2 : 3 : 1.

What is the relative atomic mass of element **A**?

A 140.5

B 141.7

C 142.0

D 143.1

2 *Use of the Data Booklet is relevant to this question.*

How many Cl atoms are present in 1 cm^3 of chlorine gas under room conditions?

A $\frac{1 \times 24\,000}{6.02 \times 10^{23}}$

B $\frac{1 \times 6.02 \times 10^{23} \times 2}{24\,000}$

C $\frac{1 \times 6.02 \times 10^{23} \times 2}{71}$

D $\frac{1 \times 6.02 \times 10^{23}}{24}$

3 A constituent of wood preservative is manufactured by heating iron(II) chromite, $FeCr_2O_4$, with sodium carbonate in air.

$$4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \rightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$$

Which species is oxidised in this process?

A chromium only

B oxygen only

C chromium and iron

D carbon and oxygen

4 An isolated gaseous species has paired electrons in at least one of its 3d orbitals and a fully filled 4s subshell.

What could be the identity of the species?

A Cu

B Fe^{3+}

C Ni^{2+}

D Sr^{2+}

5 The elements aluminium and phosphorus each form triply charged ions.

How do the atomic radii and ionic radii of these elements compare?

A P^{3-} > Al > P > Al^{3+}

B P^{3-} > P > Al > Al^{3+}

C P > Al > P^{3-} > Al^{3+}

D P > P^{3-} > Al^{3+} > Al

6 Which one of the following species is **not** planar?

A BrF_3

B ICl_4^-

C PCl_4^+

D XeF_4

[Turn over

7 Hydrazine, N_2H_4, and hydrogen peroxide, H_2O_2, are both used as rocket propellants because they can produce large volumes of hot gases from a small volume of liquid.

Which of the following statements about these two compounds are correct?

1 The bond angle in N_2H_4 is larger than that in H_2O_2.

2 The N–H bond is shorter than the O–H bond.

3 Hydrazine forms stronger intermolecular hydrogen bonds than hydrogen peroxide.

4 Both hydrazine and hydrogen peroxide are polar molecules.

A 1 and 4 only

B 2 and 3 only

C 1, 2 and 4 only

D 1, 3 and 4 only

8 Three elements, **E**, **F** and **G**, have the physical properties shown in the table.

element	melting point / °C	boiling point / °C	density / g cm^{-3}
E	–7	59	3.12
F	98	883	0.97
G	649	1107	1.74

What could be the identities of **E**, **F** and **G**?

	E	**F**	**G**
A	Br_2	Al	Si
B	Br_2	Na	Mg
C	I_2	Mg	Na
D	I_2	Si	K

9 Which statement about exothermic reactions is **incorrect**?

A On the reaction pathway diagram, the products of the reaction are lower than the reactants.

B There is a net transfer of heat energy from the reacting system to the surroundings.

C The total bond energies of the products > the total bond energies of the reactants

D The activation energy for the forward reaction is the same as that for the backward reaction.

10 A student mixed 25.0 cm^3 of 3.00 mol dm^{-3} hydrochloric acid with an equal volume of 6.00 mol dm^{-3} sodium hydroxide. The initial temperature of both solutions was 15.0 ^oC. The maximum temperature recorded was 24.5 ^oC. It was found that 15 % of the heat produced during the experiment was lost to the surroundings.

Using these results, what is the enthalpy change of neutralisation?

A –15.6 kJ mol^{-1}

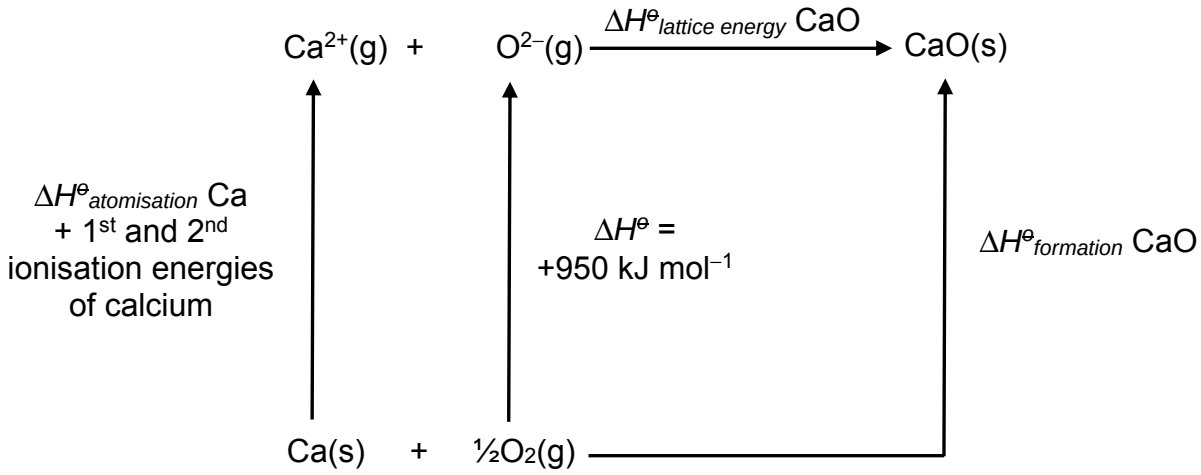
B –22.5 kJ mol^{-1}

C –31.1 kJ mol^{-1}

D –57.3 kJ mol^{-1}

11 A student calculated the lattice energy for calcium oxide using the cycle shown.

The enthalpy change of atomisation of calcium, $\Delta H^{\ominus}_{atomisation}$ Ca, is the energy needed when 1 mol of gaseous calcium atoms is formed from 1 mol of solid calcium under standard conditions.



However, the value calculated by the student for the lattice energy was **more** exothermic than the correct value.

Which errors could have been made in the calculation?

A omitting the value of +950 kJ mol^{-1}

B omitting the standard enthalpy change of formation of calcium oxide

C using the 1st and 2nd ionisation energies of magnesium instead of calcium

D using the standard enthalpy change of combustion of calcium rather than the standard enthalpy change of formation of calcium oxide

12 The graph below shows the Boltzmann distribution of molecular energies at a given temperature.

As temperature increases, which statements are correct?

1 The maximum of the curve is displaced to the right.

2 The maximum of the curve is displaced downwards.

3 The proportion of molecules with energies **above** any given value increases.

4 The proportion of molecules **with** any given energy increases.

A 1 only

B 3 only

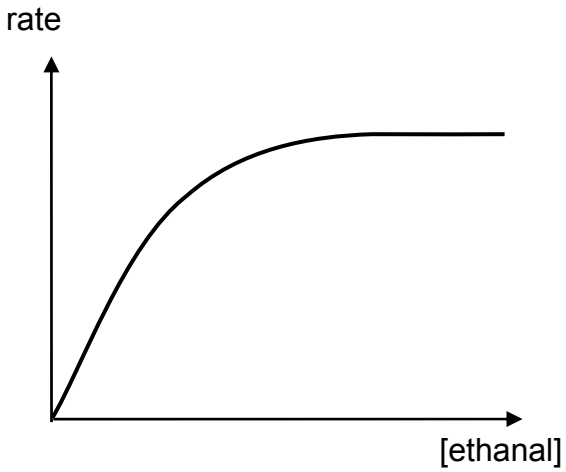
C 1, 2 and 3 only

D 1, 2, 3 and 4

13 The enzyme *alcohol dehydrogenase* catalyses an important step in the production of ethanol by fermentation.

$$CH_3CHO + 2[H] \downarrow CH_3CH_2OH$$

The graph shows how the rate of this enzyme-catalysed reaction varies with the concentration of ethanal.



Which statement best explains the reason for the flattening off of the curve?

A As the ethanol product builds up the reaction slows down.

B All the ethanal has been used up and the reaction has finished.

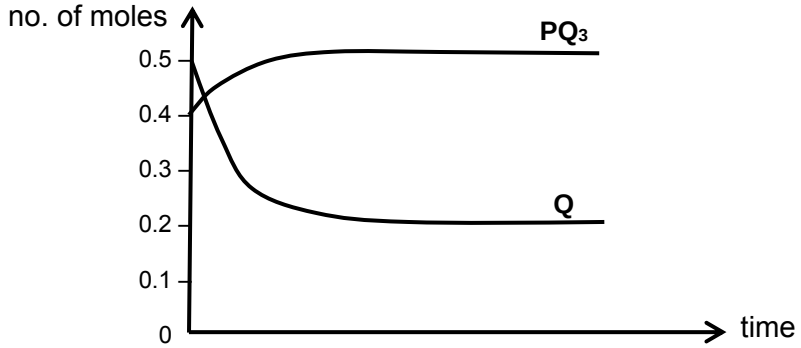
C At high ethanal concentrations the ethanal inhibits the action of the enzyme.

D At high ethanal concentration all the active sites in the enzyme molecules are occupied by ethanal molecules.

14 The system containing P, Q and PQ_3 is allowed to reach equilibrium in a 10 dm^3 vessel at a temperature of 1000 K.

$$P(g) + 3Q(g) \rightleftharpoons PQ_3(g)$$

The diagram below shows the change in number of moles of PQ_3 and Q with time. The initial amount of P was 0.2 mol.



What is the equilibrium constant K_c for the reaction?

A $\frac{0.5}{0.1\times(0.2)^3}$ **B** $\frac{0.5}{0.2\times(0.2)^3}$ **C** $\frac{0.5\times10^3}{0.1\times(0.2)^3}$ **D** $\frac{0.5\times10^3}{0.2\times(0.2)^3}$

15 Which statement is correct about a reaction for which the equilibrium constant is independent of temperature?

1 The rate constants for the forward and reverse reactions are also independent of temperature.

2 Temperature has no effect on the position of equilibrium.

3 The forward and reverse reactions have equal activation energies.

4 There is no change in number of gaseous particles during reaction.

A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

D 3 and 4 only

16 Which of the following is an **incorrect** descriptor of a weak acid?

A It has high pK_a value.

B Its conjugate acid is strong.

C It donates a proton in aqueous solution.

D It has a relatively low electrical conductivity in dilute solutions.

[Turn over

17 50 cm^3 of 0.10 mol dm^{-3} of solution **X** was added to 100 cm^3 solution of 0.10 mol dm^{-3} HCO_3^- to form a buffer.

Which of the following could be the identity of **X**?

1 H_2CO_3

2 Na_2CO_3

3 H_2SO_4

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3

18 A beaker contains a mixture of magnesium chloride, magnesium oxide, aluminium oxide and silicon dioxide. A student was asked to perform the following procedure to separate the compounds:

Step I: Add water to the mixture. Stir well and filter the mixture.
Step II: To the residue, add NaOH(aq) and stir well with a glass rod.
Step III: Filter the resulting mixture.
Step IV: To the residue, add HCl(aq) and stir well with a glass rod.
Step V: Filter to obtain the filtrate and residue.

Which of the following information is true about the above procedure?

1 The only starting species that remained unreacted after step V was silicon dioxide.

2 After step I, the filtrate contains only magnesium chloride.

3 After step III, the residue contains only aluminium oxide.

4 A gas was produced in step IV.

A 1 and 2 only

B 2 and 3 only

C 4 only

D None of the above

19 Which of the following is true about Period 3 elements and their compounds?

A The covalent character of oxides decreases from sodium to silicon.

B The lattice energy of nitrates become less exothermic from sodium to aluminium.

C The solubility of oxides decreases from sodium to silicon.

D The melting points of the elements generally decrease across the Period.

20 The following information is about three Period 3 elements, X, Y and Z.

- The chloride of X reacts with water to give a colourless acidic solution.
- The oxides of X and Y are insoluble in water.
- The oxides of X and Y have high melting and boiling points whereas the oxide of Z has low melting and boiling points.

What is the order of increasing ionic radius for these three elements?

A X, Y, Z

B Y, X, Z

C X, Z, Y

D Z, Y, X

21 Compound **E** has a straight−chain structure with a molecular formula of C_5H_8O.

Which functional groups may be present in any of the isomers of compound **E**?

1 Alcohol

2 Aldehyde

3 Ester

A 1, 2 and 3

B 1 and 2 only

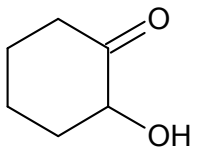
C 1 only

D 2 only

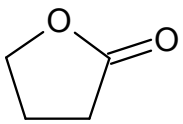
22 Hydrogen gas was passed through the following compounds in the presence of platinum.

Which compound will produce a mixture of cis-trans isomers after the reaction?

A



B



C

$CH_2{=}CHCH{=}CHCH_3$

D

$CH_3CONHCH_2CH_3$

23 Which compound does **not** have the same bond angle about all of its carbon atoms?

A benzene

B methanoic acid

C 2-ethylpentan-2-ol

D 2-bromopropene

24 $(CH_3CH_2)_3CH$ can react with chlorine under UV light to produce monochloro-compounds.

How many possible constitutional isomers of monochloro-compounds can it produce?

A 2

B 3

C 6

D 7

25 For which pair of compounds can ethanolic silver nitrate be used to distinguish between members of the pair?

A CH_3CH_2Cl and $CH_2{=}CHCH_2Cl$

B CH_3CH_2OH and CH_3CHO

C CH_3COCH_3 and CH_3CHO

D CH_3CH_2Cl and CH_3CH_2Br

26 Which compound will **not** produce a carboxylic acid when treated with hot acidified $KMnO_4$?

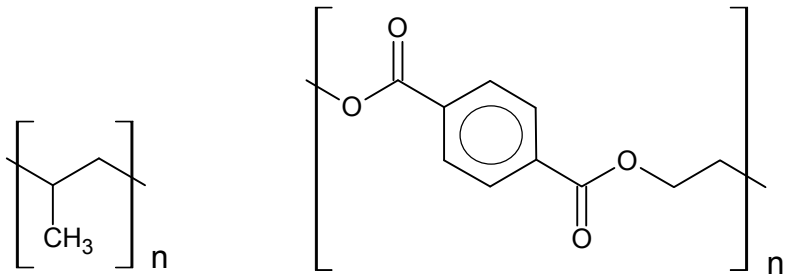
A CH_3COCH_3

B CH_3CH_2CHO

C $CH_3CH_2CH_2OH$

D $CH_3CH_2CONHCH_3$

27 Poly(propene) (PP) and poly(ethylene terephthalate) (PET) are frequently used as food grade containers.



PP PET

Which statement is correct about their uses?

A The presence of water will dissolve PET due to the formation of hydrogen bonds.

B PP cannot be used to store oily foods as the non-polar PP will be dissolved by the non-polar oil molecules.

C PP can be used to store strong alkalis but PET will be dissolved in strong alkalis due to alkaline hydrolysis of PET.

D Both are unable to store hot foods due to their weak intermolecular forces of attraction that requires small amount of energy to break.

28 Which of the following are addition polymers?

1 Polyester

2 Poly(ethene)

3 Poly(vinyl alcohol)

A 1 only

B 2 and 3 only

C 2 only

D 1, 2 and 3

[Turn over

29 Carbon nanotubes are widely researched as a potential material with many uses.

Which pairs show the correct property of carbon nanotubes with an example of their use?

	Property	Example of use
1	low density	frame of racquets
2	high tensile strength	material for building construction
3	high electrical conductivity	flat screen television
4	high porosity	material for water filtration

A 2 and 3 only

B 1, 2, 3 and 4

C 1 and 2 only

D 1, 2 and 3 only

30 Which statement about nanomaterials is correct?

A They will not pose any health risks.

B They can have a length of more than 100 nm.

C They can only be manufactured in the laboratory.

D They are all able to stick onto any type of surfaces.

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME	
CLASS	
TUTOR'S NAME	

CHEMISTRY 8873/02

Paper 2 **11 September 2018**

2 hours

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section **A**
Answer **all** the questions.

Section **B**
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
A1	/ 8
A2	/ 12
A3	/ 8
A4	/ 10
A5	/ 22
B	/ 20
Total	**/ 80**

This document consists of **25** printed pages and **1** blank page.

For examiner's use only

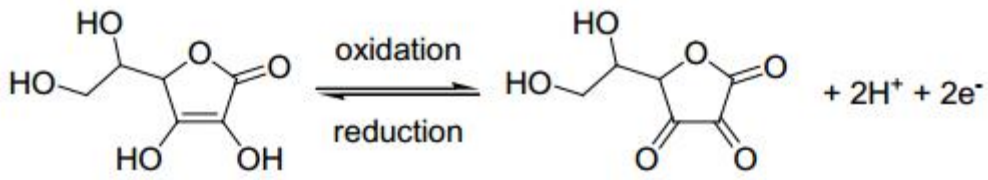
Section A

Answer **all** questions in this section in the spaces provided.

1 A sample of supplement, Appelin B12 syrup, is analysed for the concentrations of benzoic acid and Vitamin C (also known as ascorbic acid). 100 cm^3 of the Appelin B12 syrup is dissolved in water and made up to 250 cm^3.

Reaction 1: A 25.0 cm^3 aliquot requires 35.65 cm^3 of 0.018 mol dm^{-3} of sodium hydroxide for complete neutralisation.

Vitamin C (ascorbic acid) is also a mild reducing agent with the following oxidation equation.



ascorbic acid dehydroascorbic acid

Reaction 2: Another 25.0 cm^3 aliquot requires 33.40 cm^3 of 0.017 mol dm^{-3} iodine solution for complete redox reaction.

(a) Calculate the total amount of acid present in 100 cm^3 of the Appelin B12 syrup. Assume that ascorbic acid is a monoprotic acid.

[2]

(b) State the reacting mole ratio of ascorbic acid and iodine.

.....[1]

(c) Calculate the amount of ascorbic acid present in 100 cm^3 of Appelin B12 syrup.

[1]

For examiner's use only

(d) Suggest suitable indicators for both **reactions 1** and **2**.

Reaction 1: .....

Reaction 2: .....[1]

(e) Calculate the respective masses of benzoic acid and ascorbic acid in 100 cm^3 of Appelin B12 syrup.
(M_r of benzoic acid = 122.0; M_r of ascorbic acid = 176.0)

[2]

(f) Given that daily required amount of ascorbic acid for children is 50 mg, calculate the dosage (in cm^3) of Appelin B12 syrup a child should consume.

[1]

[Total: 8]

For examiner's use only

2(a) Nitrogen trichloride is a liquid found in tear gas and is a lachrymator agent which can be used as a chemical weapon that causes severe eye and respiratory pain. Nitrogen trichloride reacts with steam to form ammonia and hypochlorous acid according to the following equation.

$$NCl_3 + 3H_2O \rightarrow NH_3 + 3HOCl$$

(i) Draw 3-dimensional sketches of NCl_3 and HOCl and state the shape and bond angle of each molecule.

Compound	3-D sketch	Shape	Bond Angle
NCl_3			
HOCl			

[5]

(ii) With the aid of a diagram, explain the solubility of ammonia in water.

.....

.....

.....[2]

For examiner's use only

(b) Write an equation representing the second ionisation energy of chlorine. Hence, explain the difference in the second ionisation energies between chlorine and sulfur.

.....

.....

.....

.....

.....[2]

(c) Sodium, aluminium and phosphorus burn in oxygen to form sodium oxide, Na_2O, aluminium oxide, Al_2O_3, and phosphorus pentoxide, P_4O_{10}, respectively.
Write equations for any reactions that these oxides would have with hydrochloric acid and with sodium hydroxide. Identify any of these oxides that show no reaction by indicating *no reaction*.

Oxide	Reaction with hydrochloric acid	Reaction with sodium hydroxide
Na_2O		
Al_2O_3		
P_4O_{10}		

[3]

[Total: 12]

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3 Water, H_2O, covers about two-third of the Earth's surface and is vital to life.

(a) About 0.005% of water molecules consist of an oxygen atom bonded to two atoms of the hydrogen *isotope*, deuterium, $^{2}_{1}D$. The compound formed is deuterium oxide, D_2O and is also known as 'heavy water'.

(i) What do you understand by the term *isotope?*

.....

.....[1]

(ii) State the number of subatomic particles present in one molecule of D_2O.

Number of protons	
Number of neutrons	
Number of electrons	

[1]

(b) When pure H_2O and pure D_2O are mixed, an exchange of H and D atoms takes place and the following equilibrium is established.

$$D_2O(l) + H_2O(l) \rightleftharpoons 2HDO(l) \qquad K_c = 3.56 \text{ at } 298\text{ K}$$

When 30 g of D_2O and 27 g of H_2O are mixed, how many moles of HDO will be present at equilibrium at 298 K?

[3]

For examiner's use only

(c) In pure water, a very small fraction of water molecules donate protons to other water molecules to form hydronium ions and hydroxide ions.

$$2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

This type of reaction is known as the auto-ionisation of water and the equilibrium constant for the reaction is K_w. The extent of auto-ionisation and hence, the value of K_w is dependent on temperature.

(i) Given pH of water at 30 °C is 6.92, calculate the value of K_w at 30 °C.

[1]

(ii) By comparing your answer in **(i)** with the value of K_w at 25 °C, suggest how the enthalpy changes during the auto-ionisation of water. Explain your reasoning clearly.

.....

.....

.....

.....

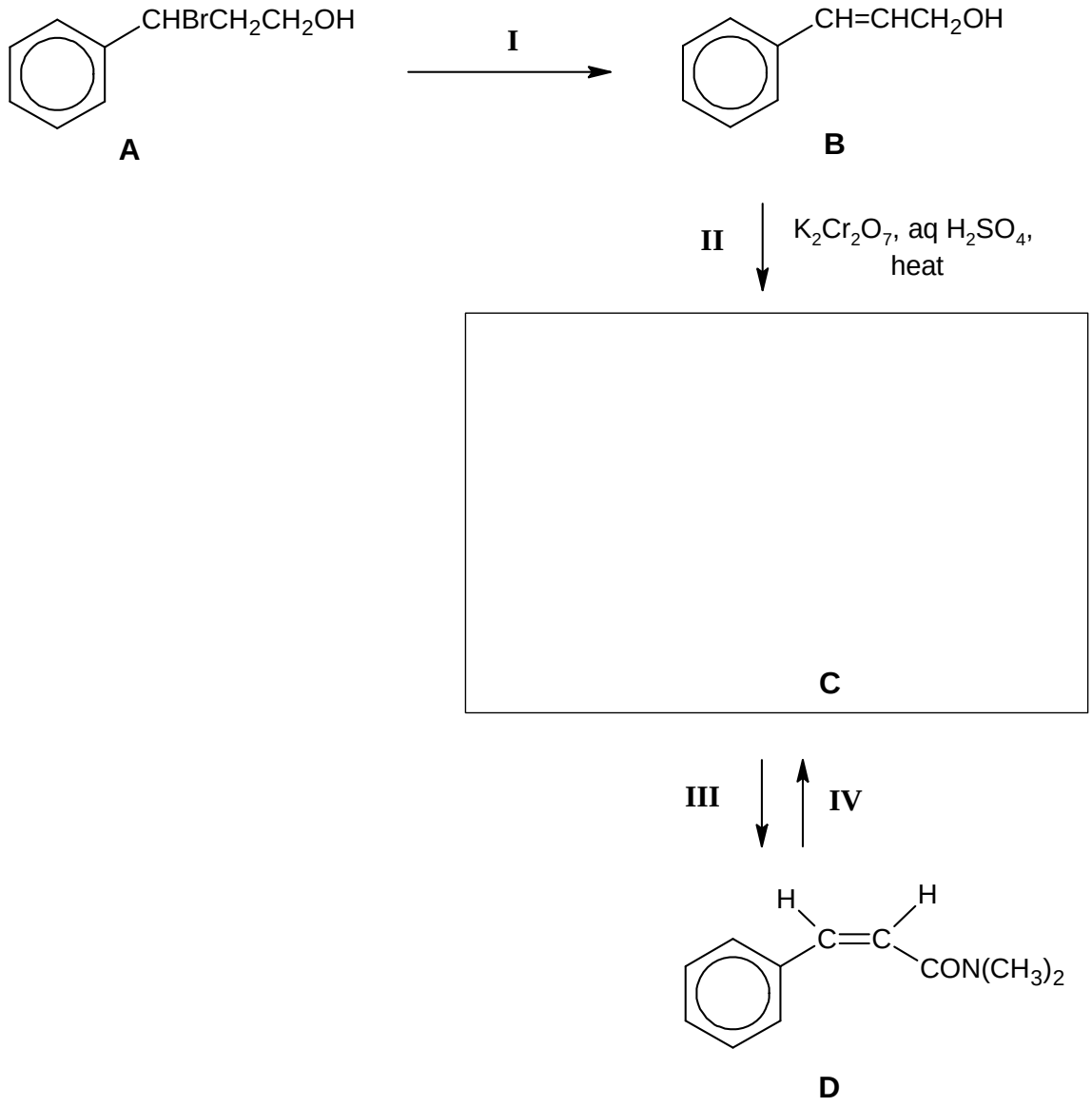
.....

.....[2]

[Total: 8]

For examiner's use only

4 Study the following reaction scheme involving compound **A** and answer the questions below.



(a) State the type of reaction for steps **I** to **IV**.

I: .....

II: .....

III: .....

IV: .....

[2]

(b) Draw the structure of **C** in the box provided above. [1]

For examiner's use only

(c) Suggest suitable reagents and conditions for steps **I**, **III** and **IV**.

I: .....

III: .....

IV: .....

[3]

(d) Write a balanced equation for step **IV**.

[1]

Compound **D** exhibits *cis-trans isomerism*.

(e) Define the term *cis-trans isomerism*.

.....

.....[2]

(f) Draw the displayed formula of the other isomer of **D**.

[1]

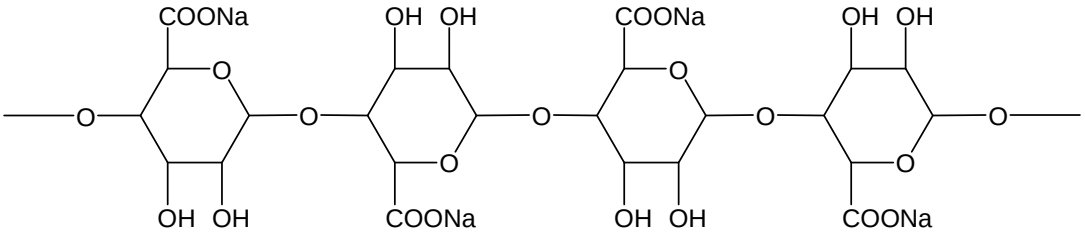
[Total: 10]

For examiner's use only

5 Molecular gastronomy is the modernist style of cuisine that combines science and cooking. Its techniques are currently being applied in the kitchens of many well-known restaurants worldwide.

One such technique is called *spherification* which involves a simple gelling reaction between sodium alginate and calcium ions to create flavoured caviar which are small spheres of flavour that burst in the mouth when they are consumed.

Sodium alginate is the sodium salt of alginic acid, a polysaccharide used by brown algae to support its cell walls. It is extracted from seaweed and used widely in industries like food and medicine.



structure of sodium alginate polymer

(a)(i) What types of bonding exist in sodium alginate?

.....[1]

(ii) The structure of sodium alginate is rigid whereby all single C-O-C bonds are unable to rotate. Draw the structure of a repeat unit of sodium alginate.

[1]

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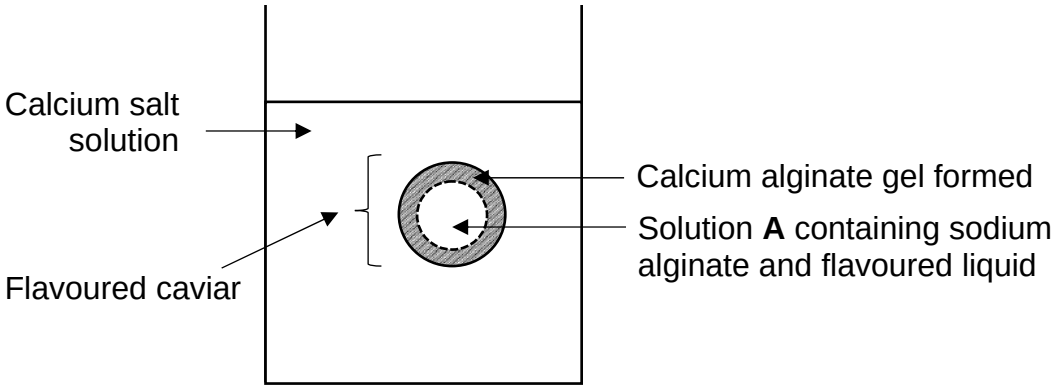
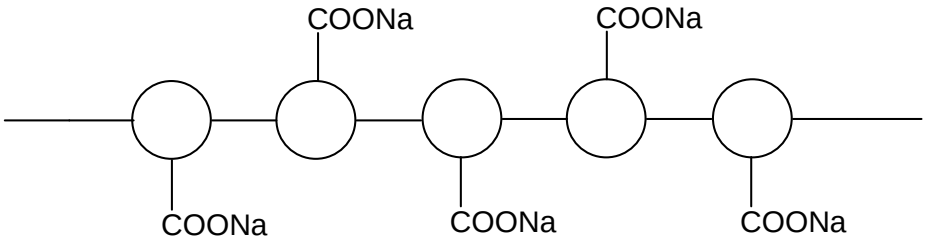
(b) The steps for spherification involving sodium alginate and calcium ions are as follows:

1. Flavoured water and sodium alginate powder are mixed and stirred to form solution **A** which is a homogeneous solution.
2. A syringe is used to add solution **A** dropwise to a calcium salt solution.
3. The calcium ions diffuse into solution **A** and the long-chain alginate polymers become cross-linked with Ca^{2+} ions, forming a gel-like substance.
4. The flavoured caviar can then be separated from the solution.



(i) A simplified diagram representing sodium alginate polymer is shown below.



Explain, in terms of bonding, how the cross-linked calcium alginate polymer is formed with the aid of a labelled diagram.

.....

.....[3]

For examiner's use only

(ii) Explain why calcium alginate is insoluble in water.

.....

.....

.....

.....[2]

Not all flavoured drinks or liquids can be used for flavoured caviar. The pH of the flavoured liquid needs to be greater than 3.6 as the sodium alginate will react and the resultant solution will thicken and coagulate. The flavoured drink should also be of a lower calcium content for spherification to be successful.

Many chefs have used the spherification technique to encapsulate certain flavourful liquids in their dishes. Some examples of liquids and their nutritional information are given below.

Flavoured liquid	Calcium content in 100 g of liquid / mg	pH
Lime juice	33	1.8
Grape juice	11	2.7
Apple juice	8	3.5
Carrot puree	20	4.8
Mango puree	4	5.0
Milkfish extract	55	5.4
Cow's Milk	125	6.8
Red cabbage juice	45	7.0
Sardine extract	382	7.3

(c) Based on the above information, suggest and explain why some of the following liquids will not be suitable for this method of spherification.

(i) Lime juice

.....

.....

.....[1]

(ii) Sardine extract

.....

.....

.....[1]

For examiner's use only

(d) Suggest and explain which of the liquids in the table on page **12** will most likely result in successful spherification of its flavoured caviar.

.....

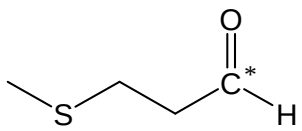
.....

.....[2]

(e) A chef wanted to serve a sphere of milkfish with lime. She mixed 50 g of milkfish extract and 10 g of lime juice. Calculate the pH of the resultant solution and deduce if the acidity of the solution is suitable for spherification.
[Assume densities of all solutions are 1 g cm^{-3}.]

[3]

(f) Only about one fifth of flavour perception comes from the tongue's taste buds; most of the flavours come from smell. When humans chew food, volatile molecules are sent to the nose where they are met by hundreds of different odour receptors.
One example of such a compound is methional. It is a volatile colourless liquid with a strong smell of cooked potatoes with bacon notes.



Methional

(i) Using VSEPR theory, explain why the shape about the sulfur and the carbon atom marked with an asterisk (*) is different.

.....

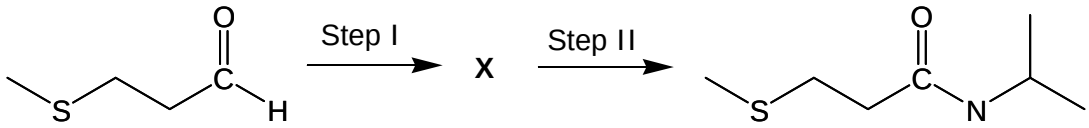
.....

.....

.....[3]

For examiner's use only

(ii) Methional can undergo a two-step reaction to form **Y**.



Methional

Y

Suggest the type of reaction and the reagents and conditions for each step. Hence, draw the structure of **X**.

	Step I	Step II
Type of reaction		
Reagents and conditions		

Structure of **X**:

[5]

[Total: 22]

Section B

Answer **one** question from this section, in the spaces provided.

For examiner's use only

6(a) Oxides of nitrogen such as NO_2 are air pollutants that are present in the exhaust gases of internal combustion engines. Modern cars are equipped with a catalytic converter that reduces emissions of these harmful compounds. The catalytic converter uses nanoparticles of platinum, palladium and rhodium which act as heterogeneous catalyst.

(i) Write an equation for the reaction involving NO_2 which occurs in the catalytic converter.

.....[1]

(ii) Explain why platinum can be described as a *heterogeneous* catalyst.

.....

.....[1]

(iii) Outline the mode of action of the catalyst used.

.....

.....

.....

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.....

.....[3]

For examiner's use only

(iv) Explain the term *nanoparticles*.

.....

.....[1]

(v) Explain the significance of using nanoparticles in the catalytic process.

.....

.....

.....

.....

.....[2]

(vi) Predict how nanoparticles of platinum could present a risk to the environment.

.....

.....

.....[1]

For examiner's use only

(b) Nitrogen dioxide, NO_2, is a brown gas while nitrogen tetroxide, N_2O_4, is a colourless gas. The following equilibrium between these two gases was set up.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H < 0$$

Describe, and explain, what you would see after the following changes have been made and the system is allowed to reach equilibrium again.

(i) The temperature is decreased.

.....

.....

.....

.....

.....[2]

(ii) The pressure is decreased.

.....

.....

.....

.....

.....[2]

For examiner's use only

(c) Nitrogen tetroxide is a strong oxidising agent. It is liquefied and used as a propellant in combination with a hydrazine-based rocket fuel.

$$2N_2H_4(l) + N_2O_4(l) \rightarrow 3N_2(g) + 4H_2O(l)$$

(i) Suggest a way to liquefy nitrogen tetroxide gas and explain your answer.

.....

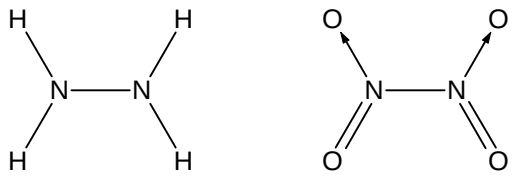
.....

.....

.....[2]

Some average bond enthalpies are given below.

bond	bond enthalpy / kJ mol^{-1}
N–O	201
N=O	607



hydrazine dinitrogen tetroxide

(ii) Use the data in the table above, and relevant data from the *Data Booklet* to calculate the enthalpy change of the reaction of hydrazine with dinitrogen tetroxide.

[2]

(iii) The theoretical standard enthalpy change of reaction is found to be –1258 kJ mol^{-1}. Suggest another reason other than the bond energies used are average values for the difference between your calculated value in **(ii)** and the theoretical value.

.....

.....

.....[1]

For examiner's use only

(d) Hydrazine is also a strong reducing agent. Warming hydrazine with nitric acid results in the production of gaseous nitrogen, N_2, and nitrogen monoxide, NO.

(i) Write a half-equation for the reduction of the nitrate ion, NO_3^- to nitrogen monoxide in acidic solution.

.....[1]

(ii) Draw a 'dot-and-cross' diagram of nitrate ion, NO_3^-.

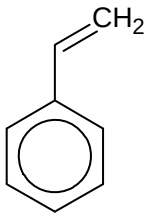
[1]

[Total: 20]

For examiner's use only

7 Polystyrene (PS) plastic is a naturally transparent thermoplastic that is available as both a typical solid plastic as well in the form of a rigid foam material. Polystyrene plastic is commonly used in a variety of consumer product applications and is also particularly useful for commercial packaging. Dow Chemical Company invented a proprietary process to make their trademarked and well-known polystyrene foam product "styrofoam" in 1941.

(a) The monomer of polystyrene is phenylethene or styrene, as shown below:



(i) Draw the structure of polystyrene. Identify the type of reaction to synthesise polystyrene.

.....[2]

(ii) State one difference in physical property between polystyrene and poly(diallyl phthalate), which has cross-links between the polymer chains.

.....

.....

.....[1]

(iii) Suggest one advantage in the use of polystyrene as compared to poly(diallyl phthalate).

.....

.....

.....[1]

For examiner's use only

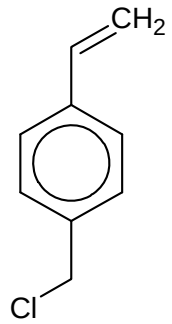
(iv) State one negative impact from the use of non-recyclable plastics.

.....

.....

.....[1]

(b) To produce plastics of different hardness and textures, the styrene monomer can be converted to other types of monomers such as the one shown below.



This compound (C_9H_9Cl) reacts with excess alcoholic ammonia, heated in a sealed tube according to the following general equation:

$$C_9H_9Cl + 2NH_3 \rightarrow C_9H_9NH_2 + NH_4Cl$$

Three sets of experiments were performed separately to determine the rate of reaction. Initial concentrations of the two reagents were varied for each experiment and the results are shown below.

Experiment	$[C_9H_9Cl]$/ mol dm^{-3}	$[NH_3]$/ mol dm^{-3}	Initial Rate $\times 10^{-3}$/ mol dm^{-3} s^{-1}
1	0.03	0.1	4.9
2	0.02	0.1	3.2
3	0.01	0.4	6.3

(i) Using the data above, determine the order of reaction with respect to C_9H_9Cl and NH_3.

[2]

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(ii) Hence, state the rate equation.

.....[1]

(iii) Using the values from experiment 3, determine the rate constant and state its units.

rate constant, k = …… units …….. [2]

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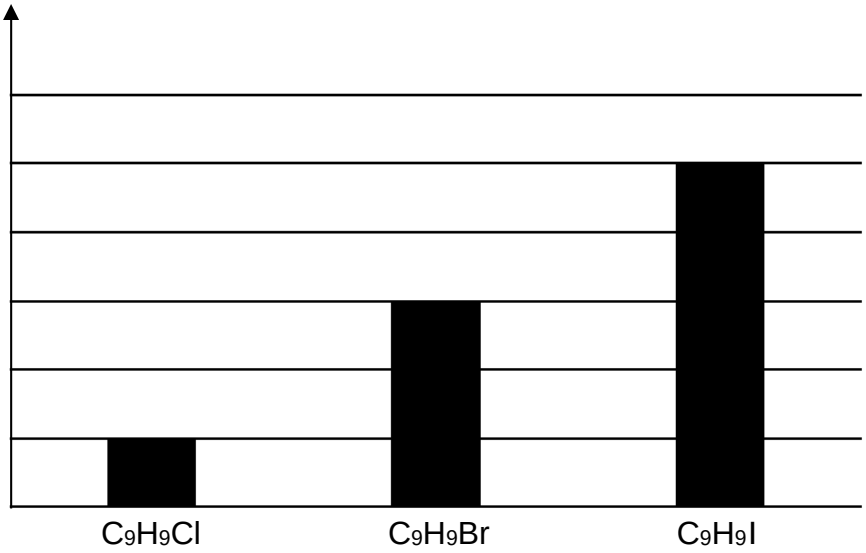
(c) Under suitable conditions, halogenoalkanes can be hydrolysed.

Equimolar samples of C_9H_9Cl, C_9H_9Br and C_9H_9I are added to separate test-tubes of ethanolic silver nitrate and warmed in a water bath at 60 ^oC for 10 minutes.

The relative amount of the respective precipitates formed are calculated.

The results are as follows:

Amount of precipitate obtained



(i) State the colour of the precipitate obtained from the reaction with C_9H_9Br.

.....[1]

(ii) With the aid of the *Data Booklet*, suggest an explanation for the trend of the amount of precipitates obtained.

.....

.....

.....

.....[2]

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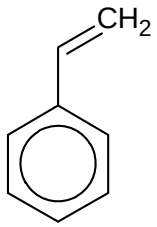
(d) Styrene, is a good starting material for synthesis reactions.



Styrene

When styrene is added to excess cold concentrated H_2SO_4, followed by water and heat, isomeric alcohols **A** and **B** are formed. One of the isomers is a primary alcohol. When isomers **A** and **B** undergo oxidation separately, **C,** a ketone, and **D**, phenylethanoic acid are produced respectively.

Styrene can also react with hydrogen in the presence of platinum catalyst at room temperature to form **E**.

(i) Explain which isomer, **A** or **B,** is the primary alcohol.

.....

.....

.....[2]

(ii) Hence, draw the structure of the primary alcohol isomer.

[1]

(iii) Draw the structure of **E**.

[1]

(iv) **B** and **D** react to form **F.** State the type of functional group present in **F**.

.....[1]

For examiner's use only

(v) Suggest a simple chemical test to differentiate styrene from **C**, with the corresponding observations.

.....

.....

.....[2]

[Total: 20]

For examiner's use only

Nanyang JC J2 Preliminary Exam 2018
H1 Chemistry 8873/01
Paper 1 MCQ Answers and Comments

Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans
1	**B**	6	**C**	11	**C**	16	**B**	21	**B**	26	**A**
2	**B**	7	**A**	12	**C**	17	**A**	22	**A**	27	**C**
3	**C**	8	**B**	13	**D**	18	**D**	23	**D**	28	**B**
4	**D**	9	**D**	14	**C**	19	**C**	24	**B**	29	**D**
5	**A**	10	**C**	15	**C**	20	**B**	25	**D**	30	**B**

1 B

Ar of **A**

$$= \frac{(140\times2)+(142\times3)+(144\times1)}{2+3+1} = \frac{850}{6}$$

= 141.67 = **<u>141.7</u>** (1 d.p)

2 B

2 Cl ≡ Cl_2

Amount of Cl atom = $\frac{1}{24\,000}\times2$ mol

No. of Cl atom = amt x Avogadro constant

$$= \frac{1\times6.02\times10^{23}\times2}{24\,000}$$

3 C

Cr is oxidised from **<u>+3 to +6</u>**
Fe is oxidised from **<u>+2 to +3</u>**
Oxygen is reduced from **<u>0 to -2</u>**

4 D

Cu: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}4s^1$
Fe^{3+}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$
Ni^{2+}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8$
Sr^{2+}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6$

5 A

Cations are smaller than their respective atoms as cations have **one electron shell less** than neutral atoms.

Anions are bigger than their respective atoms because of the extra repulsion of the added electron(s). Since the nuclear charge **remains the same**, the outermost electrons are now less attracted to the nucleus.

Anions are bigger than cations because anions contain **one more electron shell** and the increase in screening effect outweighs the increase in nuclear charge.

Atomic radius decreases across the period.

6 C

A BrF_3 : T-shaped (3bp, 2 lp)
B ICl_4^- : square planar (4bp, 2 lp)
C PCl_4^+: tetrahedral (4 bp, 0 lp)
D XeF_4: square planar (4bp, 2 lp)

7 A (1 & 4 are correct)

1 True, bond angle in N_2H_4 is 107° while bond angle in H_2O_2 is 105°

2 False, the N–H bond is *longer* than the O–H bond as the O–H covalent bond in more polar. Students can also check the DB to compare the 2 bond energies.

3 False, hydrazine forms *weaker* intermolecular hydrogen bonds than hydrogen peroxide as N is less electronegative than O.

4 True, both hydrazine and hydrogen peroxide are polar molecules. In hydrazine, the shape is trigonal pyramidal shape about N, while in hydrogen peroxide, the shape is bent shape about O. The dipoles do not cancel out.

8 B

E: must be a liquid at room temperature as its mpt < room temp < boiling pt. Hence E must be Br_2. Options C and D are eliminated.

F & G have relatively low melting points, hence they are unlikely to be Al and Si. Si having a giant covalent structure will have a mpt >1000°C. Option A is eliminated.

Option B is the best answer. Between Na and Mg, Na will have lower melting point and boiling point as Na has weaker metallic bonding due to lesser delocalised electrons available. Na will have lower density (mass divided by volume) as ionic radius of Na^+ is larger than that of Mg^{2+} and mass of Na^+ and Mg^{2+} is approximately constant.

9 D

The activation energy for the forward reaction is smaller than that for the backward reaction.

10 C

amount of water formed

$= \frac{25.0}{1000} \times 3.00 = 0.07500$ mol

heat produced

$= (25.0 + 25.0) \times 4.18 \times 9.5 \times \frac{100}{85}$

$= 2335$ J mol^{-1}

$\Delta H_n = -\frac{2335\times10^{-3}}{0.07500}$

$= -31.14$

$= -31.1$ kJ mol^{-1}

11 C

$\Delta H^{\ominus}_{lattice\ energy}$ CaO

= – ($\Delta H^{\ominus}_{atomisation}$ Ca + 1st and 2nd ionisation energies of calcium + 950)

+ $\Delta H^{\ominus}_{formation}$ CaO

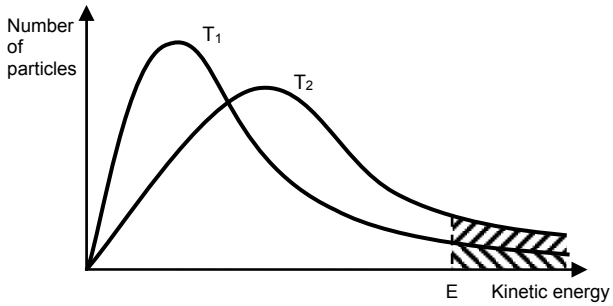
Option A: Less exothermic

Option B: Less exothermic

Option C: More exothermic as 1st and 2nd ionisation energies of magnesium are more endothermic than calcium

Option D: Standard enthalpy change of combustion of magnesium is equal to the standard enthalpy change of formation of magnesium oxide

12 C



Option 1 and 2 are correct. See peak of T2

Option 3 is correct. The area under the curve increases for energy greater than E.

Option 4 is wrong. The proportion of molecules at lower energies decreases.

13 D

At high ethanal concentration all the active sites in the enzyme molecules are occupied by ethanal molecules, hence the rate does not increase even though [ethanal] concentration increases i.e. zero order kinetics.

14 C

$[Q]_{eqm} = 0.2 / 10$ mol dm^{-3}

$[PQ_3]_{eqm} = 0.5 / 10$ mol dm^{-3}

Initial P = 0.2 mol

Since P and PQ_3 have the same mole ratio in the equation,

|change in P| = |change in PQ_3| = 0.1 (read off from graph)

Alternatively, you can also find change in P = 1/3 change in Q.

Hence $[P]_{eqm} = (0.2 - 0.1) = 0.1 / 10$ mol dm^{-3}

$$K_c = \frac{[PQ_3]}{[Q]^3[P]} = \frac{(\frac{0.5}{10})}{(\frac{0.2}{10})^3(\frac{0.1}{10})} = \frac{0.5\times10^3}{0.2^3\times0.1}$$

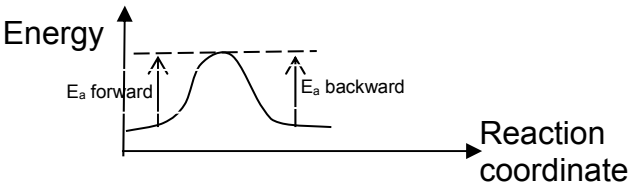
15 C

If equilibrium constant is independent of temperature, it means when temperature changes, neither forward nor backward reaction is favoured and this is only possible if ΔH is zero.

1. All rate constants are affected by temperature according to Arrhenius equation: $k = A^{-Ea/RT}$.

2. Temperature would have no effect on the position of equilibrium if ΔH is zero.

3. When ΔH is zero, activation energies for forward and backward reaction are equal as shown in the energy profile diagram below:



4. We cannot deduce any information about the number of gaseous particles unless some information about how value of equilibrium constant changes with pressure is provided.

16 B

A. A weak acid is partially dissociated in aqueous solution. A weak acid has a low K_a value hence it has a high pK_a value.

B. A weak acid has a strong conjugate <u>base</u>. Hence statement B is incorrect.

C. Acids are proton donors.

D. There is only a low concentration of ions formed as the weak acid remains mostly undissociated (as a molecule). Hence, there are few mobile ions to act as charge carriers, accounting for the low electrical conductivity.

17 A

A buffer contains a weak acid or base and its conjugate salt hence two possible buffers can be formed from HCO_3^-:
H_2CO_3 (weak acid) and HCO_3^-(conj base)
HCO_3^- (weak acid) and CO_3^{2-} (conj base)
Hence options 1 and 2 are correct.

For option 3:
$n(H^+) = 2 \times n(H_2SO_4) = n(HCO_3^-)$.
H_2SO_4 reacts completely with HCO_3^- to form H_2CO_3. No excess HCO_3^- is left hence a buffer is not formed.

18 D

Properties of:
MgO – basic oxide. Slightly soluble in water. It reacts with acid to form salt and water.
SiO_2 – insoluble in water and unreactive to dilute acids and bases.
$MgCl_2$ – soluble in water to give a weakly acidic solution.
Al_2O_3 – insoluble in water. Amphoteric in nature and reacts with both acids and bases to give salt and water.

I: <u>Add water to the mixture. Stir well and filter the mixture.</u>
Residue contains: MgO, Al_2O_3, SiO_2
Filtrate contains: $MgCl_2$, MgO as $Mg(OH)_2$

II: <u>To the residue, add NaOH(aq) and stir well with a glass rod.</u>
Only Al_2O_3 reacts with NaOH(aq)
$Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \rightarrow 2[Al(OH)_4]^-(aq)$

III: <u>Filter the resulting mixture.</u>
Residue contains: SiO_2, MgO
Filtrate contains: $[Al(OH)_4]^-(aq)$

IV: <u>To the residue, add HCl(aq) and stir well with a glass rod.</u>
Only MgO reacts with HCl.
$MgO(s) + 2H\ (aq) \rightarrow Mg^2\ (aq) + H_2O(l)$

V: <u>Filter to obtain the filtrate and residue.</u>
Residue contains: SiO_2
Filtrate contains: $Mg(OH)_2(aq)$

1 – No. Both SiO_2 and $MgCl_2$ remained unreacted. $MgCl_2$ only dissolved in water in step I therefore remained unreacted.

2 – No. Filtrate contains both $Mg(OH)_2$ and $MgCl_2$.
3 – No. The residue contains SiO_2 and MgO.
4 – No gas was produced throughout the separation procedure.

19 C

A – From Na_2O to Al_2O_3, the covalent character increases due to the increasingly higher charge density of the cation.

B – $|LE| \propto \frac{|z_+ z_-|}{r_+ + r_-}$

When the anion is large, the changes in the sum of ionic radii becomes negligible. The product of ionic charges increases from sodium to aluminium, thus lattice energy become more exothermic.

C – The oxides become less soluble across the Period from sodium to silicon. (See Periodicity notes – Reaction of oxides with water)

D – Melting points increases from sodium to silicon and decreases from silicon to argon. (Giant metallic structure → Giant molecular structure → simple molecular structure) (See Periodicity notes for full explanations on melting points)

20 B

The chloride of X react with water to give a colourless acidic solution.
The chlorides which are acidic in water are $MgCl_2$, $AlCl_3$, $SiCl_4$ and PCl_5.
$SiCl_4$ reacts with water to form a solid SiO_2.
⇒X can be Mg, Al or P.

The oxides of X and Y are insoluble in water.
Only 2 oxides in Period 3 are insoluble in water, Al or Si.
⇒ X must be Al (agree with first point)
⇒ Y must be Si

Oxides of X and Y have high melting and boiling points. Oxide of Z has low melting and boiling points.
Across Period 3, the oxides change from giant ionic structures to giant covalent structures to simple molecular structures.
⇒ Element Z has a simple molecular structure, so it is either phosphorus, sulfur or chlorine.
⇒ Element Z forms anions and has the largest ionic radius.

Order of increasing ionic radius:
Si^{4+}, Al^{3+}, P^{3-}(or S^{2-} or Cl^-)

21 B

An unsaturated 5–carbon alcohol would have molecular formula, $C_5H_{12}O$, e.g. $CH_3CH_2CH_2CH_2CH_2OH$

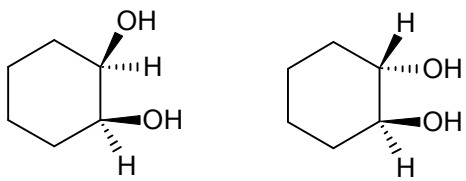
E has 4 less H atoms which implies that there is presence of 2 multiple bonds which could be C=C or C=O bond.

Hence, the possible isomers are
$CH_2=CHCH=CHCH_2OH$,
$CH_2=CHCH_2COCH_3$ and
$CH_2=CHCH_2CH_2CHO$.
Hence, there can be alkene, <u>alcohol</u>, ketone and <u>aldehyde</u> present in the isomers of C_5H_8O. (1 and 2 only)

An ester is not possible as there is only 1 oxygen atom present in E.

22 A

The product after addition reaction with H_2 is as follows:



cis trans

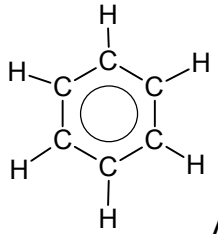
A:

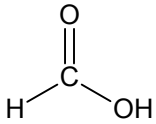
B: It is an ester and esters do not react with H_2.

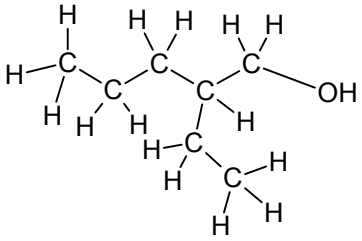
C: $CH_3CH_2CH_2CH_2CH_3$ do not exhibit cis-trans isomerism.

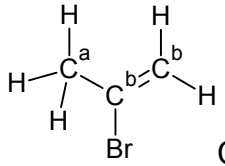
D: It is an amide and amides do not react with H_2.

23 D

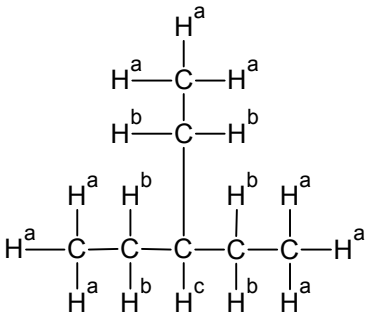
A:  All of its carbons have 3 bond pairs and 0 lone pair. Bond angle: 120°.

B:  Its carbon have 3 bond pairs and 0 lone pair. Bond angle: 120°.

C:  All of its carbons have 4 bond pairs and 0 lone pairs. Bond angle: 109.5°.

D:  C^a have 4 bond pairs and 0 lone pair. Bond angle about C^a: 109.5°. Both C^b have 3 bond pairs and 0 lone pair. Bond angle about C^b: 120°.

24 B



The chlorine atom can substitute once with H^a, H^b or H^c. (i.e. there are 3 types of hydrogen atoms - H^a, H^b and H^c, with different chemical environments) Hence, there can only be 3 possible structural isomers of monochloro-compounds.

25 D

A: Both compounds are able to liberate Cl^- to give white ppt of AgCl with ethanolic $AgNO_3$.

B: Solution remains colourless for both compounds.

C: Solution remains colourless for both compounds.

D: CH_3CH_2Cl will liberate Cl^- to give white ppt of AgCl with ethanolic $AgNO_3$ whereas CH_3CH_2Br will liberate Br^- to give cream ppt of AgBr with ethanolic $AgNO_3$.

26 A

A: CH_3COCH_3 will not get oxidised or undergo acidic hydrolysis.

B: CH_3CH_2CHO will get oxidised to CH_3CH_2COOH (propanoic acid).

C: $CH_3CH_2CH_2OH$ will get oxidised to CH_3CH_2COOH (propanoic acid).

D: $CH_3CH_2CONHCH_3$ will undergo acidic hydrolysis to give CH_3CH_2COOH (propanoic acid) and $CH_3NH_3^+$.

27 C

A: The non-polar regions of the polymer is too large to be dissolved in water.

B: PP has a giant molecular structure such that the non-polar oil molecules are unable to form favourable intramolecular forces of attraction to provide sufficient energy to overcome the extensive intermolecular forces of attraction within the PP polymer.

C: PP is unable to undergo alkaline hydrolysis but the ester groups in PET can undergo strong alkaline hydrolysis.

D: Both are able to store hot foods as they have extensive intramolecular forces of attraction that are strong enough to withstand such heat.

28 B

1: Polyesters are condensation polymers.
2: Poly(ethene) are addition polymers.
3: poly(vinyl alcohol) are addition polymers.
(2 & 3 only)

29 D

It is the low porosity of the carbon nanotubes that made them to be a suitable material for water filtration. The size of the hexagonal 'holes' in carbon nanotubes are small enough to allow water molecules to pass through but not for other larger species (e.g. other ions, particles etc).

30 B

A: Their health risks are poorly understood. They may pose potential health risks.

B: Nanomaterials can have a length of more than 100 nm as they just need at least one dimension in the size of 1 to 100 nm.

C: Nanomaterials can be both man-made and exist biologically.

D: Not all nanomaterials can stick onto surfaces (e.g. catalytic converter).

2018 H1 Chemistry Prelim Paper 2 Answers

1 **(a)** Amount of NaOH = 35.65/1000 x 0.018 = <u>6.42 x 10^{-4} mol</u> [1]

Amount of acid in 250 cm^3 = 0.00700 x 250/25 = <u>6.42 x 10^{-3} mol</u> [1]

(b) 1 mol of ascorbic acid reacts with 1 mol of iodine [1]

(c) Amount of ascorbic acid in 100 ml syrup
= [(33.40/1000) x 0.017] x (250/25)
= 0.005678
= <u>5.68 x 10^{-3} mol</u> [1] ecf if b(i) wrong

(d) Reaction 1 (Neutralisation) – Screened methyl orange/ methyl orange/ thymol blue
(Reaction 2) Redox reaction – Starch [1]

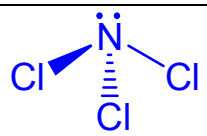
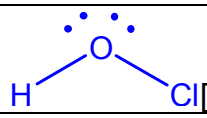
(e) Amount of benzoic acid = 0.006417 – 0.005678 = 7.39 x 10^{-4} mol

Mass of benzoic acid = 7.39 x 10^{-4} x 122.0 = <u>0.0902 g</u> [1]
Mass of ascorbic acid = 0.00568 x 176.0 = <u>1.00 g</u> [1] ecf in **(b)(ii)** wrong

(f) Since 1g (= 1000 mg) of ascorbic acid is found in 100 cm^3 of Appelin Syrup,

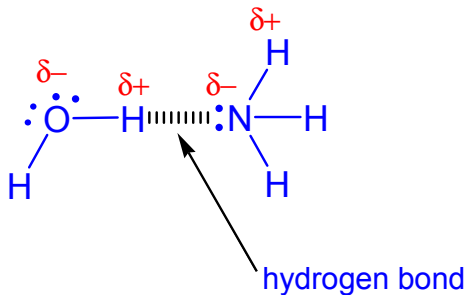
Dosage of Appelin B12 Syrup = (50/1000) x 100
= 5 cm^3 [1]

2 **(a)** **(i)**

Compound	3D sketch	Shape	Bond Angle
NCl_3	 [1]	Trigonal pyramidal [1]	107°
HOCl	 [1]	Bent [1]	105°

[1] for correct bond angles for both molecules

(ii) The energy released in forming strong hydrogen bonds between ammonia and water molecules is sufficient to overcome the hydrogen bonds between water molecules and the hydrogen bonds between ammonia molecules. [1]



[1] – lone pairs, hydrogen bond, partial charges, label

(b) $Cl^{+}(g) \rightarrow Cl^{2+}(g) + e$ [1]

Cl^{+}: $[Ne]3s^2\ 3p_x^2\ 3p_y^1\ 3p_z^1$
S^{+}: $[Ne]3s^2\ 3p_x^1\ 3p_y^1\ 3p_z^1$
Less energy is required to remove the <u>paired $3p_x$ electron in Cl^{+}</u> as it experiences <u>inter-electron repulsion</u>. [1]

(c)

Oxide	Reaction with hydrochloric acid	Reaction with sodium hydroxide
Na_2O	$Na_2O(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l)$	No reaction
Al_2O_3	$Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$	$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2NaAl(OH)_4(aq)$
P_4O_{10}	No reaction	$P_4O_{10}(s) + 12NaOH(aq) \rightarrow 4Na_3PO_4(aq) + 6H_2O(l)$

[1] for each row

3 **(a)** **(i)** Isotopes are <u>atoms of the same element</u> which have the same atomic number/number of protons but different nucleon number/number of neutrons. [1]

(ii) Number of protons : 10
Number of neutrons: 10
Number of electrons: 10 [1]

(b)

	D_2O	H_2O	HDO
Initial amt/ mol	30 / 20.0 = 1.5	27 / 18.0 = 1.5	0
Change/ mol	-x	-x	+2x
Eqm amt/ mol	1.5 – x	1.5 – x	2x

[1] for initial amounts

Let volume of mixture be V dm^3.

$$\frac{(\frac{2x}{V})^2}{(\frac{1.5-x}{V})^2} = 3.56$$

$$\frac{2x}{1.5-x} = 1.886$$ [1] for correct substitution. Mark for V?

$x = 0.7279$

n(HDO) = $2x = 1.46$ mol [1]

*Note if students got M_r of D_2O wrong. They will not be able to solve the wrong quadratic equation (only max 1 out of 3 marks).

(c) **(i)** $[H^+] = 10^{-6.92} = 1.202 \times 10^{-7}$ mol dm^{-3}
Since water is neutral, $[OH^-] = [H^+] = 1.202 \times 10^{-7}$ mol dm^{-3}
$K_w = [H^+][OH^-] = (1.202 \times 10^{-7})^2 = 1.45 \times 10^{-14}$ mol^2 dm^{-6} [1] for value

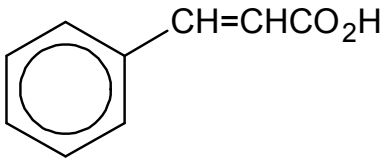
(ii) Value of K_w at 25 °C is 1.0×10^{-14}

At <u>higher temperature</u> of 30 °C, <u>K_w increases</u>. <u>Positon of equilbrium has shifted to the right</u> and the <u>forward endothermic reaction is favoured</u>. [1]

Hence the <u>forward reaction (auto-ionisation of water) is endothermic</u>. **<u>Enthalpy increases</u>** (more positive/ more endothermic) during reaction. [1]

4 **(a)** **I**: Elimination
II: Oxidation
III: Condensation
IV: Acidic hydrolysis

(b)

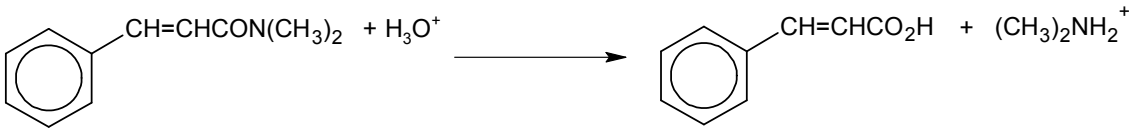


(c) **I**: Ethanolic NaOH, heat under reflux – ***heat under reflux is a must to be written for this R&C.***

III: $(CH_3)_2NH$ or dimethylamine
N,N' Dicyclohexylcarbodiimide with 5% DMAP catalyst
Many have missed out the amine reagent or included heat under reflux (which was unnecessary).

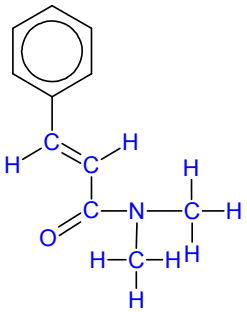
IV: Dilute H_2SO_4, heat (under reflux) – ***aq or dilute acid should be mentioned but students often missed out.***

(d) Equation for step **IV**:



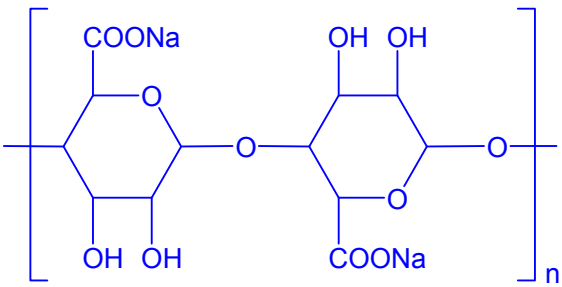
(e) Cis-trans isomerism occurs when there is <u>restricted rotation</u> about <u>a C=C π bond</u> in an aliphatic alkene [1] and when there are <u>two different groups on each carbon of the double bond</u>. [1]

(f)



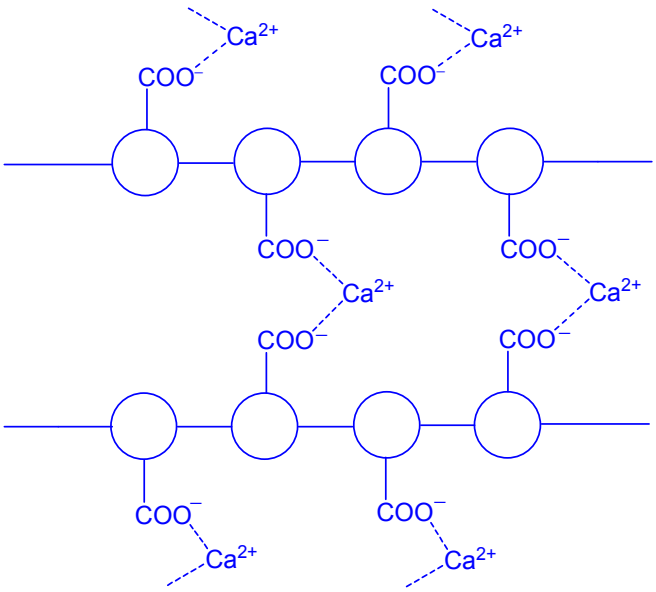
5 **(a)** **(i)** Ionic bonds (between oppositely charged ions) and covalent bonds (between atoms) [1]

(ii)



[1]

(b) **(i)**



[1] – show at least two chains crosslinking
[1] – Ca^{2+} near to two opposite chain $-COO^-$ groups

It is held by ionic bonds between one Ca^{2+} and two alginate monomers. [1]

(ii) The energy released when calcium alginate forms ion-dipole interactions (and hydrogen bonds) with the water molecules is insufficient to overcome the strong ionic bonds between calcium ions and alginate ions. [2]

(c) **(i)** Lime juice has a pH lower than 3.6. The high concentration of H^+ in lime juice will acidify sodium alginate to form alginic acid (acid-base reaction) which prevents spherification from occurring. [1]

(ii) Sardine extract has a very high calcium content and will solidify in the sodium alginate solution immediately to form calcium alginate. [1]

(d) Mango puree. [1]
Its pH is greater than 3.6 and it has the lowest calcium content. [1]

(e) H^+] from milkfish extract = $10^{-5.4}$ = 3.981×10^{-6} mol dm^{-3}
[H^+] from lime juice = $10^{-1.8}$ = 0.01585 mol dm^{-3} [1]

$$[H^+] \text{ of solution} = \frac{3.981\times10^{-6}\left(\frac{50}{1000}\right)+0.01585\left(\frac{10}{1000}\right)}{\frac{50+10}{1000}} \quad [1]$$

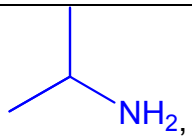
= 0.002644 mol dm^{-3}

pH = –log (0.002644) = 2.57 (pH < 3.6)
The solution is too acidic. It is unsuitable for spherification. [1]

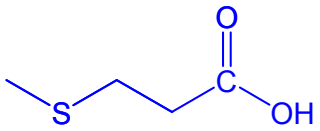
(f) **(i)**
- There are 3 bond pair and 0 lone pair of electrons about C* atom.
- There are 2 bond pairs and 2 bond pairs of electrons about S atom.
- According to the VSEPR theory, the electron pairs will arrange themselves as far apart as possible to minimise repulsions.
- Hence the shape about C* atom is trigonal planar and
- the shape about S atom is bent.

5 points – [3], 4points – [2], 3-2 points – [1]

(ii)

	Step I	Step II
Type of reaction	Oxidation [1]	Condensation [1]
Reagents and conditions	$K_2Cr_2O_7$(aq), H_2SO_4(aq), heat under reflux **or** $KMnO_4$(aq), H_2SO_4(aq), heat under reflux [1]	 DCC (N,N'-Dicyclohexylcarbodiimide) with 5% DMAP catalyst [1]

Structure of Compound X:



[1]

6 **(a)** **(i)** $NO_2 \rightarrow ½N_2 + O_2$ [1]

Accept $2CO + NO_2 \rightarrow ½ N_2 + 2CO_2$

(ii) The reactants and catalyst are in different phases. [1]

(iii) Reactant molecules diffuse towards the platinum catalyst surface.

Reactant molecules become chemically adsorbed on neighbouring active sites by forming bonds with the catalyst surface.

This caused the covalent bonds within the molecules to weaken, hence lowering the activation energy of the reaction.

The adsorbed molecules are also held in the right orientation for reaction to occur, hence increasing the frequency of effective "collisions".

Eventually, the molecules dissociate, forming highly reactive intermediates which then react to form the products.

After reaction, the product molecules desorbed and diffuse away from the surface.

[3] for 4 points, [2] for 3 points, [1] for 2 points

(iv) Nanoparticles are discrete particles with all three dimensions in the size range between 1 to 100 nm. [1]

(v) When the particles used are in the nanoscale, they provide a larger surface area to volume ratio compared to particles in larger dimensions.

Hence, there will be greater number of active sites for reactions to occur.

This increases the ratio of platinum ions on the surface of a platinum nanoparticle to platinum ions that are buried inside the same platinum nanoparticle.

[2] for 3 points, [1] for 2 points

(vi) Nanoparticles which are released into the environment might be taken in by bacteria and protozoa through their cell membranes, thus allowing the nanomaterials to enter the biological food chain. [1]

(b) **(i)** By Le Chatelier's Principle, a decrease in temperature will favour the exothermic reaction to compensate the lowered heat which is the forward reaction. Hence the position of equilibrium will shift to the right.

The mixture is decolourised.

[2] for 3 points and [1] for 2 points

(ii) By Le Chatelier's Principle, a decrease in pressure will favour the reaction that produced a greater amount of gas which is the backward reaction. Hence the position of equilibrium shifts to the left.

The brown colour of the mixture is intensified.

[2] for 3 points and [1] for 2 points

(c) **(i)** By exerting high pressure [1]
At high pressure, the molecules are pushed closer together, resulting in the forming of intermolecular forces of attraction between the molecules. [1]

or

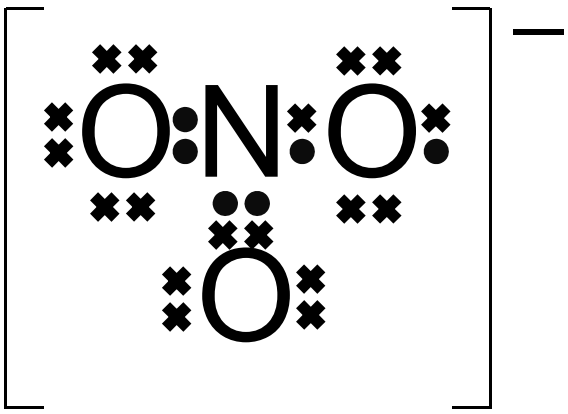
By lowering the temperature [1]
At low temperature, the molecules will move at a slower speed. This helps to bring the molecules closer together, resulting in the forming of intermolecular forces of attraction between the molecules. [1]

(ii) $\Delta H_{rxn} = \sum$ BE(bonds broken) – $\sum$ BE(bonds formed)
=160(3) + 390(8) + 201(2) + 607(2) – 944(3) – 460(8) [1]
= –1296
= –1300 kJ mol^{-1} [1]

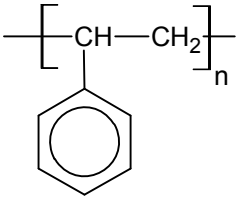
(iii) Nitrogen tetroxide, hydrazine and water exists as liquids and the enthalpy change of vapourisation of these compounds have to be taken into account.[1]

(d) **(i)** $NO_3^- + 4H^+ + 3e \rightarrow NO + 2H_2O$ [1]

(ii)



7 (a) (i)



[1]

Addition polymerisation [1]

(ii) Polystyrene is a thermoplastic which has low melting point (or flexible; low tensile strength) while poly (diallyl phthalate) is a thermoset polymer which has high melting point (or rigid; high tensile strength) [1]

(iii) Polystyrene is highly recyclable or has very good reshaping capability [1]

(iv) Plastics are finite resources (economic factor)
Harm to environment, human health (environment factor)
[1] for any logical answer

(b) (i) (By reasoning method)
Comparing experiment 1 and 2
When $[C_9H_9Cl]$ is increased by 1.5 times, the initial rate of reaction increases by approximately 4.9/3.2 ≈ 1.5.
Hence, the order of reaction wrt C_9H_9Cl is 1. [1]

Comparing experiment 2 and 3
When $[C_9H_9Cl]$ is halved and $[NH_3]$ is increased by 4 times, the initial rate of reaction is almost doubled (6.3/3.2)
Hence, the order of reaction wrt NH_3 is 1. [1]

Can accept calculation method.

(ii) Rate = $k[C_9H_9Cl]^1 [NH_3]^1$ [1]

(iii) Rate = $k[C_9H_9Cl]^1 [NH_3]^1$
$6.3 \times 10^{-3} = k (0.01)(0.4)$
k = 1.58 [1] $mol^{-1} dm^3 s^{-1}$ [1] including units

(c) (i) Rate of hydrolysis depends on the strength of the C–X bond.

- Down the group, bond length increases: C–Cl < C–Br < C–I
- Orbital overlap becomes less effective down the group.
- Strength of C-X bond: C–Cl (340) > C–Br (280) > C–I (240)

Or atomic radius: Cl (0.099) < Br (0.114) < I (0.133)

- Rate of hydrolysis: $C_9H_9Cl < C_9H_9Br < C_9H_9I$

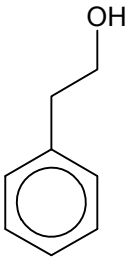
Amount of ppt from R-X: $C_9H_9Cl < C_9H_9Br < C_9H_9I$

[2] for 4 points

(ii) Pale cream precipitate [1]

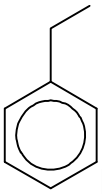
(d) **(i)** Compound **B** [1]
Primary alcohol can be oxidized to form carboxylic acid. Since **D** is a carboxylic acid, **B** has to be a primary alcohol. [1]

(ii)

Primary alcohol: 

[1]

(iii)


[1]

(iv) Compound **F** is an <u>ester</u>. [1]

(v) Add Br_2 in CCl_4 to separate test tubes of styrene and C. [1]

Observation
Styrene: Orange-red Br_2 decolourises
C: Orange-red Br_2 remains [1]

OR

Add $KMnO_4$, dilute H_2SO_4 to separate test tubes of styrene and C

Observation
Styrene: Purple colour decolourises
C: Purple colour remains

Name:	Index No.:	CT Group: 17

PIONEER JUNIOR COLLEGE, SINGAPORE

JC2 PRELIMINARY EXAMINATIONS
HIGHER 1

CHEMISTRY **8873/01**

Paper 1 Multiple Choice **21 September 2018**

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, index number and CT group on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

This document consists of **13** printed pages.

Section A

For each question, there are four possible answers labelled **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.

1 In an experiment, 20 cm^3 of an organic compound in the gaseous state was sparked with an excess of oxygen. 40 cm^3 of carbon dioxide and 20 cm^3 of nitrogen were obtained among the products. All gas volumes were measured at the same temperature and pressure.

Which compound would fit the above data?

A $C_2H_8N_2$ **B** C_2H_7N **C** $C_6H_5NO_2$ **D** $C_4H_{12}N_2$

2 During a laboratory practical, a student tried to determine the concentration of $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$ in a given mixture through two different experiments.

1. 25.0 cm^3 aliquot of the $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$ mixture solution required 15.00 cm^3 of 0.1 mol dm^{-3} of acidified $KMnO_4$ solution for complete oxidation.

2. Using another 25.0 cm^3 aliquot, all the $Fe^{3+}(aq)$ was first reduced to $Fe^{2+}(aq)$ using zinc metal before requiring 34.20 cm^3 of the same $KMnO_4$ solution for complete oxidation.

What is the concentration of $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$ in the given mixture?

A 0.012 mol dm^{-3} $Fe^{2+}(aq)$ and 0.0154 mol dm^{-3} $Fe^{3+}(aq)$

B 0.180 mol dm^{-3} $Fe^{2+}(aq)$ and 0.230 mol dm^{-3} $Fe^{3+}(aq)$

C 0.300 mol dm^{-3} $Fe^{2+}(aq)$ and 0.384 mol dm^{-3} $Fe^{3+}(aq)$

D 0.300 mol dm^{-3} $Fe^{2+}(aq)$ and 0.684 mol dm^{-3} $Fe^{3+}(aq)$

Use of the Data Booklet is relevant to this question.

3 Which ion has only one unpaired electron?

A Al^{3+} **B** At^- **C** Cu^+ **D** V^{4+}

4 The table shows the fifth ionisation energies of four consecutive elements in the Periodic Table

Element	Q	R	S	T
Fifth ionisation energy / kJ mol^{-1}	32828	37832	9445	10989

What is the formula of chloride of Q?

A QCl_2 **B** QCl_3 **C** QCl_4 **D** QCl_5

5 Which one of the following **cannot** be explained by hydrogen bonds?

A CH_3CHO has a higher boiling point than C_3H_6.

B CH_3CHO is miscible in water.

C CH_3COOH has a M_r of 120 in benzene.

D HF has a higher boiling point than HC*l*.

6 Which of the following has the largest bond angle?

A ClF_3 **B** H_3O^+

C SO_2 **D** NO_3^-

7 Which statements concerning the lattice structures of graphite and diamond are correct?

1 The C-C-C bond angle between nearest neighbours is smaller in diamond than in graphite.

2 The shortest carbon-carbon bond occurs in diamond.

3 All covalent bonds in diamond are of the same strength but those in graphite are not.

A **1** only **B** **2** only **C** **1** and **3** **D** **2** and **3**

8 Which statements about endothermic reactions are correct?

1 There is a net transfer of heat energy from the surroundings to the reacting system.

2 On the reaction pathway diagram the products of the reaction are lower than the reactants.

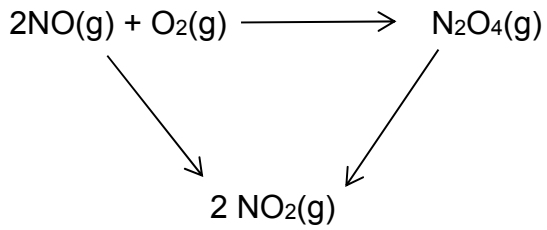
3 The total bond energies of the reactants are greater than the total bond energies of the products.

A **1**, and **2** **B** **1** and **3** **C** **2** and **3** **D** **1, 2** and **3**

9

$$2NO(g) + O_2(g) \rightarrow N_2O_4(g) \qquad \Delta H^{\ominus} = -171 \text{ kJ mol}^{-1}$$

$$NO(g) + \frac{1}{2}O_2(g) \rightarrow NO_2(g) \qquad \Delta H^{\ominus} = -56.6 \text{ kJ mol}^{-1}$$



Given the above data and energy cycle, what is the standard enthalpy change of the following reaction $N_2O_4(g) \rightarrow 2NO_2(g)$?

A +57.8 kJ mol^{-1} **B** –57.8 kJ mol^{-1} **C** +114 kJ mol^{-1} **D** –114 kJ mol^{-1}

10 The enthalpy change of formation of carbon monoxide and carbon dioxide are given below.

ΔH_f (CO)= –110 kJ mol^{-1}
ΔH_f (CO_2)= –393 kJ mol^{-1}

Which of the following statements is correct?

A The enthalpy change of combustion of carbon is –283 kJ mol^{-1}.

B ΔH_f (CO_2) – ΔH_c (CO) has the same value as enthalpy change of formation of CO.

C Carbon monoxide is energetically more stable than carbon dioxide.

D The amount of energy evolved when 1 mole of carbon monoxide is completely burnt is greater than that of carbon.

11 An industrial plant illegally dumped some radioactive waste in a landfill.

This waste composed of two radioactive isotopes **X** and **Y** in the proportion 4:1.

The decay of radioactive isotopes follows first-order kinetics.

The half-life of **X** is 2 days whereas that of **Y** is 4 days. By the time the authorities found out about this illegal dumping and analysed a sample of the waste, they found equal amounts of **X** and **Y**.

How long was the waste in the landfill before the authorities arrived?

A 2 days **B** 4 days **C** 8 days **D** 16 days

12 Using a calorimeter, the following reaction is studied by finding the time taken for a coloured reactant, **F**, to decolourise. The reaction is catalysed by **H**. The following results are obtained.

$$\mathbf{F} + \mathbf{G} \xrightarrow{\mathbf{H}} \mathbf{J} + \mathbf{K}$$

Expt	Volume of **F**/ cm^3	Volume of **G**/ cm^3	Volume of **H**/ cm^3	Volume of H_2O/ cm^3	Time taken/ s
1	10	20	10	10	20
2	10	10	10	20	40
3	10	20	5	15	40
4	5	20	10	15	20

What is the rate equation for the reaction?

A rate = k[**G**][**H**]

B rate = k[**F**][**H**]

C rate = k[**F**][**G**]

D rate = k[**F**][**G**][**H**]

13 Which series is correctly arranged in order of increasing values ?

A electrical conductivity of Mg, A*l*, Si

B electronegativity of P, S, C*l*

C melting point of P, S, C*l*

D melting point of the chlorides of Na, Mg, A*l*

14 Element **X** is one of the first five elements in Period 3 of the Periodic Table. The following four statements were made about the properties of element **X** or its compounds.

Three statements are correct descriptions and one is false.

Which statement does **not** fit with the other three?

A The oxide of **X** dissolves in excess dilute NaOH(aq).

B The oxide of **X** has a very high melting point.

C The chloride of **X** reacts with water to give an acidic solution with pH 1.

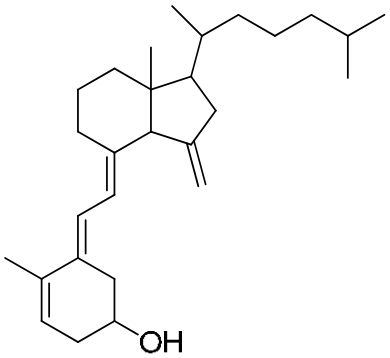
D **X** exhibits only one possible oxidation number in its chloride, which is not a solid at room temperature.

15 Which of the reagents / tests can be used to differentiate compound 1 and 2?

	Compound 1	Compound 2	Reagents / tests
1	NaC*l*	MgO	Dilute H_2SO_4
2	$SiCl_4$	PCl_5	damp blue litmus paper
3	$AlCl_3$	Al_2O_3	H_2O

A **1** only **B** **1** and **2** **C** **2** and **3** **D** **3** only

16 Compound **G** has the following structure.

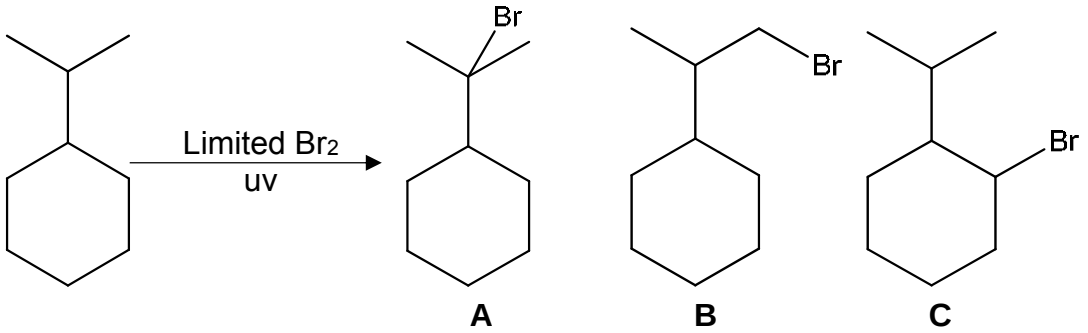


compound **G**

How many cis-trans isomers does compound **G** have?

A 2 **B** 2^2 **C** 2^3 **D** 2^4

17 Isopropylcyclohexane reacts with bromine to form different mono–substituted products. Three of the products are shown below.



The rate of abstraction of primary, secondary and tertiary hydrogen is given.

Primary	Secondary	Tertiary
H | H—C—H | R	H | R'—C—H | R	R" | R'—C—H | R
2	3	6

What is the expected ratio of the mono–substituted products **A : B : C** formed?

A 1 : 1 : 1 **B** 1 : 2 : 2 **C** 1 : 6 : 4 **D** 6 : 2 : 3

18 Compound **X**, $CH_2(OH)CH(CHO)CH_3$, is heated under reflux with an excess of acidified $K_2Cr_2O_7$ to form compound **Y**. Both **X** and **Y** are separately warmed with Fehling's solution and the observations noted.

What are the observations?

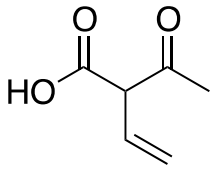
A Both **X** and **Y** give a red precipitate.

B Only **X** gives a red precipitate.

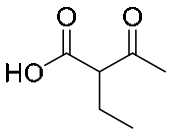
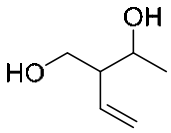
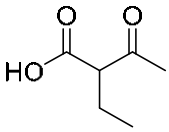
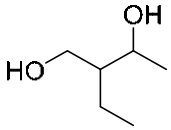
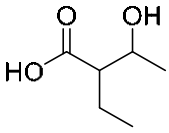
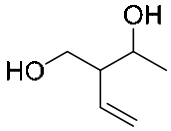
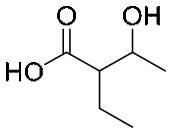
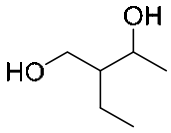
C Only **Y** gives a red precipitate.

D Neither **X** nor **Y** gives a red precipitate.

19 Which are the products formed when compound **S** reacts with the following reducing agents?

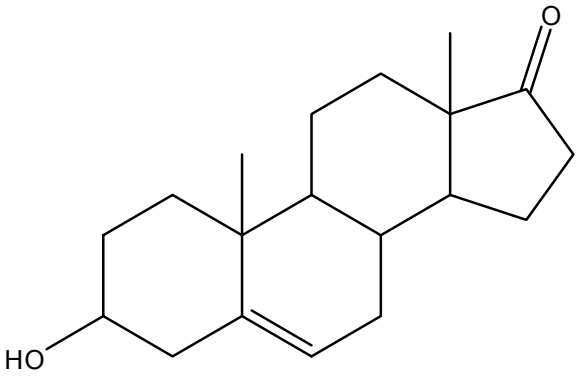


compound **S**

	H_2, Pt	**$LiAlH_4$ in dry ether**
A		
B		
C		
D		

20 Athletes taking part in the Olympics could be disqualified and have their medal revoked for using banned performance–enhancing drugs.

DHEA, a steroid hormone, is illegally used as a performance–enhancing drug as it has minimal side effects.



DHEA

Which reagents would react with DHEA?

1 Thionyl chloride, $SOCl_2$

2 Bromine

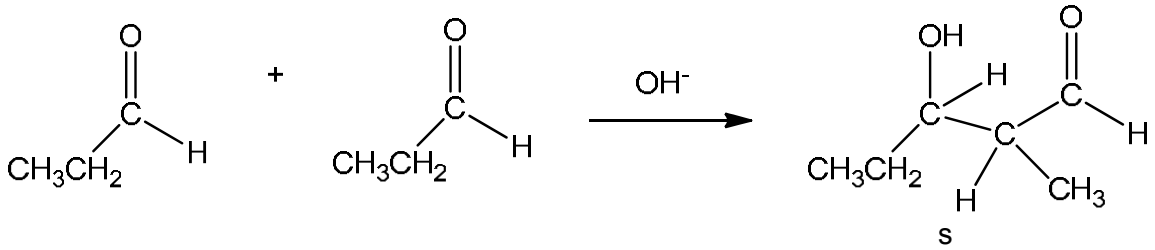
3 Acidified $KMnO_4$

4 Tollens' reagent

A **2** and **4** only **B** **1** and **3** only **C** **1**, **2** and **3** **D** **2**, **3** and **4**

21 In the presence of a strong base, aldehydes and ketones may undergo addition reaction to form an *aldol* compound (hydroxycarbonyl).

A reaction of propanal with sodium hydroxide to form an *aldo* compound is as shown below.



s

aldol compound

Which product can be formed when sodium hydroxide is added to a mixture of butanal, $CH_3CH_2CH_2CHO$, and propanone, CH_3COCH_3?

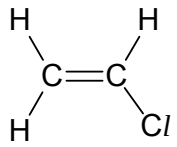
A $CH_3CH_2CH_2CH(OH)CH_2CH_2CH_2CHO$

B $(CH_3)_2C(OH)CH_2CH_2CH_2CHO$

C $(CH_3CH_2)_2C(OH)CH_2COCH_3$

D $CH_3CH_2CH_2CH(OH)CH_2COCH_3$

22 The diagram shows the monomer used to make polyvinyl chloride, PVC.



Assuming that one particular molecule of the polymer forms from *n* molecules of the monomer (where *n* is many thousands), which statements are correct?

1 The relative molecular mass of this polymer molecule is approximately 62.5*n*.

2 There are *n* sp^3 carbon atoms in this polymer molecule.

3 There are 5*n* σ bonds in one polymer molecule.

A **2** and **3** **B** **1** and **2** **C** **2** only **D** **1** only

23 A reaction involved in the Contact process is shown.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197 \text{kJ mol}^{-1}$$

The reaction is investigated at 200 kPa and 700K and the value of the equilibrium constant, K_c, is found to be Y. The reaction is then investigated at 1000 kPa and 700K and the value of K_c is found to be Z. Which statement comparing Y and Z is correct?

A Y and Z are the same.

B Y is greater than Z.

C Z is 2.2 times greater than Y.

D Z is 5.0 times greater than Y.

24 An equilibrium can be represented by the equation below.

W (aq) + **X** (aq) ⇌ **Y** (aq) + **Z** (aq)

In 0.50 dm^3 of a certain mixture, the concentrations of these substances at equilibrium were as shown.

Species	**W**	**X**	**Y**	**Z**
Concentration / mol dm^{-3}	1.00	2.00	2.00	1.00

A certain amount of **Y** was added to this equilibrium mixture.

What is the number of moles of **Y** added such that the new equilibrium [**W**] is 1.20 mol dm^{-3}? Assume that the temperature remained constant throughout.

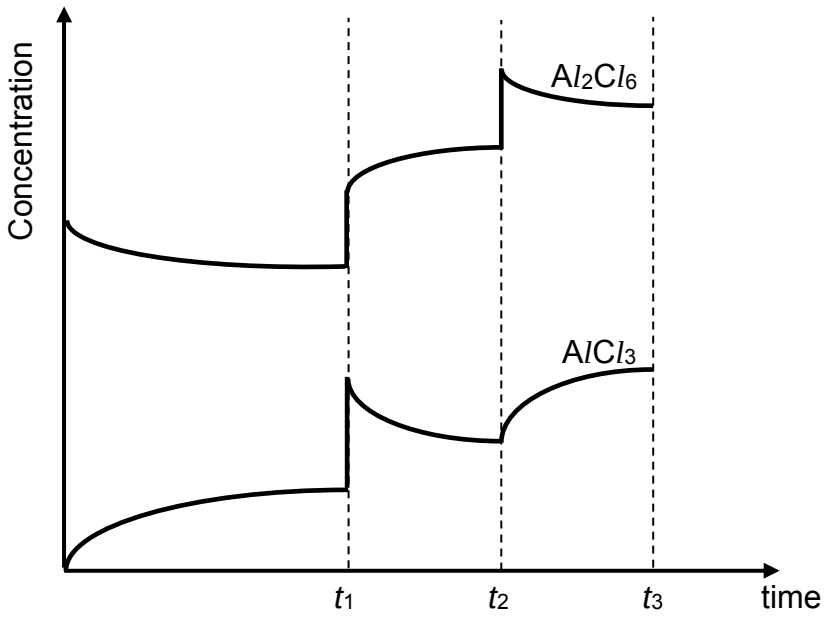
A 0.10 **B** 0.20 **C** 0.75 **D** 1.50

25 Aluminium chloride exists in two different forms in the vapour state. When some Al_2Cl_6 was added into a reaction vessel, the following equilibrium is slowly set up.

$$Al_2Cl_6\,(g) \rightleftharpoons 2AlCl_3\,(g) \qquad \Delta H = +ve$$

At different times during the experiment, changes were made to the conditions in the reaction vessel. At each time, there was only one change made to the conditions in the reaction vessel.

The change in the concentrations in the mixture with time is shown in the graph below.



Which conclusion can be drawn from the graph?

A At t_2, a catalyst was added to the system.

B The temperature of the mixture at t_2 was higher than that at t_1 min.

C The value equilibrium constant, K_c, is different at t_1 and t_3.

D At t_1, the pressure of the system was increased by decreasing the volume.

26 Values for the ionic product of water, K_w, at two different temperatures are given below

Temperature / °C	K_w / mol^2dm^{-6}
25	1.00×10^{-14}
62	1.44×10^{-14}

Which statement is correct for pure water at 30°C?

A pH < 7

B pH = 7

C $[H^+] > [OH^-]$

D $[H^+] = 1.44 \times 10^{-7}$

27 Which aqueous mixture will resist changes in pH on the addition of small amounts of an acid or a base?

A ammonia + sodium hydroxide

B hydrochloric acid + propanoic acid

C propanoic acid + sodium propanoate

D sodium propanoate + sodium hydroxide

28 A mixture is made by adding 20 cm^3 of 0.1 $moldm^{-3}$ of H_2SO_4 with 80 cm^3 of 0.1 $moldm^{-3}$ NaOH. What is the pH of the final solution at 25°C?

A 11.60

B 11.80

C 12.60

D 12.80

29 In humans it is important for blood to be maintained at a pH between 7.35 and 7.45. One of the ways it does this is by using a buffer of CO_2(aq) and HCO_3^-(aq).

What are the equation(s) that represent how the blood acts as a buffer when small amounts of acid and alkalis are added?

1 $HCO_3^- + OH^- \rightarrow H_2O + CO_3^{2-}$

2 $CO_2 + OH^- \rightarrow HCO_3^-$

3 $HCO_3^- + H^+ \rightarrow H_2CO_3$

A **1** only **B** **2** only **C** **1** and **3** **D** **2** and **3**

30 The gecko, a small lizard, can climb up a smooth glass window. The gecko has millions of microscopic hairs on its toes and each hair has thousands of pads at its tip. The result is that the molecules in the pads are extremely close to the glass surface on which the gecko is climbing. What is the interaction between the gecko's toe pads and the glass surface?

A dative bonds

B effective nuclear charge

C instantaneous dipole–induced dipole attractions

D permanent dipole dipole attractions

Answers

1	A	**11**	C	**21**	D
2	C	**12**	D	**22**	D
3	D	**13**	B	**23**	A
4	B	**14**	A	**24**	C
5	A	**15**	D	**25**	D
6	D	**16**	B	**26**	A
7	A	**17**	B	**27**	C
8	B	**18**	B	**28**	C
9	A	**19**	C	**29**	D
10	B	**20**	C	**30**	C

7 – A
7 – B
8 – C
8 – D

PIONEER JUNIOR COLLEGE, SINGAPORE

JC1 PRELIMINARY EXAMINATIONS
HIGHER 1

CANDIDATE NAME	

CT GROUP	1	7				INDEX NUMBER				

CHEMISTRY **8873/02**

Paper 2 Structured **10 September 2018**

2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number and name on all work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough workings.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer only **one** question.

You are advised to show all working in calculations.

The use of an approved scientific calculator is expected, where appropriate.

The number of marks is given in brackets [ ] at the end of each question or part question.

At the end of the examination, fasten all your work securely together.

FOR EXAMINER'S USE					
Paper 1		**Paper 2 Section A**		**Paper 2 Section B**	
Total	/ 30	4	/ 10	Total	/ 20
		5	/ 6		
Paper 2 Section A		6	/ 7	Penalty	s.f. / units
1	/ 4	7	/ 5	**TOTAL**	**/ 110**
2	/ 9	8	/ 8	**GRADE**	
3	/ 11	**TOTAL**	**/ 60**		

This document consists of **20** printed pages.

Answer **all** the questions in this section, in the spaces provided.

1 Fig. 1.1 shows a sketch of the logarithm of the first fourteen ionisation energies, log (IE), of element **A** against the number of electrons removed.

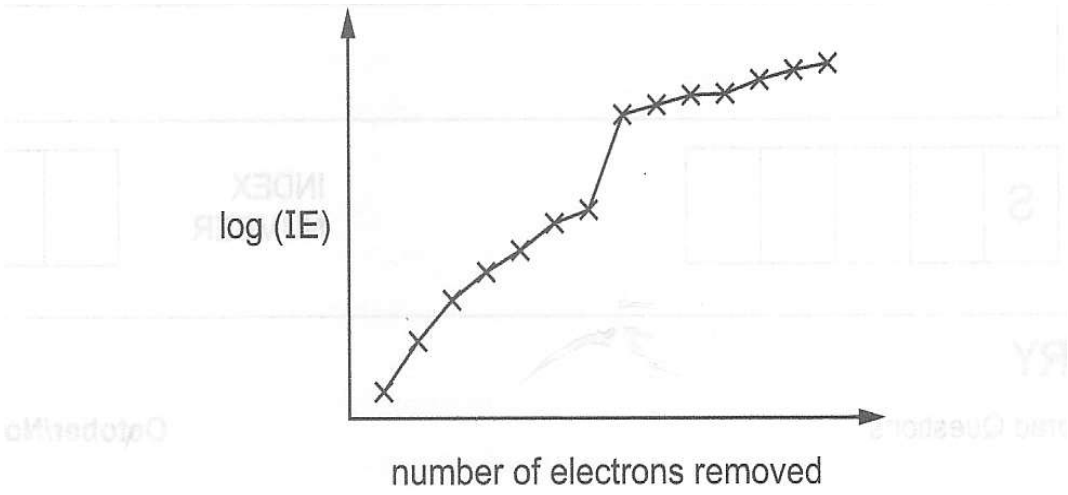


Fig. 1.1

(a) Write an equation for the second ionisation energy of element **A**. [1]

$A^{+}(g) \rightarrow A^{2+}(g) + e^{-}$

(b) Explain the following features of Fig. 1.1.

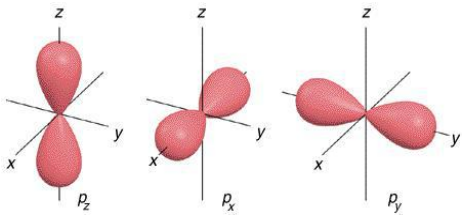
(i) The increase in ionisation energies as the electrons are removed. [1]

Ionisation energies increases generally because electrons are removed from an increasingly positive charged gaseous ion.

(ii) The significant jump in values from the 7th to the 8th ionisation energy. [2]
The eighth electron to be removed comes from the inner quantum shell, which is nearer to and less shielded from the nucleus, hence stronger attractive forces by the nucleus

(c) Sketch the shape of the orbital of element A that is not fully filled. [1]

Students to sketch the p orbital aligned on any of the x,y or z axis.

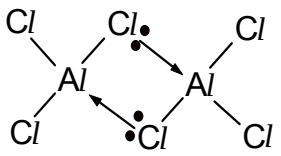


[Total: 4]

2 When dry chlorine is passed over heated aluminium foil in a hard glass tube, a vapour is produced which condenses to a yellow-white solid in the cooler parts of the tube. At low temperatures the vapour has the empirical formula $AlCl_3$ and an M_r of 267.

(a) Suggest the molecular formula of the vapour, and draw a structure to describe its bonding. [2]

Al_2Cl_6



The yellow-white solid reacts with water in two separate ways.

- When a few drops of water are added to the solid, steamy white fumes are evolved and a white solid remains, which is insoluble in water.
- When a large amount of water is added to the solid, a clear, weakly acidic solution results

(b) Write equations, including state symbols, for these two reactions and explain the observations. [4]

$AlCl_3$ (s) + $3H_2O$ (l) → 3HCl (g) + $Al(OH)_3$ (s)

$AlCl_3$ reacts with small amount of water to give white steamy fumes of HCl and white solid of $Al(OH)_3$.

$AlCl_3$ (s) + $6H_2O$(l) → $[Al(H_2O)_6]^{3+}$ (aq) + $3Cl^-$ (aq)
$[Al(H_2O)_6]^{3+}$ (aq) + H_2O (l) $\rightleftharpoons$ $[Al(H_2O)_5(OH)]^{2+}$ (aq) + H_3O^+ (aq)

Hydrolysis occurs and H_3O^+ is produced which makes the solution acidic.

(c) Describe and explain what you would see when a sample of Na_2O(s) and P_4O_{10} is added to a solution of litmus in water separately. Write equations for the reaction that occur. [3]

Note: The litmus solution is a purple solution when it is added to a neutral solution.

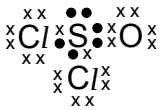
Na_2O + H_2O → 2 NaOH
The litmus solution changed from purple to blue.

P_4O_{10}(s) + 6 H_2O(*l*) → 4 H_3PO_4(aq)
The litmus solution changed from purple to red.

[Total: 9]

3 **(a)** In a molecule of $SOCl_2$, the sulfur atom has four bonds.

Draw a 'dot and cross' diagram of $SOCl_2$. [1]



(b) When $SOCl_2$ is reacted with a carboxylic acid to produce an acyl chloride, two acidic gases are fomed.

$$SOCl_2(l) + RCOOH(l) \rightarrow ROCl(l) + SO_2(g) + HCl(g)$$

A 1.00g sample of a carboxylic acid RCOOH was treated in this way, and the gases were absorbed in 60.0cm^3 of 0.500 mol dm^{-3} NaOH(aq), in excess.

(i) Write equations for the reactions between NaOH and SO_2. [1]

$2NaOH + SO_2 \rightarrow H_2O + Na_2SO_3$

The excess NaOH was titrated with 0.500 mol dm^{-3} H^+(aq). It required 10.8 cm^3 of the H^+(aq) solution to reach the end-point.

(ii) Calculate the total amount, in moles of NaOH that reacted with the SO_2 and HC*l*. [2]

Initial amt of NaOH = 0.5 × 60 / 1000 = 3.00 × 10^{-2} mol
Amt of NaOH unreacted = 0.5 × 10.8 / 1000 = 5.40 × 10^{-3} mol

Amt of NaOH reacted = (30–5.4) × 10^{-3} = 2.46 × 10^{-2} mol

(iii) Calculate the amount, in moles of RCOOH that produced the SO_2 and HC*l*. [1]

Amt of RCOOH = (2.46 × 10^{-2}) / 3 = 8.20 × 10^{-3} mol

(iv) Hence calculate the M_r of the carboxylic acid, RCOOH. [1]

M_r = 1.00 / (8.20 × 10^{-3}) = 121.95 (=122)

(v) The R group contains carbon and hydrogen only. Suggest the molecular formula of RCOOH. [1]

$C_7H_6O_2$ OR $C_6H_5CO_2H$

(c) The following synthetic route shows how a carboxylic acid can be converted into an amine.

$$CH_3CO_2H \xrightarrow{SOCl_2} CH_3COCl \xrightarrow{NH_3} CH_3CONH_2 \xrightarrow{\text{Step 3}} CH_3CH_2NH_2$$

(i) Suggest a reagent for step 3. [1]

$LiAlH_4$ or $H_2(g)$

Angelic acid, $C_5H_8O_2$, is a natural product isolated from the roots of the angelica plant.

- Angelic acid reacts with H_2 + Ni to form **T**, $C_5H_{10}O_2$.
- **T** undergoes the above synthetic route to form the amine **U**, $C_5H_{13}N$.
- **U** can also be made by reacting 1-bromo-2-methylbutane with ammonia.

Angelic acid displays *cis-trans* isomerism.

(ii) Suggest the structures for angelic acid, **T** and **U**. [3]

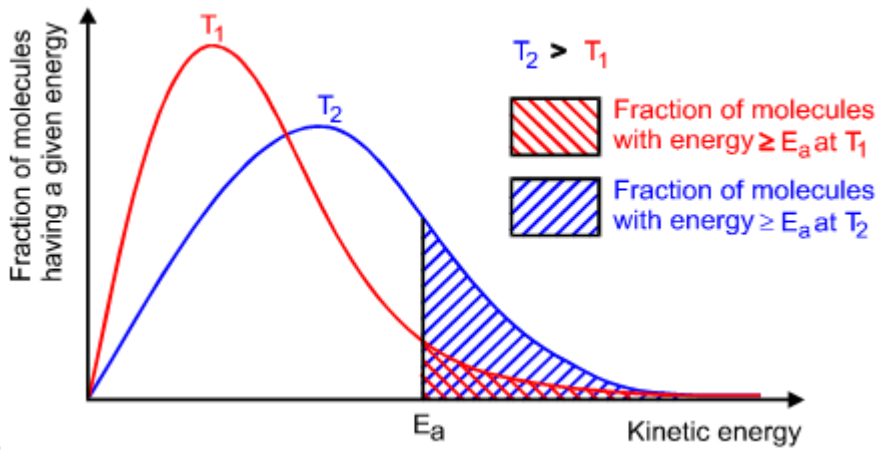
$CH_3CH{=}C(CH_3)COOH$	$CH_3CH_2CH(CH_3)COOH$	$CH_3CH_2CH(CH_3)CH_2NH_2$
Angelic acid	**T**	**U**

[Total: 11]

4 At 450K phosphorus(V) chloride, $PCl_5(g)$ decomposes to form phosphorus(III) chloride, $PCl_3(g)$, and chlorine, $Cl_2(g)$. A dynamic equilibrium is established as shown.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g) \qquad \Delta H = +124 \text{ kJ mol}^{-1}$$

(a) **(i)** With the use of a Boltzmann distribution curve, explain why an increase in temperature will increase the rate of decomposition of $PCl_5(g)$. [4]



When temperature is increased, there is:

- an increase in the average kinetic energy of the particles, resulting in,

- an increase in frequency of collision
- an increase in the number of reacting particles with energy $\geq E_a$
- an increase in the frequency of effective collisions between reacting particles

Boltzmann distribution curve

- correct axis,
- legend
- the graph drawn correctly
  (assymetrical shape, T_2 peak shifted right and downwards),
- indicating the E_a as cut off for area under curve.

(ii) State and explain the effect of increasing temperature on the percentage of $PCl_5(g)$ that decomposes. [2]

Increase in temperature will always favour endothermic reaction. Equilibrium shifts to the right / forward endothermic reaction is favoured to absorb some of the added heat. The percentage decomposition of $PCl_5(g)$ will increase.

(b) Explain the meaning of the term dynamic equilibrium and the conditions necessary for it to become established. [2]

Dynamic equilibrium: When the rates of forward and reverse / backward reactions are equal
Conditions: closed / sealed system/container

(c) When 2.00 mol of $PCl_5(g)$ are decomposed at 450K and 1.00×10^5 Pa in a 7.5 dm^3 container, the resulting equilibrium mixture contains 0.800 mol of $Cl_2(g)$.

Calculate the value of K_c and state its units. [2]

	$PCl_5(g)$	$\rightleftharpoons$	$PCl_3(g)$	+	$Cl_2(g)$
Initial amount / mol	2.00		0		0
Change in amount / mol	–0.800		+0.800		+0.800
Equilibrium amount / mol	1.20		0.800		0.800
Equilibrium conc / mol dm^{-3}	$\frac{1.2}{7.5}=0.160$		$\frac{0.8}{7.5}=0.1067$		$\frac{0.8}{7.5}=0.1067$

$$K_c = \frac{(0.1067)^2}{(0.160)} = 0.0711 \text{ mol dm}^{-3}$$

[Total: 10]

5 (a) Magnesium(I) chloride, $MgCl$, is an unstable compound and readily decomposes as shown.

$$2MgCl(s) \longrightarrow Mg(s) + MgCl_2(s)$$

Use the following data to calculate the enthalpy change of this reaction. [1]

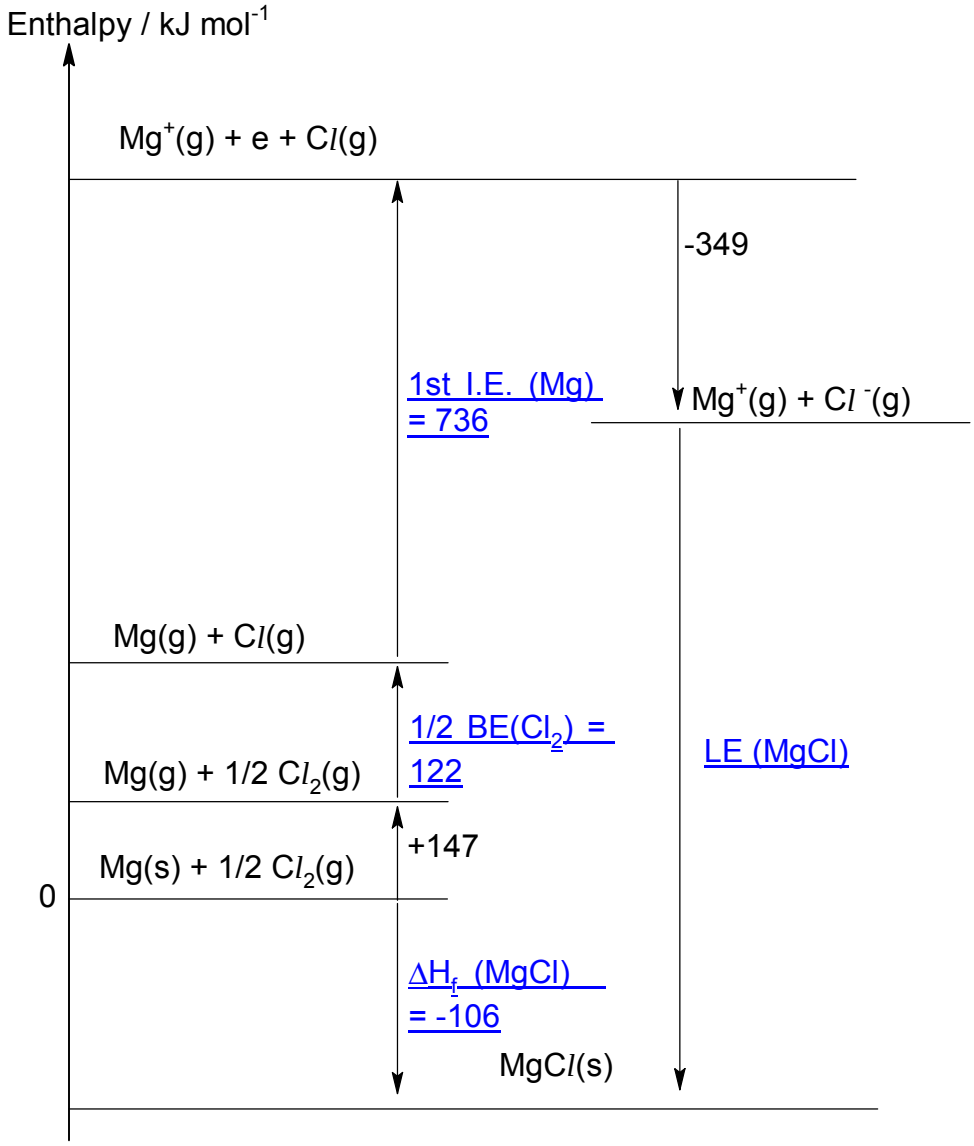
ΔH_f MgC*l*(s) = –106 kJ mol^{-1};
ΔH_f MgC*l*$_2$(s) = –642 kJ mol^{-1}

enthalpy change = (–642) – (2 × –106) = –430 kJ mol^{-1}

(b) **(i)** The equation for which ΔH is the lattice energy for MgC*l* is shown.

$$Mg^+(g) + Cl^-(g) \longrightarrow MgCl(s)$$

Label the relevant enthalpy changes in the energy cycle below. [2]



(ii) Use the energy cycle above and relevant data from the *Data Booklet* to calculate a value for the lattice energy of MgC*l*. [1]

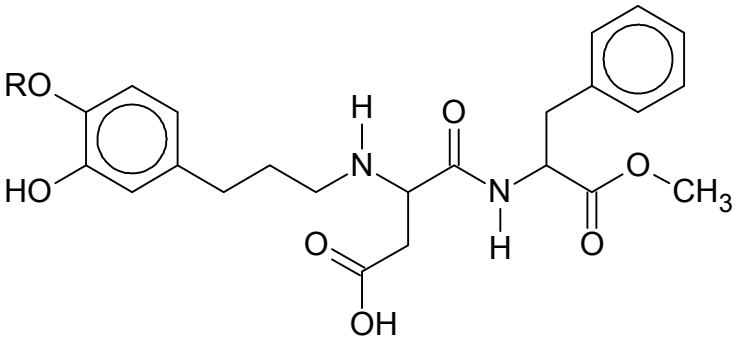
By Hess' Law,
-106 = 147 + 122 + 736 + (-349) + LE (MgC*l*)
LE(MgC*l*) = -762 kJ mol^{-1}

(iii) Suggest how the lattice energy of $MgCl_2$ will compare to that of MgC*l*. Explain your answers. [2]

The lattice energy of $MgCl_2$ is <u>more exothermic / more negative</u> than that of MgC*l*. This is due to <u>higher charge and smaller radius of Mg^{2+}</u> cation compared to that of Mg^+.

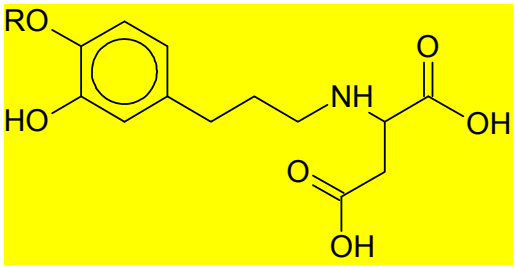
[Total: 6]

6 The compound *Advantame* is a sweetener that tastes approximately 25000 times sweeter than sucrose.



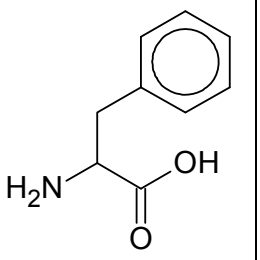
Advantame

(a) The decomposition of *Advantame* produces three molecules, **J**, **K** and **L**. The RO– group in *Advantame* is unreactive.



J

+



K

+

CH_3OH

L

(i) Name the type of reaction occurring. [1]

Hydrolysis

(ii) Draw the structure of **J** in the box above. [1]

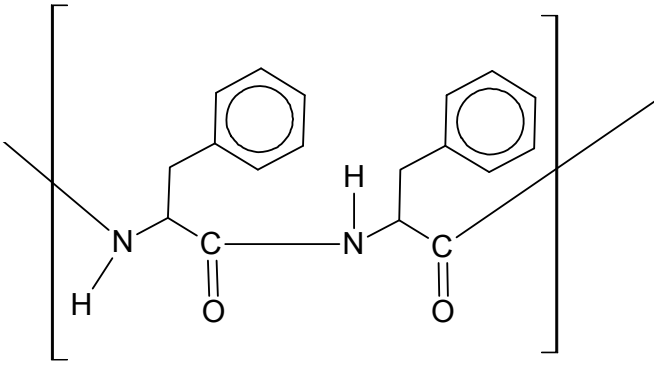
(b) **(i)** State what you would observe when acidified potassium manganate(VII) is added to a solution of **L**. [2]

Purple potassium manganate(VII) decolourised. Carbon dioxide gas evolved which gives a white ppt with limewater.

(ii) Write balanced equation for the reaction taking place in **(b)(i)**. [1]

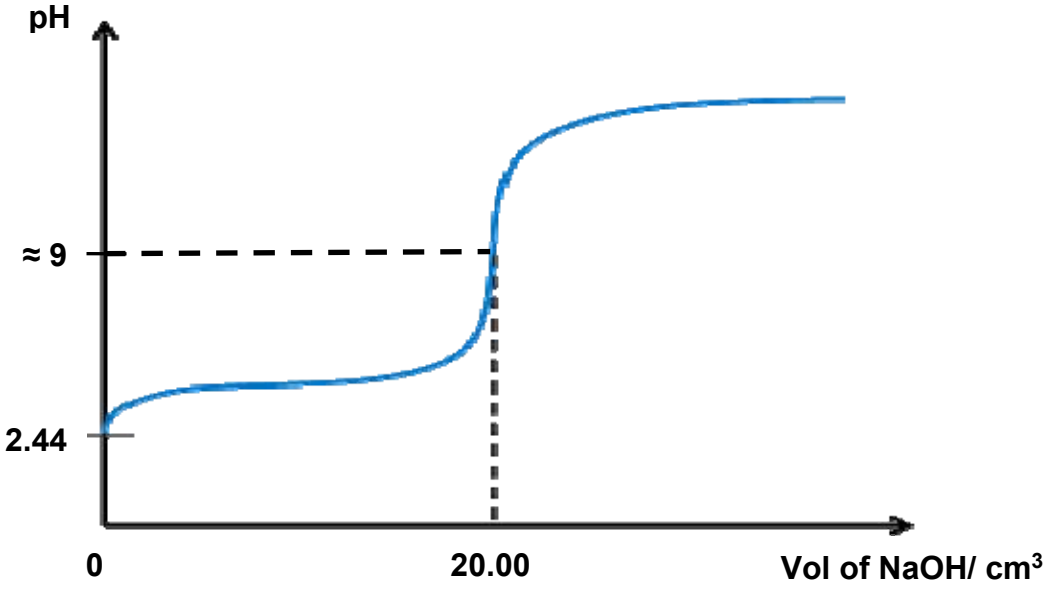
$CH_3OH + 3[O] \longrightarrow CO_2 + 2H_2O$

(c) **K** can be polymerised. Draw the structure of the polymer showing two repeat units. The linkage between the monomer units should be fully displayed. [2]



[Total: 7]

7 A 25.0 cm^3 of 0.72 mol dm^{-3} of CH_3COOH in a conical flask was titrated against aqueous sodium hydroxide and the pH of the solution in the conical flask was plotted against volume of NaOH(aq).



(a) **(i)** Using the graph, determine the concentration of aqueous sodium hydroxide in the burette. [1]

$KOH(aq) + HA(aq) \rightarrow NaA(aq) + H_2O(l)$

$n(KOH) = n(HA) = \underline{(25.0/ 1000) \times 0.72}$

$[KOH] = \dfrac{(25.0/ 1000) \times 0.72}{(20.00/1000)} = \underline{0.90}$ mol dm^{-3}

(ii) Using the data in the graph, show that ethanoic acid is a weak acid. [1]

$[H^+]_{eqm} = 10^{-2.44} = 3.63 \times 10^{-3}$ mol dm^{-3} < $[CH_3COOH]_{initial} = 0.72$ mol dm^{-3}
hence it does not dissociate completely

(b) Circle the region on the graph on this question paper where a buffer solution is produced from the titration. [1]

Circle the region before equivalence point and after 0 cm^3 of NaOH(aq) added.

(c) Phenolphthalein indicator is used in this titration. Using the information in the table provided below, give two reasons why phenolphthalein is a good indicator. [2]

Indicator	pH range	Colour change	
		Colour in acid < pH 8.2	Colour in alkali > 10.0
Phenolphthalein	8.2 – 10.0	Colourless	Red

The equivalence point of pH ≈ 9 coincides within the phenolphthalein working pH range from pH = 8.2 – 10.0

or
The pH working range from pH 8.2-10.0 coincides within the rapid change of pH of the titration curve

And
There is a distinct colour change of the indicator from colourless to pink at the end point.

[Total: 5]

8 Many elements have *allotropes*. Carbon has a number of allotropes including diamond, graphite and graphene. Each of these allotropes has different properties. This means the allotropes can be used for different purposes.

Diamond is hard and does not conduct electricity.
Graphite is soft and has high electrical conductivity.
Graphene is a nanomaterial and has high electrical conductivity. A large layer of graphene would be very strong.

(a) **(i)** Describe what is meant by allotropes. [1]

Different structures containing the same type of atoms.

(ii) Describe the structure of graphene. Explain how this structure gives graphene the properties of high strength and high electrical conductivity.

You may find it useful to include a labelled diagram in your answer. [3]

A single layer of graphite (monoatomic layer of carbon), with sp^2 hybridised carbon atoms arranged in a hexagonal lattice and unhybridised 2p orbitals above and below the plane of the sheet.

Each carbon atom uses all three sp^2 orbitals to overlap head-on with the sp^2 orbitals of three adjacent carbon atoms, forming three carbon-carbon bonds. Because of the network of strong covalent bonds between the sp^2 hybridised carbon atoms, graphene has a very high tensile strength.

The unhybridised 2p orbitals of the carbon atoms overlap sideways with one another to form a delocalised pi electron cloud above and below the plane of carbon atoms.

The remaining electron in the unhybridised 2p orbitals per atom is delocalised over the whole graphene layer and responsible for the excellent electrical conductivity.

(b) Research in nanotechnology is growing and many new nanomaterials are being produced with ever more uses. Uses of nanoparticles and nanomaterials is relatively new and there are concerns about their direct impact on human health and environment.

For example, nanoparticles are used to deliver drugs within cells.

(i) State the difference between a nanoparticle and a nanomaterial in terms of size. [1]

Nanoparticles ALL dimensions 1—100nm/on the nanoscale
AND nanomaterial (at least) one dimension 1—100nm/on the nanoscale

(ii) Suggest what properties of nanoparticles enable them to deliver drugs within cells. Explain your answer. [2]

Nanoparticles are smaller than (animal) cells or they can pass through the cell membrane or pass into/between cells
larger amount of Drugs can be EASILY bound to/enclosed by the nanoparticle due to large surface to volume ratio of the nanoparticle.

(iii) Give one example of an impact of nanoparticles on the environment. [1]

Any valid answer

Use of photocatalytic copper tungsten oxide nanoparticles to break down oil into biodegradable compounds.

Use of gold nanoparticles embedded in a porous manganese oxide as a room temperature catalyst to breakdown volatile organic pollutants in air

[Total: 8]

Section B

Answer **one** question from this section, in the spaces provided.

1 If potassium iodide and ammonium peroxodisulfate are mixed in the presence of starch and sodium thiosulfate, the iodine liberated reacts with the thiosulfate ions until they are all used up.

$S_2O_8^{2-} + 2I^- \rightarrow I_2 + 2SO_4^{2-}$
$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$

When no thiosulfate ions are left, any iodine formed reacts with starch and the dark blue colour of the starch-iodine complex appears. The time taken for the dark blue colour to appear with a constant quantity of sodium thiosulfate present depends on the rate of formation of iodine

Table of results

Experiment	**Volume of I^- / cm^3**	**Volume of $S_2O_8^{2-}$ / cm^3**	**Volume of deionised water / cm^3**	***Volume of starch / cm^3***	***t / s***
1	**10.00**	**20.00**	**0.0**	**1.0**	**23**
2	**10.00**	**10.00**	**10.0**	**1.0**	**46**
3	**10.00**	**10.00**	**10.0**	**1.0**	***40***

(a) **(i)** Using the results in your table, deduce the order of the reaction with respect to the peroxodisulfate ions. Explain clearly how you arrived at your answer. [2]

Comparing expt 1 and 2,keeping [I^-] constant
Halve [$S_2O_8^{2-}$], time is doubled, hence rate is halved, hence first order wrt $S_2O_8^{2-}$

Or substitution method

(ii) Instead of washing the beaker as required before performing experiment **3**, a student simply just poured away the reaction mixture. There were some left over reaction mixture in the beaker when he performed experiment **3**. State and explain why the time is shorter than in experiment **2**, assuming all other conditions are kept constant. [1]

The excess I_2 left in the flask will react with the $S_2O_3^{2-}$ in the new experiment. As there is less $S_2O_3^{2-}$ for the new experiment, less I_2 is reacted.

the time taken to produce lesser I_2 will be shorter than 46 seconds and hence observe the blue colour faster.

(iii) Explain why a fixed amount of sodium thiosulfate is required. [1]

To ensure an equal amount of iodine is reacted before the solution turns dark blue in each experiment.

(b) It was reported that the order of reaction with respect to iodide ions is one.

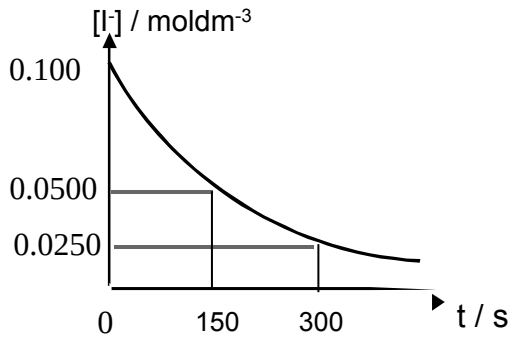
In order to substantiate this information, the chemistry teacher gives out these instructions to his class.

1) Prepare a solution mixture containing 0.100 mol dm^{-3} potassium iodide and 1.00 $moldm^{-3}$ of ammonium peroxodisulfate.

2) Record the concentration of the iodide ions against time from the start of the reaction.

3) Plot a graph of concentration of iodide ions against time

(i) Sketch the graph of concentration of iodide ions against time, given that the half life is 150 seconds, showing the values and important features of your graph to show that it is first order reaction with respect to iodide. [2]



(ii) A student mistakenly prepared a solution containing 1.00 mol dm^{-3} potassium iodide and 0.100 mol dm^{-3} of ammonium peroxodisulfate instead.

He recorded the concentration of the peroxodisulfate ions against time from the start of the reaction and plot a graph of concentration of peroxodisulfate ions against time on a piece of graph paper.

On realising the mistake, the teacher instructed him to carry another experiment by preparing a solution containing 2.00 mol dm^{-3} potassium iodide and 0.100 mol dm^{-3} of ammonium peroxodisulfate.

He recorded the concentration of the peroxodisulfate ions against time and plot the data on the same graph paper.

Based on the data from both experiments on the graph paper, describe how the student can determine that it is first order reaction with respect to iodide ions. [2]

Draw a tangent at time = 0 s for both graphs, the second set of data will give a gradient that has magnitude that is twice of the gradient of the first set of data

(c) It is reported that Fe^{3+} catalyses the reaction between ammonium peroxodisulfate and iodide ions.

Explain how Fe^{3+} acts as a catalyst. [2]

The catalyst provides an alternative reaction pathway with a lower E_a. Greater proportion of molecules with energy greater than E_a will result in higher frequency of effective collisions. Hence, rate of reaction increases.

(d) The table below gives the melting points, in °C, of the fluorides and chlorides of two elements in Period 3.

	iron	silicon
chlorides	677	-70
iodides	587	120.5

Explain, in terms of structure and bonding, the differences in melting point between

(i) $FeCl_2$ and $SiCl_4$ [2]

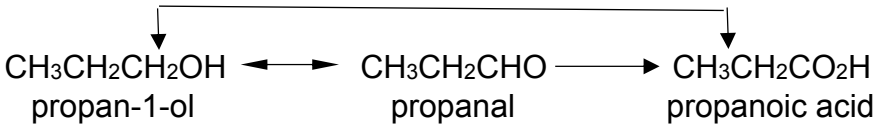
$FeCl_2$ has a giant ionic lattice structure while $SiCl_4$ has a simple molecular structure

Between Fe^{2+} and Cl^- ions, there are strong ionic bonds while between $SiCl_4$ molecules there is weak instantaneous dipole induced dipole attractions. Hence more energy is required to overcome the strong ionic bonds in $FeCl_2$ than the weak instantaneous dipole induced dipole attractions in $SiCl_4$.

(ii) SiI_4 and $SiCl_4$ [2]

SiI_4 and $SiCl_4$ has simple molecular structure
SiI_4 has more electrons to be polarised than $SiCl_4$, leading to stronger instantaneous dipole induced dipole attractions. Hence more energy required to overcome the instantaneous dipole induced dipole attraction in SiI_4.

(e) The Harcourt and Esson reaction is a redox reaction just like the reaction between I^- and $S_2O_8^{2-}$. The type of reaction also occurs in organic, as the following transformations from



(i) State a reagent you could use to convert propanoic acid into propan1-ol. [1]

$LiAlH_4$ in dry ether

(ii) Both propanal and propanoic acid can be obtained from propan-1-ol.

State the reagents you could use to carry these reactions. [2]

$K_2Cr_2O_7$(aq), H_2SO_4(aq), distill for propan-1-ol to oxidise to propanal
$KMnO_4$ (aq) or $K_2Cr_2O_7$(aq), H_2SO_4(aq), heat under relux for propan-1-ol to oxidise to propanoic acid

(iii) During the reduction of propanoic acid to propan-1-ol, it was suspected that there are traces of unreacted propanoic acid together with propan-1-ol after the reaction.

Suggest a chemical test to confirm the presence of the unreacted propanoic acid, state the observation that you will see. [2]

Get a small sample of the product, add solid or aqueous sodium carbonate [1]
effervescene of CO_2 (which gives a white ppt with limewater) will be seen if propanoic acid is present

Reject Na since propan-1-ol will test positive too
Reject PCl_5 since propan-1-ol will test positive too

(iv) State the type of reaction that has occurred in **(e)(iii).** [1]

Acid base reaction

[Total: 20]

2 The halogens are a group in the Periodic Table consisting of five chemically related elements: fluorine, chlorine, bromine, iodine and astatine. The group of halogens is the only periodic table group that contains elements in all three main states of matter at standard temperature and pressure.

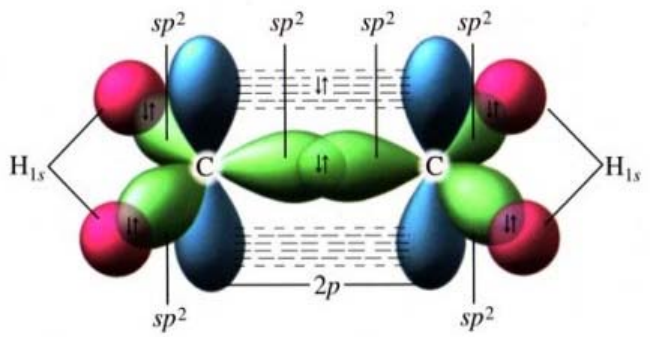
(a) Explain the trend in boiling points of halogens down the group. [2]

The halogens have simple molecular structure with weak instantaneous dipole-induced dipole between the non-polar molecules.

Going down the group, the number of electrons in the halogen molecule increases. The electron cloud becomes more polarisable (i.e. more easily distorted), thus the strength of instantaneous dipole- induced dipole forces increases. More energy is required to overcome the stronger instantaneous dipole- induced dipole forces down the group. This results in an increase in boiling point.

(b) Ethene can react with halogens like chlorine and bromine to form 1,2–dichloroethane and 1,2–dibromoethane respectively.

(i) Describe the bonding between the two carbon atoms in ethene in terms of orbital overlap. You may draw a diagram to illustrate your answer. [2]



The two carbon atoms form double bond (one sigma bond and one pi bond) with each other.

The sp^2 hybrid orbitals of the carbon atoms overlap head on to form a sigma bond.

The unhybridised p orbitals of the carbon atoms overlap sideways to form a pi bond.

(ii) The enthalpy change of combustion of ethene is given as –1390 kJ mol^{-1}. Calculate the mass of water at 30°C that can be brought to the boiling point by burning 2.0 dm^3 of ethene.

Assume that 75% of the heat from the ethene is absorbed by the water and volume of gas is measured at room temperature and pressure. [2]

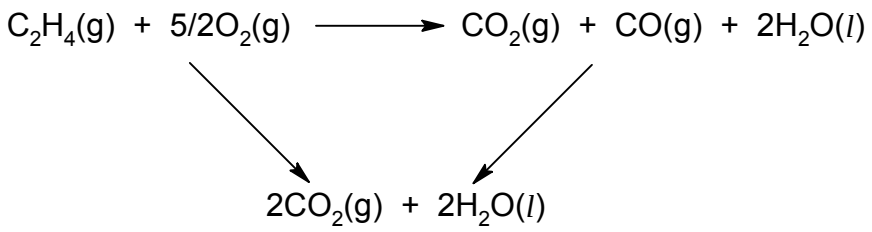
Amt of ethene = 2.0/24 = 0.08333 mol

Heat evolved = 0.08333 x 1390 = 115.8 kJ

Heat gained by water = 115.8 x 0.75 = 86.88 kJ

Mass of water = 86.88 x 1000 / (4.18 x 70) = 297g

(iii) When burnt in a limited supply of air, ethene forms carbon dioxide, carbon monoxide and water according to the equation below.

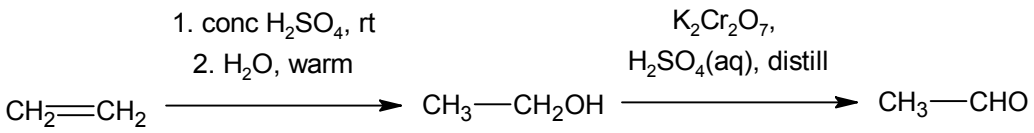


Calculate the ΔH of the reaction given the energy cycle and following data.

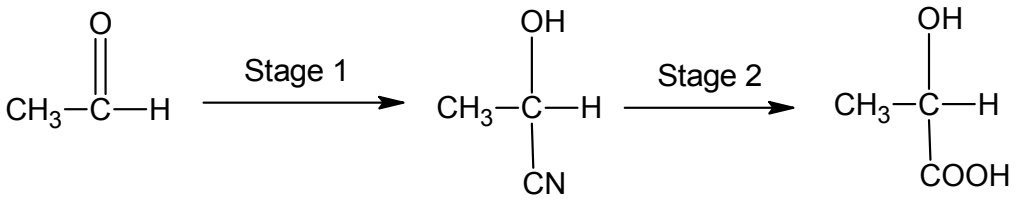
ΔH_c (ethene) = –1390 kJ mol^{-1};
ΔH_f (carbon dioxide) = –394 kJ mol^{-1}
ΔH_c (carbon monoxide) = –283 kJ mol^{-1} [1]

ΔH = –1390 – (–283) = –1107 = –1110 kJ mol^{-1}

(iii) Ethene can be converted to ethanal. State the reagents, conditions needed and the intermediate products formed in the conversion. [3]



(c) Ethanal undergoes a 3 stage synthesis to form lactic acid as follows.



(i) Name the type of reaction in Stage 1. [1]

Addition

Lactic acid, $CH_3CH(OH)COOH$ is a monoprotic acid.

(i) Give the equation which represent the dissociation of lactic acid in water. Identify the acid conjugate base pairs in the equation. [2]

$CH_3CH(OH)COOH + H_2O \rightleftharpoons CH_3CH(OH)COO^- + H_3O^+$

$CH_3CH(OH)COOH$ is an acid. $CH_3CH(OH)COO^-$ is the conjugate base.
H_2O is a base. H_3O^+ is the conjugate acid of H_2O.

$CH_3CH(OH)COOH$ and $CH_3CH(OH)COO^-$ is a conjugate acid-base pair, while H_2O and H_3O^+ is another conjugate acid-base pair.

(ii) Explain, using equations, why an aqueous mixture of lactic acid and sodium lactate can act as a buffer solution

(I) on the addition of acid,

(II) on the addition of alkali. [2]

When a small amount of H^+ is added,
$CH_3CH(OH)COO^- + H^+ \longrightarrow CH_3CH(OH)COOH$

When a small amount of OH^- is added,
$CH_3CH(OH)COOH + OH^- \longrightarrow CH_3CH(OH)COO^- + H_2O$

(e) Lactic acid, $CH_3CH(OH)COOH$ is the raw material for the polymer, "polylactide" or PLA.

(i) What type of reaction takes place in this polymerisation? [1]

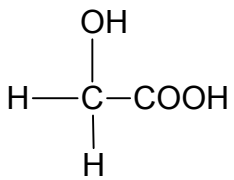
Condensation

One of the reasons PLA has attracted so much attention is that it is biodegradeable. This does, however, restrict some potential uses. The simple polymer has a melting poing of around 175°C, but softens between 60-80°C. However, its thermoplastic properties enable it to have a range of uses in fibres and in food packaging.

(ii) Explain why PLA would not be a suitable packing material for foods pickled in vinegar. [1]

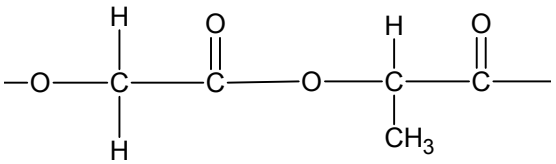
The acid present in vinegar will hydrolyse the ester linkage.

Lactic acid can also be co-polymerised with glycolic acid.



glycolic acid

(iii) Draw a section of the co-polymer showing one repeat unit. [1]



(iv) Suggest what type of bonding will occur between chains of this co-polymer, indicating the groups involved. [1]

There are van der Waals' forces between methyl groups or permanent dipole-dipole between the ester groups.

[Total: 20]

End of Paper

PIONEER JUNIOR COLLEGE, SINGAPORE

JC2 PRELIMINARY EXAMINATIONS
HIGHER 1

CANDIDATE NAME	

CT GROUP	1	7				INDEX NUMBER				

CHEMISTRY **8873/02**

Paper 2 Structured **11 September 2018**

2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number and name on all work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough workings.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer only **one** question.

You are advised to show all working in calculations.

The use of an approved scientific calculator is expected, where appropriate.

The number of marks is given in brackets [ ] at the end of each question or part question.

At the end of the examination, fasten all your work securely together.

FOR EXAMINER'S USE					
Paper 1		**Paper 2 Section A**		**Paper 2 Section B**	
Total	/ 30	4	/ 10	Total	/ 20
		5	/ 6		
Paper 2 Section A		6	/ 7	Penalty	s.f. / units
1	/ 4	7	/ 5	**TOTAL**	**/ 110**
2	/ 9	8	/ 8	**GRADE**	
3	/ 11	**TOTAL**	**/ 60**		

This document consists of **22** printed pages.

Answer **all** the questions in this section, in the spaces provided.

1 Fig. 1.1 shows a sketch of the logarithm of the first fourteen ionisation energies, log (IE), of element **A** against the number of electrons removed.

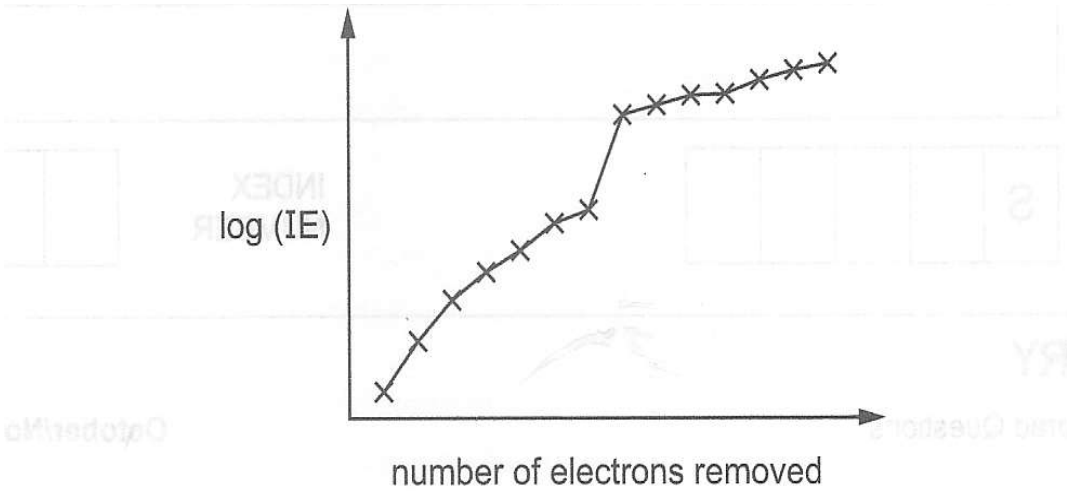


Fig. 1.1

(a) Write an equation for the second ionisation energy of element **A**. [1]

……

(b) Explain the following features of Fig. 1.1.

(i) The increase in ionisation energies as the electrons are removed. [1]

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(ii) The significant jump in values from the 7th to the 8th ionisation energy. [1]

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(c) Sketch the shape of the orbital of element **A** that is not fully filled. [1]

[Total: 4]

2 When dry chlorine is passed over heated aluminium foil in a hard glass tube, a vapour is produced which condenses to a yellow-white solid in the cooler parts of the tube. At low temperatures the vapour has the empirical formula $AlCl_3$ and an M_r of 267.

(a) Suggest the molecular formula of the vapour, and draw a structure to describe its bonding. [2]

The yellow-white solid reacts with water in two separate ways.

- When a few drops of water are added to the solid, steamy white fumes are evolved and a white solid remains, which is insoluble in water.
- When a large amount of water is added to the solid, a clear, weakly acidic solution results

(b) Write equations, including state symbols, for these two reactions and explain the observations. [4]

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(c) Describe and explain what you would see when a sample of $Na_2O(s)$ and P_4O_{10} is added to a solution of litmus in water separately. Write equations for the reaction that occur. [3]

Note: The litmus solution is a purple solution when it is added to a neutral solution.

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[Total: 9]

3 **(a)** In a molecule of $SOCl_2$, the sulfur atom has four bonds.

Draw a 'dot and cross' diagram of $SOCl_2$. [1]

(b) When $SOCl_2$ is reacted with a carboxylic acid to produce an acyl chloride, two acidic gases are fomed.

$$SOCl_2(l) + RCOOH(l) \rightarrow ROCl(l) + SO_2(g) + HCl(g)$$

A 1.00g sample of a carboxylic acid RCOOH was treated in this way, and the gases were absorbed in 60.0cm^3 of 0.500 mol dm^{-3} NaOH(aq), in excess.

(i) Write equations for the reactions between NaOH and SO_2. [1]

……...

The excess NaOH was titrated with 0.500 mol dm^{-3} H^+(aq). It required 10.8 cm^3 of the H^+(aq) solution to reach the end-point.

(ii) Calculate the total amount, in moles of NaOH that reacted with the SO_2 and HC*l*. [2]

(iii) Calculate the amount, in moles of RCOOH that produced the SO_2 and HC*l*. [1]

(iv) Hence calculate the M_r of the carboxylic acid, RCOOH. [1]

(v) The R group contains carbon and hydrogen only. Suggest the molecular formula of RCOOH. [1]

……

(c) The following synthetic route shows how a carboxylic acid can be converted into an amine.

$$CH_3CO_2H \xrightarrow{SOCl_2} CH_3COCl \xrightarrow{NH_3} CH_3CONH_2 \xrightarrow{\text{Step 3}} CH_3CH_2NH_2$$

(i) Suggest a reagent for step 3. [1]

……...

Angelic acid, $C_5H_8O_2$, is a natural product isolated from the roots of the angelica plant.

- Angelic acid reacts with H_2 + Ni to form **T**, $C_5H_{10}O_2$.
- **T** undergoes the above synthetic route to form the amine **U**, $C_5H_{13}N$.
- **U** can also be made by reacting 1-bromo-2-methylbutane with ammonia.

Angelic acid displays *cis-trans* isomerism.

(ii) Suggest the structures for angelic acid, **T** and **U**. [3]

Angelic acid	**T**	**U**

[Total: 11]

4 At 450K phosphorus(V) chloride, $PCl_5(g)$ decomposes to form phosphorus(III) chloride, $PCl_3(g)$, and chlorine, $Cl_2(g)$. A dynamic equilibrium is established as shown.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g) \qquad \Delta H = +124 \text{ kJ mol}^{-1}$$

(a) **(i)** With the use of a Boltzmann distribution curve, explain why an increase in temperature will increase the rate of decomposition of $PCl_5(g)$. [4]

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(ii) State and explain the effect of increasing temperature on the percentage of $PCl_5(g)$ that decomposes. [2]

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(b) Explain the meaning of the term dynamic equilibrium and the conditions necessary for it to become established. [2]

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(c) When 2.00 mol of $PCl_5(g)$ are decomposed at 450K and 1.00×10^5 Pa in a 7.5 dm^3 container, the resulting equilibrium mixture contains 0.800 mol of $Cl_2(g)$.

Calculate the value of K_c and state its units. [2]

[Total: 10]

5 **(a)** Magnesium(I) chloride, MgC*l*, is an unstable compound and readily decomposes as shown.

$$2MgCl(s) \longrightarrow Mg(s) + MgCl_2(s)$$

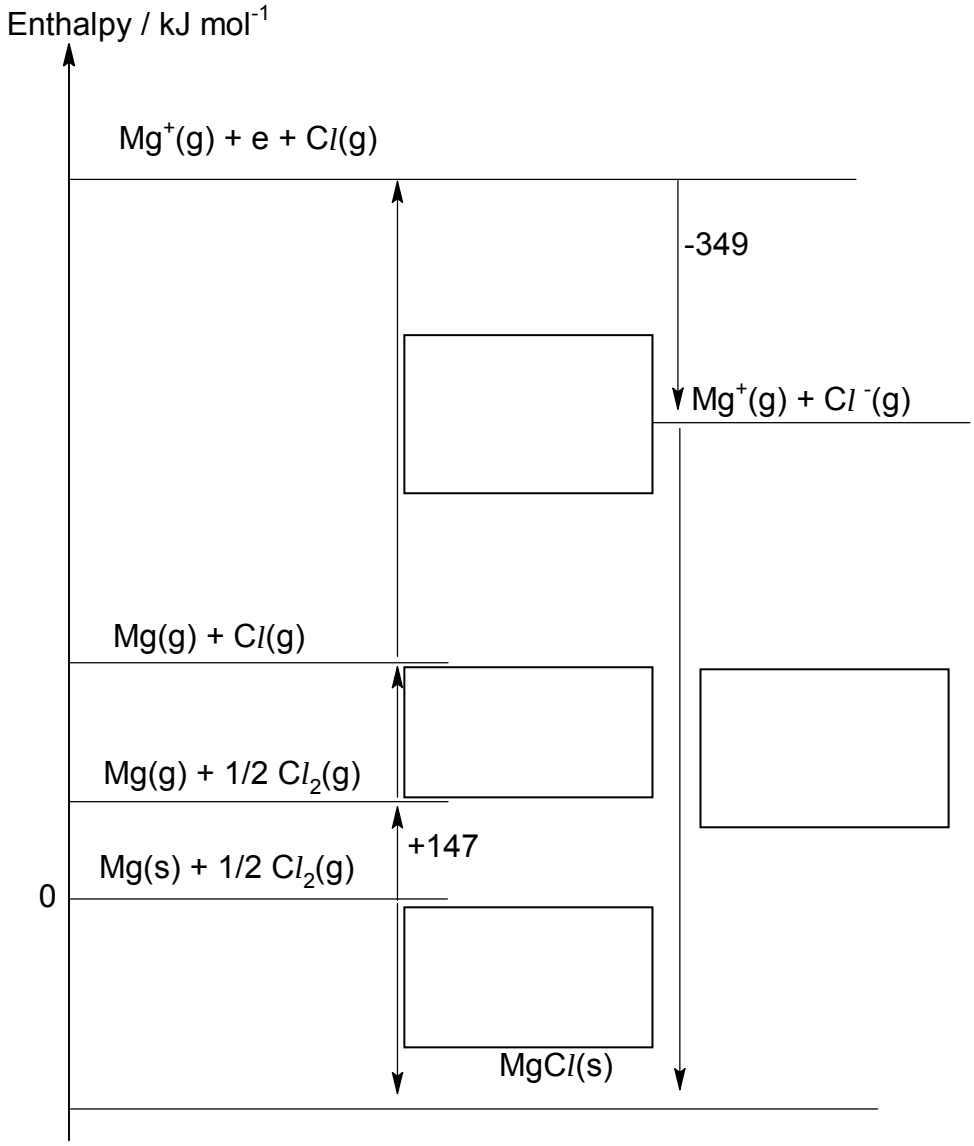
Use the following data to calculate the enthalpy change of this reaction. [1]

ΔH_f $MgCl(s)$ = –106 kJ mol^{-1};
ΔH_f $MgCl_2(s)$ = –642 kJ mol^{-1}

(b) **(i)** The equation for which ΔH is the lattice energy for MgC*l* is shown.

$$Mg^{+}(g) + Cl^{-}(g) \longrightarrow MgCl(s)$$

Label the relevant enthalpy changes in the energy cycle below. [2]



(ii) Use the energy cycle above and relevant data from the *Data Booklet* to calculate a value for the lattice energy of MgC*l*. [1]

(iii) Suggest how the lattice energy of $MgCl_2$ will compare to that of $MgCl$. Explain your answers. [2]

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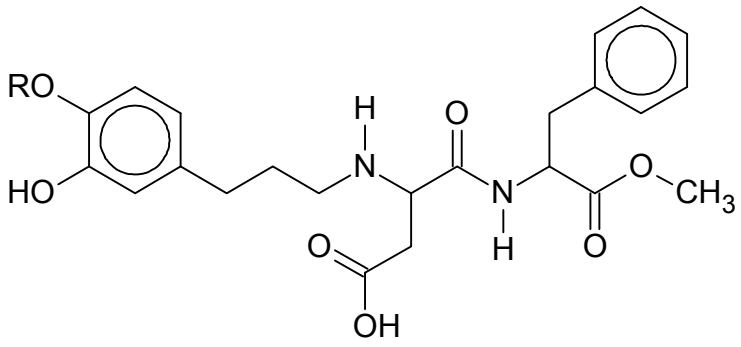
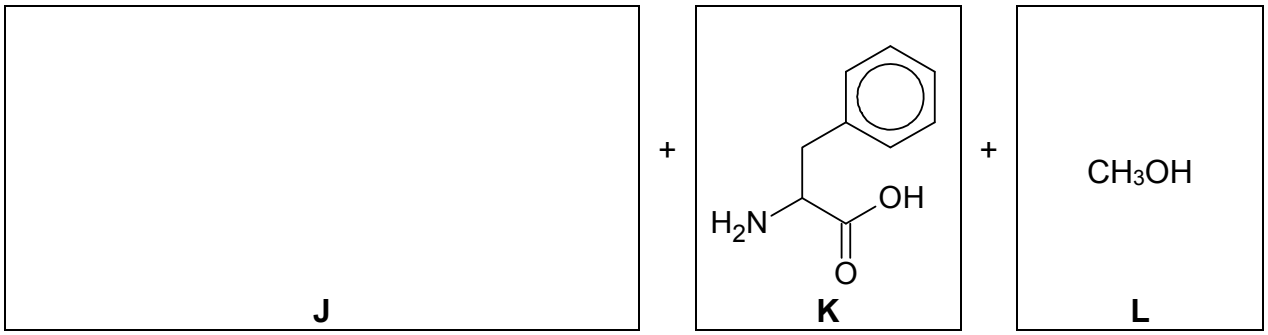
[Total: 6]

6 The compound *Advantame* is a sweetener that tastes approximately 25000 times sweeter than sucrose.



Advantame

(a) The decomposition of *Advantame* produces three molecules, **J**, **K** and **L**. The RO–group in *Advantame* is unreactive.



(i) Name the type of reaction occurring. [1]

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(ii) Draw the structure of **J** in the box above. [1]

(b) **(i)** State what you would observe when acidified potassium manganate(VII) is added to a solution of **L**. [2]

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(ii) Write balanced equation for the reaction taking place in **(b)(i)**. [1]

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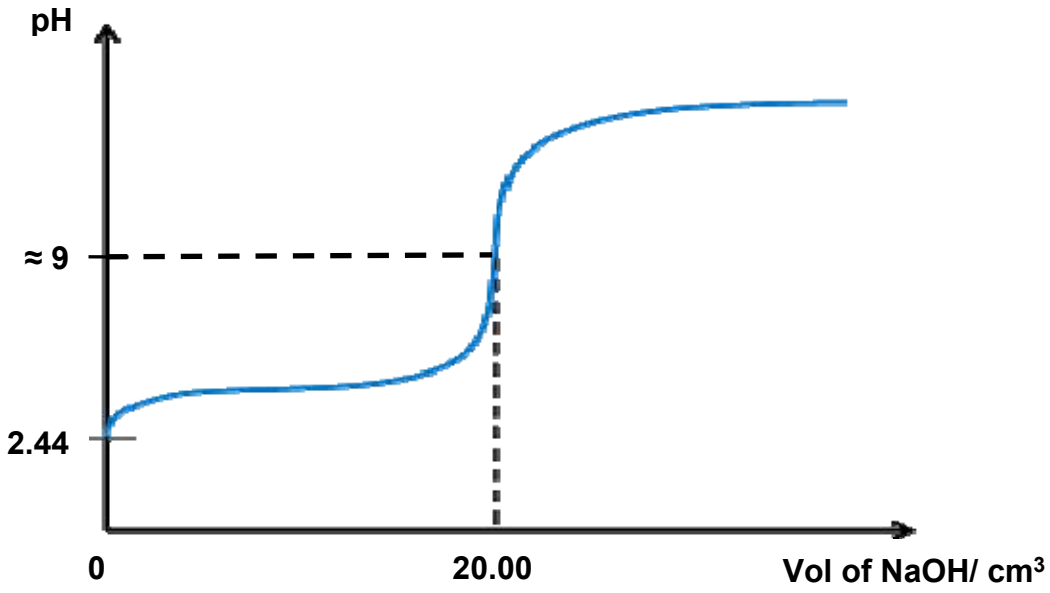
(c) **K** can be polymerised. Draw the structure of the polymer showing two repeat units. The linkage between the monomer units should be fully displayed. [2]

[Total: 7]

7 A 25.0 cm^3 of 0.72 mol dm^{-3} of CH_3COOH in a conical flask was titrated against aqueous sodium hydroxide and the pH of the solution in the conical flask was plotted against volume of NaOH(aq).



(a) **(i)** Using the graph, determine the concentration of aqueous sodium hydroxide in the burette. [1]

(ii) Using the data in the graph, show that ethanoic acid is a weak acid. [1]

(b) Circle the region on the graph on this question paper where a buffer solution is produced from the titration. [1]

(c) Phenolphthalein indicator is used in this titration. Using the information in the table provided below, give two reasons why phenolphthalein is a good indicator. [2]

Indicator	pH range	Colour change	
		Colour in acid < pH 8.2	Colour in alkali > 10.0
Phenolphthalein	8.2 – 10.0	Colourless	Red

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[Total: 5]

8 Many elements have *allotropes*. Carbon has a number of allotropes including diamond, graphite and graphene. Each of these allotropes has different properties. This means the allotropes can be used for different purposes.

Diamond is hard and does not conduct electricity.
Graphite is soft and has high electrical conductivity.
Graphene is a nanomaterial and has high electrical conductivity. A large layer of graphene would be very strong.

(a) **(i)** Describe what is meant by allotropes. [1]

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(ii) Describe the structure of graphene. Explain how this structure gives graphene the properties of high strength and high electrical conductivity.

You may find it useful to include a labelled diagram in your answer. [3]

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(b) Research in nanotechnology is growing and many new nanomaterials are being produced with ever more uses. Uses of nanoparticles and nanomaterials is relatively new and there are concerns about their direct impact on human health and environment.

For example, nanoparticles are used to deliver drugs within cells.

(i) State the difference between a nanoparticle and a nanomaterial in terms of size. [1]

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(ii) Suggest what properties of nanoparticles enable them to deliver drugs within cells. Explain your answer. [2]

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(iii) Give one example of an impact of nanoparticles on the environment. [1]

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[Total: 8]

Section B

Answer **one** question from this section, in the spaces provided.

1 If potassium iodide and ammonium peroxodisulfate are mixed in the presence of starch and sodium thiosulfate, the iodine liberated reacts with the thiosulfate ions until they are all used up.

$$S_2O_8^{2-} + 2I^- \rightarrow I_2 + 2SO_4^{2-}$$
$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

When no thiosulfate ions are left, any iodine formed reacts with starch and the dark blue colour of the starch-iodine complex appears. The time taken for the dark blue colour to appear with a constant quantity of sodium thiosulfate present depends on the rate of formation of iodine

Table of results

Experiment	**Volume of I^- / cm^3**	**Volume of $S_2O_8^{2-}$ / cm^3**	**Volume of deionised water / cm^3**	***Volume of starch / cm^3***	***t / s***
1	**10.00**	**20.00**	**0.0**	**1.0**	**23**
2	**10.00**	**10.00**	**10.0**	**1.0**	**46**
3	**10.00**	**10.00**	**10.0**	**1.0**	***40***

(a) **(i)** Using the results in your table, deduce the order of the reaction with respect to the peroxodisulfate ions. Explain clearly how you arrived at your answer. [2]

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(ii) Instead of washing the beaker as required before performing experiment **3**, a student simply just poured away the reaction mixture. There were some left over reaction mixture in the beaker when he performed experiment **3**. State and explain why the time is shorter than in experiment **2**, assuming all other conditions are kept constant. [1]

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(iii) Explain why a fixed amount of sodium thiosulfate is required. [1]

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(b) It was reported that the order of reaction with respect to iodide ions is one.

In order to substantiate this information, the chemistry teacher gives out these instructions to his class.

1) Prepare a solution mixture containing 0.100 mol dm^{-3} potassium iodide and 1.00 $moldm^{-3}$ of ammonium peroxodisulfate.

2) Record the concentration of the iodide ions against time from the start of the reaction.

3) Plot a graph of concentration of iodide ions against time

(i) Sketch the graph of concentration of iodide ions against time, given that the half-life is 150 seconds, showing the values and important features of your graph to show that it is first order reaction with respect to iodide. [2]

(ii) A student mistakenly prepared a solution containing 1.00 mol dm^{-3} potassium iodide and 0.100 mol dm^{-3} of ammonium peroxodisulfate instead.

He recorded the concentration of the peroxodisulfate ions against time from the start of the reaction and plot a graph of concentration of peroxodisulfate ions against time on a piece of graph paper.

On realising the mistake, the teacher instructed him to carry another experiment by preparing a solution containing 2.00 mol dm^{-3} potassium iodide and 0.100 mol dm^{-3} of ammonium peroxodisulfate.

He recorded the concentration of the peroxodisulfate ions against time and plot the data on the same graph paper.

Based on the data from both experiments on the graph paper, describe how the student can determine that it is first order reaction with respect to iodide ions. [2]

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(c) It is reported that Fe^{3+} catalyses the reaction between ammonium peroxodisulfate and iodide ions.

Explain how Fe^{3+} acts as a catalyst. [2]

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(d) The table below gives the melting points, in °C, of the fluorides and chlorides of two elements in Period 3.

	iron	silicon
chlorides	677	-70
iodides	587	120.5

Explain, in terms of structure and bonding, the differences in melting point between

(i) $FeCl_2$ and $SiCl_4$ [2]

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(ii) SiI_4 and $SiCl_4$ [2]

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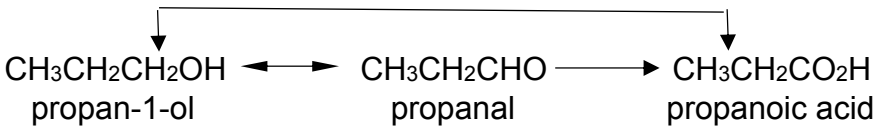
(e) The Harcourt and Esson reaction is a redox reaction just like the reaction between I^- and $S_2O_8^{2-}$. The type of reaction also occurs in organic, as the following transformations from



(i) State a reagent you could use to convert propanoic acid into propan1-ol. [1]

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(ii) Both propanal and propanoic acid can be obtained from propan-1-ol.

State the reagents you could use to carry these reactions. [2]

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(iii) During the reduction of propanoic acid to propan-1-ol, it was suspected that there are traces of unreacted propanoic acid together with propan-1-ol after the reaction.

Suggest a chemical test to confirm the presence of the unreacted propanoic acid, state the observation that you will see. [2]

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(iv) State the type of reaction that has occurred in **(e)(iii).** [1]

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[Total: 20]

2 The halogens are a group in the Periodic Table consisting of five chemically related elements: fluorine, chlorine, bromine, iodine and astatine. The group of halogens is the only periodic table group that contains elements in all three main states of matter at standard temperature and pressure.

(a) Explain the trend in boiling points of halogens down the group. [2]

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(b) Ethene can react with halogens like chlorine and bromine to form 1,2–dichloroethane and 1,2–dibromoethane respectively.

(i) Describe the bonding between the two carbon atoms in ethene in terms of orbital overlap. You may draw a diagram to illustrate your answer. [2]

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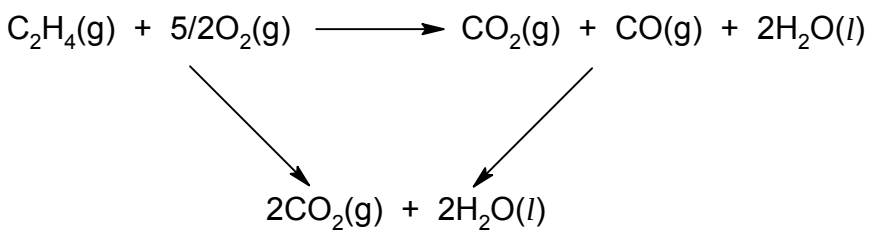
(ii) The enthalpy change of combustion of ethene is given as –1390 kJ mol^{-1}. Calculate the mass of water at 30°C that can be brought to the boiling point by burning 2.0 dm^3 of ethene.

Assume that 75% of the heat from the ethene is absorbed by the water and volume of gas is measured at room temperature and pressure. [2]

(iii) When burnt in a limited supply of air, ethene forms carbon dioxide, carbon monoxide and water according to the equation below.

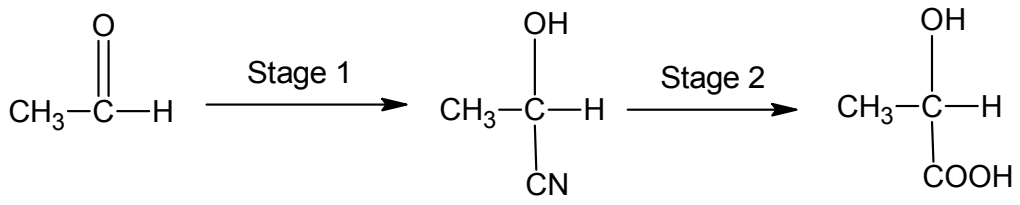


Calculate the ΔH of the reaction given the energy cycle and following data.

ΔH_c (ethene) = –1390 kJ mol^{-1};
ΔH_f (carbon dioxide) = –394 kJ mol^{-1}
ΔH_c (carbon monoxide) = –283 kJ mol^{-1} [1]

(iv) Ethene can be converted to ethanal. State the reagents, conditions needed and the intermediate products formed in the conversion. [3]

(c) Ethanal undergoes a 3 stage synthesis to form lactic acid as follows.



(i) Name the type of reaction in Stage 1. [1]

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Lactic acid, $CH_3CH(OH)COOH$ is a monoprotic acid.

(ii) Give the equation which represent the dissociation of lactic acid in water. Identify the acid conjugate base pairs in the equation. [2]

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(iii) Explain, using equations, why an aqueous mixture of lactic acid and sodium lactate can act as a buffer solution

(I) on the addition of acid,

(II) on the addition of alkali. [2]

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(e) Lactic acid, $CH_3CH(OH)COOH$ is the raw material for the polymer, “polylactide” or PLA.

(i) What type of reaction takes place in this polymerisation? [1]

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One of the reasons PLA has attracted so much attention is that it is biodegradeable. This does, however, restrict some potential uses. The simple polymer has a melting poing of around 175°C, but softens between 60-80°C. However, its thermoplastic properties enable it to have a range of uses in fibres and in food packaging.

(ii) Explain why PLA would not be a suitable packing material for foods pickled in vinegar. [1]

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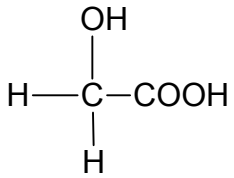
Lactic acid can also be co-polymerised with glycolic acid.



glycolic acid

(iii) Draw a section of the co-polymer showing one repeat unit. [1]

(iv) Suggest what type of bonding will occur between chains of this co-polymer, indicating the groups involved. [1]

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[Total: 20]

End of Paper

RAFFLES INSTITUTION
2018 YEAR 6 PRELIMINARY EXAMINATION

Higher 1

CHEMISTRY 8873/01

Paper 1 Multiple Choice **24 September 2018**

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not open this question booklet until you are told to do so.

Write in **soft pencil**.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and index number in the spaces provided on the Answer Sheet.

There are **thirty** questions in this section. Answer **all** questions.

For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the one you consider correct and record your choice in soft pencil on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in the question booklet.

This document consists of **15** printed pages.

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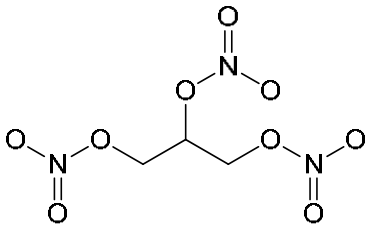
For each question, there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 Nitroglycerin is an explosive that decomposes to form carbon dioxide, water, nitrogen and oxygen only.



nitroglycerin

Which row shows the number of moles of the products formed when 4 mol of nitroglycerin decomposes?

	carbon dioxide	water	nitrogen	oxygen
A	8	8	6	6
B	8	8	12	12
C	12	10	6	1
D	12	10	12	2

2 *Use of the Data Booklet is relevant to this question.*

A 10.0 g sample of H_2S was collected. How many H atoms are in this sample of H_2S? [L = Avogadro constant]

A $\dfrac{10.0 \times L \times 2}{34.1}$

B $\dfrac{L \times 34.1}{2 \times 10.0}$

C $\dfrac{2L}{10.0 \times 34.1}$

D $\dfrac{2 \times 10.0 \times 34.1}{L}$

3 Which of the following species would undergo the greatest deflection in an electric field?

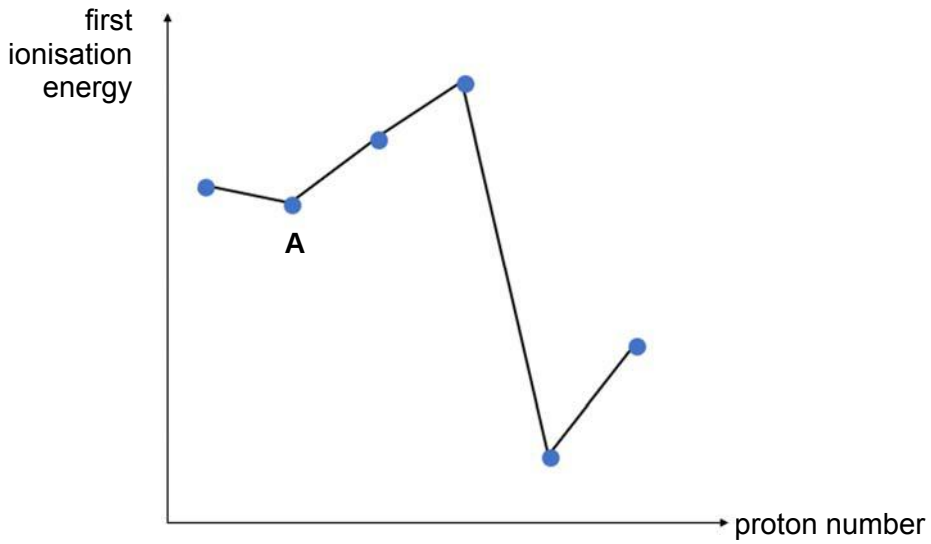
A $^{2}H_2^{+}$

B $^{7}Li^{2+}$

C $^{4}He^{+}$

D $^{9}Be^{3+}$

4 The diagram shows the variation of first ionisation energy with proton number for seven elements of consecutive proton numbers between 1 and 20.



Which of the following is element **A**?

A Mg
B Si
C S
D K

5 The boiling point of hexane is 69 °C while the boiling point of 2-methylpentane is 60 °C.

Which statement best explains the higher boiling point of hexane?

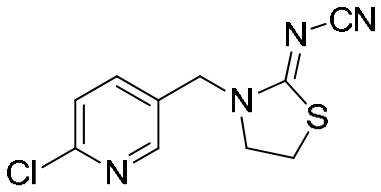
A Hexane has a higher density as it has better packing.

B Hexane has stronger intermolecular permanent dipole-permanent dipole interactions as it is more polar.

C Hexane has stronger intermolecular instantaneous dipole-induced dipole interactions as it has a larger surface area.

D Hexane has stronger intermolecular instantaneous dipole-induced dipole interactions as it has a larger number of electrons.

6 Thiacloprid is an insecticide widely used for pest control in agriculture.



thiacloprid

Which of the following shows the correct number of σ and π bonds in thiacloprid?

	σ bonds	π bonds
A	16	4
B	16	6
C	26	4
D	26	6

7 Which of the following statements can be explained by the presence of intermolecular hydrogen bonding?

1 HF is a weak acid.
2 NaC*l* readily dissolves in water.
3 Ice has a lower density than water.
4 The relative molecular mass of ethanoic acid in benzene is 120.

A 1, 2 and 3
B 1 and 4
C 2 and 3
D 3 and 4

8 Which of the following shows the correct number of bonded electron pairs, number of lone pairs and the shape around each N atom in N_2H_4?

	number of bonded electron pairs around N atom	number of lone pairs around N atom	shape
A	3	0	trigonal planar
B	3	1	trigonal pyramidal
C	3	1	tetrahedral
D	4	0	tetrahedral

9 When 25.0 cm^3 of 0.70 mol dm^{-3} NaOH(aq) is added to 25.0 cm^3 of 0.70 mol dm^{-3} CH_3COOH(aq), the temperature of the mixture rise by 4.7 °C.

$$CH_3COOH(aq) + NaOH(aq) \longrightarrow CH_3COONa(aq) + H_2O(l)$$

Assume that the density and specific heat capacity of the final mixture are 1.0 g cm^{-3} and 4.18 J g^{-1} K^{-1} respectively.

What is the enthalpy change of neutralisation for the above process?

A +28.1 kJ mol^{-1}

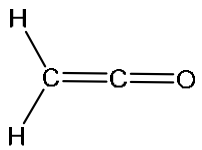
B +56.1 kJ mol^{-1}

C –28.1 kJ mol^{-1}

D –56.1 kJ mol^{-1}

10 *Use of the Data Booklet is relevant to this question.*

Ethenone, CH_2CO, has the following structure.



ethenone

The reaction of gaseous ethenone with oxygen gas is given below.

$$CH_2CO(g) + 2O_2(g) \longrightarrow 2CO_2(g) + H_2O(g) \qquad \Delta H_r$$

What is the enthalpy change, ΔH_r, for this reaction?

A –632 kJ mol^{-1}

B –718 kJ mol^{-1}

C –762 kJ mol^{-1}

D –978 kJ mol^{-1}

11 Which statement about the order of a chemical reaction is correct?

A It is the sum of the number of species included in the rate equation.

B It is the sum of the number of species involved before the rate determining step.

C It is the sum of the powers of the concentrations of species included in the rate equation.

D It is the sum of the number of moles on the left-hand side of the balanced chemical equation.

12 In a kinetic study of the reaction D + E → products at constant temperature, the following data were obtained.

[D] / mol dm^{-3}	[E] / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
0.01	0.05	1.9×10^{-4}
0.02	0.05	3.9×10^{-4}
0.02	0.01	4.0×10^{-4}

If the rate constant doubles for each 10 °C rise in temperature, which of the following will give the greatest rate of reaction?

	[D] / mol dm^{-3}	[E] / mol dm^{-3}	temperature / °C
A	0.1	0.2	40
B	0.2	0.2	30
C	0.3	0.4	20
D	0.4	0.1	30

13 The initial rate of the reaction between aqueous H_2O_2 and acidified KI solution was found to be first order with respect to both H_2O_2 and I^-, and zero order with respect to H^+.

What is the units for the rate constant of this reaction?

A s^{-1}

B mol dm^{-3} s

C mol^{-1} dm^3 s^{-1}

D mol^{-2} dm^6 s^{-1}

14 Which of the following is correct for a system at dynamic equilibrium?

A The rates of both forward and backward reactions are zero.

B The concentration of reactants is equal to the concentration of products.

C There is no net change in the concentrations of the reactants and products.

D The rate constant of the forward reaction is equal to the rate constant of the backward reaction.

15 An equilibrium is represented by the following equation.

$$3F(g) + G(s) \rightleftharpoons 3J(g) \qquad \Delta H < 0$$

Which of the following is **incorrect** for the indicated changes?

	indicated changes	position of equilibrium	forward rate	backward rate
A	increase total pressure by compression	no change	increase	increase
B	increase temperature	shifts left	decrease	increase
C	adding catalyst	no change	increase	increase
D	adding more F	shifts right	increase	no change

16 Which of the following is a conjugate acid-base pair in the reaction below?

$$HSO_4^-(aq) + HPO_4^{2-}(aq) \rightleftharpoons SO_4^{2-}(aq) + H_2PO_4^-(aq)$$

	base	conjugate acid
A	HPO_4^{2-}	$H_2PO_4^-$
B	HPO_4^{2-}	HSO_4^-
C	HSO_4^-	HPO_4^{2-}
D	HSO_4^-	SO_4^{2-}

17 The ionic product of water, K_w, at two different temperatures are given below.

temperature / °C	K_w / mol^2 dm^{-6}
25	1.00×10^{-14}
62	1.00×10^{-13}

Which statements are **incorrect** for pure water?

1 The self-ionisation of water is an exothermic process.
2 At 62 °C, pH = 14 − pOH.
3 At 62 °C, pH < pOH.

A 1 only
B 3 only
C 2 and 3 only
D 1, 2 and 3

18 The first ionisation energies, in kJ mol^{-1}, of a sequence of elements of increasing proton (atomic number) are given below.

519 900 799 1090 1400 1310

Where is this sequence of elements likely to be located in the Periodic Table?

A Group 2
B Group 17
C from Li to N
D from N to Na

19 **L** and **M** are elements in the Periodic Table.

Element **L** forms an insoluble oxide.

Element **M** forms an acidic oxide that is unable to react with dilute NaOH.

What is the identity of elements **L** and **M**?

	L	**M**
A	Na	Si
B	Mg	S
C	Al	Si
D	Si	P

20 The table shows the results of experiments in which the halogens X_2, Y_2 and Z_2 were added to separate aqueous solutions containing X^-, Y^- and Z^- ions.

	X^-(aq)	Y^-(aq)	Z^-(aq)
X_2	no reaction	no reaction	no reaction
Y_2	X_2 formed	no reaction	Z_2 formed
Z_2	X_2 formed	no reaction	no reaction

Which of the following shows X_2, Y_2 and Z_2 in order of increasing oxidising strength?

A $X_2 \rightarrow Y_2 \rightarrow Z_2$

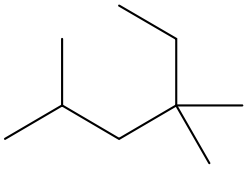
B $X_2 \rightarrow Z_2 \rightarrow Y_2$

C $Y_2 \rightarrow Z_2 \rightarrow X_2$

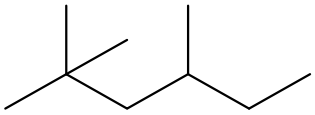
D $Y_2 \rightarrow X_2 \rightarrow Z_2$

21 What is the skeletal formula of 2,4,4-trimethylhexane?

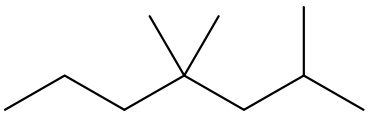
A



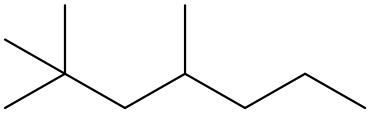
B



C



D



22 The diagram shows a reaction scheme involving 2-bromobutane.

$$C_4H_{10} \xrightarrow{X} \underset{\text{2-bromobutane}}{CH_3CH(Br)CH_2CH_3} \xrightarrow{Y} C_4H_{10}O$$

What types of reaction are reaction X and reaction Y?

	X	Y
A	addition	substitution
B	substitution	substitution
C	addition	oxidation
D	substitution	oxidation

23 How many different alkenes, including *cis-trans* isomers, could be produced when $CH_3CH_2C(CH_3)BrCH_2CH_2CH_3$ is treated with hot ethanolic KOH?

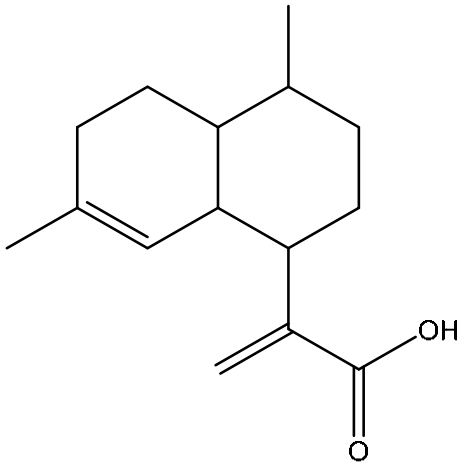
A 2
B 3
C 4
D 5

24 An ester, W, of molecular formula $C_6H_{12}O_2$ undergoes acid hydrolysis to produce a carboxylic acid and an alcohol. The alcohol is found to have no reaction with hot acidified sodium dichromate(VI).

What could be the structural formula of ester W?

A $CH_3CO_2C(CH_3)_3$
B $(CH_3)_3CCO_2CH_3$
C $CH_3CH_2CO_2CH(CH_3)_2$
D $CH_3CH_2CO_2CH_2CH_2CH_3$

25 Artemisinic acid is a useful intermediate for making the anti-malarial drug, artemisin.



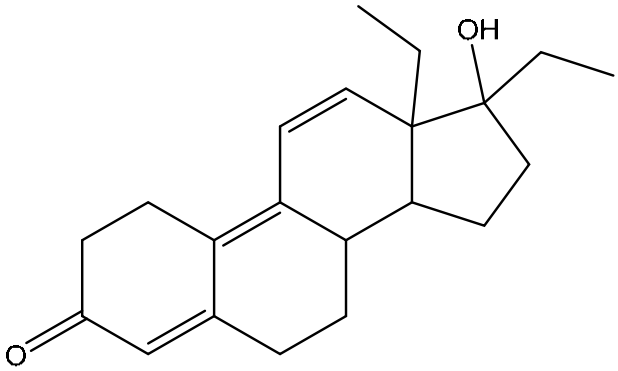
artemisinic acid

Which statements about artemisinic acid are correct?

1 It decolourises two moles of greenish-yellow chlorine.
2 It can be formed from the oxidation of an aldehyde.
3 It can be reduced by hydrogen gas.

A 1,2 and 3
B 1 and 2
C 1 and 3
D 2 and 3

26 THG is an anabolic steroid that mimics the effects of natural hormones, like testerone, found in the body. It promotes muscle growth and its misuse has led to many athletes being disqualified from international competitions, such as The Olympic Games.



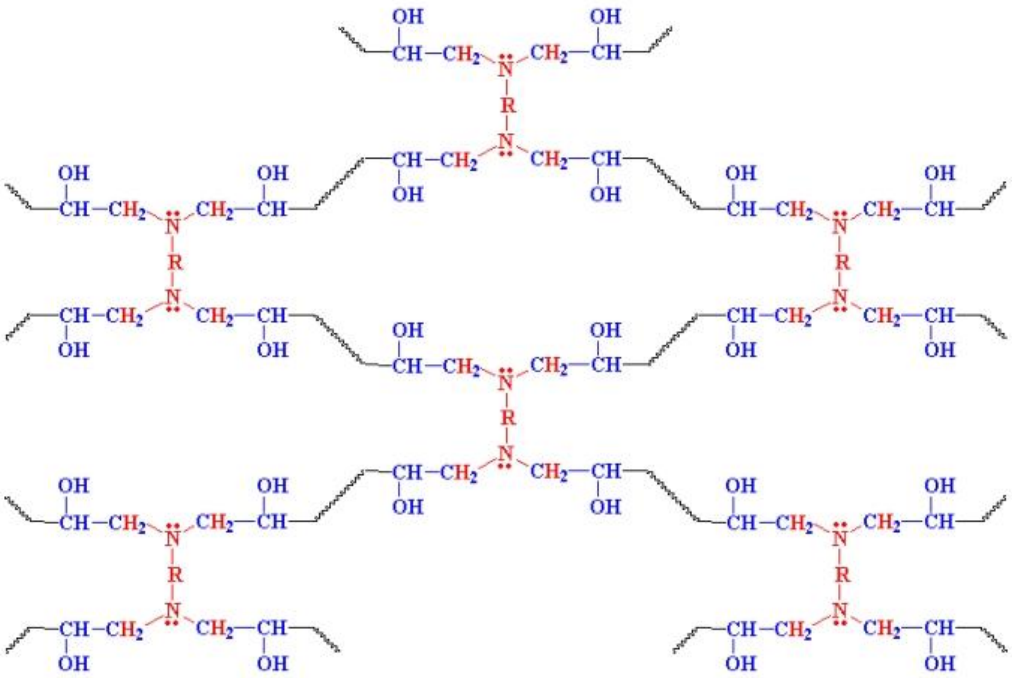
THG

Which statements about THG are correct?

1 It forms a C=C bond when heated with dilute sulfuric acid.
2 It reacts with sodium borohydride to form a secondary alcohol.
3 It is oxidised by potassium dichromate(VI) to a carboxylic acid.

A 2 only
B 1 and 2
C 1 and 3
D 2 and 3

27 Epoxy resins are renowned for their strong adhesive qualities. A segment of an epoxy resin is given below.



epoxy resin

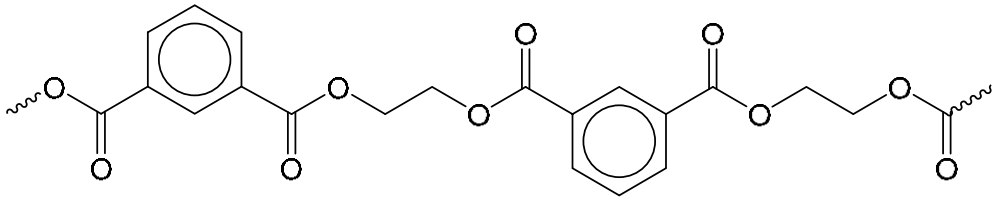
Which statements about an epoxy resin are correct?

1 It is a thermoset.
2 It contains the amide functional group.
3 It forms strong polar bonds with hydroxyl surfaces.

A 1 and 2
B 1 and 3
C 2 and 3
D 1, 2 and 3

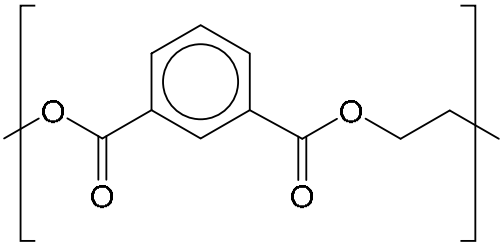
28 Football jerseys are commonly made from polymers, such as PET, as it is lightweight, durable and only absorbs 0.4% of its weight of water.

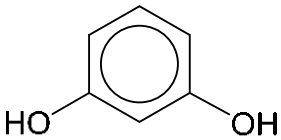
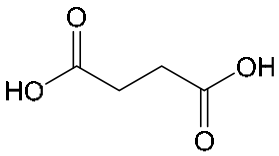
A polymer chain of PET is given below.

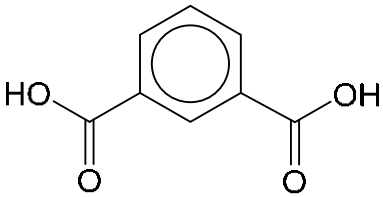
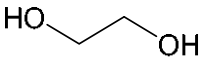


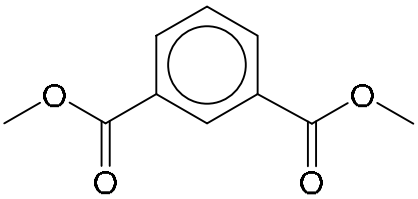
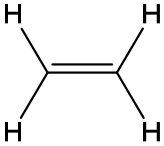
PET

Which are the monomers of PET?

A 

B  and 

C  and 

D  and 

29 What is the maximum size, in at least one dimension, of a nanomaterial?

A 1×10^{-6} m

B 1×10^{-7} m

C 1×10^{-8} m

D 1×10^{-9} m

30 The honeycomb structure is commonly used to make blankets and is also found in catalytic converters and graphene.

Which statement about the honeycomb structure is **incorrect**?

A It allows air to be trapped.

B It will be easily deformed by pressure.

C Its large surface area to volume ratio increases catalytic efficiency.

D It has high tensile strength due to the network of strong covalent bonds within each layer.

– END OF PAPER –

RAFFLES INSTITUTION
2018 YEAR 6 PRELIMINARY EXAMINATION

Higher 1

CANDIDATE NAME	
CLASS	
INDEX NUMBER	

CHEMISTRY 8873/02

Paper 2 Structured Questions **11 SEPTEMBER 2018**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not open this question booklet until you are told to do so.

Write your name, class and index number in the spaces provided at the top of this page.
Write in dark blue or black pen in the spaces provided.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **one** question.

For Examiner's Use		
Section A	1	/ 13
	2	/ 5
	3	/ 20
	4	/ 11
	5	/ 11
Section B (Please circle the question you have attempted)	6	/ 20
	7	/ 20
Total		/ 80

A Data Booklet is provided. Do not write anything in it.

You are reminded of the need for good English and clear presentation in your answers.

The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **22** printed pages.

Section A

For examiner's use

Answer **all** questions in this section, in the spaces provided.

1 **(a)** A student performed an experiment which involved two complexes of Co(II) ions and their colours are given below.

$$\underset{\text{pink}}{Co(H_2O)_6^{2+}(aq)} + 4Cl^-(aq) \rightleftharpoons \underset{\text{blue}}{CoCl_4^{2-}(aq)} + 6H_2O(l) \qquad \Delta H > 0$$

(i) Write the K_c expression for this reaction and state its units.

units .....[2]

(ii) Solution **X** was prepared in which the initial concentrations of $Co(H_2O)_6^{2+}$ and Cl^- ions were 1.80 mol dm^{-3} and 4.00 mol dm^{-3} respectively. After equilibrium was reached, the concentration of $CoCl_4^{2-}$ ions was 0.92 mol dm^{-3}.

Calculate the value of K_c for this equilibrium.

value of K_c .....[2]

(iii) Two experiments were conducted using solution **X** and some experimental observations and deductions were given in Table 1.1.

Table 1.1

test	observations	equilibrium position	predominant ions present
① Test-tubes 1 and 2 contain solution **X**.	violet solution	near the centre	
② Place test-tube 2 in a beaker of hot water.	violet solution turns blue		

Complete Table 1.1. [2]

For examiner's use

(iv) Explain the observations in test ② using Le Chatelier's Principle.

……

……

……

……

……

……[2]

(b) *Use of the Data Booklet is relevant to this question.*

The same student then performed a different experiment to investigate the solubility of iodine in aqueous solution and hexane.

$$I_2(aq) \rightleftharpoons I_2(hexane)$$

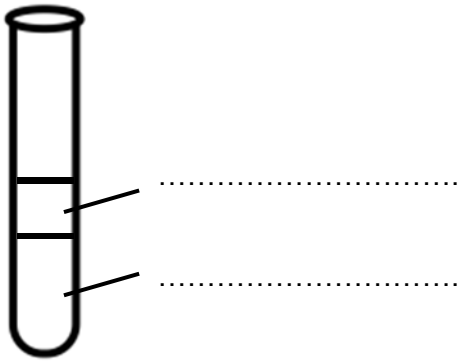
(i) State the colour of iodine in

aqueous solution …….

hexane ……. [1]

(ii) Hexane was added to a test-tube containing iodine dissolved in water and the mixture was shaken well for 10 seconds and allowed to settle. Two immiscible layers were observed.

Given that the densities of hexane and water are 0.655 g cm^{-3} and 1.00 g cm^{-3} respectively, label the colour of the two layers in this test-tube and explain your answer.



explanation ……..

……[1]

For examiner's use

(iii) Explain why iodine is more soluble in hexane than in water.

……

……

……

……[2]

(iv) Iodine can form the tri-iodide ion, I_3^-, with potassium iodide according to the reaction as shown.

$$I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq)$$

The tri-iodide ion is soluble in water. Explain why this is so.

……

……[1]

[Total: 13]

For examiner's use

2 Poly(ethene) exists in two different forms, namely the low density poly(ethene) (LDPE) which has lots of side chains, and the high density poly(ethene) (HDPE), which has fewer and shorter side chains.

(a) Explain, with the aid of suitable diagrams, why the presence of fewer and shorter side chains results in high density poly(ethene).

LDPE	HDPE

explanation ……

……..

……..

……[2]

(b) The manufacture of Lego bricks uses polymers which are commonly made from crude oil. These polymers are inert, very durable and less likely to fade in colour.

Explain why the disposal of such polymers is an environmental concern and suggest a strategy to overcome this problem.

explanation ……

……..

strategy ……..

……..……..[2]

(c) Much research has been done to promote the use of alternative starting materials instead of crude oil. Recently, Lego has started using poly(ethene) derived from sugar cane.

The ethanol in sugar cane is converted to ethene as shown in the reaction below.

$$CH_3CH_2OH \longrightarrow CH_2{=}CH_2 + H_2O$$

Name the type of reaction.

……[1]

[Total: 5]

For examiner's use

3 **(a)** The element oxygen can exist as a number of isotopes.

Table 3.1

isotopic species	protons	neutrons	electrons	electronic configuration
$^{16}_{8}O$				$1s^2$
		10	8	$1s^2$

Complete Table 3.1. [2]

(b) The Haber-Weiss reaction generates highly reactive free radicals from H_2O_2.

A free radical is formed when the O–O covalent bond in H_2O_2 breaks. Explain, with the aid of a 'dot-and-cross' diagram, why the free radical is highly reactive.

explanation ……..…….[2]

(c) Hydrogen peroxide can undergo disproportionation reaction in the presence of the Fe^{2+} catalyst.

$$H_2O_2 \longrightarrow H_2O + \tfrac{1}{2}O_2 \qquad \Delta H = -196.1 \text{ kJ mol}^{-1}$$

The uncatalysed reaction has an activation energy of +49 kJ mol^{-1}.

(i) Using the data provided, draw a labelled energy profile diagram for the uncatalysed reaction on Fig 3.2.

Fig 3.2

[2]

For examiner's use

(ii) Explain what is meant by the term *activation energy*.

……

……[1]

(iii) With the aid of a Boltzmann distribution curve, explain the effect of a catalyst on the rate of reaction.

explanation ……..

……....

……

……

……

……

……

……

……[3]

For examiner's use

(d) The Harcourt and Esson reaction involves hydrogen peroxide and acidified potassium iodide.

$$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \longrightarrow 2H_2O(l) + I_2(aq)$$

The rate of reaction can be followed by measuring the concentration of H_2O_2 remaining at various times. The following table shows how $[H_2O_2]$ varies as the reaction proceeds.

time / s	0	100	200	300	400	500	600	700
$[H_2O_2]$ / mol dm^{-3}	0.030	0.024	0.019	0.015	0.012	0.010	0.0080	0.0060

(i) Plot a graph of $[H_2O_2]$ against time on Fig 3.1. [1]

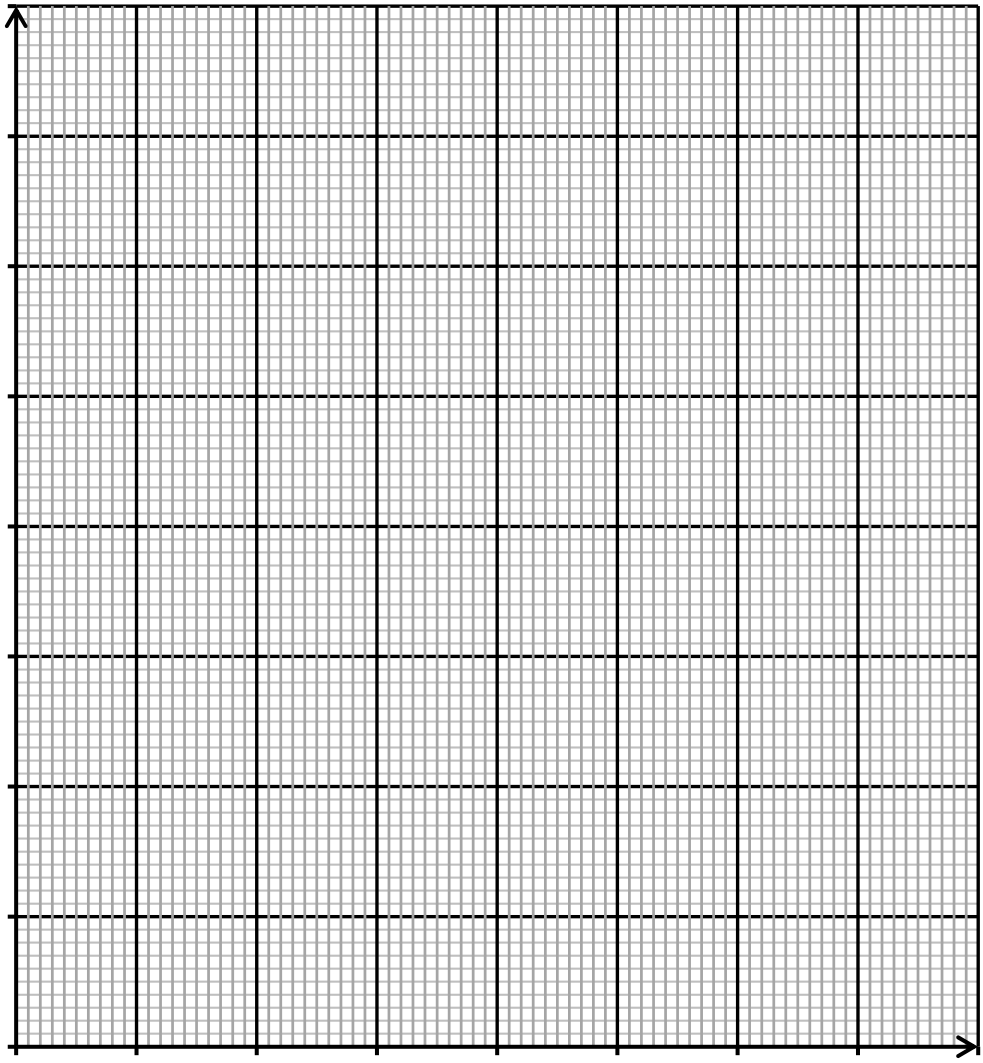


Fig 3.1

Use Fig 3.1 for **(d)(ii)** and **(d)(iii)**. By showing all your working and drawing clearly any construction lines on your graph, determine

For examiner's use

(ii) the order of reaction with respect to [H_2O_2],

order of reaction …… [2]

(iii) the initial rate, in mol dm^{-3} s^{-1}.

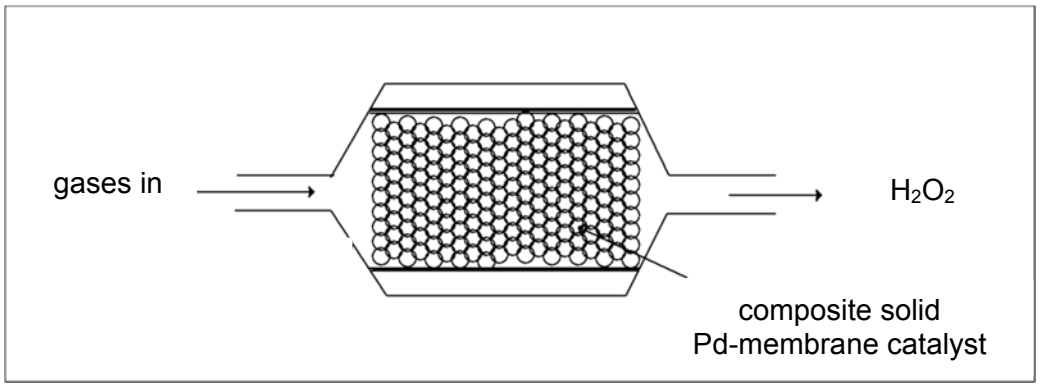
initial rate …… mol dm^{-3} s^{-1} [1]

For examiner's use

(e) H_2O_2 is in high demand in chemical industries as it is considered an environmentally-friendly oxidising agent.

Industries have been finding ways to produce H_2O_2 in a more economical manner by direct oxidation of H_2 with O_2.

In recent times, a novel composite solid palladium membrane catalyst for the direct oxidation of H_2 to H_2O_2 has been used.



(i) Explain why it is environmentally-friendly to use H_2O_2 as an oxidising agent.

……[1]

(ii) Write a balanced equation for the direct oxidation of H_2 to H_2O_2.

……[1]

(iii) State the type of catalyst involved in the direct oxidation of H_2 to H_2O_2.
Describe how this type of catalyst speeds up the gaseous reaction.

type of catalyst ……..

……

……

……

……

……

……

……[4]

[Total: 20]

For examiner's use

4 (a) (i) Describe the reactions of the chlorides of magnesium, aluminium and phosphorus with water.

Include the approximate pH value of any resulting solutions and write equations for any reactions that occur.

……

……

……

……

……

……

……

……

……

……

……

……[4]

(ii) Suggest what influence the type of bonding present in the chlorides of magnesium and phosphorus has on their reaction with water.

……

……

……

……

……[2]

For examiner's use

(b) Unlike aluminium, boron is a non-metal and share more similarities with carbon and silicon than with the other Group 13 elements.

(i) Like $SiCl_4$, BCl_3 undergoes hydrolysis to form compound **M** and white fumes.

Suggest the formula of compound **M** and write an equation for this reaction.

compound **M** ……

equation ……..……...[1]

(ii) Similar to carbon, boron nitride, BN, exists in a diamond-like form and in a graphite-like form.

In the diamond-like form, each nitrogen atom is bonded to four boron atoms, and each boron atom to four nitrogen atoms.

In the graphite-like form, each layer of BN consists of alternating boron and nitrogen atoms.

In the boxes provided below, draw the diamond-like and graphite-like structures of BN and predict a different physical property for each structure.

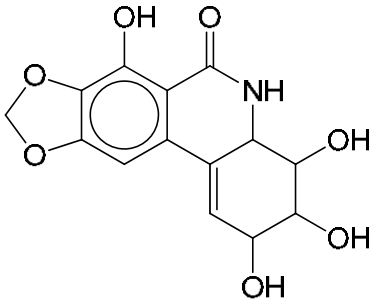
	diamond-like form	graphite-like form
structure		
physical property		

[4]

[Total: 11]

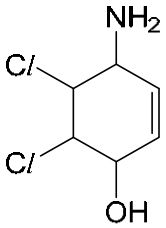
For examiner's use

5 Daffodils are bright yellow flowers which bloom in spring. When placed in a vase together with other flowers, they can cause premature wilting and death of these flowers. This is due to the toxic alkaloid compounds found in the daffodil mucilage. An example of the toxic alkaloid compounds found in daffodils is narciclasine.



narciclasine

Compound **P** is used in the synthesis of narciclasine.



P

(a) State the functional groups present in **P**.

……..……..….[3]

(b) Use the table of characteristic infra-red absorption frequencies in the *Data Booklet* to answer this question.

Infra-red absorptions can be used to identify functional groups in organic compounds. For example, carbonyl compounds show absorption at 1670 – 1740 cm^{-1}.

Use the table to identify an infra-red absorption range that will be shown by

(i) narciclasine but not by **P**

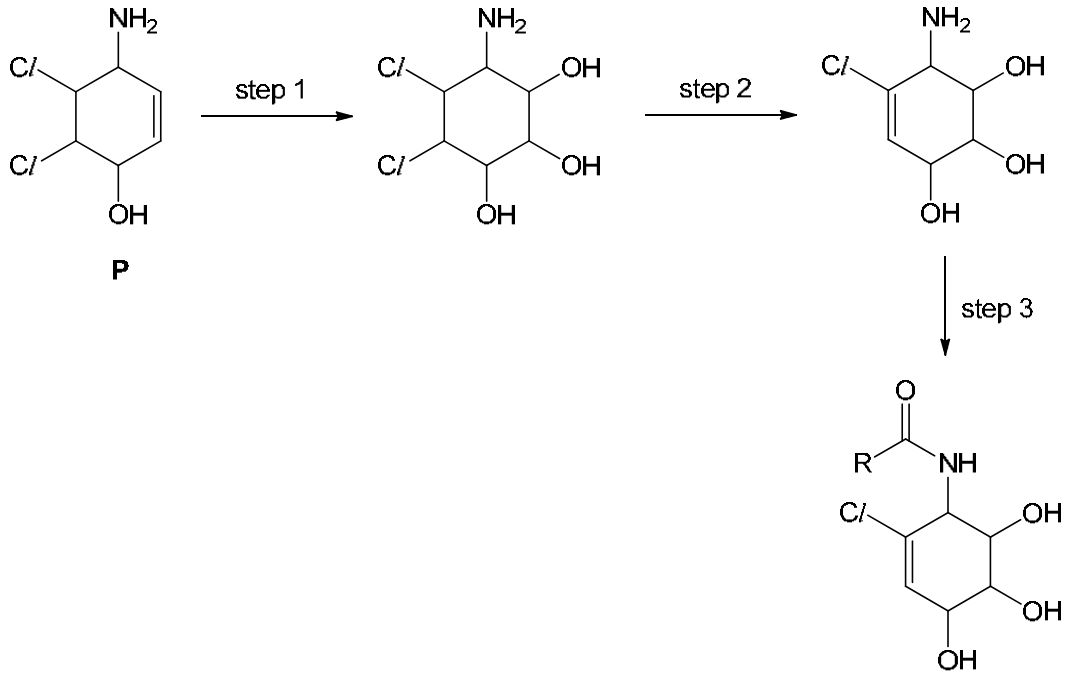
…… cm^{-1}

(ii) **P** but not by narciclasine

…… cm^{-1} [2]

For examiner's use

The following shows part of the synthesis of narciclasine from compound **P**.



(c) **(i)** Step 1 involves the oxidation of **P**.
Write a balanced equation for this reaction using the [O] notation.

……[1]

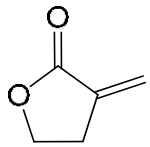
(ii) State the reagents and conditions for steps 2 and 3.

step 2: ……..

step 3: ……[2]

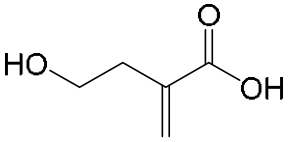
For examiner's use

(d) Tulip is one of the flowers with reduced vase life when placed together with daffodils. When handling tulips, skin contact with the tulip bulbs should be avoided to prevent 'tulips fingers', which is an allergic reaction caused by tulipalin A.



tulipalin A

Tulipalin A can be formed from compound **Q**.



Q

(i) State the type of reaction and the reagents and conditions required.

type of reaction ……

reagents and conditions ……..…[2]

(ii) Draw the displayed formula of the product formed when **Q** is heated with acidified aqueous $K_2Cr_2O_7$.

[1]

[Total: 11]

Section B

For examiner's use

Answer **one** question from this section, in the spaces provided.

6 **(a)** Iron is widely used in the manufacture of steel.

(i) Describe the structure and bonding in iron. Draw a diagram to illustrate your answer.

……..……..

……..……..

……[2]

(ii) By considering your answer to **(a)(i)**, state **two** physical properties that you would expect iron to possess. Explain why it possesses these properties.

property ……

explanation ……..

……

property ……

explanation ……..

……...[2]

For examiner's use

(b) Anaemia is a condition caused by a lack of iron in the body.

Iron tablets containing iron(II) sulfate, $FeSO_4$, are administered to patients suffering from anaemia. The amount of iron(II) sulfate in the tablets can be determined titrimetrically using acidified potassium manganate(VII), $KMnO_4$.

In an experiment, five iron tablets were crushed and dissolved in dilute sulfuric acid. This solution was made up to 250 cm^3 with deionised water.

25.0 cm^3 of the diluted solution required 27.55 cm^3 of 0.005 mol dm^{-3} acidified potassium manganate(VII) for complete reaction.

(i) Write a balanced equation for the overall reaction between Fe^{2+} and MnO_4^-.

……..…….[1]

(ii) Calculate the amount, in moles, of iron(II) sulfate present in the original 250 cm^3 solution.

[3]

(iii) Hence, calculate the mass of iron(II) sulfate present in one tablet.

[2]

(iv) A student decided to repeat the experiment, but dissolved the crushed tablets in hydrochloric acid instead.

State, with reasoning, what effect this will have on the volume of acidified $KMnO_4$ required for complete reaction and on the calculated mass of $FeSO_4$ in one tablet.

……..……..

……

……..……..…

…….…..[2]

For examiner's use

(c) The melting points of GeO_2 and SeO_3 are 1115 °C and 118 °C respectively.

(i) By considering the melting points of the oxides and the positions of Ge and Se in the Periodic Table, suggest the structure and type of bonding present in each of the oxides.

……..……..

……

……..……..

……..……[2]

(ii) SeO_3 can react with either sodium hydroxide or hydrochloric acid. Write a balanced equation for its reaction with either hydrochloric acid or sodium hydroxide.

……..……..[1]

(d) Ethanol can be used as a fuel. Most existing car engines can run on blends of 15% ethanol and 85% gasoline.

Ethanol is commonly produced by the fermentation of glucose, $C_6H_{12}O_6$.

(i) Calculate the average oxidation number of carbon in glucose.

[1]

(ii) Write a balanced equation for the disproportionation reaction of glucose to produce ethanol and carbon dioxide only, by using oxidation numbers or otherwise.

……..……....[1]

(e) Gasoline contains a mixture of alkanes, including octane, $CH_3(CH_2)_6CH_3$.

(i) Write a balanced equation, including state symbols, for the complete combustion of liquid octane under standard conditions.

……..……..…..[1]

For examiner's use

(ii) Some relevant standard enthalpy change of formation values, $\Delta H_f^{\ominus}$, are given in Table 6.1. Using your answer to **(e)(i)** and the data in Table 6.1, calculate the standard enthalpy change of combustion of liquid octane.

Table 6.1

compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$CH_3(CH_2)_6CH_3(l)$	–249.7
$CO_2(g)$	–393.5
$H_2O(l)$	–285.8

standard enthalpy change of combustion of octane……[2]

[Total: 20]

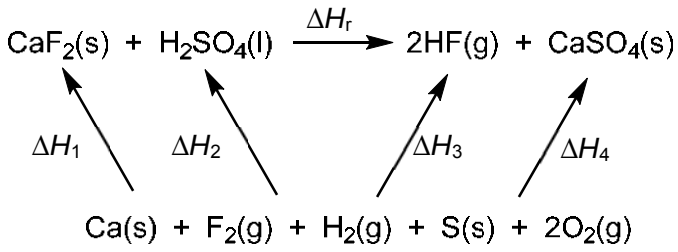
For examiner's use

7 (a) Hydrofluoric acid, HF, can be manufactured by treating calcium fluoride, CaF_2, with concentrated sulfuric acid, H_2SO_4.

(i) Draw a 'dot-and-cross' diagram to show the bonding in H_2SO_4. State the shape of the molecule around the S atom.

shape of molecule around the S atom .....[2]

(ii) The diagram below shows an energy cycle involving the reaction of calcium fluoride with concentrated sulfuric acid.



ΔH_1 = –1220 kJ mol^{-1}

ΔH_2 = –814 kJ mol^{-1}

ΔH_3 = –542 kJ mol^{-1}

ΔH_4 = –1434 kJ mol^{-1}

Using the energy cycle and data provided, calculate the

① enthalpy change of formation of gaseous hydrogen fluoride, ΔH_f,
② enthalpy change of the reaction, ΔH_r.

ΔH_f .....

ΔH_r .....[3]

For examiner's use

(b) Compared to other hydrogen halides, HF shows significantly different chemical and physical properties.

(i) By quoting relevant values from the *Data Booklet*, describe and explain the trend in thermal stability of the hydrogen halides HF, HC*l* and HBr.

……..……..

……..……..

……

……

……

……

……..……..[3]

(iii) Calculate the pH of a 0.050 mol dm^{-3} solution of HC*l*.

[1]

(ii) With the aid of an equation, briefly explain why HF is a weak acid.

……

……

……..……..[2]

(iv) A student proposed diluting a solution of HF so as to
① increase its acid dissociation constant, K_a and
② lower its pH value.
Explain if the student is correct.

……

……

……

……..……..[2]

For examiner's use

(c) To standardise a solution of aqueous ammonia, a titration was carried out with 0.050 mol dm^{-3} solution of aqueous hydrochloric acid. During this titration, hydrochloric acid is added gradually from a burette until the end-point is reached.

(i) Write a balanced equation for the reaction of aqueous ammonia with aqueous hydrochloric acid.

……[1]

(ii) Suggest a suitable indicator for the titration and indicate the colour change at the end-point.

indicator ……..……

colour change ……...……[2]

(iii) 25.0 cm^3 of aqueous ammonia required 22.00 cm^3 of aqueous hydrochloric acid for complete reaction. Calculate the concentration of aqueous ammonia.

[1]

(iv) During the addition of the first 11.00 cm^3 of hydrochloric acid, the mixture is behaving as a buffer. Explain how the mixture is behaving as a buffer at this stage of the titration.
Include an equation in your answer.

……

……

……

……

……

……[3]

[Total: 20]

– END OF PAPER –

Suggested Answers for 2018 Y6 H1 Chemistry Preliminary Examination

Paper 1:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
C	A	D	C	C	D	D	B	D	D	C	D	C	C	B	A	D	C	C	B

21	22	23	24	25	26	27	28	29	30
A	B	D	A	A	A	B	C	B	B

Paper 2
Section A

1(a)(i)

$K_c = \frac{[CoCl_4^{2-}]}{[Co(H_2O)_6^{2+}][Cl^-]^4}$ units = $mol^{-4}dm^{12}$

1(a)(ii)

	$Co(H_2O)_6^{2+}(aq)$	$+ 4Cl^-(aq)$	⇌	$Co(Cl)_4^{2-}(aq)$	$+ 6H_2O(l)$
I	1.80	4.00		0	-
C	−0.92	−4(0.92)		+0.92	-
E	0.88	0.32		0.92	-

value of $K_c = \frac{(0.92)}{(0.88)(0.32)^4} = 99.7$

1(a)(iii)

test	obsn	eqm pos	predominant species present
①	violet soln	near the centre	mixture of pink $Co(H_2O)_6^{2+}$ ions and blue $CoCl_4^{2-}$ ions
②	violet soln turns blue	right	$CoCl_4^{2-}$ ions

1(a)(iv)

When test-tube 2 is placed in a beaker of hot water, the temperature of the solution increases. This causes the position of equilibrium to shift right, favouring the forward endothermic reaction.

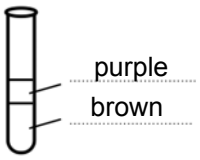
This is in accordance to Le Chatelier's principle as the system attempts to counteract the increase in temperature by absorbing heat.

Hence with the forward reaction favoured, the concentration of pink $Co(H_2O)_6^{2+}$ ions decreases, concentration of blue $CoCl_4^{2-}$ ions increases, causing the solution to turn from violet to blue.

1(b)(i)

iodine in aqueous solution <u>brown</u>
iodine in hexane <u>purple</u>

1(b)(ii)



<u>explanation</u>
Hexane has a lower density than water. Since iodine dissolves in hexane to give purple colour, the purple layer is the upper layer.

1(b)(iii)

Iodine is non-polar and will form instantaneous dipole-induced dipole interactions with non-polar hexane molecules.

Iodine cannot form hydrogen bonds with polar water molecules.

1(b)(iv)

Tri-iodide ion can form ion-dipole interaction with water. (which is stronger than the hydrogen bonding in water)

2(a)

HDPE is largely unbranched / linear and allows for more efficient/close packing of the polymer chains. Hence there is more mass packed into the same volume.

2(b)

Either <u>one</u> of these explanations and strategies

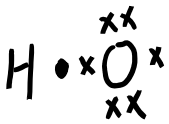
explanation	strategy
produced from crude oil, a non-renewable resource	use renewable resources
do not decompose/biodegrade	develop biodegradable polymers/ recycle polymers
produce toxic gases on burning	

2(c)
elimination

3(a)

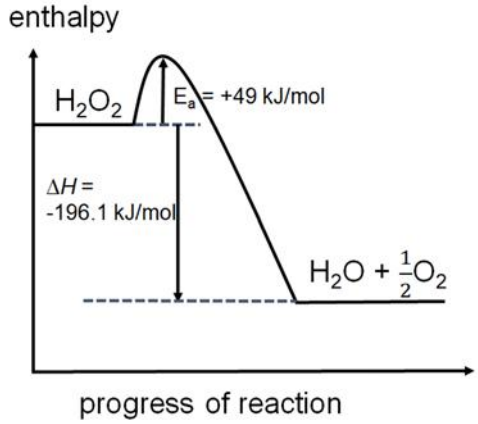
isotopic species	protons	neutrons	electrons	electronic configuration
$^{16}_{8}O$	8	8	8	$1s^2 2s^2 2p^4$
$^{18}_{8}O$	8	10	8	$1s^2 2s^2 2p^4$

3(b)



The free radical is highly reactive as it has a single unpaired electron.

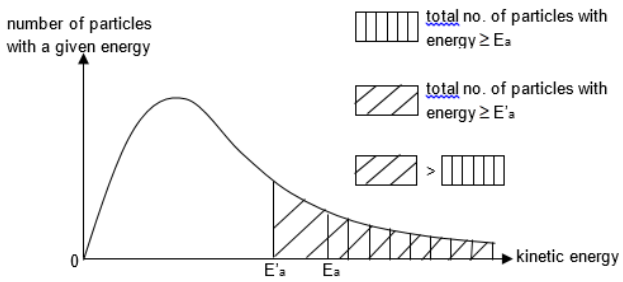
3(c)(i)



3(c)(ii)
The activation energy (E_a) of a reaction is the minimum amount of energy that the reactant particles must possess before their collisions can result in a reaction.

3(c)(iii)
In the catalysed reaction, since the activation energy is lower than that of the uncatalysed reaction, there is a greater proportion of reacting particles having energy greater than or equal to the activation energy than in the uncatalysed reaction.

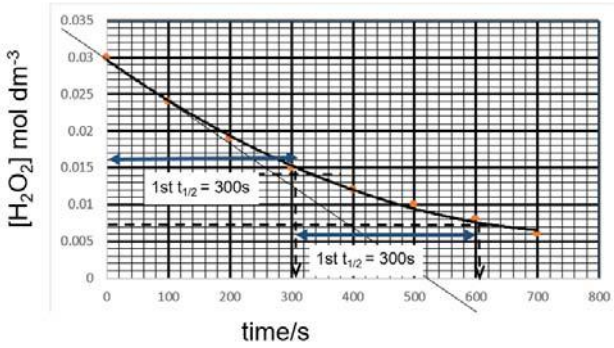
This is shown by the larger shaded area in the Maxwell-Boltzmann distribution curve.



Frequency of effective collision increases accordingly, and hence, the reaction rate increases.

Lower activation energy also results in the reaction having a larger rate constant, and hence, the reaction rate is increased.

3(d)(i)



3(d)(ii)
From the graph, 1st $t_{½}$ ≈ 2nd $t_{½}$ = 300 s
Hence, the reaction is first order wrt H_2O_2.

3(d)(iii)
Initial rate = –gradient of tangent to graph at time = 0
= 0.03 / 520 = 5.77 x 10^{-5} mol dm^{-3} s^{-1}

3(e)(i)
The product of oxidation is water which is clean/non-pollutants.

3(e)(ii)
$H_2 + O_2 \longrightarrow H_2O_2$

3(e)(iii)
type of catalyst: heterogeneous catalyst
(as the catalyst and the reactants are in different phases)

For heterogeneous catalysis to occur, the reactant molecules need to be readily adsorbed onto the catalyst surface, i.e. the formation of weak bonds between the catalyst surface active sites and the reactant molecules.

The adsorption of the reactant molecules at the catalyst surface increases the reaction rate because it

1. weakens the covalent bonds within the reactant molecules, thereby reducing the activation energy for the reaction.

2. increases the concentration of reactant molecules at the catalyst surface and allows the reactant molecules to come into close contact with proper orientation for reaction.

4(a)(i)
When $MgCl_2$ and $AlCl_3$ dissolves in water, the Mg^{2+} and Al^{3+} gets hydrated.

The hydrated Mg^{2+} undergoes slight hydrolysis to give H_3O^+. The resultant solution has a pH ≈ 6.5.
$MgCl_2 + 6H_2O \rightarrow [Mg(H_2O)_6]^{2+} + 2Cl^-$
$[Mg(H_2O)_6]^{2+} + H_2O \rightleftharpoons [Mg(OH)(H_2O)]^+ + H_3O^+$

The hydrated Al^{3+} undergoes appreciable hydrolysis to give H_3O^+. The resultant solution has a pH ≈ 3.

$AlCl_3 + 6H_2O \rightarrow [Al(H_2O)_6]^{3+} + 3Cl^-$
$[Al(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} + H_3O^+$

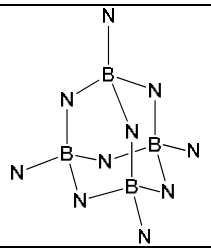
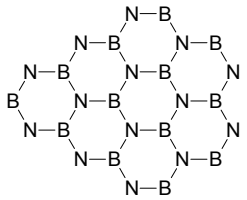
PCl_5 hydrolyses in water to give H_3O^+ as shown. The resultant solution has a pH ≈ 2.
$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

4(a)(ii)
Ionic chlorides such as $MgCl_2$ dissolve in water to give an almost neutral (slightly acidic) solution

Covalent chlorides such as PCl_5 hydrolyse in water to give an acidic solution.

4(b)(i)
$BCl_3 + 3H_2O \rightarrow B(OH)_3 + 3HCl$
M
(also accept: $2BCl_3 + 3H_2O \rightarrow B_2O_3 + 6HCl$)

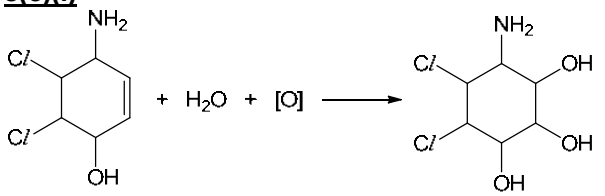
4(b)(ii)

	diamond-like form	graphite-like form
structure		
physical property	• high m.p./b.p • or does not conduct electricity • or hard	• conducts electricity • or high m.p./b.p. • or soft

5(a)
alkene, 2° alcohol, 1° amine, chloroalkane (any 3)

5(b)(i)
1640 – 1690 cm^{-1} (or 1475 – 1625 cm^{-1})

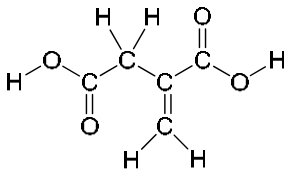
5(b)(ii)
700 – 800 cm^{-1}

5(c)(i)


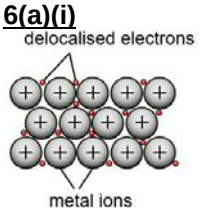
P

5(c)(ii)
step 2: ethanolic NaOH, heat
step 3: RCOOH, DCC

5(d)(i)
type of reaction: condensation
reagents and condns: (catalytic) conc H_2SO_4, heat

5(d)(ii)


Section B

6(a)(i)


Iron exists as a giant metallic structure with strong electrostatic attraction / metallic bonds between positively charged iron ions and delocalised electrons.

6(a)(ii)
property: good electrical conductivity
explanation: presence of mobile charge carriers (delocalised electrons) in metallic structure.

property: high melting point
explanation: A large amount of energy is needed to break the strong electrostatic attraction between positively charged iron ions and delocalised electrons.

6(b)(i)
$5Fe^{2+} + MnO_4^- + 8H^+ \longrightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$

6(b)(ii)
In 25 cm^3 of solution
Amt of MnO_4^- = $\frac{27.55}{1000}$ x 0.005 = 1.3775 x 10^{-4} mol
Amt of $FeSO_4$ = Amt of Fe^{2+}
= 5 x 1.3775 x 10^{-4} = 6.8875 x 10^{-4} mol

In 250 cm^3 of solution
Amt of $FeSO_4$ = 10 x 6.8875 x 10^{-4} = 6.89 x 10^{-3} mol

6(b)(iii)
Mass of $FeSO_4$ in 5 tablets
= 6.8875 x 10^{-3} x 151.9 = 1.046 g

Mass of $FeSO_4$ in 1 tablet = 1.046 ÷ 5 = 0.209 g

6(b)(iv)
As $KMnO_4$ will oxidise Cl^- to Cl_2.
- volume of $KMnO_4$(aq) required for complete reaction is larger
- calculated amount of $FeSO_4$ in each tablet will be larger than actual
- calculated mass of $FeSO_4$ in each tablet will be larger than actual.

6(c)(i)
From its high melting point and position of Ge in the Periodic Table (diagonal relationship with A*l*), GeO_2 has a giant ionic structure with strong ionic bonds between Ge^{4+} and O^{2-} ions. **(or GeO_2 is giant covalent)**

From its low melting point and position of Se in the Periodic Table, SeO_3 has a simple covalent structure with weak instantaneous dipole-induced dipole interactions between molecules.

6(c)(ii)
$SeO_3(s) + 2NaOH(aq) \longrightarrow Na_2SeO_4(aq) + H_2O(l)$

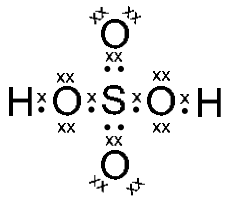
6(d)(i)
Let x be the average oxidation number of C.
$6x + 12(+1) + 6(-2) = 0 \rightarrow x = 0$

6(d)(ii)
Average O.N. of C in ethanol = –2
O.N. of C in CO_2 = +4
There are 2 C atoms in ethanol and 1 C atom in CO_2
$\rightarrow C_2H_5OH \equiv CO_2$
$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$

6(e)(i)
$CH_3(CH_2)_6CH_3\ (l) + 12.5\ O_2(g) \longrightarrow 8CO_2(g) + 9H_2O(l)$

6(e)(ii)
$\Delta H_{rxn}^{\ominus} = \Sigma n\Delta H_f^{\ominus}(\text{pdts}) - \Sigma m\Delta H_f^{\ominus}(\text{rxts})$
$= [8(-393.5) + 9(-285.8)] - [1(-249.7) + 12.5(0)]$
$= -5470\ \text{kJ mol}^{-1}$ (3 sf)

7(a)(i)



It is tetrahedral around the S atom.

7(a)(ii)
ΔH_f of HF = ½ (–542) = –271 kJ mol^{-1}

By Hess' Law,
$\Delta H_r = \Delta H_3 + \Delta H_4 - \Delta H_1 - \Delta H_2$
$= 1220 + 814 - 542 - 1434 = +58\ \text{kJ mol}^{-1}$

7(b)(i)
Thermal stability of the hydrogen halides (HX) is related to the H–X bond strength.

More endothermic bond dissociation energy suggests that the H–X bond is stronger and that HX is more thermally stable.

Since bond dissociation energy of H–X bond (in kJ mol^{-1}) decreases in the order:
H–F (+562) > H–C*l* (+431) > H–Br (+366)
thermal stability thus decreases in the order:
H–F > H–C*l* > H–Br

7(b)(ii)
Since HC*l* is a strong acid,
$[H^+] = [HCl] = 0.050\ \text{mol dm}^{-3}$
pH = –lg(0.050) = 1.30

7(b)(iii)
HF is partially dissociated (or ionised) in aqueous solution.

$HF(aq) \rightleftharpoons H^+(aq) + F^-(aq)$

7(b)(iv)
(1) The K_a of the acid remains constant when it is diluted as it is a constant at constant temperature.

(2) Dilution will result in a lower $[H^+(aq)]$. Since pH = –lg$[H^+]$, pH should increase with dilution.

7(c)(i)
$HCl(aq) + NH_3(aq) \longrightarrow NH_4^+(aq) + Cl^-(aq)$
or $H^+ + NH_3(aq) \longrightarrow NH_4^+(aq)$

7(c)(ii)
methyl orange
yellow to orange

7(c)(iii)
Amt of HC*l* = (22.00/1000)(0.050) = 1.10 x 10^{-3} mol
$[NH_3(aq)] = 1.10 \times 10^{-3} / (25.0/1000)$
$= 0.0440\ \text{mol dm}^{-3}$

7(c)(iv)
NH_3 and NH_4^+ is a buffer solution which resists changes in pH upon the addition of a small amount of acid or base.

Or it contains a large reservoir of weak base, NH_3, and its conjugate acid, NH_4^+.

When a small amount of H^+ ions is added to the solution, the following reaction occurs:
$NH_3(aq) + H^+(aq) \longrightarrow NH_4^+(aq)$

The presence of a large reservoir of unionised NH_3 molecules in the solution ensures that nearly all the added H^+ ions are removed.

Hence $[H^+]$ in the solution changes very little and the pH is kept approximately constant.

Name:		Class:	

ST ANDREW'S JUNIOR COLLEGE

JC2 Preliminary Examinations

Chemistry **8873/1**

Higher 1 **17 Sep 2018**

Paper 1 **1300 − 1400**

Candidates answer on separate paper.

Additional Materials: Data Booklet and OAS

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write you name, civics group and index number on the OAS provided unless this has been done for you.

There are **thirty** questions on this paper. Answer all questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the one you consider correct and record your choice in **soft pencil** on the separate OAS.

Read the instructions on the OAS very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

This document consists of **16** pages including a blank page.

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1 *Use of the Data Booklet is relevant to this question.*

Which sample of gas contains the same number of atoms as 2 g of hydrogen gas?

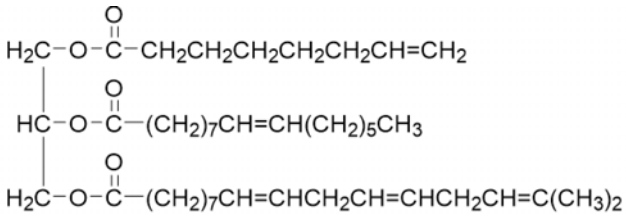
A 22 g of carbon dioxide

B 12 g of steam

C 10 g of neon

D 8 g of methane

2 The diagram shows the structure of a tri-ester.



What is the total number of cis-trans isomers possible for this tri-ester?

A 2^1 **B** 2^3 **C** 2^4 **D** 2^5

3 Ethanedioate ions, $C_2O_4^{2-}$, are oxidised by acidified aqueous potassium manganate(VII) to give carbon dioxide according to the following equation:

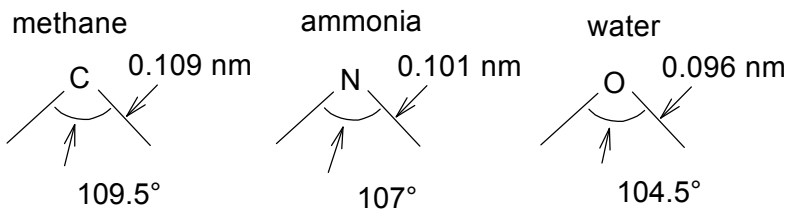
$$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$$

What volume of 0.020 mol dm^{-3} potassium manganate(VII) is required to completely oxidise 1.0×10^{-3} mol of the salt $KHC_2O_4.H_2C_2O_4$?

A 20 cm^3 **B** 40 cm^3

C 80 cm^3 **D** 100 cm^3

4 The bond lengths and bond angles in the molecules of methane, ammonia and water may be represented as follow:



What causes this trend in the bond angles shown?

1 Lone pair–bond pair repulsion is greater than bond pair-bond pair repulsion.

2 Decreasing repulsion between the bond pair of electrons as the electronegativity of the central atom increases.

3 Increasing repulsion between hydrogen atoms as the bond length decreases.

A **1** only

B **1** and **2** only

C **2** and **3** only

D **1**, **2** and **3**

5 2,3-Dimethylbutane can undergo free radical substitution with chlorine gas. Ignoring any stereoisomers, how many different mono-chlorinated organic products are formed when it is heated with limited chlorine gas?

A 2 **B** 3 **C** 4 **D** 6

6 Which statement about Group 1 metals is correct?

A Melting point increases down the group.

B Reducing strength increases down the group.

C Each ground state atom contains a pair of electrons in its valence shell.

D The second electron is more difficult to be removed than the first electron, as M^+ has a noble gas configuration.

7 An enzyme may be described as being specific in its activity.
What is meant by this this statement?

A The enzyme will denature at high temperature.

B The enzyme helps to increase the speed of a chemical reaction.

C The enzyme will catalyse a narrow range of chemical reactions.

D The enzyme is a biological catalyst which remains chemically unchanged at the end of the reaction.

8 Chlorate (I) ion undergoes disproportionation to give chloride ion and another chlorine containing product.

Which of the following could be the chlorine-containing product?

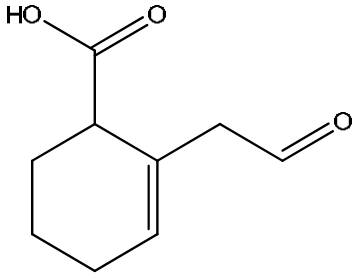
A Cl_2

B Cl_2O

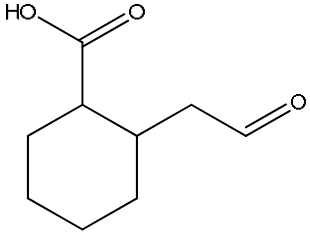
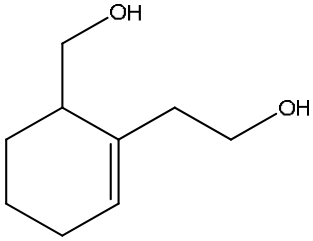
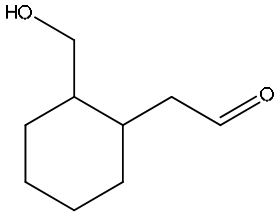
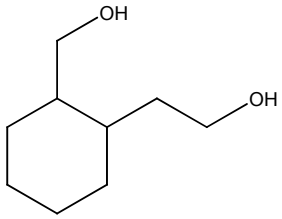
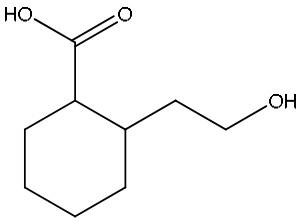
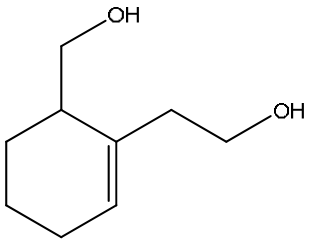
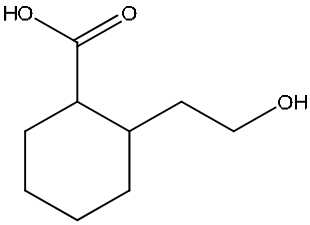
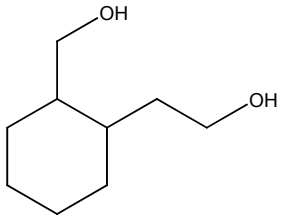
C ClO^-

D ClO_3^-

9 Which are the products formed when compound **X** reacts with the following reducing agents?



compound **X**

	H_2, Pt	$LiAlH_4$ in dry ether
A		
B		
C		
D		

10 A substance **Y** has the following properties.

- melting point – 39 ^{0}C
- boiling point 357 ^{0}C
- conduct electricity when solid and molten

What is the structure of **Y**?

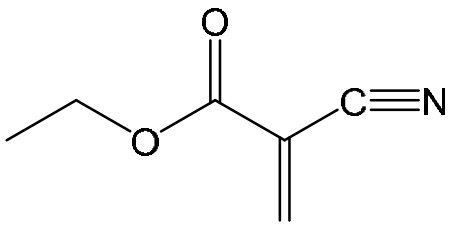
A ionic

B metallic

C giant molecular

D simple molecular

11 Ethyl cyanoacrylate, $C_6H_7O_2N$, is the major component of superglue.



ethyl cyanoacrylate

Which statements about the molecule are true?

1 It contains 5 lone pairs of electrons.

2 It reacts with Br_2 to give a pair of cis-trans isomers.

3 It contains 4 π bonds.

4 It can be hydrolysed by dilute NaOH to give a carboxylic acid and an alcohol.

A **1** only

B **1** and **3** only

C **2** and **3** only

D **3** and **4**

12 Which equation represents the third ionisation energy of bromine?

A $Br\ (g) \rightarrow Br^{3+}(g) + 3e$

B $Br^{2-}(g) + e \rightarrow Br^{3-}(g)$

C $Br^{2+}(g) \rightarrow Br^{3+}(g) + e$

D $Br\ (g) + 3e \rightarrow Br^{3-}(g)$

13 When 20 cm^3 of 0.5 mol dm^{-3} NaOH(aq) is neutralised with an equal volume of 0.5 mol dm^{-3} HNO_3(aq), the temperature of the mixture rose by 5.2 ^oC.

What would be the temperature change if 40 cm^3 of 0.25 mol dm^{-3} NaOH(aq) is reacted with an equal volume of 0.25 mol dm^{-3} HNO_3(aq)?

A 1.3 ^oC **B** 2.6 ^oC **C** 5.2 ^oC **D** 10.4 ^oC

14 Iodine–131 is a radioactive isotope with a half-life of 10 days. Given that radioactive decay is a first-order reaction, what fraction of the isotope would remain after 50 days?

A $\frac{1}{10}$ **B** $\frac{1}{20}$ **C** $\frac{1}{32}$ **D** $\frac{1}{50}$

15 The molar mass of ethanoic acid is 120.0 g mol^{-1} when dissolved in ether but 60.0 g mol^{-1} when dissolved in water.

Which one of the following statements best explains the phenomenon?

A Ethanoic acid is more soluble in ether than in water.

B Ethanoic acid molecules form strong covalent bonds with ether molecules.

C Ethanoic acid molecules form extensive hydrogen bonds with water molecules.

D Ethanoic acid molecules form dative bonds with another ethanoic acid molecule when dissolved in ether.

16 The enthalpy change of reaction for the conversion of sulfur dioxide to sulfur trioxide is shown below.

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \qquad \Delta H = -196\ \text{kJ mol}^{-1}$$

Which of the following statements is correct?

A When the volume of the vessel is compressed, the yield of SO_3 decreases.

B When a catalyst is introduced to the system, the yield of SO_3 increases.

C When the temperature is increased, only the rate of the backward reaction is increased.

D When the temperature is increased, K_c decreases.

17 Bromine has two isotopes, ^{79}Br and ^{81}Br.
Propene can react with bromine liquid in the dark to form organic products with different relative molecular mass.

How many different relative molecular mass values does the organic products have?

A 2

B 3

C 4

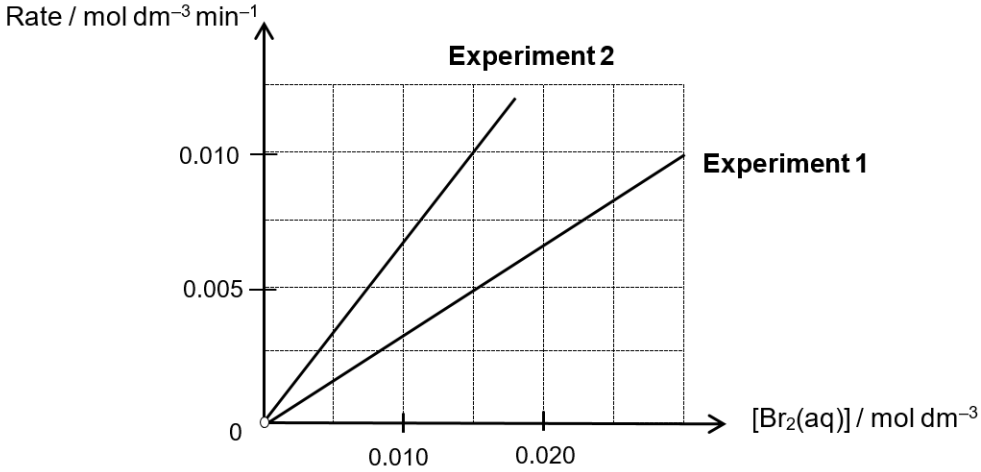
D 5

18 Two separate experiments were conducted to study the kinetics of the following reaction in the presence of excess methanoic acid.

$$HCO_2H(aq) + Br_2(aq) \rightarrow 2H^+(aq) + 2Br^-(aq) + CO_2(g)$$

Experiment	Initial $[HCO_2H]$ / mol dm^{-3}
1	0.8
2	1.6

The experimental results were represented in the graph as shown.



Which of the following is the correct rate equation for above the reaction?

A Rate = $k\,[Br_2]$

B Rate = $k\,[HCO_2H]$

C Rate = $k\,[HCO_2H][Br_2]$

D Rate = $k\,[HCO_2H]^2[Br_2]$

19 The chloride of **X** and oxide of **Y** respectively are separately mixed with water. The two resulting mixtures have different effect on litmus.

Which of the following represents the correct elements?

	X	**Y**
A	A*l*	S
B	Mg	P
C	Si	P
D	P	Na

20 A pure sample of $NH_3(g)$ is introduced into a vessel of constant volume and an equilibrium is established as shown below.

$$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$$

The value of the final pressure is then found to be 25 % greater than if only NH_3 were present. What is the mole fraction of N_2 in the reaction mixture?

A 0.10

B 0.25

C 0.45

D 0.75

21 What is the correct description of the bonding between the two carbon atoms in benzene?

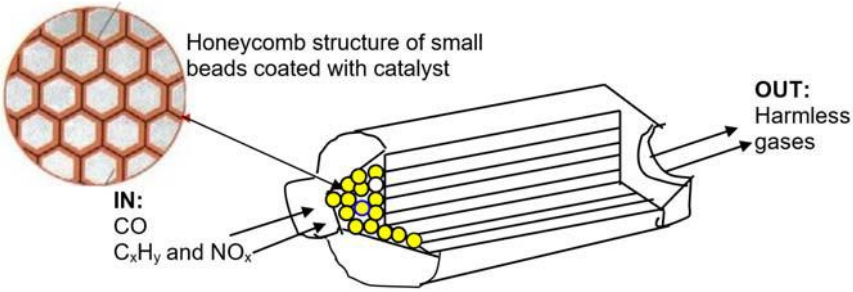
A two pi bonds that are longer than a C—C single bond.

B two pi bonds that are shorter than a C—C single bond.

C a sigma and a pi bond that are longer than a C—C single bond.

D a sigma and a pi bond that are shorter than a C—C single bond.

22 Catalytic converters in car exhaust system helps to convert harmful emission gases into harmless ones. The following diagram shows the interior of a catalytic converter.



Which of the following statement is correct?

A The forces of attraction holding the carbon monoxide, unburnt hydrocarbons and oxides of nitrogen onto the surface of the catalyst are stronger than the forces of attraction holding on the product molecule onto the surface.

B The catalyst coated on the honeycomb surface provides a small surface area to volume ratio to increase the rate of reaction.

C Homogenous catalyst is used in the catalytic converted to lower the activation energy for conversion of harmful gases

D Nitrogen dioxide gas is one of the products of the reactions.

23 What is the electronic configuration of copper in Cu_2O?

A [Ar] $3d^9$

B [Ar] $3d^{10}$

C [Ar] $3d^9\,4s^1$

D [Ar] $3d^9\,4s^2$

24 Which of the following statements about the Period 3 elements sodium to chlorine, and their compounds, is correct?

1 The ionic radius decreases across the period.

2 The oxide of the elements become more acidic across the period.

3 The boiling points of the elements decreases in the order phosphorus, sulfur, chlorine.

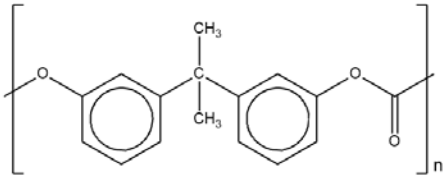
A 2 only

B 2 and 3 only

C 1 and 2 only

D 1,2 and 3

25 Polycarbonates (PC) are polymers containing carbonate groups in their chemical structures. Some major smartphone manufacturers such as Samsung and Apple started using PC in their phones casing.



PC

Which row correctly describes PC?

	type of polymer	reaction of polymer with ethanoic acid
A	addition	no reaction
B	condensation	no reaction
C	addition	hydrolysis
D	condensation	hydrolysis

26 Which reaction will give propanoic acid as one of the products?

A heating $CH_3CH_2CH_2OH$ under immediate distillation with potassium dichromate.

B heating $CH_3CH_2CONHCH_3$ under reflux with dilute aqueous sulfuric acid.

C heating $CH_3CH_2OCOCH_3$ under reflux with dilute aqueous sulfuric acid.

D heating $CH_3(CH_2)_2COOCH_3$ under reflux with dilute aqueous sulfuric acid.

27 What is the maximum size, in at least one dimension, of a nanomaterial?

A 1×10^{-6} m

B 1×10^{-7} m

C 1×10^{-8} m

D 1×10^{-9} m

28 The two most common isotopes of titanium are $^{56}_{22}Ti$ and $^{58}_{22}Ti$.
Which statement about the isotopes of titanium is correct?

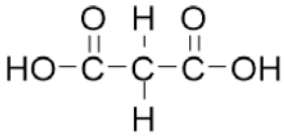
A Both isotopes have same numbers of neutrons.

B One of the isotopes has more protons than the other.

C The electronic configuration of Ti^{2+} ion for both isotopes is the same.

D In the same electric field strength, $^{58}_{22}Ti^{+}$ will be deflected more than $^{56}_{22}Ti^{+}$.

29 The diagram shows the structure of the malonic acid.



Which of the following shows the correct set of the bond angles present in the malonic acid?

A 105^0, 109^0 , 120^0

B 109^0 , 180^0 only

C 120^0 , 180^0 only

D 105^0, 109^0 only

30 Ammonia gas can react with sodium hydride in the following equation:

$$NH_3 + NaH \rightarrow NaNH_2 + H_2$$

Which statement correctly describes the behaviour of ammonia in this reaction?

A It acts as an Arrhenius acid.

B It acts as an Arrhenius base.

C It acts as Bronsted-Lowry acid.

D It acts as Bronsted-Lowry base.

END OF PAPER

Name:		Class:	

ST ANDREW'S JUNIOR COLLEGE

Preliminary Examinations

Chemistry **8873/2**

Higher 1 **12 Sep 2018**

Paper 2 **0800 − 1000**

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST
Write your name and civics group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A:
Answer **ALL** the questions in this section in the spaces provided.

Section B:
Answer **ONE** question from in this section in the spaces provided.

You are reminded of the need for good English and clear presentation in your answers. The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiners use only:

Section A		Section B	
Question	**Marks**	**Question**	**Marks**
1	16	1/2	20
2	29		
3	15		
Total	60	Total	20
TOTAL (Section A + Section B)			80

This document consists of **26** pages including a blank page.

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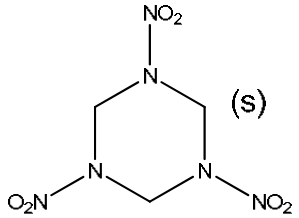
Section A

Answer **all** the questions in this section, in the spaces provided.

1 The explosive RDX is a white crystalline solid first prepared in 1899 but wasn't used as an explosive until 1920 by a German chemist called Herz. He prepared RDX by direct nitration of hexamine and found it be very sensitive to denotation by impact or friction. During World War 2, it was added to TNT to increase its explosive power. The explosive decomposition of RDX is as shown by the equation below.



RDX

$$\text{RDX (s)} \longrightarrow 3CO\ (g) + 3H_2O\ (g) + 3N_2\ (g)$$

(a) **(i)** Calculate the volume of gases, in cm^3, produced at s.t.p during the explosive decomposition of 2.22 g of RDX given that the relative molecular mass of RDX is 222.

[2]

(ii) Write an equation to represent the standard enthalpy change of formation of RDX.

…… **[1]**

(iii) Use the enthalpies of formation shown below to calculate the standard enthalpy change for the explosive decomposition of RDX.

Compound	**ΔH_f / kJ mol^{-1}**
RDX (s)	+ 62
CO (g)	- 111
H_2O (g)	- 242

[2]

1 (a) (iv) Scientific literature usually quote the enthalpy change of formation for chemical explosives in kJ kg^{-1}. Calculate the enthalpy change of formation of RDX from kJ mol^{-1} to kJ kg^{-1}.

[1]

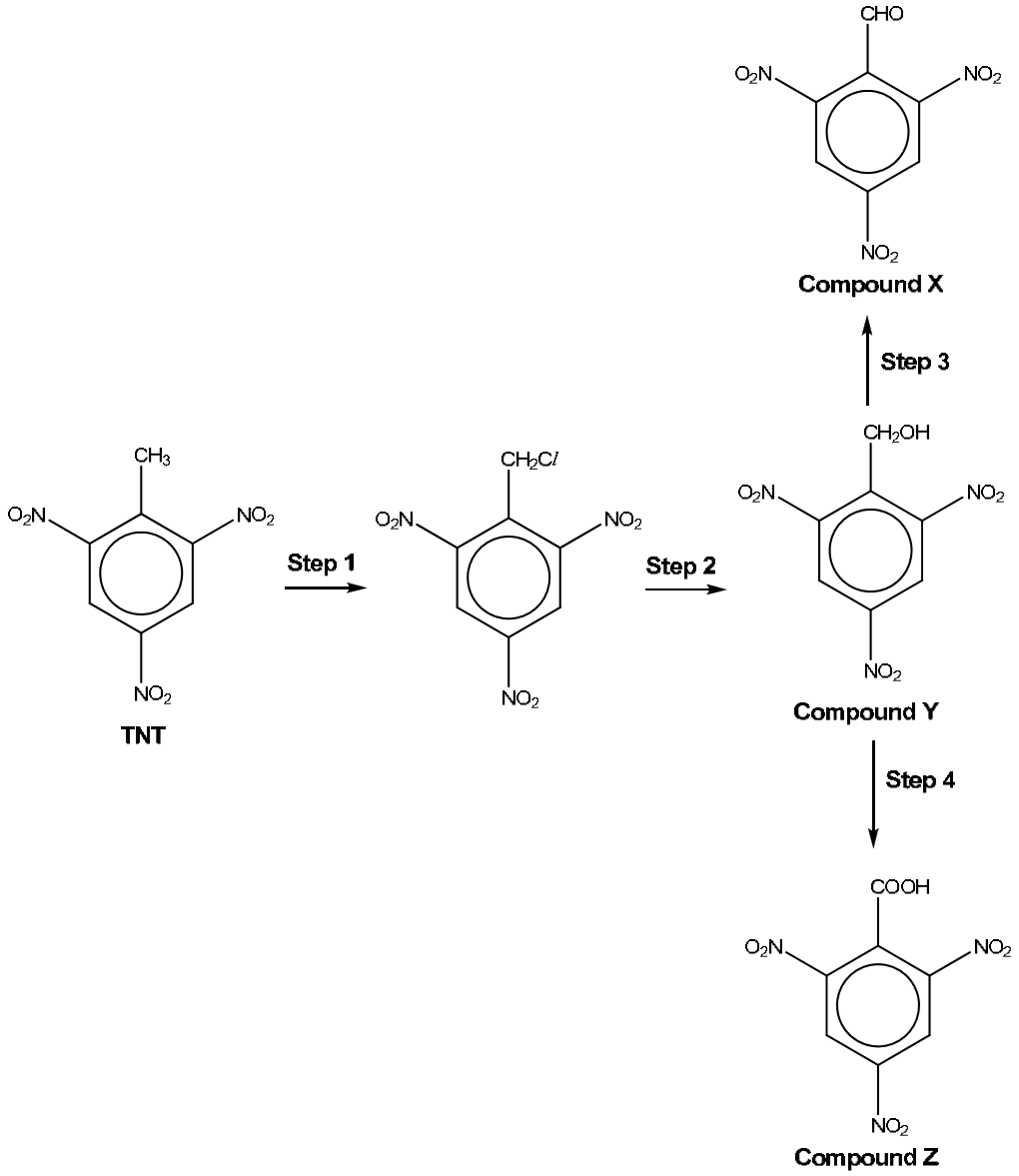
(v) With reference to your answer in **(iii)**, suggest if RDX is more stable than the products of decomposition.

…….....

…….....

[1]

1 (b) The reaction scheme below shows the reactions involving TNT.



(i) State the reagent and condition for Steps **1 – 4**.

Step **1**: .....

Step **2**: .....

Step **3**: .....

Step **4**: ..... **[4]**

1 (b) (ii) Besides lithium aluminium hydride, state the reagent and condition that can reduce compound **X** into compound **Y**. Write a balanced equation for this reaction.

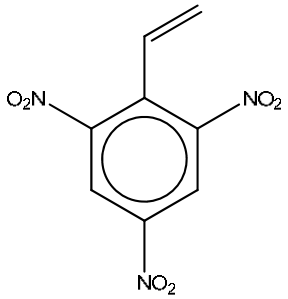
Reagent and condition: ……..

Balanced equation:

……...

[2]

(iii) Compound **Z** can also be synthesised by the oxidation of the following compound **W**.



Compound W

State and explain if the above compound exhibits cis-trans isomerism.

…….....

[1]

(iv) Suggest a suitable chemical test to distinguish between Compound **W** and TNT.

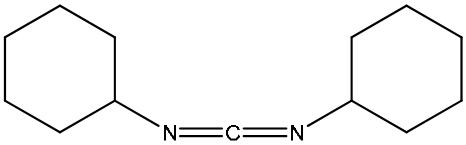
……

……

[2]

[Total: 16]

2 N,N-dicyclohexylcarboiimide often abbreviated as DCC, is used to couple amino acids during artificial peptide synthesis. The structure of DCC is as shown below.



DCC

(a) **(i)** Define the term *relative molecular mass*.

……..……

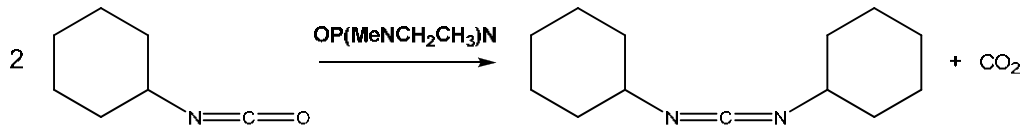
……..……

[1]

(ii) Calculate the relative molecular mass of DCC to 1 decimal place.

[1]

(b) DCC can also be prepared by reacting isocyanate in the presence of a catalyst, $OP(MeNCH_2CH_3)N$, as shown by the following equation. The yield of the reaction is typically 92.0%.



Isocyanate **DCC**

(i) A student prepared DCC via the above synthesis method by using 0.100 g of isocyanate and 0.035 g of DCC was produced. Calculate the percentage yield of his experiment and hence suggest if the student's experimental technique is accurate given that the M_r of isocyanate is 125.0.

[2]

2 (b) (ii) Explain, with the aid of an energy distribution diagram, how the addition of $OP(MeNCH_2CH_3)N$ affects the rate of the above chemical reaction.

……..…….

……..…….

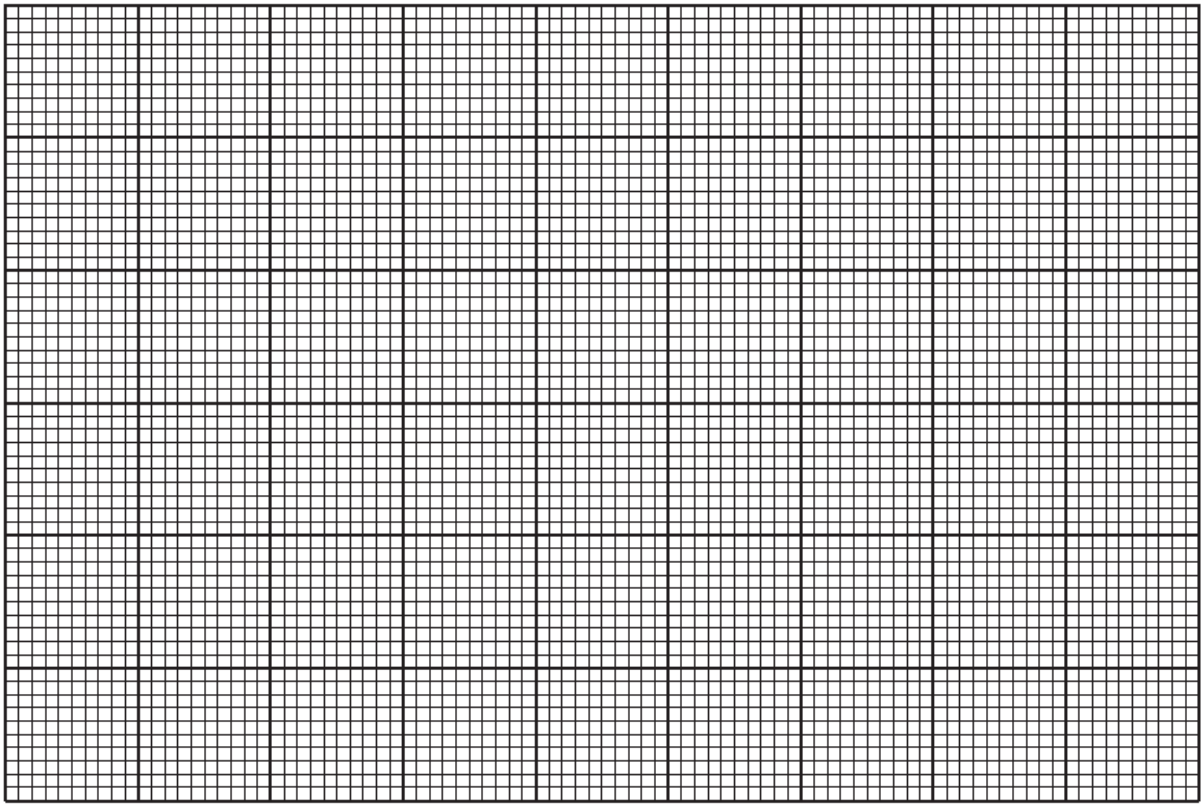
……..…….

……..…….

[3]

2 (b) (iii) The progress of the reaction can be followed by plotting the concentration of isocyanate against time. Plot the experimental results on the grid below to determine the rate equation for this reaction.

Time/ min	[Isocyanate] / mol dm^{-3}
0	0.0100
40	0.0079
80	0.0062
120	0.0049
160	0.0038
200	0.0030
240	0.0024



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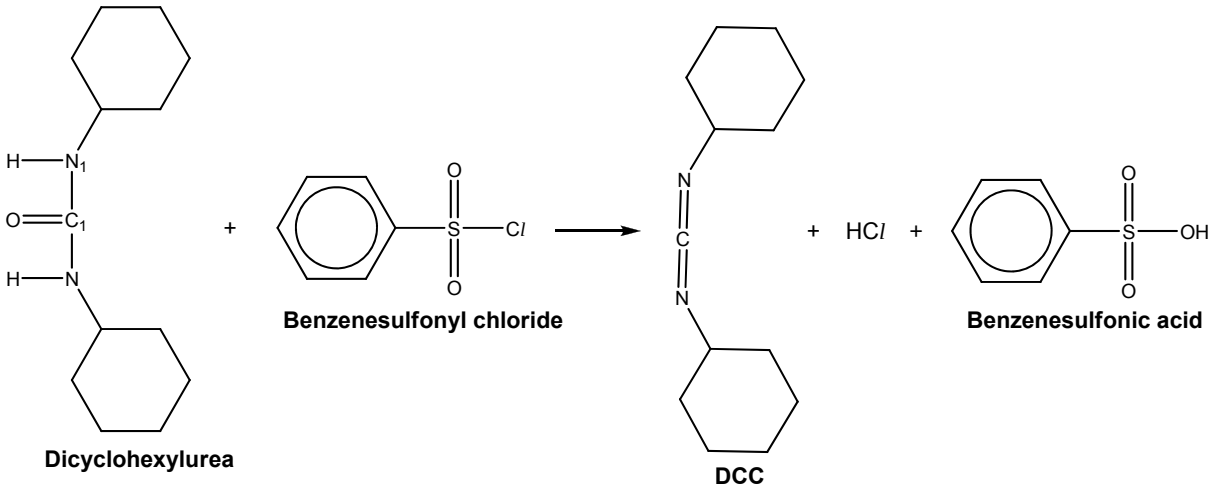
……**[3]**

2 (c) DCC can also be synthesised from dicyclohexylurea and benzenesulfonyl chloride as shown in the following equation.



(i) State the VSEPR (valence shell electron pair repulsion) theory to predict the shape about N_1 and C_1 in dicyclohexylurea.

……

……

……

……

[3]

(ii) Draw the structural formulae of the products formed when dicyclohexylurea reacts with hot aqueous sodium hydroxide.

[2]

2 (c) (iii) Benzenesulfonic acid has a benzene ring. Describe the bonding in benzene in terms of orbital overlap. Draw relevant diagrams to illustrate your answer.

……

……

……

……

[4]

(iv) Weak acids typically have a K_a value that is less than 1. The pK_a value of benzenesulfonic acid is -2.8. Deduce if benzenesulfonic acid is a weak acid.

……

……

[1]

2 (c) (v) Define the term conjugate base. Hence, draw the structural formula for the conjugate base of benzenesulfonic acid.

……

……

[2]

(vi) Benzenesulfonic acid can be converted into benzenesulfonyl chloride by using a period 3 chloride such as phosphorus pentachloride. Two other chlorides of period 3 elements include silicon chloride and magnesium chloride.

Using the chlorides of magnesium, silicon and phosphorus as examples, describe the reactions of the chlorides of the third period of the Periodic table with water, writing equations where appropriate.

Hence, suggest what influence the type of bonding present in these chlorides has on their reaction with water.

……

……

……

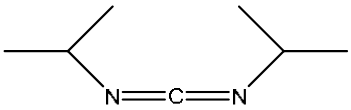
……

……

……

[5]

2 (d) N,N-diisopropylcarbodiimide, DPC, was developed as an alternative to DCC. DPC is identical to DCC in nearly every way except that DPC is less likely to cause an allergic reaction. Furthermore, as a liquid, DPC is easier to handle than DCC which is a waxy solid. Explain the difference in physical states between DCC and DPC.



DPC

……...…….

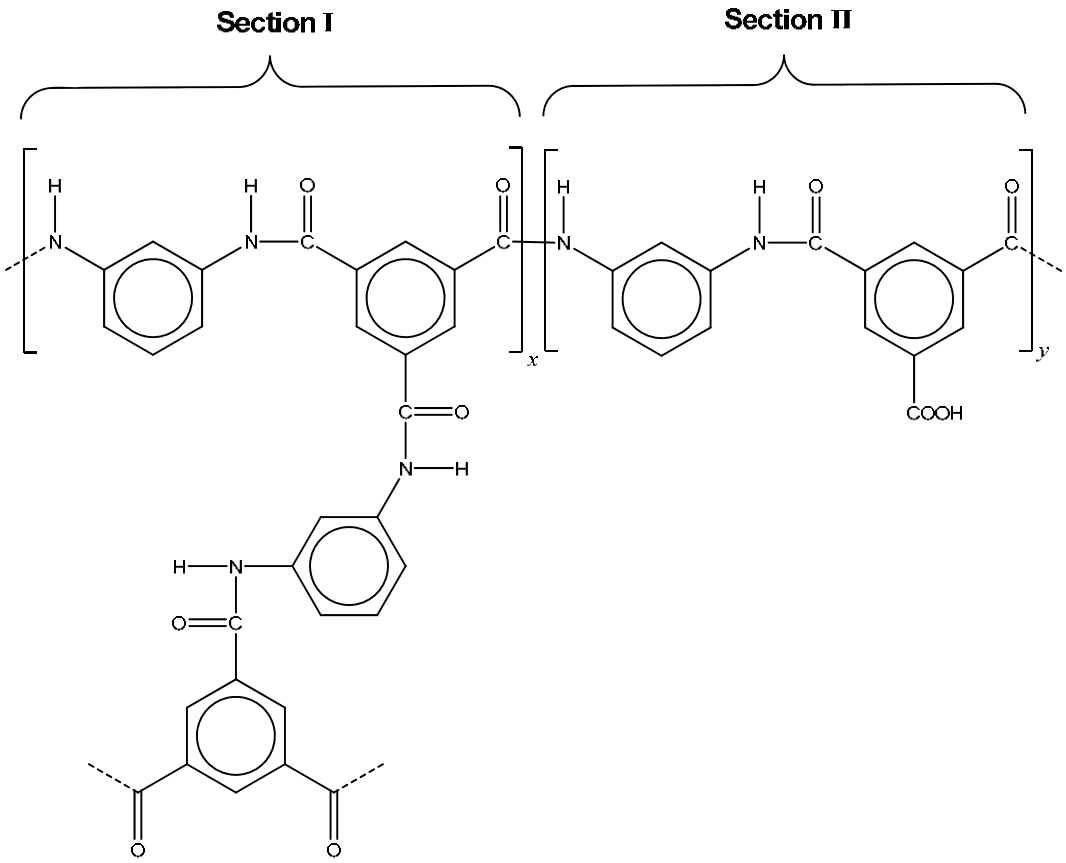
……...…….

……...…….

[2]

[Total: 29]

3 Nomex is a class of aramid fibres used as a heat-resistant and strong synthetic fibres in aerospace and military applications. Two sections of the polymer, Nomex, is as shown below.



Nomex

(a) Define polymer.

……

……

[1]

3 (b) (i) With reference to Section **II**, draw the structural formula of the monomers in Nomex. Hence, state the type of polymerisation involved.

Monomers:

Type of polymerisation: …….. **[3]**

(ii) Classify the polymer represented by Section **I**. Hence, use its structure to explain a property of this polymer.

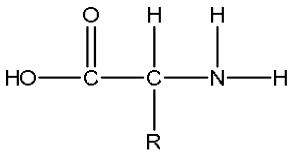
……..……..

……..……..

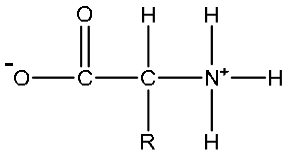
……..……..…

[3]

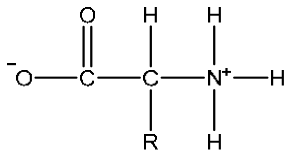
(c) Wool is a texture fibre obtained from sheep and other animals. Wool consists of a polymer chain constructed from amino acids. The general structure of an amino acid is as shown below.



In water, amino acids forms zwitterions as shown below.

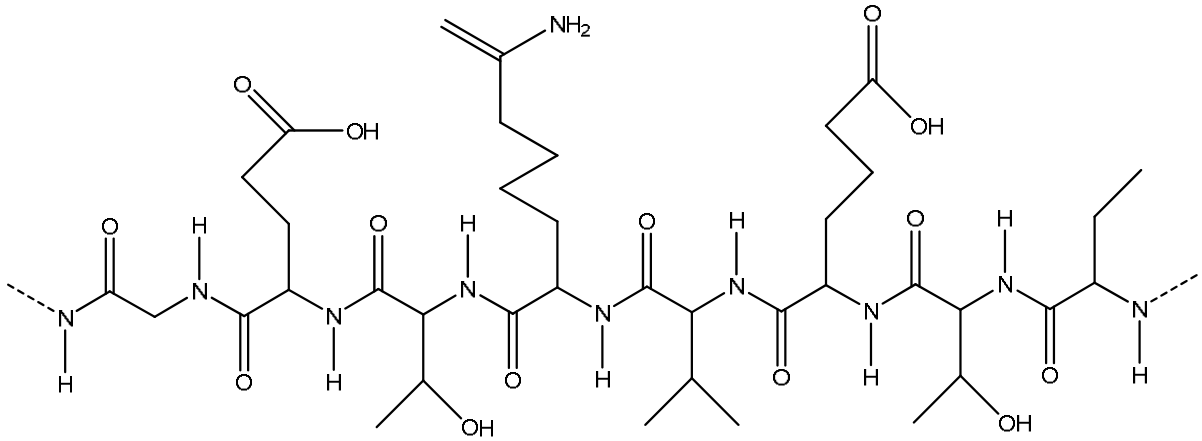


3 (c) (i) Hygroscopy is the phenomenon of attracting moisture from the surrounding environment. Using the structure of zwitterion in the diagram below, show with the aid of a labelled diagram the hygroscopic nature of zwitterions.



[2]

The structure of a section of wool is shown below. This section consists of a number of amino acids.



(ii) On the structure above, **circle** and **name** 4 different functional groups present in wool.

Functional groups:

……..……..

[2]

(iii) How many amino acids are present in this portion of wool?

……....**[1]**

[Turn Over

3 **(c)** **(iv)** One of these amino acids are present more than once. Draw the displayed formula for this amino acid.

[1]

(d) Silver nanoparticles are used to colour wool fibres as well as to impart antimicrobial properties. Define the term nanoparticles and explain with reference to its structure, the advantages of using silver nanoparticles.

……..……....……

……..……....

……..……

[2]

[Total: 15]

Section B

Answer **one** question from this section, in the spaces provided.

1 (a) (i) State the type of bonding in magnesium and chlorine. Use a labelled diagram to illustrate each of your structure.

…….....

…….....

[4]

(ii) Describe the structure of graphene.

…….....

…….....

[2]

(iii) State the similarities in the structure of magnesium and graphene that allow both of them to conduct electricity. Hence, state another physical property that both magnesium and graphene will have in common.

…….....

…….....

[2]

1 (b) Magnesium is an element in Period 3.

(i) Define the term nucleon number.

……

……

[1]

In a particular experiment set-up, protons are deflected through an angle of +15°.

(ii) State one way in which the behaviour of electrons in an electric field differs from that of protons.

……

……

[1]

(iii) Calculate the angle of deflection of a Mg^+ particle.

[1]

(iv) Explain how the first ionisation energy of Mg would vary with the element before and after it.

……

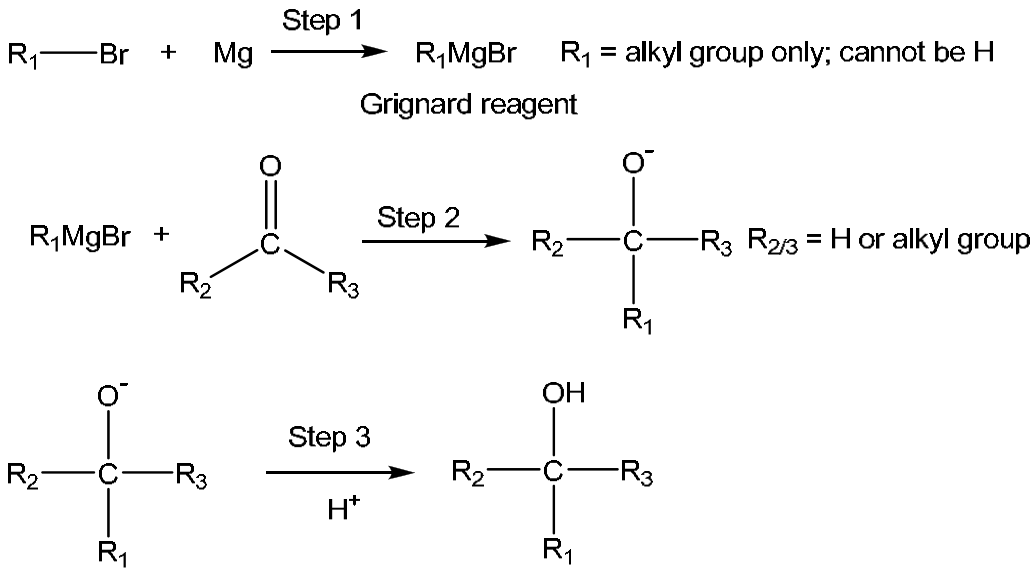
……

……

……

[3]

1 (c) Grignard reagents are formed by the reaction of magnesium metal with an organic compound. They can then be used to react with a carbonyl compound to obtain an alcohol as the final product. This is known as the Grignard reaction and can be represented by the following reaction scheme.



(i) Name the functional group of the organic compound that reacted with magnesium to form the Grignard reagent in Step 1.

.....

[1]

(ii) Suggest the type of reaction that took place in Step 2.

.....

[1]

1 (c) (iii) Draw the structural formula and give the IUPAC name of the alcohol that is formed when bromoethane was used to form the Grignard reagent and subsequently reacted with butanal.

……

[2]

(iv) Butan-2-ol is an alcohol that can be obtained via the Grignard reaction. Draw the structure of a primary alcohol that is a constitutional isomer of butan-2-ol.

[1]

(v) Suggest the functional group of the compound formed when carbon dioxide, CO_2, is used in the Grignard reaction instead of the carbonyl compound.

……

[1]

[Total: 20]

2 Aluminium and sulfur are elements found in Period 3. When burnt in excess oxygen, their oxides, Al_2O_3 and SO_3, will be produced.

(a) Using relevant equations, justify the nature of both oxides.

……..

……..

……..

[3]

(b) **(i)** Draw the dot-and-cross diagram of SO_2.

[1]

(ii) Hence or otherwise, deduce whether SO_2 or SO_3 has a smaller bond angle and explain your answer.

……

……

[1]

2 Sulfuric acid (H_2SO_4) is a commonly used chemical reagent in many industrial processes and is manufactured through the Contact process. This takes place in 3 stages.

Stage 1:

In this stage, SO_2 is produced via burning pyrite, a compound containing only Fe and S, in excess oxygen. The equation at this stage is as follows:

$$4FeS_{\mathbf{x}}\,(s) + 11O_2\,(g) \longrightarrow 2Fe_2O_3(s) + 4\mathbf{x}SO_2(g)$$

Stage 2:

In this stage, the SO_2 produced is converted to SO_3 according to the following equation:

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -\,197\ \text{kJ mol}^{-1}$$

Stage 3:

In this stage, the SO_3 produced is converted to H_2SO_4 via 2 reactions. The first reaction involves dissolving the SO_3 produced in concentrated H_2SO_4 to obtain $H_2S_2O_7$.

The $H_2S_2O_7$ produced can then be safely added to water to produce H_2SO_4 in the second reaction. The equations at this stage are as follows:

$$H_2SO_4\,(l) + SO_3\,(g) \longrightarrow H_2S_2O_7(l)$$

$$H_2S_2O_7(l) + H_2O(l) \longrightarrow 2H_2SO_4\,(l)$$

To produce H_2SO_4 in a laboratory, a technician would first burn 10 g of pyrite in excess oxygen. The SO_2 produced would then be extracted and pumped into a 2 dm^3 vessel with more oxygen and allowed to react again at a moderately high temperature. When equilibrium has established, the SO_3 produced was quickly extracted and pumped into 50 cm^3 of concentrated H_2SO_4 before the resultant solution was added to 50 cm^3 of deionised water to produced H_2SO_4.

The H_2SO_4 produced was tested for its concentration where 25.0 cm^3 of the resultant solution required 23.50 cm^3 of 2.00 mol dm^{-3} NaOH for complete titration.

(c) **(i)** Given that pyrite contained 53.5% of sulfur by mass, show that the value of **x** in $FeS_{\mathbf{x}}$ is 2.

[1]

2 **(c)** Using the information given above,

(ii) Calculate the number of moles of SO_2 produced from the combustion of pyrite.

[1]

(iii) Calculate the total number of moles of H_2SO_4 obtained by the technician and hence the number of moles of SO_3 produced.

[2]

(iv) Write an expression for the equilibrium constant, K_c, for the Contact process in **stage 2**.

[1]

2 (c) (v) Using your answers obtained in **2(c)(ii) – (iv)**, complete **Table 2.1**.

Table 2.1

	SO_2	O_2	SO_3
initial amount/mol		1	
change/mol			
equilibrium amount/mol			

Hence or otherwise, calculate the value of K_c.

[2]

(vi) To ensure a reasonable yield of SO_3, the technician conducted the reaction between SO_2 and O_2 at moderately high temperatures. Explain why this is so.

……

……

……

[2]

2 (d) **X** has a molecular formula of $C_4H_{10}O_2$. 1 mole of **X** reacts with 1 mole of sodium to give 1 mole of hydrogen gas.

When acidified potassium manganate (VII) is heated with **X**, the solution turns colourless to give only **Y**.

When 1 mole **Y** is added to methanol in the presence of concentrated sulfuric acid, **Z** is obtained together with 2 moles of water.

Deduce the structures of **X**, **Y** and **Z**, explaining the chemistry of the reactions described.

[6]

[Total: 20]

END OF PAPER

Worked Solution for 2018 H1 Chem Prelim

1	2	3	4	5	6	7	8	9	10
B	**B**	**B**	**A**	**A**	**B**	**C**	**D**	**C**	**B**
11	12	13	14	15	16	17	18	19	20
B	**C**	**B**	**C**	**C**	**D**	**B**	**C**	**D**	**A**
21	22	23	24	25	26	27	28	29	30
D	**A**	**B**	**A**	**D**	**B**	**B**	**C**	**A**	**C**

1 *Use of the Data Booklet is relevant to this question.*

Which sample of gas contains the same number of atoms as 2 g of hydrogen gas?

A 22 g of carbon dioxide

B 12 g of steam

C 10 g of neon

D 8 g of methane

Amount of H_2 = 2/2 = 1 mol
Number of moles of H atoms = 2

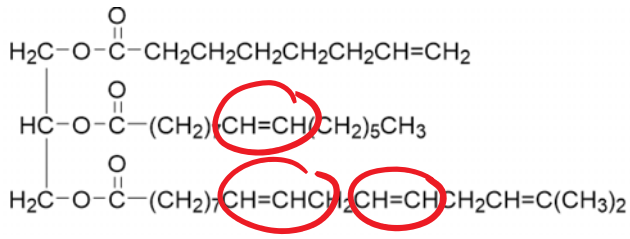
Amount of CO_2 gas = 22/44 = 0.5 mol
Number of moles of atoms of CO_2 = 0.5 x 3 = 1.5 mol

amount of H_2O = 12/18 = 2/3 mol
Number of moles atoms from H_2O = 2/3 x 3 = 2 mol

Amount of Ne gas = Number of moles of atoms = 10/20 = 0.5 mol

Amount of methane = 8/16 = 0.5 mol
Number of moles of atoms from methane = 0.5 x 5 = 2.5 mol

2 The diagram shows the structure of a tri-ester.



What is the total number of cis-trans isomers possible for this tri-ester?

Criteria of cis-trans; C=C and different atoms/grps attached to the C in C=C.

A 2^1 **B** 2^3 **C** 2^4 **D** 2^5

3 Ethanedioate ions, $C_2O_4^{2-}$, are oxidised by acidified aqueous potassium manganate(VII) to give carbon dioxide according to the following equation:

$$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$$

What volume of 0.020 mol dm^{-3} potassium manganate(VII) is required to completely oxidise 1.0 x 10^{-3} mol of the salt $KHC_2O_4.H_2C_2O_4$?

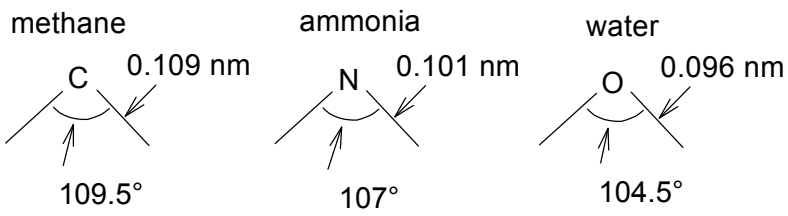
A 20 cm^3 **B** 40 cm^3

C 80 cm^3 **D** 100 cm^3

Mole ratio of MnO_4^- : $C_2O_4^{2-}$ = 2: 5

Amount of $C_2O_4^{2-}$ = 2(1.0 x 10^{-3})
= 2.0 x 10^{-3} mol
Amount of MnO_4^- = 2/5 x 2.0 x 10^{-3}
= 0.0008 mol
Volume of MnO_4^- = 0.0008 / 0.020
= 40 cm^3

4 The bond lengths and bond angles in the molecules of methane, ammonia and water may be represented as follow:



What causes this trend in the bond angles shown?

1 Lone pair–bond pair repulsion is greater than bond pair-bond pair repulsion.

2 Decreasing repulsion between the bond pair of electrons as the electronegativity of the central atom increases.

3 Increasing repulsion between hydrogen atoms as the bond length decreases.

Bond angle in a molecule depends on the number of bond pair and lone pair of electrons. By VSEPR theory, lone pair-lone pair repulsion > lone pair-bond pair repulsion > bond pair-bond pair repulsion.

Methane: 4 bond pairs around C
Ammonia: 3 bond pairs, 1 lone pair around N
Water: 2 bond pairs, 2 lone pairs around O

Hence, option 1is correct.

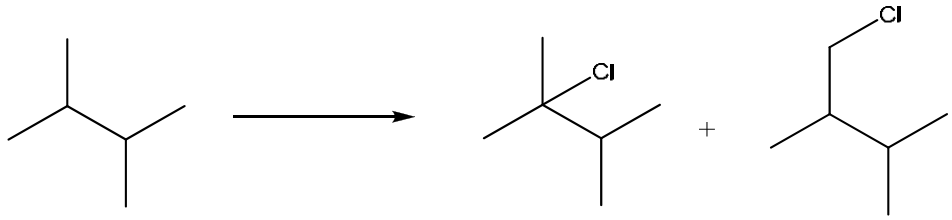
A **1** only

B **1** and **2** only

C **2** and **3** only

D **1**, **2** and **3**

5 2,3-Dimethylbutane can undergo free radical substitution with chlorine gas. Ignoring any stereoisomers, how many different mono-chlorinated organic products are formed when it is heated with limited chlorine gas?



A 2 **B** 3 **C** 4 **D** 6

6 Which statement about Group 1 metals is correct?

A Melting point increases down the group.

False: strength of metallic bond depends on the size of cation and no of delocalised electrons. Down the grp, ionic radius increases, hence weaker the attraction b/w sea of delocalised electrons and cation. Thus weaker the metallic bond strength.

B Reducing strength increases down the group.

Down the grp, size of cation increases hence weaker the attraction of valence electrons to the nucleus. Thus, it is easier to lose electron down the group → stronger the reducing agent.

C Each ground state atom contains a pair of electrons in its valence shell.

False: The atom contain an electron

D The second electron is more difficult to be removed than the first electron, as M^+ has a noble gas configuration.

False: it is more difficult to lose the 2nd electron as a lot of energy is required to remove the inner quantum shell electrons since it is nearer to the nucleus, which experience strong attraction.

7 An enzyme may be described as being specific in its activity.
What is meant by this this statement?

A The enzyme will denature at high temperature.

B The enzyme helps to increase the speed of a chemical reaction.

C The enzyme will catalyse a narrow range of chemical reactions.

D The enzyme is a biological catalyst which remains chemically unchanged at the end of the reaction.

8 Chlorate (I) ion undergoes disproportionation to give chloride ion and another chlorine containing product.

Which of the following could be the chlorine-containing product?

Disproportionation: same element is oxidised and reduce at the same time.

Chlorate (I) ion, Cl = +1

Chloride, Cl = -1

Hence the other Cl shd have a O.S higher than +1

A Cl_2

O.S of Cl = zero

B Cl_2O

O.S of Cl = +1

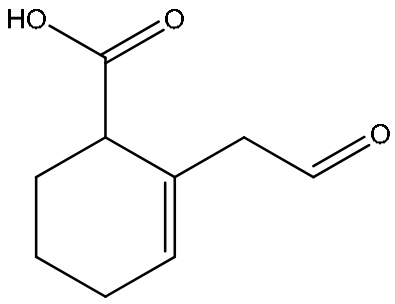
C ClO^-

O.S of Cl = -1 + 2 = +1

D ClO_3^-

O.S of Cl = -1 + 6 = +5

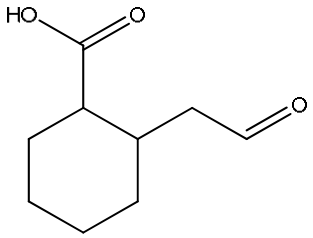
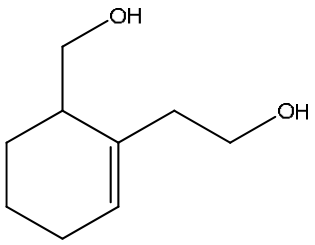
9 Which are the products formed when compound **X** reacts with the following reducing agents?

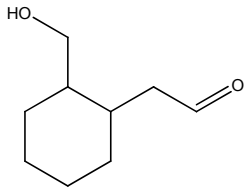
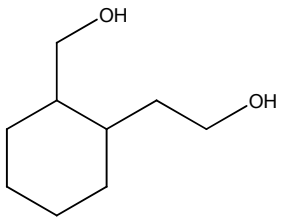
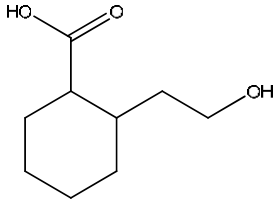
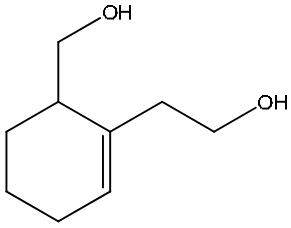
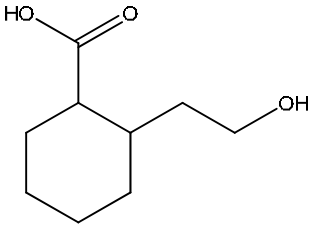
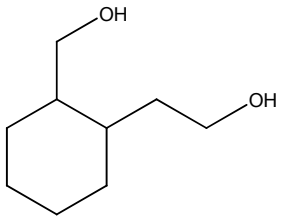


compound **X**

H2, Pt: reduce alkenes → alkanes and aldehyde → primary alcohol

LiAlH4 in dry ether: reduce carboxylic acid → primary alcohol and aldehyde → primary alcohol

	H_2, Pt	LiA/H_4 in dry ether
A		

B		
C		
D		

10 A substance **Y** has the following properties.

- melting point – 39 ^{0}C
- boiling point 357 ^{0}C
- conduct electricity when solid and molten

What is the structure of **Y**?

Since X can conduct electricity when solid and molten it must be metallic or giant molecular (graphite). All giant molecular cpd will have high melting and boiling point.

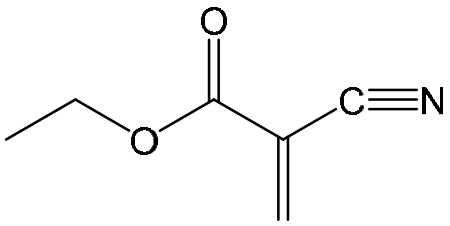
A ionic

B metallic

C giant molecular

D simple molecular

11 Ethyl cyanoacrylate, $C_6H_7O_2N$, is the major component of superglue.



ethyl cyanoacrylate

Which statements about the molecule are true?

1 It contains 5 lone pairs of electrons.
True: 2 lone pairs on each of oxygen atom and 1 lone pair of electrons on N.

2 It reacts with Br_2 to give a pair of cis-trans isomers.
False: no cis-trans in the product due to the absence of C=C

3 It contains 4 π bonds.
True: 1 π on C=O and C=C and 2 π on CN.

4 It can be hydrolysed by dilute NaOH to give a carboxylic acid and an alcohol.
False: carboxylate salt is formed due to alkaline condition.

A **1** only

B **1** and **3** only

C **2** and **3** only

D **3** and **4**

12 Which equation represents the third ionisation energy of bromine?

A $Br\ (g) \rightarrow Br^{3+}(g) + 3e$

B $Br^{2-}(g) + e \rightarrow Br^{3-}(g)$

C $Br^{2+}(g) \rightarrow Br^{3+}(g) + e$

D Br (g) + 3e → Br^{3-}(g)

13 When 20 cm^3 of 0.5 mol dm^{-3} NaOH(aq) is neutralised with an equal volume of 0.5 mol dm^{-3} HNO_3(aq), the temperature of the mixture rose by 5.2 °C.

What would be the temperature change if 40 cm^3 of 0.25 mol dm^{-3} NaOH(aq) is reacted with an equal volume of 0.25 mol dm^{-3} HNO_3(aq)?

Magnitude of temperature rise depends on moles of water produced and the total volume of solution.

Temperature increases with no of moles of water produced.
Temperature decreases with volume of solution. since q = mcΔT

Experiment 1: mole of water produced = 0.01 mol
Total volume = 40 cm^3

Experiment 2: mole of water produced = 0.01 mol
Total volume = 80 cm^3

Since volume is doubles as compared to experiment 1, ΔT will be reduced by half; 5.2/2 = 2.6 °C

A 1.3 °C **B** 2.6 °C **C** 5.2 °C **D** 10.4 °C

14 Iodine–131 is a radioactive isotope with a half-life of 10 days. Given that radioactive decay is a first-order reaction, what fraction of the isotope would remain after 50 days?

No of half- life = 50/10 = 5

1 → 1/2 →1/4→ 1/8 →1/16→ 1/32

A $\frac{1}{10}$ **B** $\frac{1}{20}$ **C** $\frac{1}{32}$ **D** $\frac{1}{50}$

15 The molar mass of ethanoic acid is 120.0 g mol^{-1} when dissolved in ether but 60.0 g mol^{-1} when dissolved in water.

Which one of the following statements best explains the phenomenon?

Mr x 2 → dimer is only formed (via hydrogen bonding) when ethanoic acid is dissolved in ether.

A Ethanoic acid is more soluble in ether than in water.

B Ethanoic acid molecules form strong covalent bonds with ether molecules.

C Ethanoic acid molecules form extensive hydrogen bonds with water molecules.

D Ethanoic acid molecules form dative bonds with another ethanoic acid molecule when dissolved in ether.

16 The enthalpy change of reaction for the conversion of sulfur dioxide to sulfur trioxide is shown below.

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \qquad \Delta H = -196\ \text{kJ mol}^{-1}$$

Which of the following statements is correct?

A When the volume of the vessel is compressed, the yield of SO_3 decreases.

False: Pressure is increases. POE shifts right where there are fewer gaseous particles.

B When a catalyst is introduced to the system, the yield of SO_3 increases.

False: Catalyst only increases the rate of reaction.

C When the temperature is increased, only the rate of the backward reaction is increased.

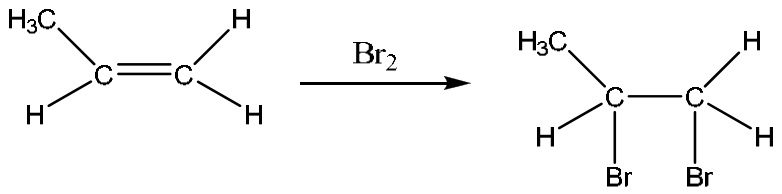
False: rate of backward and forward will increases with temperature but to different extent.

D When the temperature is increased, K_c decreases.

True: temperature is increased, POE shifts left to favour endothermic reaction to absorb excess heat. Rate of backward reaction increases more than forward. Hence Kc decreases.

17 Bromine has two isotopes, ^{79}Br and ^{81}Br.
Propene can react with bromine liquid in the dark to form organic products with different relative molecular mass.

How many different relative molecular mass values does the organic products have?



A 2

B 3 (^{79}Br ^{81}Br, ^{79}Br ^{79}Br or ^{81}Br ^{81}Br)

C 4

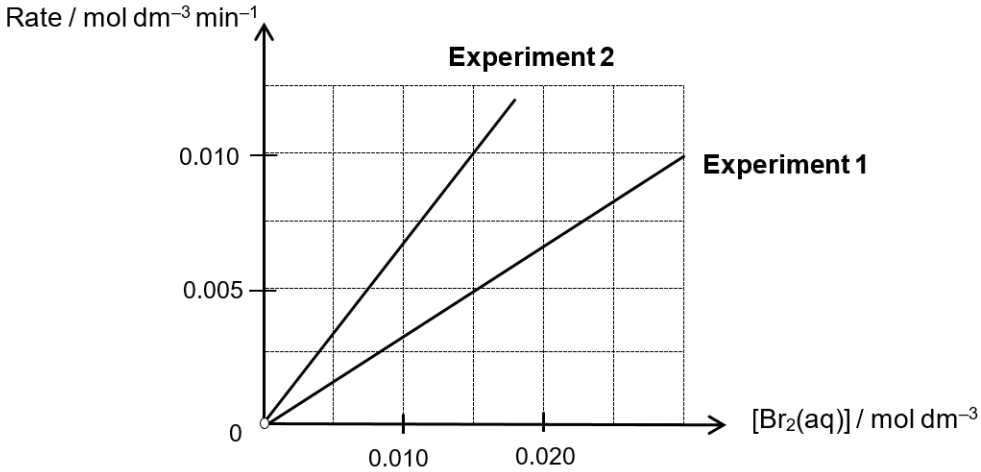
D 5

18 Two separate experiments were conducted to study the kinetics of the following reaction in the presence of excess methanoic acid.

$$HCO_2H(aq) + Br_2(aq) \rightarrow 2H^+(aq) + 2Br^-(aq) + CO_2(g)$$

Experiment	Initial $[HCO_2H]$ / mol dm^{-3}
1	0.8
2	1.6

The experimental results were represented in the graph as shown.



Which of the following is the correct rate equation for above the reaction?

Straight line, rate is **directly proportional** to $[Br_2]$. 1st order w.r.t to [Br]

Comparing 2 experiments,
When $[Br_2]$ is the same in both experiments, the rate increases by 2x when $[HCO_2H]$ increase by 2 times. Hence it is 1st order reaction w.r.t to $[HCO_2H]$

A Rate = k $[Br_2]$

B Rate = k $[HCO_2H]$

C Rate = k $[HCO_2H][Br_2]$

D Rate = k $[HCO_2H]^2[Br_2]$

19 The chloride of **X** and oxide of **Y** respectively are separately mixed with water. The two resulting mixtures have different effect on litmus.

Which of the following represents the correct elements?
$AlCl_3$, $MgCl_2$, $SiCl_4$ and PCl_5 hydrolyses in water to give H^+
SO_3 and P_4O_{10} are acidic oxide
MgO and NaO basic oxide

	X	**Y**
A	Al	S

B	Mg	P
C	Si	P
D	P	Na

20 A pure sample of $NH_3(g)$ is introduced into a vessel of constant volume and an equilibrium is established as shown below.

$$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$$

The value of the final pressure is then found to be 25 % greater than if only NH_3 were present. What is the mole fraction of N_2 in the reaction mixture?

A 0.10

B 0.25

C 0.45

D 0.75

	$2NH_3(g)$	$\leftrightarrow N_2(g)$	$+ 3H_2(g)$
Initial/ mol	1	0	0
Change/mol	-2x	+x	+3x
Equilibrium/mol	1-2x	x	3x

Pressure α moles since Pt is found to be 25% more at equilibrium as compared to initial; this implies that the total no of moles is 1 x 125%= 1.25 mol

1.25 = 1-2x + x + 3x

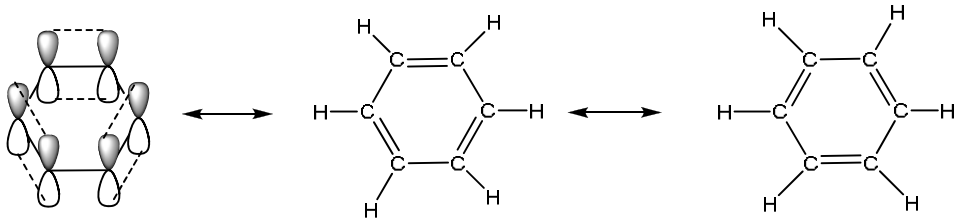
0.25 = 2x

0.125 = x

Mole fraction of N_2 = x/(1+2x) = 0.125/1.25 = 0.10

21 What is the correct description of the bonding between the two carbon atoms in benzene?

Benzene, C_6H_6



A two pi bonds that are longer than a C—C single bond.

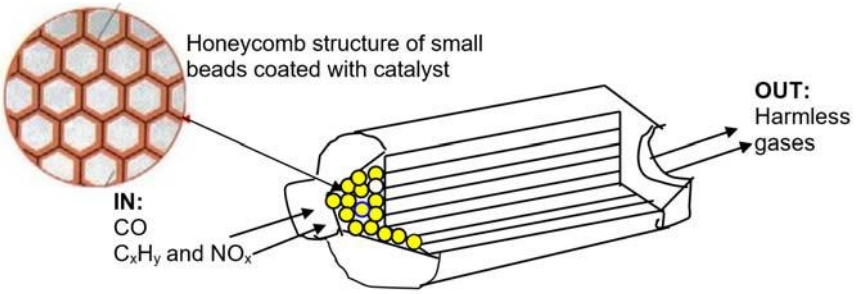
B two pi bonds that are shorter than a C—C single bond.

C a sigma and a pi bond that are longer than a C—C single bond.

D a sigma and a pi bond that are shorter than a C—C single bond.

(C-C bond in benzene is like a 1.5 C=C bond)

22 Catalytic converters in car exhaust system helps to convert harmful emission gases into harmless ones. The following diagram shows the interior of a catalytic converter.



Which of the following statement is correct?

A The forces of attraction holding the carbon monoxide, unburnt hydrocarbons and oxides of nitrogen onto the surface of the catalyst are stronger than the forces of attraction holding on the product molecule onto the surface.

B The catalyst coated on the honeycomb surface provides a small (shd be large) surface area to volume ratio to increase the rate of reaction.

C Homogenous (shd be heterogenous) catalyst is used in the catalytic converted to lower the activation energy for conversion of harmful gases

D Nitrogen dioxide gas (N_2 gas) is one of the products of the reactions.

23 What is the electronic configuration of copper in Cu_2O?

O.S of Cu in Cu_2O = +1

Cu = [Ar] $3d^{10}4s^1$

Cu^+ = [Ar] $3d^{10}$

A [Ar] $3d^9$

B [Ar] $3d^{10}$

C [Ar] $3d^9 4s^1$

D [Ar] $3d^9 4s^2$

24 Which of the following statements about the Period 3 elements sodium to chlorine, and their compounds, is correct?

1 The ionic radius decreases across the period.
Size of cation and anion decreases across the period. However, the ionic of all cations is smaller than the anions across the period.

2 The oxide of the elements become more acidic across the period.
Basic oxide → amphoteric oxide → acidic oxide

3 The boiling points of the elements decreases in the order phosphorus, sulfur, chlorine.
Boiling point of P_4 < S_8 (highest boiling point due to larger electron cloud→ stronger id-id)
Boiling point of S_8 > Cl_2

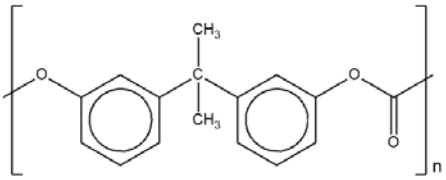
A 2 only

B 2 and 3 only

C 1 and 2 only

D 1,2 and 3

25 Polycarbonates (PC) are polymers containing carbonate groups in their chemical structures. Some major smartphone manufacturers such as Samsung and Apple started using PC in their phones casing.



PC

Which row correctly describes PC?

	type of polymer	reaction of polymer with ethanoic acid
A	addition	no reaction
B	condensation	no reaction
C	addition	hydrolysis
D	condensation	hydrolysis

Ester bond in the polymer chain→ condensation polymerisation which can hydrolyses in acidic medium (vinegar solution is ethanoic acid)

26 Which reaction will give propanoic acid as one of the products?

A heating $CH_3CH_2CH_2OH$ under immediate distillation with potassium dichromate.

Aldehyde is formed

B heating $CH_3CH_2CONHCH_3$ under reflux with dilute aqueous sulfuric acid.

Acidic hydrolysis → $CH_3CH_2COOH + CH_3NH_3^+$

C heating $CH_3CH_2OCOCH_3$ under reflux with dilute aqueous sulfuric acid.

Acidic hydrolysis → $CH_3CH_2OH + CH_3COOH$

D heating $CH_3(CH_2)_2COOCH_3$ under reflux with dilute aqueous sulfuric acid.

$CH_3(CH_2)_2COOCH_3 \rightarrow CH_3(CH_2)_2COOH + CH_3OH$

27 What is the maximum size, in at least one dimension, of a nanomaterial?

1-100 nm → $100 \times 10^{-9} = 10^{-7}$ m

A 1×10^{-6} m

B 1×10^{-7} m

C 1×10^{-8} m

D 1×10^{-9} m

28 The two most common isotopes of titanium are $^{56}_{22}Ti$ and $^{58}_{22}Ti$.

Which statement about the isotopes of titanium is correct?

A Both isotopes have the same numbers of neutrons.

neutrons = mass no – proton no

B One of the isotopes has more protons than the other.

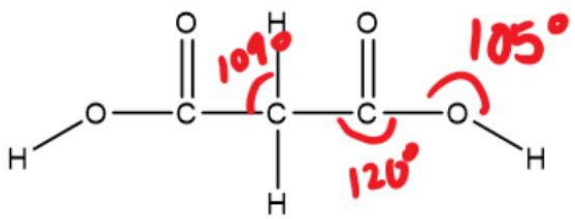
C The electronic configuration of Ti^{2+} ion for both isotopes is the same.

Electronic configuration depends on number of electrons.

D In the same electric field strength, $^{58}_{22}Ti^{+}$ will be deflected more than $^{56}_{22}Ti^{+}$.

Angle of deflection α charge/mass

29 The diagram shows the structure of the malonic acid.



Which of the following shows the correct set of the bond angles present in the malonic acid?

A 105^0, 109^0 , 120^0

B 109^0 , 180^0 only

C 120^0 , 180^0 only

D 105^0, 109^0 only

30 Ammonia gas can react with sodium hydride in the following equation:

$$NH_3 + NaH \rightarrow NaNH_2 + H_2$$

Which statement correctly describes the behaviour of ammonia in this reaction?

A It acts as an Arrhenius acid.

B It acts as an Arrhenius base.

C It acts as Bronsted-Lowry acid.

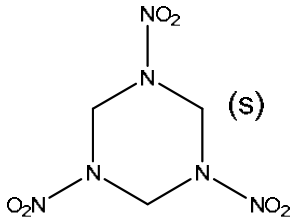
NH_3 donated a H^+ → NH_2^-

D It acts as Bronsted-Lowry base.

END OF PAPER

2018 H1 Chem Prelim P2 (Suggested Solutions)

1 The explosive RDX is a white crystalline solid first prepared in 1899 but wasn't used as an explosive until 1920 by a German chemist called Herz. He prepared RDX by direct nitration of hexamine and found it be very sensitive to denotation by impact or friction. During World War 2, it was added to TNT to increase its explosive power. The explosive decomposition of RDX is as shown by the equation below.



(s) $\longrightarrow$ $3CO\ (g) + 3H_2O\ (g) + 3N_2\ (g)$

RDX

(a) **(i)** Calculate the volume of gases, in cm^3, produced at s.t.p during the explosive decomposition of 2.22 g of RDX given that the relative molecular mass of RDX is 222. [2]

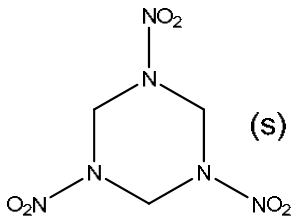
Moles of RDX = 2.22 / 222 = 0.01 mol

Moles of gas formed = 9 x 0.01 = 0.09 mol

Volume of gases = 0.09 x 22.7 = 2.04 dm^3 = 2040 cm^3

(ii) Write an equation to represent the standard enthalpy change of formation of RDX. [1]

$3C(s) + 3H_2(g) + 3N_2(g) + 3O_2(g) \longrightarrow$



(s)

RDX

State symbol needed

(iii) Use the enthalpies of formation shown below to calculate the standard enthalpy change for the explosive decomposition of RDX.

Compound	ΔH_f / kJ mol^{-1}
RDX (s)	+ 62
CO (g)	- 111
H_2O (g)	- 242

[2]

$\Delta H_{decomposition}$ = [3(-111)+3(-242)] – 62]

= - 1121 kJ mol^{-1}

(iv) Scientific literature usually quote the enthalpy change of formation for chemical explosives in kJ kg^{-1}. Calculate the enthalpy change of formation of RDX from kJ mol^{-1} to kJ kg^{-1}. [1]

1 mole = +62 kJ

Hence, 222 g = +62 kJ

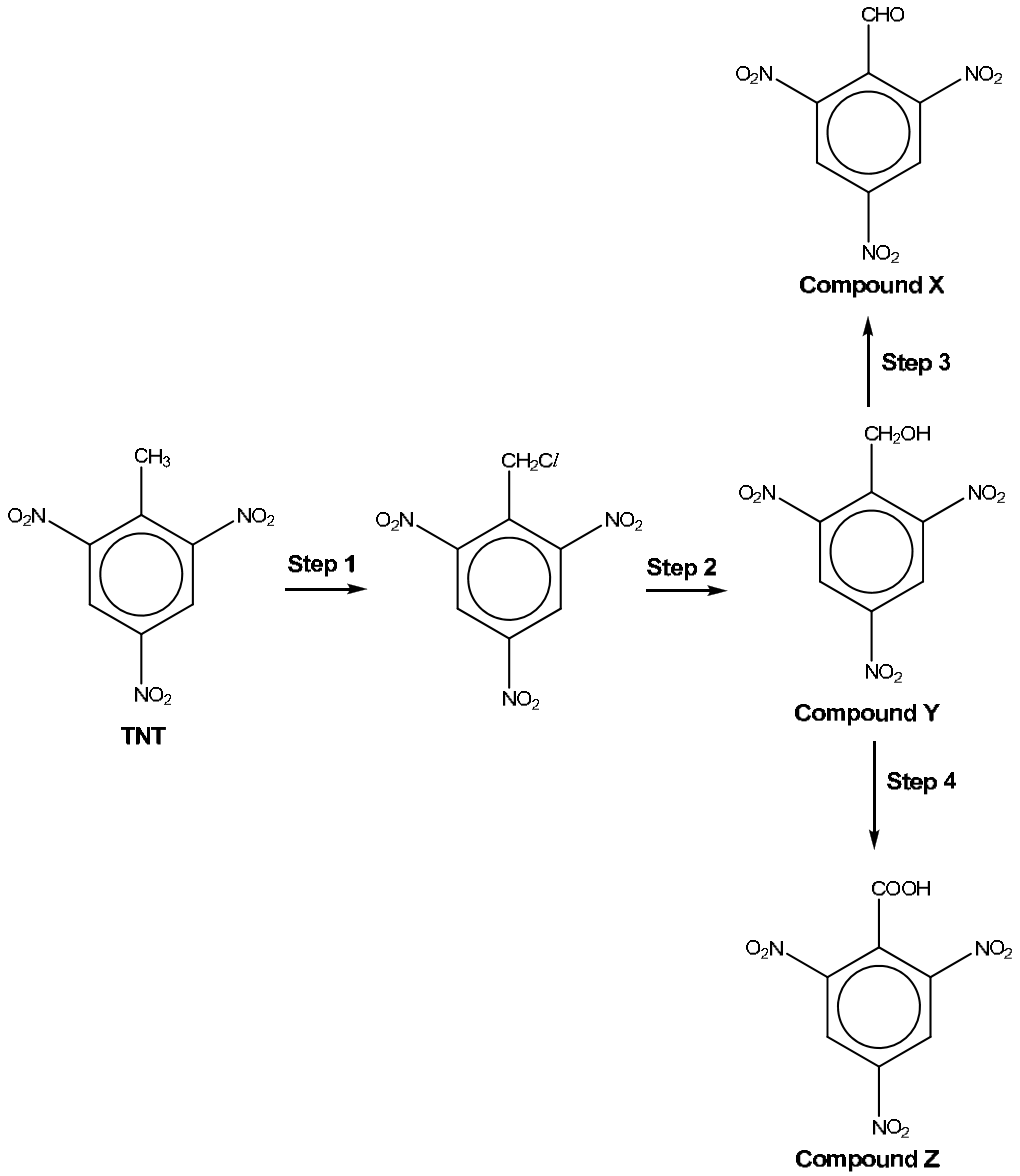
1 kg = + 279 kJ

ΔH_f of RDX = + 279 kJ kg^{-1}

(v) With reference to your answer in **(iii)**, suggest if RDX is more stable than the products of decomposition. [1]

RDX is less stable than the products.

(b) The reaction scheme below shows the reactions involving TNT.



(i) State the reagent and condition for Steps **1 – 4**. [4]

Step 1: limited chlorine, UV light

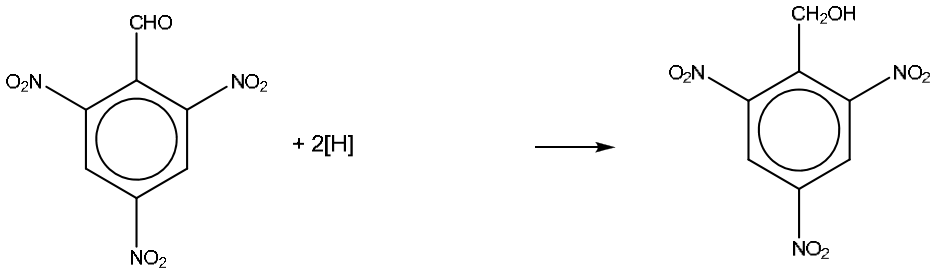
Step 2: NaOH (aq) heat

Step 3: $K_2Cr_2O_7$, H_2SO_4 (aq)/dilute/ heat with distillation

Step 4: $KMnO_4$ / $K_2Cr_2O_7$, H_2SO_4 (aq)/dilute heat

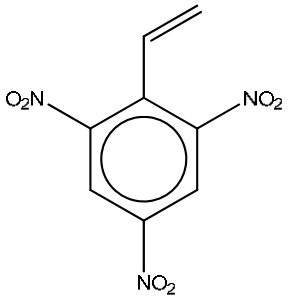
(ii) Besides lithium aluminium hydride, state the reagent and condition that can reduce compound **X** into compound **Y**. Write a balanced equation for this reaction. [2]

$NaBH_4$ or hydrogen gas with nickel/ platinum, heat



Compound X **Compound Y**

(iii) Compound **Z** can also be synthesised by the oxidation of the following compound **W**.



Compound W

State and explain if the above compound exhibits cis-trans isomerism. [1]

Compound W does not exhibit cis-trans isomerism as the carbon of the double bond is connected to the same atom.

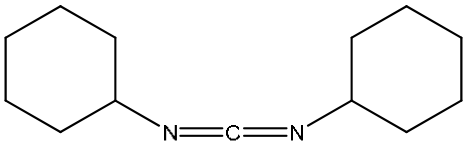
(iv) Suggest a suitable chemical test to distinguish between Compound **W** and TNT. [2]

Reagent and condition: Bromine liquid (dark)

Observation: orange-red will turn colourless for Compound W. orange-red colour will remain for TNT.

[Total: 16]

2 N,N-dicyclohexylcarboiimide often abbreviated as DCC, is used to couple amino acids during artificial peptide synthesis. The structure of DCC is as shown below.



DCC

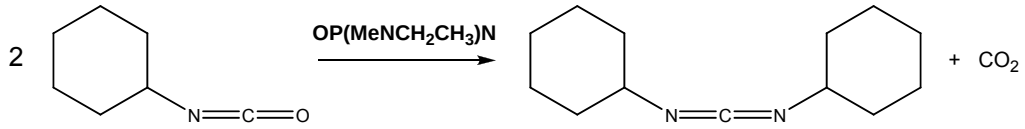
(a) **(i)** Define the term *relative molecular mass*. [1]

The relative molecular mass (M_r) of a substance is defined as the ratio of average mass of one molecule of the substance to $\frac{1}{12}$ the mass of an atom of ^{12}C isotope based on the ^{12}C scale.

(ii) Calculate the relative molecular mass of DCC to 1 decimal place. [1]

$C_{13}H_{22}N_2$. Relative molecular mass = 206.0

(b) DCC can also be prepared by reacting isocyanate in the presence of a catalyst, $OP(MeNCH_2CH_3)N$, as shown by the following equation. The yield of the reaction is typically 92.0%.



Isocyanate **DCC**

(i) A student prepared DCC via the above synthesis method by using 0.100 g of isocyanate and 0.035 g of DCC was produced. Calculate the percentage yield of his experiment and hence suggest if the student's experimental technique is accurate given that the M_r of isocyanate is 125.0. [2]

Mole of isocynate = 0.100 / 125 = 8 x 10^{-4} mol

Mole of DCC = 4 x 10^{-4} mol

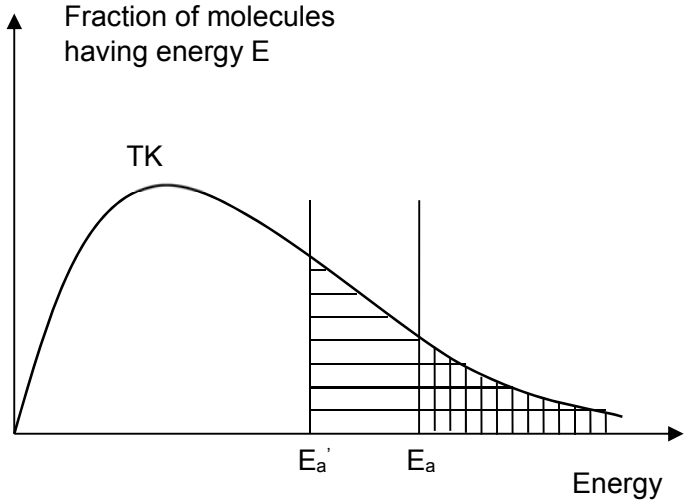
Theoretical yield of DCC = 4 x 10^{-4} x 206 = 0.0824 g

% yield of DCC = 0.035 / 0.0824 x 100% = 42.5 %

(Since % yield is < 92.0%, hence the student's experimental technique is inaccurate.

(ii) Explain, with the aid of an energy distribution diagram, how the addition of $OP(MeNCH_2CH_3)N$ affects the rate of the above chemical reaction. [3]

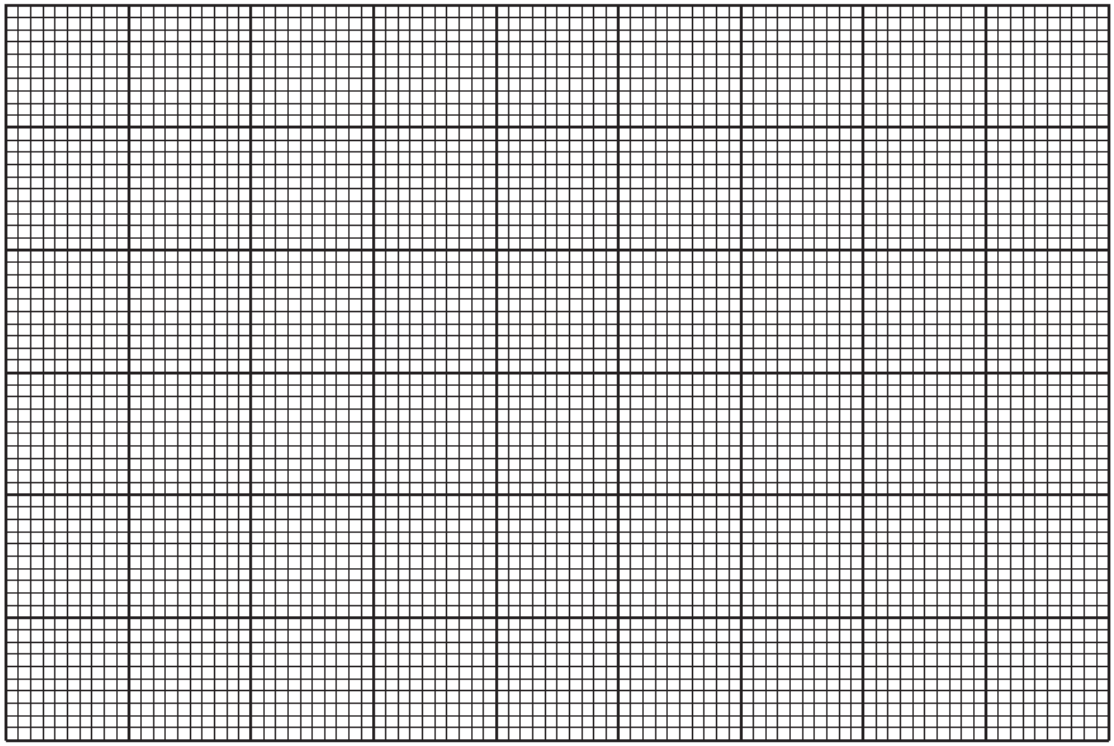
- A catalyst lowers the activation energy of a reaction by providing an alternative reaction pathway.
- Increase in the number of molecules having energy greater than or equal to the lowered activation energy.
- Frequency of effective collisions increases.
- Reaction rate thus increases.
- Diagram

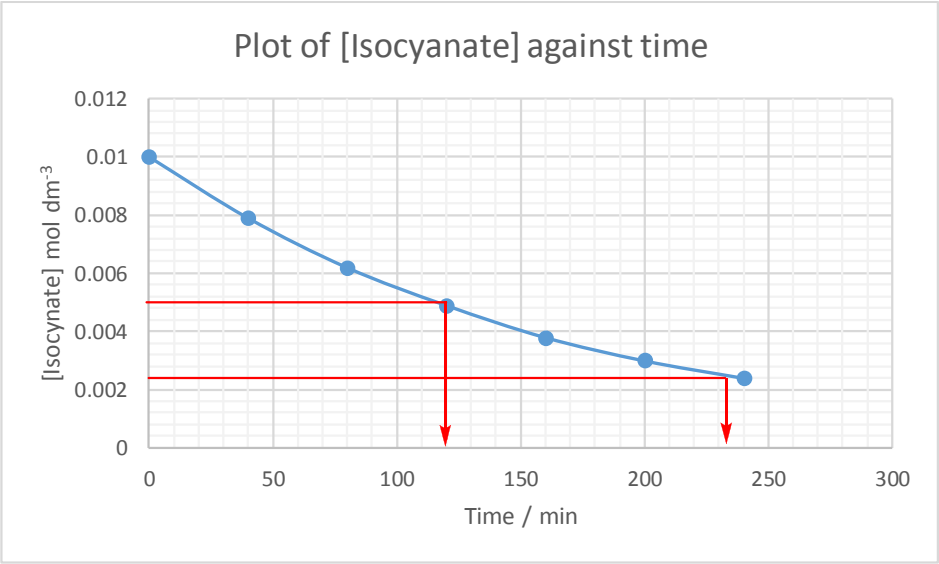


(iii) The progress of the reaction can be followed by plotting the concentration of isocyanate against time. Plot the experimental results on the grid below to determine the rate equation for this reaction.

Time/ min	**[Isocyanate] / mol dm^{-3}**
0	0.0100
40	0.0079
80	0.0062
120	0.0049
160	0.0038
200	0.0030
240	0.0024

[3]



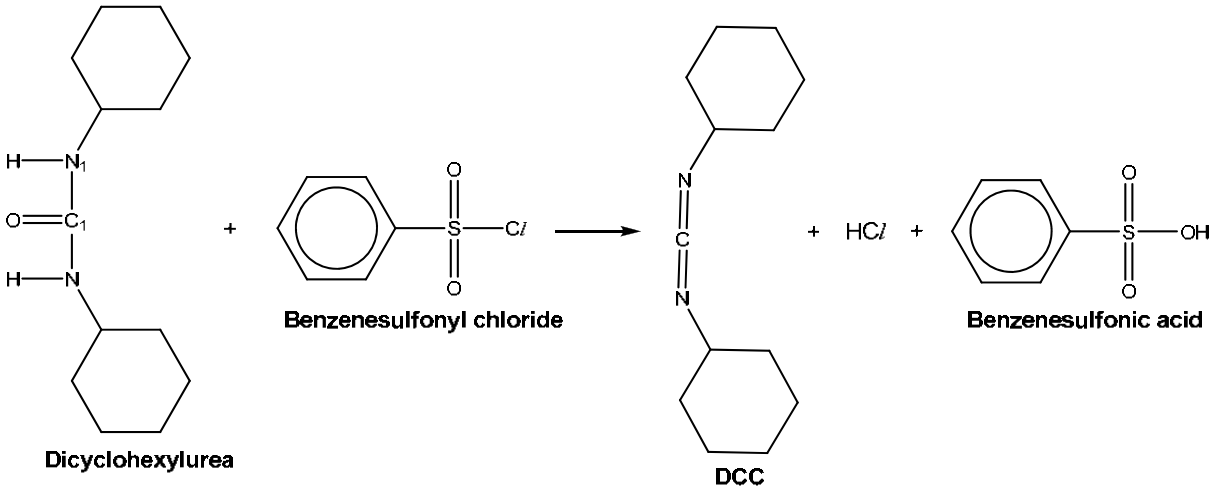


- Plot of graph with axes (and units)
- 1st t ½ = 116 min; 2nd t ½ = 114 min ⇒ Average t ½ = 115 min show on graph or working

- Since t ½ is a constant, order of reaction is 1st order wrt [isocyanate].

Rate = k [isocyanate]

(c) DCC can also be synthesised from dicyclohexylurea and benzenesulfonyl chloride as shown in the following equation.

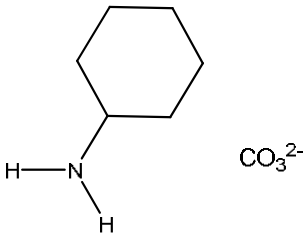


(i) State the VSEPR (valence shell electron pair repulsion) theory to predict the shape about N_1 and C_1 in dicyclohexylurea. [3]

Electron pairs **repel** each other and arrange themselves as far apart as possible to maximise stability and minimise electrostatic repulsion.

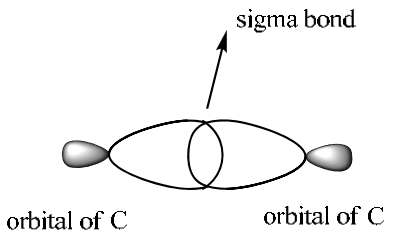
The shape is trigonal pyramidal about N_1 as there are 3 bond pairs and 1 lone pair. The shape is trigonal planar about C_1 as there are 3 bond pairs.

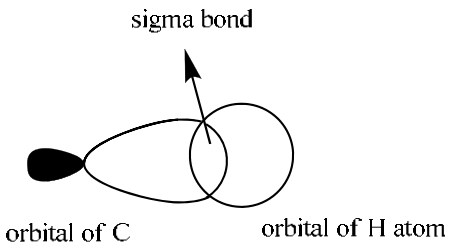
(ii) Draw the structural formulae of the products formed when dicyclohexylurea reacts with hot aqueous sodium hydroxide. [2]

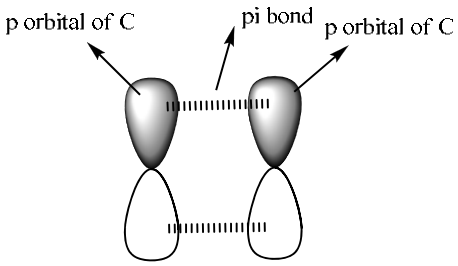


(iii) Benzenesulfonic acid has a benzene ring. Describe the bonding in benzene in terms of orbital overlap. Draw relevant diagrams to illustrate your answer. [4]

- Each carbon atom will overlap head on with 2 neighbouring carbon atom as well as the s orbital of one H atom to form 3 σ (sigma) bonds
- Each carbon will also have an p orbital that would overlap side-on, both above and below the ring of carbon atoms , with the p orbitals of the 2 neighbouring carbon atom, forming a delocalised ring of π (pi) electrons





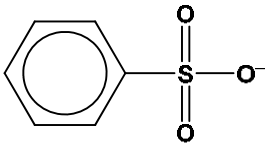


(iv) Weak acids typically have a K_a value that is less than 1. The pK_a value of benzenesulfonic acid is -2.8. Deduce if benzenesulfonic acid is a weak acid. [1]

The K_a of benzenesulfonic acid is $10^{2.8}$, which is **more than one**. Hence, benzenesulfonic acid is not a weak acid.

(v) Define the term conjugate base. Hence, draw the structural formula for the conjugate base of benzenesulfonic acid. [2]

Conjugate base refers to a base **differing from its acid by 1 H^+**.



(vi) Benzenesulfonic acid can be converted into benzenesulfonyl chloride by using a period 3 chloride such as phosphorus pentachloride. Two other chlorides of period 3 elements include silicon chloride and magnesium chloride. [5]

Using the chlorides of magnesium, silicon and phosphorus as examples, describe the reactions of the chlorides of the third period of the Periodic table with water, writing equations where appropriate.

Hence, suggest what influence the type of bonding present in these chlorides has on their reaction with water.

$MgCl_2$ partially hydrolyses in water

$[Mg(H_2O)_6]^{2+}$ (aq) + H_2O (*l*) $\rightleftharpoons$ $[Mg(H_2O)_5OH]^+$ (aq) + H_3O^+ (aq)

$SiCl_4$ and PCl_5 undergo complete hydrolysis in water.

$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

$SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2$ (s) + $4HCl$(aq)

OR

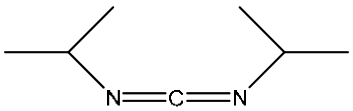
$SiCl_4(l) + 4H_2O(l) \rightarrow SiO_2.2H_2O$ (s) + $4HCl$(aq)

$MgCl_2$ has ionic bonds with covalent character

Chlorides of Si and P have covalent bonds.

As the covalent character of the chlorides increase, the more complete the hydrolysis in water hence producing a more acidic solution.

(d) N,N-diisopropylcarbodiimide, DPC, was developed as an alternative to DCC. DPC is identical to DCC in nearly every way except that DPC is less likely to cause an allergic reaction. Furthermore, as a liquid, DPC is easier to handle than DCC which is a waxy solid. Explain the difference in physical states between DCC and DPC.



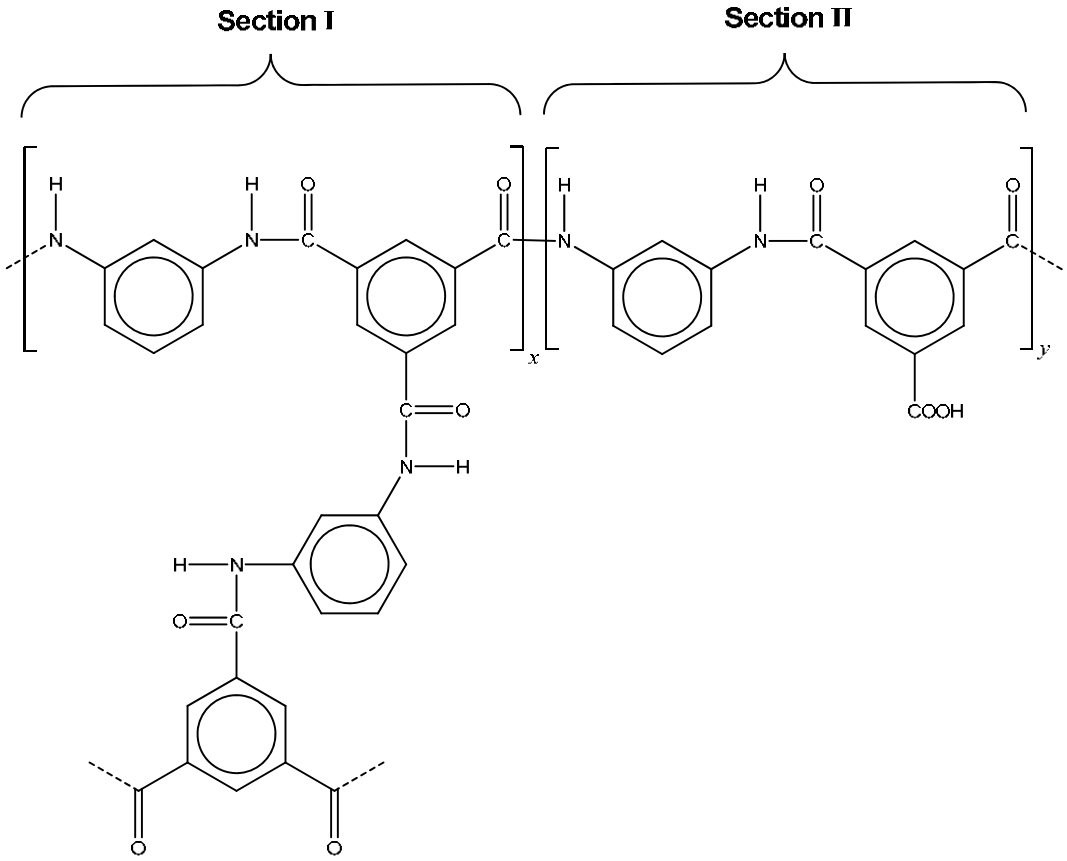
DPC

[2]

Both DPC and DCC are polar simple covalent molecules. DPC has a smaller electron cloud than DCC hence the instantaneous dipole-induced dipole interactions between DPC is weaker. Hence, less energy is required to overcome the intermolecular forces of attraction between DPC than DCC. Hence, DCC will exist as a solid due to the stronger intermolecular forces of attraction.

[Total: 29]

3 Nomex is a class of aramid fibres used as a heat-resistant and strong synthetic fibres in aerospace and military applications. Two sections of the polymer, Nomex, is as shown below.



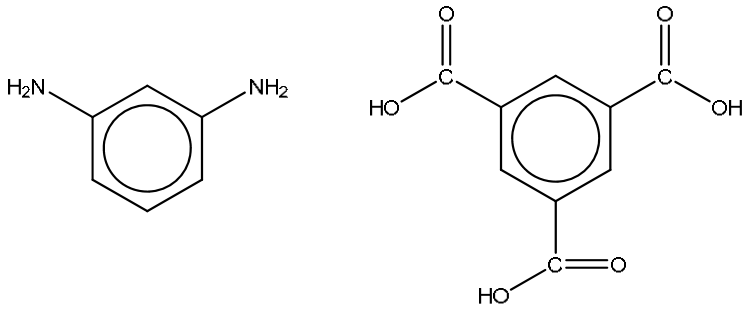
Nomex

(a) Define polymer. [1]

Polymers are macromolecules built up from monomers, with average molar mass of at least 1000 or at least 100 repeat units.

(b) **(i)** With reference to Section **II**, draw the structural formula of the monomers in Nomex. Hence, state the type of polymerisation involved. [3]

Type of polymerisation: Condensation

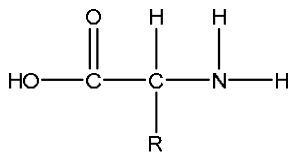


(ii) Classify the polymer represented by Section **I**. Hence, use its structure to explain a property of this polymer. [3]

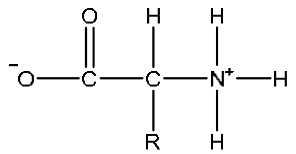
Section **I** : Thermoset/cross-linked

Thermoset: It does not melt / soften / decomposes / lose its shape on heating due to strong covalent bonds holding the chains together which does not break upon heating.

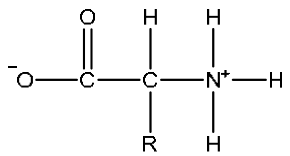
(c) Wool is a texture fibre obtained from sheep and other animals. Wool consists of a polymer chain constructed from amino acids. The general structure of an amino acid is as shown below.

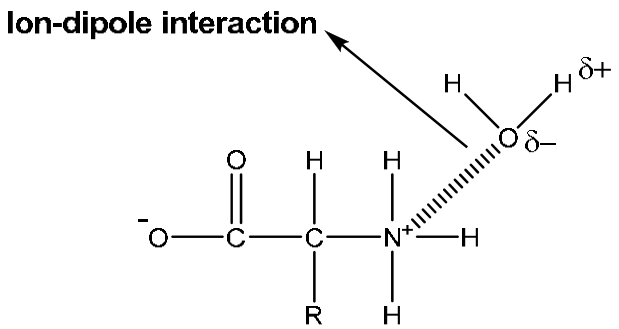


In water, amino acids forms zwitterions as shown below.

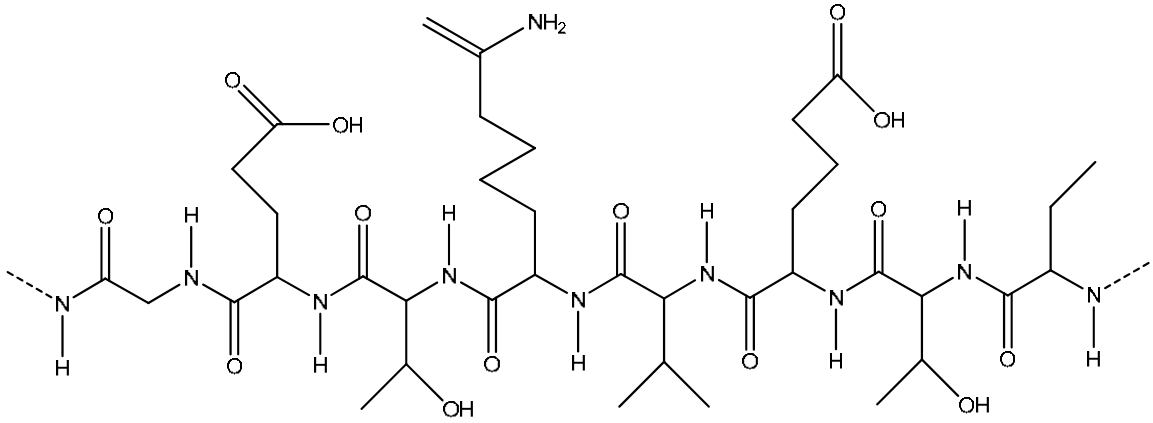


(i) Hygroscopy is the phenomenon of attracting moisture from the surrounding environment. Using the structure of zwitterion in the diagram below, show with the aid of a labelled diagram the hygroscopic nature of zwitterions. [2]

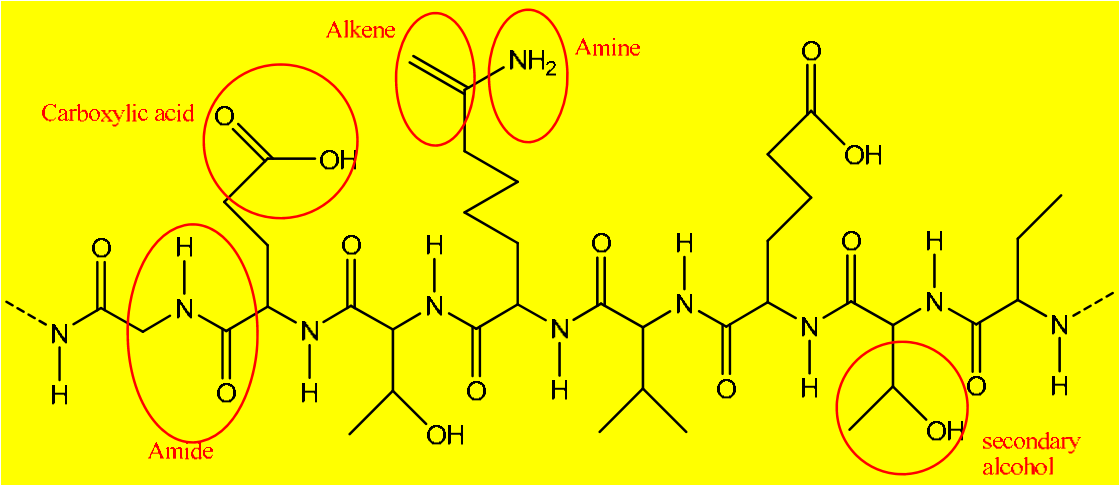




The structure of a section of wool is shown below. This section consists of a number of amino acids.



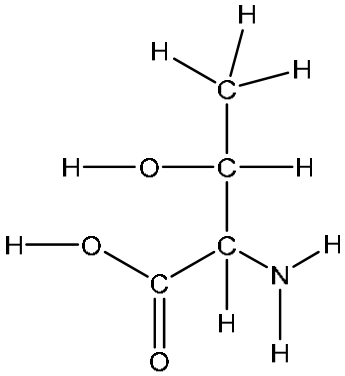
(ii) On the structure above, **circle** and **name** 4 different functional groups present in wool. [2]



(iii) How many amino acids are present in this portion of wool? [1]

8

(iv) One of these amino acids are present more than once. Draw the displayed formula for this amino acid. [1]



(d) Silver nanoparticles are used to colour wool fibres as well as to impart antimicrobial properties. Define the term nanoparticles and explain with reference to its structure, the advantages of using silver nanoparticles. [2]

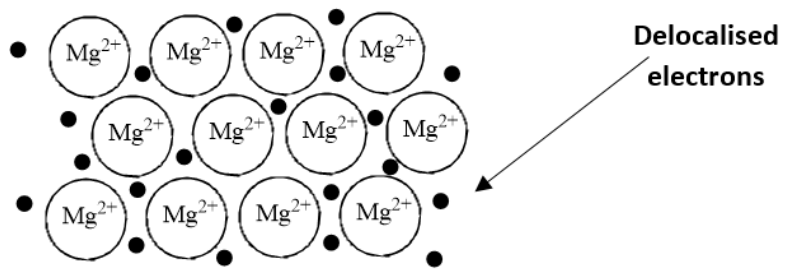
Nanoparticles are defined as particles with all dimensions between 1-100 nm on the nanoscale. The nanoparticle size helps to increase the surface area to volume ratio which increases the rate of the reaction.

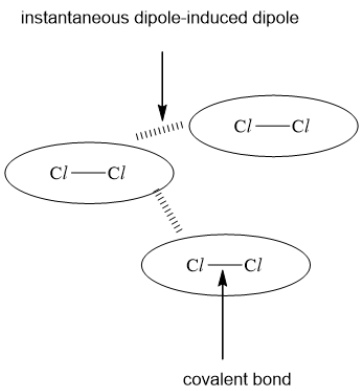
[Total: 15]

Section B

Answer **one** question from this section, in the spaces provided.

1 (a) (i) State the type of bonding in magnesium and chlorine. Use a labelled diagram to illustrate each of their structure.





Words:

Mg: Metallic bonding

Cl_2: covalent bond (between C*l* atoms/within the molecule)

instantaneous dipole-induced dipole between molecules

[4]

(ii) Describe the structure of graphene.

Graphene has a single layer hexagonal lattice Each carbon atom will overlap with 3 other carbon atoms to form 3 strong covalent bonds.

Each carbon atom also has an electron in the p orbital that can delocalize with neighbouring carbon atoms.

[2]

(iii) State the similarities in the structure of magnesium and graphene that allow both of them to conduct electricity. Hence, state another physical property that both magnesium and graphene will have in common.

Both have delocalised electrons allowing both to also conduct heat

[2]

1 (b) Magnesium is an element in Period 3.

(i) Define the term nucleon number. **[1]**

Nucleon number is the total number of proton and neutrons in an atom.

In a particular experiment set-up, protons are deflected through an angle of +15°.

(ii) State one way in which the behaviour of electrons in an electric field differs from that of protons. **[1]**

Electrons are deflected to different plate/terminal from the protons (positive for electrons while negative for protons) OR electrons have a larger angle of deflection compared to protons.

(iii) Calculate the angle of deflection of a Mg^+ particle. **[1]**

Angle of deflection = (1/24.3) x 15 = 0.617°

(iv) Explain how the first ionisation energy of Mg would vary with the element before and after it. **[3]**

Mg has a higher nuclear charge than Na due to more protons

Increase in shielding effect is relatively constant as electron is added to the same quantum shell

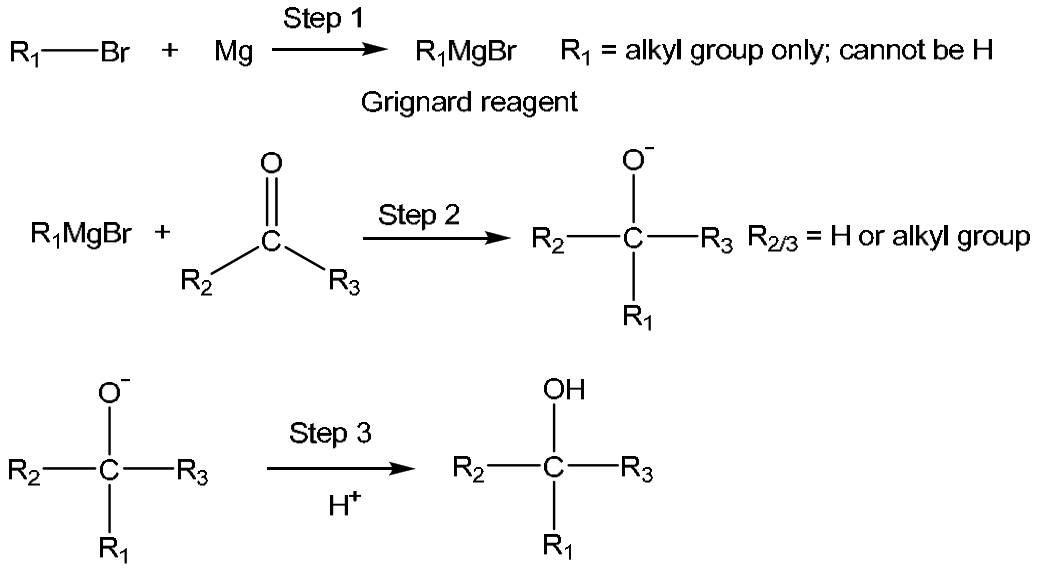
Effective nuclear charge larger for Mg and hence higher first IE

Valence electron for Al is in the 3p orbital which is further away from the nucleus

It also experience shielding from the 3s electrons

Outweighs the increase in nuclear charge hence first IE of Al is lower than Mg

(c) Grignard reagents are formed by the reaction of magnesium metal with an organic compound. They can then be used to react with a carbonyl compound to obtain an alcohol as the final product. This is known as the Grignard reaction and can be represented by the following reaction scheme.



(i) Name the functional group of the organic compound that reacted with magnesium to form the Grignard reagent in Step 1.

Halogenoalkane/Alkyhalide (alkylbromide)

[1]

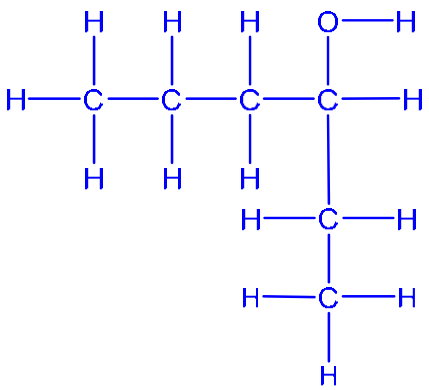
1 (c) (ii) Suggest the type of reaction that took place in Step 2.

Addition

[1]

(iii) Draw the structural formula and give the IUPAC name of the alcohol that is formed when bromoethane was used to form the Grignard reagent and subsequently reacted with butanal.

Hexan-3-ol



[2]

(iv) Butan-2-ol is an alcohol that can be obtained via the Grignard reaction. Draw the structure of a primary alcohol that is a constitutional isomer of butan-2-ol.

$CH_3CH(CH_3)CH_2OH$ or $CH_3CH_2CH_2CH_2OH$

[1]

(v) Suggest the functional group of the compound formed when carbon dioxide, CO_2, is used in the Grignard reaction instead of a carbonyl compound.

Carboxylic acid

[1]

[Total: 20]

2 Aluminium and sulfur are elements found in Period 3. When burnt in excess oxygen, their oxides, Al_2O_3 and SO_3, will be produced.

(a) Using relevant equations, justify the nature of both oxides.

$Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$

$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2Na[Al(OH)_4]$

$SO_3(g) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$

[3]

(b) **(i)** Draw the dot-and-cross diagram of SO_2. **[1]**

(ii) Hence or otherwise, deduce whether SO_2 or SO_3 has a smaller bond angle. Explain your answer. **[1]**

SO_2 has a smaller bond angle/ resulting in the bond pairs in SO_2 to be forced closer together.

This is due to lone-pair bond-pair repulsion in SO_2 is stronger than bond-pair bond pair repulsion in SO_3, resulting in the bond pairs in SO_2 to be forced closer together.

Sulfuric acid (H_2SO_4) is a commonly used chemical reagent in many industrial processes and is manufactured through the Contact process. This takes place in 3 stages.

Stage 1:

In this stage, SO_2 is produced via burning pyrite, a compound containing only Fe and S, in excess oxygen. The equation at this stage is as follows:

$$4FeS_x\,(s) + 11O_2\,(g) \longrightarrow 2Fe_2O_3(s) + 4\mathbf{x}SO_2(g)$$

Stage 2:

In this stage, the SO_2 produced is converted to SO_3 according to the following equation:

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197\ \text{kJ mol}^{-1}$$

Stage 3:

In this stage, the SO_3 produced is converted to H_2SO_4 via 2 reactions. The first reaction involves dissolving the SO_3 produced in concentrated H_2SO_4 to obtain $H_2S_2O_7$.

The $H_2S_2O_7$ produced can then be safely added to water to produce H_2SO_4 in the second reaction. The equations at this stage are as follows:

$$H_2SO_4\,(l) + SO_3\,(g) \longrightarrow H_2S_2O_7(l)$$

$$H_2S_2O_7(l) + H_2O(l) \longrightarrow 2H_2SO_4\,(l)$$

To produce H_2SO_4 in a laboratory, a technician would first burn 10 g of pyrite in excess oxygen. The SO_2 produced would then be extracted and pumped into a 2 dm^3 vessel with more oxygen and allowed to react again at a moderately high temperature. When equilibrium has established, the SO_3 produced was quickly extracted and pumped into 50 cm^3 concentrated H_2SO_4 before the resultant solution was added to 50 cm^3 of deionised water to produced H_2SO_4.

The H_2SO_4 produced was tested for its concentration where 25.0 cm^3 of the resultant solution required 23.50 cm^3 of 2.00 mol dm^{-3} NaOH for complete titration.

(c) **(i)** Given that pyrite contained 53.5% of sulfur by mass, show that the value of **x** in FeS_x is 2. **[1]**

	Fe	S
%	46.5	53.5
/Ar	46.5/55.8 = 0.833	53.5/32.1 = 1.667
Smallest ratio	0.833/0.833 = 1	1.667/0.833 = 2

Since the formula is FeS_x

x= 2 (shown)

Using the information given above,

(ii) Calculate the number of moles of SO_2 produced from the combustion of pyrite.

[1]

No. of moles of pyrite = 10/120 = 0.08333

No. of moles of SO_2 produced = 0.08333 x 2 = 0.167

(iii) Calculate the total number of moles of H_2SO_4 obtained by the technician and hence the number of moles of SO_3 produced.

[2]

No. of moles of NaOH = (23.50/1000) x 2 = 0.047

No. of moles of H_2SO_4 (25 cm^3) = 0.047 / 2 = 0.0235

No. of moles of H_2SO_4 (100 cm^3) = 0.0235 x 4 = 0.094

No. of moles of SO_3 produced = 0.094 /2 = 0.0470

(iv) Write an expression for the equilibrium constant, K_c, for the Contact process in **stage 2**.

[1]

$K_c = [SO_3]^2 / ([SO_2]^2[O_2])$

(v) Using your answers obtained in **2(c)(ii) – (iv)**, complete **Table 2.1**.

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3(g)$$

Table 2.1

	SO_2	O_2	SO_3
initial amount/mol	0.167	1	0
change/mol	- 0.0470	-0.0235	+0.0470
equilibrium amount/mol	0.12	0.9765	0.0470

Hence or otherwise, calculate the value of K_c. **[2]**

$K_c = [SO_3]^2 / ([SO_2]^2[O_2])$

$= (0.0470/2)^2 / ((0.12/2)^2(0.9765/2))$

$= 0.3141$

$= 0.314\ (mol^{-1}\ dm^3)$

(vi) To ensure a reasonable yield of SO_3, the technician conducted the reaction between SO_2 and O_2 at moderately high temperatures. Explain why this is so.

[2]

Low temperature favours the production of SO_3 as position of equilibrium will shift to the right given the forward reaction is exothermic.

However, at low temperature, rate would be very slow

Temperature is kept moderately high so that the rate of the reaction is not too slow and yet favour a reasonable yield of SO_3.

(d) **X** has a molecular formula of $C_4H_{10}O_2$. 1 mole of **X** reacts with 1 mole of sodium to give 1 mole of hydrogen gas.

When acidified potassium manganate (VII) is heated with **X**, the solution turns colourless to give only **Y**.

When 1 mole **Y** is added to methanol in the presence of concentrated sulfuric acid, **Z** is obtained together with 2 moles of water.

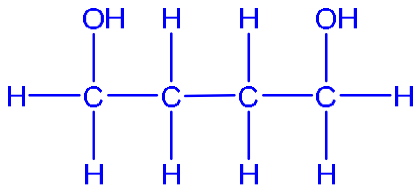
Deduce the structures of **X**, **Y** and **Z**, explaining the chemistry of the reactions described.

[6]

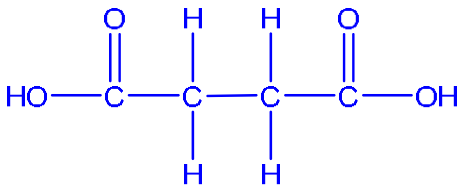
Observation	Deduction
1mole of **X** react with 1 mole of sodium to give 1 mole of hydrogen gas	**X** undergoes redox reaction with Na metal. Since 1 mole of **X** reacts with 1 mole of Na to give 1 mole of H_2 gas, it has 2 -OH/alcohol groups.
X reacts with acidified potassium manganate (VII) when heated to give only **Y**	**X** is oxidised to give **Y** **X** contained either primary or secondary alcohol **Y** contain carboxylic acids or ketone
1 mole of **Y** reacts with CH_3OH to give **Z** and 2 moles of water	**Y** undergo condensation [1/2] with CH_3OH to give **Z**. Since 2 moles of water are produced, 2 esters bonds in Z (diesters) Y contains 2 carboxylic acids

[5.5] max [3]

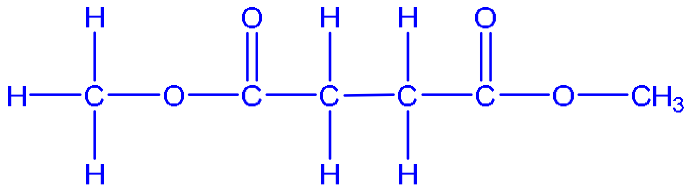
X:



Y:

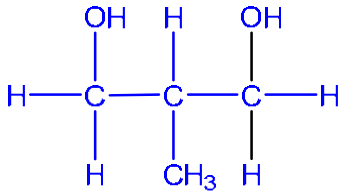


Z:

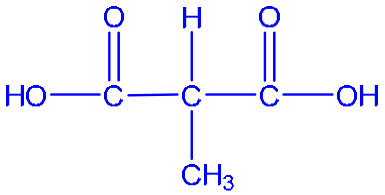


(alternative answer)

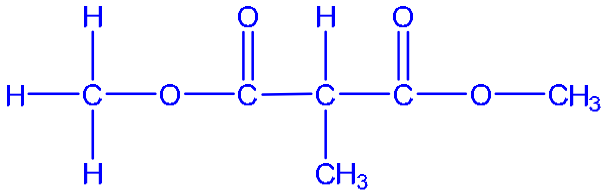
X:



Y:



Z:



END OF PAPER

SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME	
CLASS	

CHEMISTRY 8873/01

JC2 Preliminary Examination **20 September 2018**
Paper 1 Multiple Choice **1 hour**

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D**.
Choose the **one** you consider correct and record your choice in soft pencil on the separate Answer Sheet.

Each correct answer will score one mark. A mark will not be deducted for wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator expected, where appropriate.

This document consists of **14** printed pages and **2** blank pages.

1 Use of the *Data Booklet* is relevant to this question.

What is the number of atoms in 800 cm^3 of hydrogen gas under room temperature conditions?

A 2.0×10^{22}

B 4.0×10^{22}

C 2.0×10^{25}

D 4.0×10^{25}

2 Use of the *Data Booklet* is relevant to this question.

The relative abundances of the isotopes of a sample of carbon are shown in the table below.

relative isotopic mass	12	13	14
relative abundance	100	1.08	0.01

What is the relative atomic mass of carbon in this sample?

A 12.00 **B** 12.01 **C** 12.10 **D** 12.15

3 Four substances **E**, **F, G** and **H** have physical properties as shown.

substance	melting point/ °C	boiling point/ °C	electrical conductivity	
			of solid	of liquid
E	17	45	Poor	Poor
F	64	759	Good	Good
G	1132	1950	Poor	Good
H	3550	3825	Good	Unknown

What could be the identities of **E**, **F, G** and **H**?

	E	**F**	**G**	**H**
A	PCl_5	SO_3	Na_2O	Al_2O_3
B	PCl_5	Al_2O_3	K	Na_2O
C	SO_3	PCl_5	C (graphite)	Na_2O
D	SO_3	K	Na_2O	C (graphite)

4 10 cm^3 of hydrogen peroxide was diluted to 250 cm^3 using a standard flask. 25.0 cm^3 of the diluted solution was reacted with 10 cm^3 of concentrated potassium iodide in the presence of dilute sulfuric acid. The resulting mixture was then titrated with 0.10 mol dm^{-3} sodium thiosulfate. It was found that 21.00 cm^3 of thiosulfate was required to reach end-point.

The following shows the reactions described above.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow I_2 + 2H_2O$$
$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

What is the initial concentration of the hydrogen peroxide used?

A 0.04 mol dm^{-3}

B 0.08 mol dm^{-3}

C 1.05 mol dm^{-3}

D 2.10 mol dm^{-3}

5 Which of the following is a redox reaction?

A $NaOH + HBr \rightarrow NaBr + H_2O$

B $FeCl_3 + 6H_2O \rightarrow [Fe(H_2O)_6]^{3+} + 3Cl^-$

C $H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2\ H_2O$

D $Cu + NH_3 + O_2 + H_2O \rightarrow [Cu(NH_3)_4](OH)_2$

6 Which of the following statements is **untrue** about the second ionisation energies of Period 2 elements?

A The general trend is similar to that of first ionisation energies.

B Increase in shielding effect outweighs the increase in nuclear charge.

C The anomalies lie between group 13 and 14, and between 16 and 17 elements.

D There is increasing electrostatic forces of attraction between the nucleus and valance electrons.

7 When $_4He$ nuclei was pass through an electric field, it was deflected 4°.

Which of the following ions would be deflected half as much as the $_4He$ nuclei in the opposite direction?

A C^{3-}

B N^{3-}

C Na^{+}

D Mg^{2+}

8 Which of the following statements is true for Al^{3+}?

A There are no d orbitals occupied.

B There are a total of five subshells occupied.

C There are a total of three s orbitals occupied.

D The last electron removed to obtain Al^{3+} came from the 3p orbital.

9 A chloride and an oxide of the elements in the third period of the Periodic Table were dissolved in two separate portions of water to form aqueous solutions.

Both of the resulting solutions could dissolve Al_2O_3 but only one of the two could dissolve P_4O_{10}.

Which of the following pairs could be the chloride and the oxide used?

1	$NaCl$	SO_3
2	$MgCl_2$	MgO
3	$SiCl_4$	Na_2O

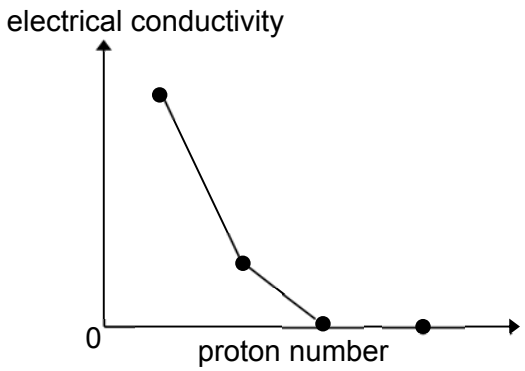
A **2** only

B **1** and **3**

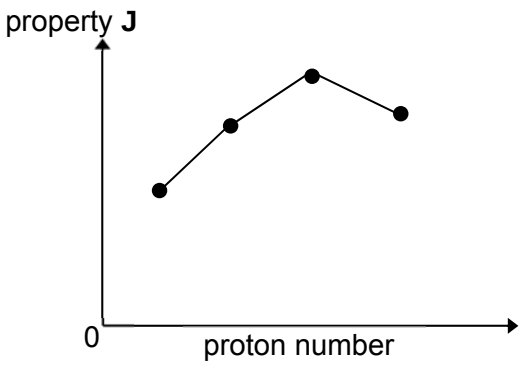
C **2** and **3**

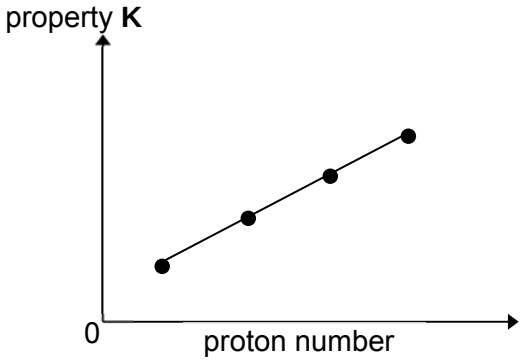
D **1, 2** and **3**

10 The diagram represents the melting points of four consecutive elements in the third period of the Periodic Table.



The sketches below represent another two properties of the elements.





What are properties **J** and **K**?

	property **J**	property **K**
A	first ionisation energy	electronegativity
B	number of valence electrons	melting point
C	ionic radius	nuclear charge
D	boiling point	atomic radius

11 Which one of the following **cannot** be explained using hydrogen bonding?

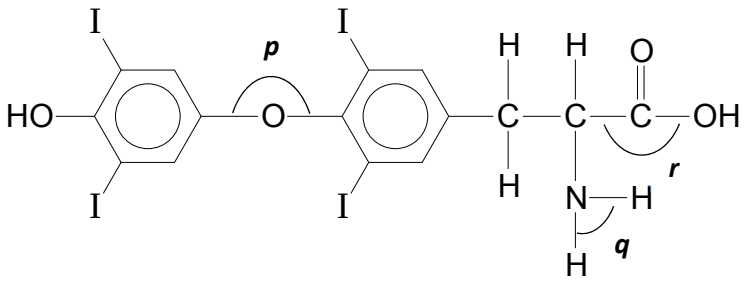
A CH_3CHO has a higher boiling point than C_2H_6.

B CH_3COOH has a M_r of 120 in benzene.

C HF has a higher boiling point than HC*l*.

D CH_3COCH_3 is miscible with water.

12 The thyroid gland concentrates iodine and uses it to produce thyroxine, which is a hormone that controls the metabolic rate.

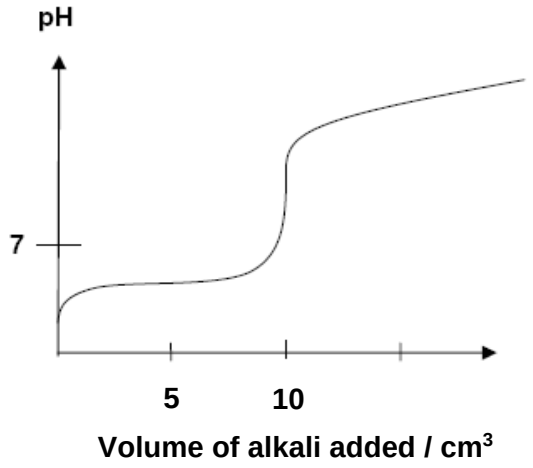


Thyroxine

What are the values of the bond angles ***p***, ***q*** and ***r***?

	p	***q***	***r***
A	105°	107°	180°
B	105°	107°	120°
C	109°	120°	180°
D	109°	120°	120°

13 The following graph shows the changes in pH of 20.0 cm^3 of 1.0 mol dm^{-3} CH_3COOH when excess 1.0 mol dm^{-3} alkali solution is added gradually.



Which one of the following alkali solution with a suitable indicator could have resulted in the graph below?

	Alkali	Indicator
A	NaOH	Methyl orange
B	NaOH	Phenolphthalein
C	$Ba(OH)_2$	Methyl orange
D	$Ba(OH)_2$	Phenolphthalein

14 Which of these mixtures will form a buffer solution?

A 20 cm^3 sodium hydroxide and 10 cm^3 sulfuric acid of the same concentration

B Equal volumes of 1.0 mol dm^{-3} sodium hydroxide and 2.0 mol dm^{-3} ammonia

C Equal volumes of 1.0 mol dm^{-3} ethanoic acid and 1.0 mol dm^{-3} ammonia

D 10 cm^3 ethanoic acid and 20 cm^3 sodium ethanoate of the same concentration

15 Given the following data, determine the enthalpy of hydrogenation of ethene, $CH_2{=}CH_2$ to ethane, CH_3CH_3.

compound	enthalpy change of combustion ΔH_c^θ
$CH_2{=}CH_2$ (g)	–1411
H_2 (g)	–286
CH_3CH_3 (g)	–1560

$$CH_2{=}CH_2\ (g) + H_2\ (g) \xrightarrow{\Delta H^\theta_{hydrogenation}} CH_3CH_3\ (g)$$

A +137 kJ mol^{-1}

B –137 kJ mol^{-1}

C +1084 kJ mol^{-1}

D –1084 kJ mol^{-1}

16 Which of these statements account for the lower melting point of aluminium oxide as compared to magnesium oxide?

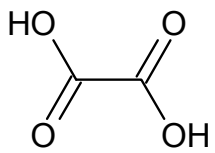
A Aluminium oxide is a simple molecular structure.

B Aluminium oxide has weaker intermolecular forces of attraction.

C Aluminium oxide has a greater covalent character than magnesium oxide.

D Aluminium oxide has a larger magnitude of lattice energy than magnesium oxide.

17 Which statement best explains the reason why the reaction between 10 cm^3 of 0.1 mol dm^{-3} sodium hydroxide with 5 cm^3 of oxalic acid 0.1 mol dm^{-3} is more exothermic than between sodium hydroxide with hydrochloric acid of the same respective volumes and concentrations?



Oxalic acid

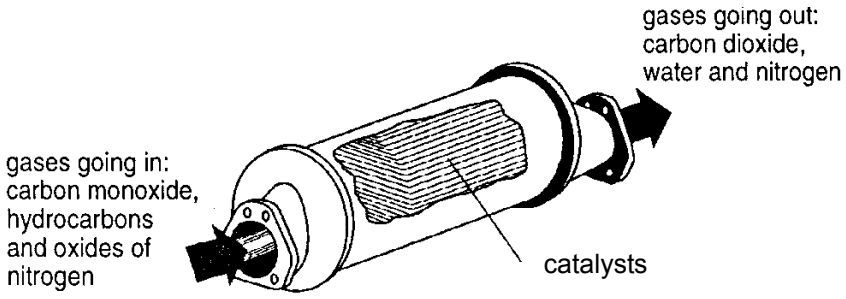
A Some energy is required to further dissociate the weak acid.

B More molecules of water are produced in the first reaction.

C Both acids are limiting reagents.

D Heat loss to the surrondings.

18 The diagram shows the structure of a catalytic converter as fitted into the exhaust system of a car. It also describes the substances involved in the exhaust gases.



Which processes take place in the catalytic converter?

1 Platinum and cobalt catalyse redox reactions.

2 Carbon monoxide and oxides of nitrogen react together.

3 Carbon monoxide and hydrocarbons react together.

4 Hydrocarbons and oxides of nitrogen react together.

A 1 and 2

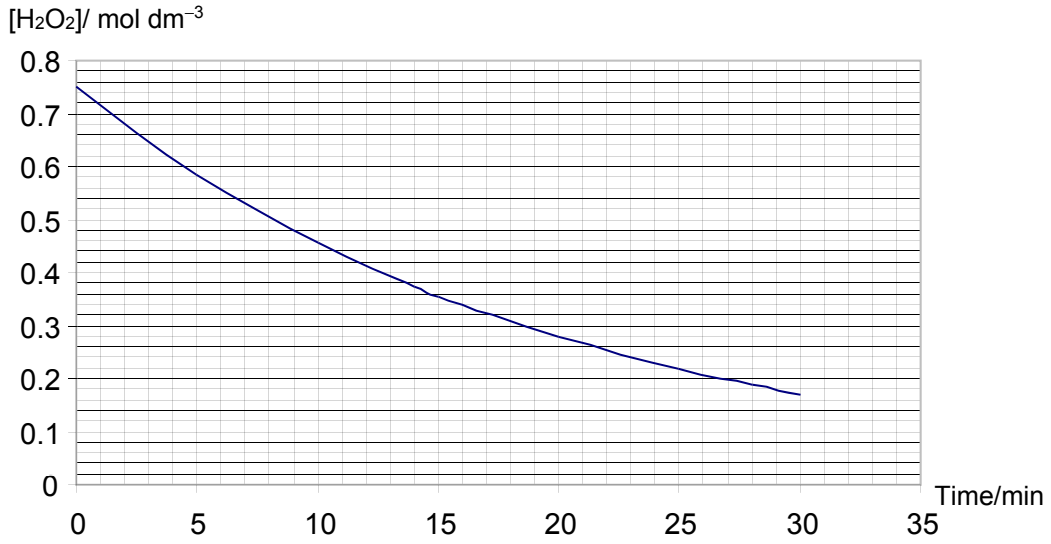
B 2 and 3

C 2 and 4

D 1 and 3

19 The following graph was obtained for the decomposition of 0.75 mol dm^{-3} H_2O_2, given by the equation below.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$



What would be the half-life of H_2O_2 when the experiment was repeated with 1.5 mol dm^{-3} of $H_2O_2(aq)$?

A 3.5 min

B 7 min

C 14 min

D 28 min

20 A piece of bone from an archaeological dig was found to contain 6.25 x 10^{-4} mol of C^{14} atoms. Given that the estimated original amount of C^{14} in that piece was supposed to be 0.01 mol, calculate how old this piece of bone is.

(half-life of C^{14} = 5730 years)

A 16 years

B 8267 years

C 22 920 years

D 91 680 years

21 At 35°C, K_c = 1.6 x 10^{-5} mol dm^{-3} for the following reaction

$$2\ NOCl\ (g) \rightleftharpoons 2\ NO\ (g) + Cl_2\ (g) \qquad \Delta H > 0$$

Which one of the following statements is correct?

A [NO] < [NOC*l*] at equilibrium

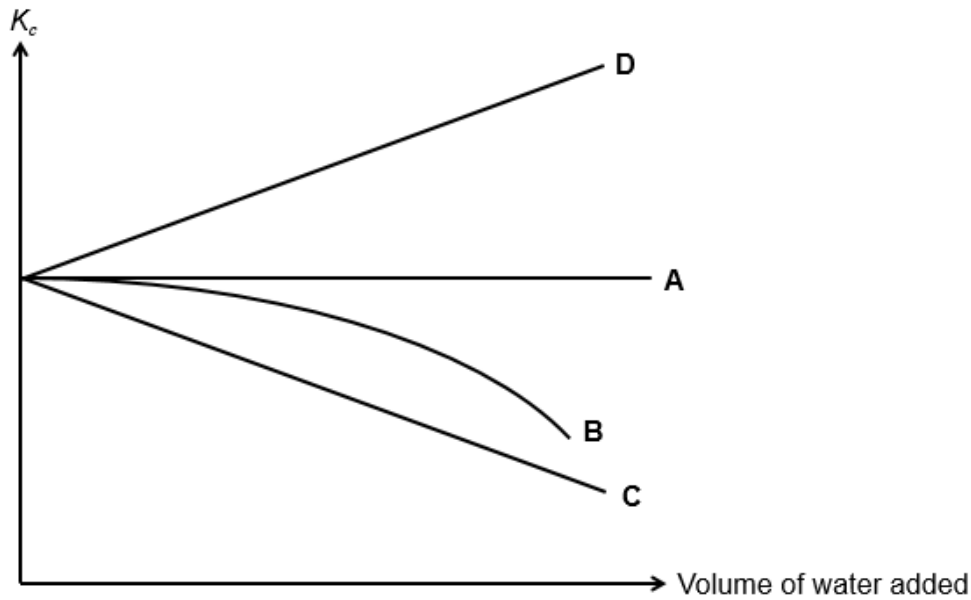
B K_c will decreases when temperature increases.

C Addition of catalyst will cause more Cl_2 to be formed.

D Position of equilibrium will shift to the right when total pressure of the system increases.

22 Which of these graphs is correct for the equilibrium shown below?

$$A\ (aq) + B\ (aq) \rightleftharpoons C\ (s) + D\ (aq)$$



23 Which of the following compounds on reaction will produce ethanoic acid?

1 $CH_3CH{=}CH_2$ and steam

2 CH_3COOCH_3 and dilute HCl, reflux

3 CH_3CH_2CHO and acidified $KMnO_4$, reflux

4 CH_3CH_2OH and acidified $K_2Cr_2O_7$, reflux

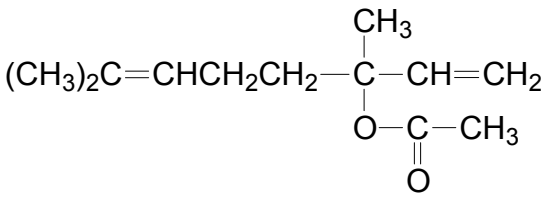
A 1 and 2

B 2 and 3

C 3 and 4

D 2 and 4

24 Linalyl acetate is a naturally-occurring compound and it is a principal component of the essential oils of lavender.



Linalyl acetate

Which one of the statements is **not** true about linalyl acetate?

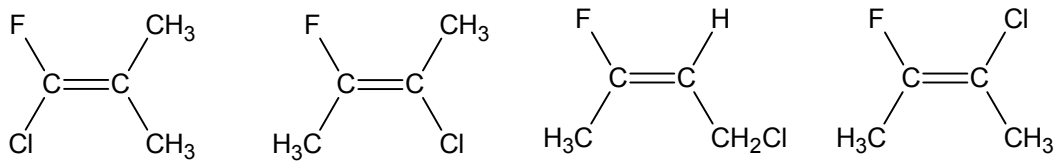
A It is a condensation polymer.

B It cannot exhibit cis-trans isomerism.

C It reacts with hot sulfuric acid.

D It reacts with 2 mol of hydrogen gas.

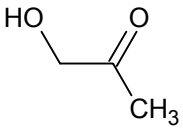
25 Which of the molecular structures below will have the smallest overall dipole?

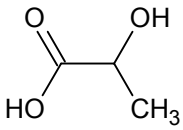


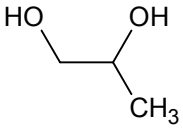
A **B** **C** **D**

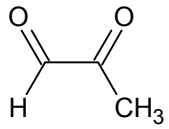
26 Propene reacts with aqueous bromine. The product was collected and subsequently reacted with hot potassium manganate(VII), followed by hot sodium hydroxide.

Which of this is **not** a possible correct structure of the final product?

A 

B 

C 

D 

27 Which of these statements is incorrect for a sheet of graphene?

A It is able to conduct electricity.

B It has a giant molecular structure.

C It is a nanoparticle.

D It is a planar molecule.

28 Which of these statements are correct?

A Nanomaterials have one of its dimensions within 10 nm to 100 nm.

B Lizards are able to climb on wet surfaces due to hydrogen bonding.

C The vivid pink colour of flamingo feathers are due to nanostructures.

D Picoscopic (10^{-12}) volcanic dust pose no threat when inhaled.

29 Which of these statements are inconsistent with the properties of a polyamide shirt?

A It is able to absorb water well.

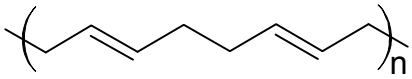
B It is prone to creasing.

C It is a condensation polymer.

D It is resistant to basic hydrolysis.

30 Which of these shows an example of an addition polymer?

A



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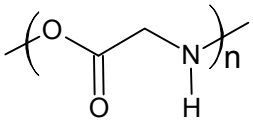

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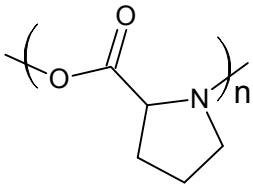
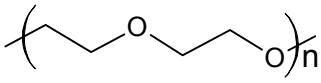


D



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SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME	
CLASS	

CHEMISTRY 8873/02

JC2 Preliminary Examination **12 September 2018**
Paper 2 Structured Questions **2 hours**

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in the brackets [ ] at the end of each question or part questions.

For Examiner's Use	
1	/17
2	/9
3	/8
4	/12
5	/14
6 / 7	/20
TOTAL	/ **80**

This document consists of **23** printed pages and **1** blank page.

Section A

Answer all the questions in this section in the spaces provided.

1 Combustion data can be used to calculate the empirical formula, molecular formula and relative molecular mass of many organic compounds.

(a) Define the term *relative molecular mass.*

.....

.....

.....
[1]

(b) **B** is an alcohol, C_xH_yO.

A 20 cm^3 gaseous sample of **B** was completely burnt in 200 cm^3 of oxygen (an excess). The final volume, measured under the same conditions as the gaseous sample, was 250 cm^3.

Under these conditions, all water present was vaporised. Removal of the water vapour from the gaseous mixture decreased the volume to 170 cm^3. The remaining gaseous mixture was treated with concentrated alkali, and the eventual volume was decreased to 110 cm^3.

Given the equation for the complete combustion of **B**, answer the questions below.

$$C_xH_yO + zO_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

Calculate the value of ***x*** and ***y***.

[2]

(c) Period 3 elements also react with oxygen to form oxides.

Sodium oxide and sulfur dioxide are two such oxides.

(i) Write chemical equations, with state symbols, when each of the above oxides react with water.

sodium oxide ……

sulfur dioxide ……

[2]

(ii) State and explain the pattern of change of oxidation number which occurs to both oxygen and the Period 3 elements (sodium to silicon) when they react together.

.....

.....

.....

[2]

(d) The first ionisation energies of elements across Period 3 show a general increase.

Aluminium and sulfur do **not** follow this general trend.

(i) Write an equation to define the first ionisation energy of aluminium.

.....

[1]

(ii) Explain the general increase in ionisation energy across Period 3.

.....

.....

.....

[2]

(iii) Explain why aluminium has a lower first ionisation energy than magnesium.

.....

.....

[1]

(e) Silicon is an element in Period 3 displaying unique properties such as electrical conductivity at high temperatures and high melting point.

(i) Complete the sketch of the melting point trend for Period 3 elements in **Figure 1.1**.

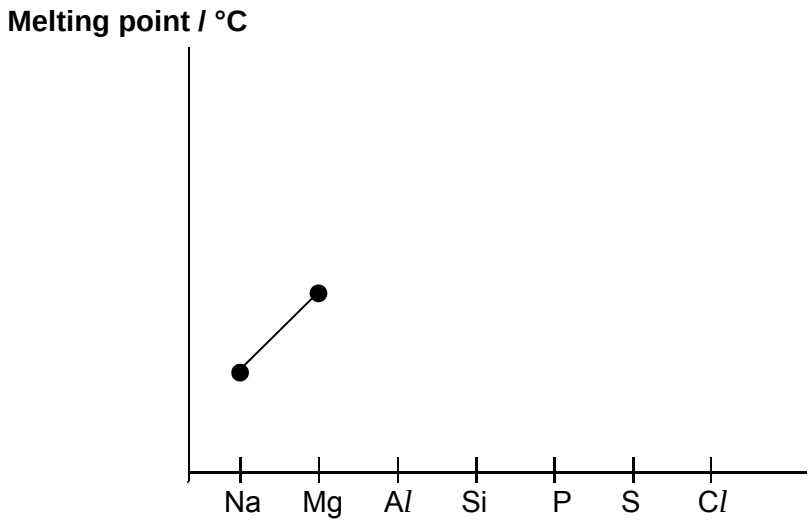


Figure 1.1

[1]

(ii) With the aid of a well-labelled diagram, explain the abnormally high melting point of silicon, using concepts of structure and bonding.

.....

.....

.....

.....

[3]

(iii) When silicon reacts with magnesium, Mg_2Si forms. Mg_2Si is thought to contain the Si^{4-} ion.

State the full electronic configuration of Si^{4-}.

$1s^2$…… [1]

(iv) Solid Mg_2Si reacts with dilute hydrochloric acid to form gaseous SiH_4 and a solution of magnesium chloride.

Write an equation to show the reaction described above. Include state symbols.

..... [1]

[Total: 17]

2 Hydrazine has many industrial uses such as rocket fuel, pesticides and to prepare gas precursors used in air bags. Liquid hydrazine undergoes combustion according to the following equation:

$$N_2H_4\,(l) + O_2\,(g) \rightarrow N_2\,(g) + 2H_2O\,(l)$$

A chemist conducted an experiment to determine the standard enthalpy change of combustion of hydrazine where 0.420 g of hydrazine was burnt to heat up a beaker containing 200 cm^3 of water. The temperature of water in the beaker was recorded as follows:

Initial temperature /ºC	29.3
Final temperature / ºC	37.4

(a) **(i)** Draw the dot-and-cross diagram of hydrazine.

[1]

(ii) Explain what is meant by *standard enthalpy change of combustion of hydrazine.*

.....

.....

[1]

(iii) Calculate the standard enthalpy change of combustion of hydrazine.

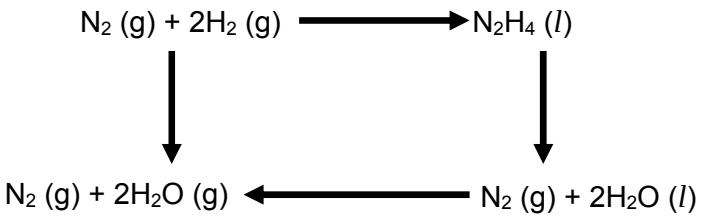
You may assume the process has 80 % efficiency.

[2]

(iv) Given the following data:

enthalpy change of formation of steam = −242 kJ mol^{-1}
enthalpy change of vapourisation of water = +44 kJ mol^{-1}

Using the value you have calculated in **(a)(iii),** complete the following energy cycle to determine the standard enthalpy of formation of hydrazine.



[2]

(b) **(i)** The standard enthalpy change of formation of hydrazine gas is +235 kJ mol^{-1}.

Using appropriate data from the *Data Booklet*, calculate the bond energy of N−H in hydrazine gas.

[2]

(ii) Suggest a reason for the difference in the N−H bond energy value obtained from **(b)(i)** with the value given in the *Data Booklet*.

.....

.....
[1]

[Total: 9]

3 This question is about nanoparticles and its applications.

(a) Finely divided nanoparticles of nickel are found to be extremely good heterogeneous catalyst for many organic synthesis reactions.

(i) Define the term *catalyst*.

.....

.....
[1]

(ii) State the difference between a *nanoparticle* and a *nanomaterial*.

.....

.....
[1]

(iii) Briefly explain how nickel nanoparticles operate as heterogeneous catalyst.

.....

.....

.....

.....
[2]

(b) One study found that 85 % of sunscreens available in Singapore are likely to contain titanium dioxide nanoparticles due to its ability to block UV radiation while remaining transparent on the skin.

Although the health risk posed by these sunscreen creams is minimal, this is not so for aerosol spray sunscreens. Suggest a reason why aerosol spray sunscreens pose a greater health risk.

.....

.....
[1]

(c) Geckoes and many insects have adopted nanoscale fibrillary structures on their feet as adhesion devices. Many have the remarkable ability to run at any orientation on just about any smooth or rough, wet or dry, clean or dirty surface.

Using your understanding of molecular forces, suggest why a gecko can support its own weight and stick to the wall.

.....

.....

.....

.....

.....

[3]

[Total: 8]

4 Acids are an important component in both winemaking and the finished product of wine. They have a direct influence on the colour and taste of the wine. The measure of the amount of acid in wine is known as the "total acidity".

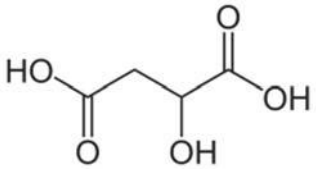
A label on a bottle of wine describes it as having a "total acidity" of 5.8 g dm^{-3}.

(a) **(i)** The acids found in wine behave as *Brønsted-Lowry acids*. Define a *Brønsted-Lowry acid*.

.....

[1]

(ii) One of the most common acid present in wine is malic acid.



malic acid
M_r = 134.0
K_a = 3.98 x 10^{-4} mol dm^{-3}

Assuming that malic acid behaves effectively as a monobasic acid, RCOOH. Write an equation to show the dissociation of malic acid.

.....

[1]

(iii) Calculate the concentration in, mol dm^{-3}, of malic acid and the pH of the wine.

[2]

(iv) The dissociation of malic acid is endothermic. Explain the impact on its pH **and** K_a when temperature increases.

.....

.....

.....

.....
[3]

(v) During the ingestion of wine, mouth saliva interacts with it through a buffering action involving CO_3^{2-} / HCO_3^-. Use an equation to illustrate how the buffer system in saliva maintains pH when wine is consumed.

.....
[1]

(b) Malic acid undergoes elimination with concentrated sulfuric acid.

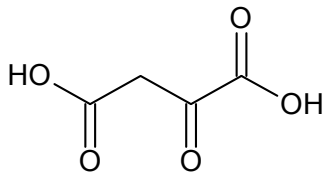
(i) Write a balanced equation for the reaction that took place.

.....
[1]

(ii) Draw two possible isomers formed in **(b)(i)** and state the type of isomerism.

[2]

(c) Suggest the reagent required for the synthesis of malic acid from the following compound.

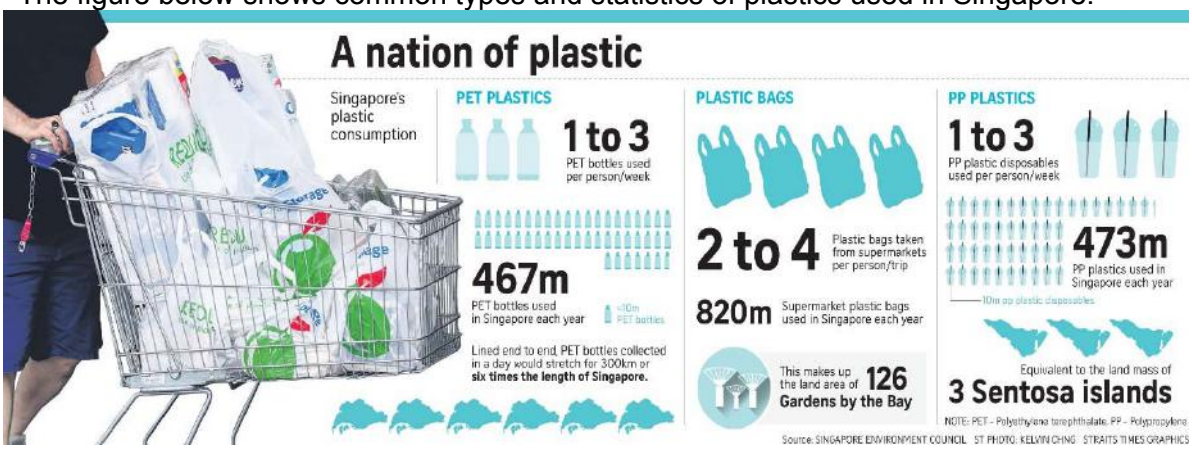


.....
[1]

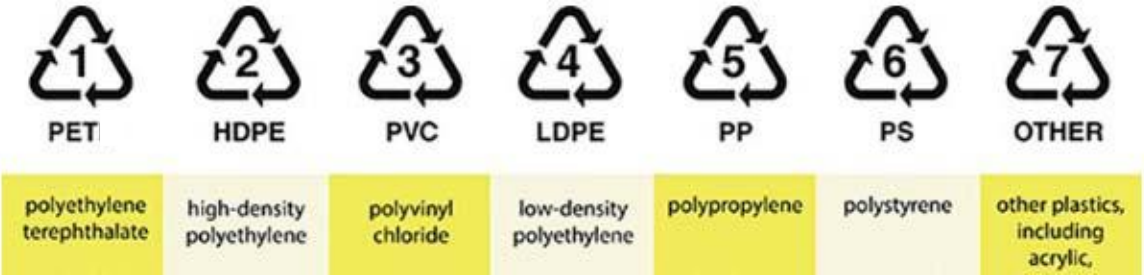
[Total: 12]

5 Singapore uses almost one plastic item per person per day, but fewer than 20% of these are recycled, according to the Singapore Environment Council (SEC). According to the National Environment Agency (NEA), only 6% by mass of plastics are recycled.

The figure below shows common types and statistics of plastics used in Singapore:



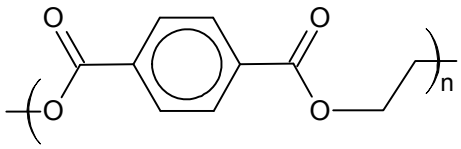
The ASTM International Resin Identification Coding System, often abbreviated as the RIC, is a set of symbols appearing on plastic products that identify the plastic resin out of which the product is made. Understanding the seven plastic codes will make it easier to choose plastics and to know which plastics to recycle:



The methods to reduce on waste in Singapore follows the three “Rs” – Reduce, Reuse and Recycle. However, not all plastics can be reused or recycled.

According to some environmental watch groups, in order for a material to be reused, especially with applications on food and drink, it should not leach compounds that are toxic to human consumption (e.g. benzene derivatives). In order for a material to be recycled, it must be able to be melted and remoulded under high heat, and not decompose or char.

(a) **(i)** PET polymers are thermoplastics and are observed to have the repeat unit shown below.

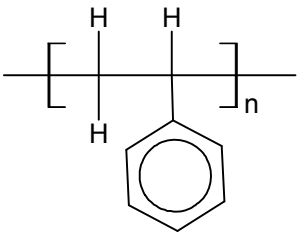


Draw the monomers of PET and suggest the classification of this polymerisation.

Class of polymerisation: ……..

[2]

(ii) PS polymers are thermosets and are observed to have the repeat unit shown below.



Draw the monomer of PS and suggest the classification of this polymerisation.

Class of polymerisation: ……..

[2]

(iii) With the aid of a simple well-labelled diagram, explain how thermoplastics differ from thermosets in their bonding between polymer chains.

.....

.....

.....
[4]

(iv) State if PET and PS can be recycled or reused.

.....

.....
[1]

(b) Explain the relative rigidity and state possible uses of both LDPE and HDPE.

.....

.....

.....

.....

.....
[3]

(c) A school performed a survey on 1000 students and 200 staff members. The survey found that the average person in school would purchase a drink in a plastic cup, and use two pieces of plastic crockery, for lunch every day. Each of those items used had a symbol emblazoned at the base shown below.

Identify the polymer used, and calculate the percentage waste contributed by this school in Singapore in a year in relation to the type of polymer resin used.

Polymer used: …….

[2]

[Total: 14]

Section B

Answer **one** question from this section in the spaces provided.

6 (a) Transition metals are used in many commercial applications such as catalysts. The manufacture of sulfuric acid via the Contact process uses vanadium(V) oxide as catalyst.

Stage one of this process involves the conversion of sulfur dioxide into sulfur trioxide.

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \qquad \Delta H = -196\ \text{kJ mol}^{-1}$$

2.00 moles of SO_2(g) and 2.00 moles of O_2(g) are sealed in a 40 dm^3 container with the addition of catalyst, at constant temperature and pressure. The resulting equilibrium contains 1.98 moles of SO_3(g).

(i) Use the information above to calculate the K_c value for the reaction, stating its units clearly.

[3]

(ii) State and explain the effect of increasing pressure on the **rate** of production of SO_3.

.....

.....

.....

[2]

(iii) State and explain the effect of increasing pressure on the **yield** of SO_3.

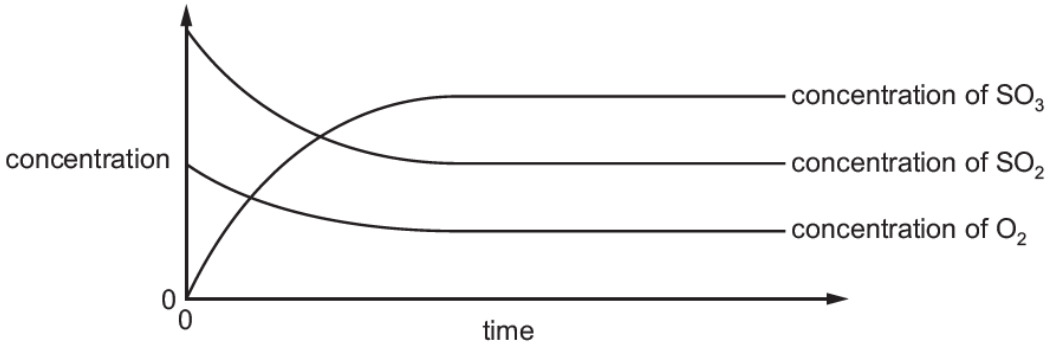
.....

.....

.....
[2]

(iv) Another experiment of stage one was carried out.

The following graph showing how the concentrations of the three species in the system change with time was sketched.



Study the graph and explain the following:

(I) the gradients of the SO_2 and O_2 lines decrease with time

.....

.....

.....

(II) the initial gradient of the SO_2 line is steeper than that of the O_2 line

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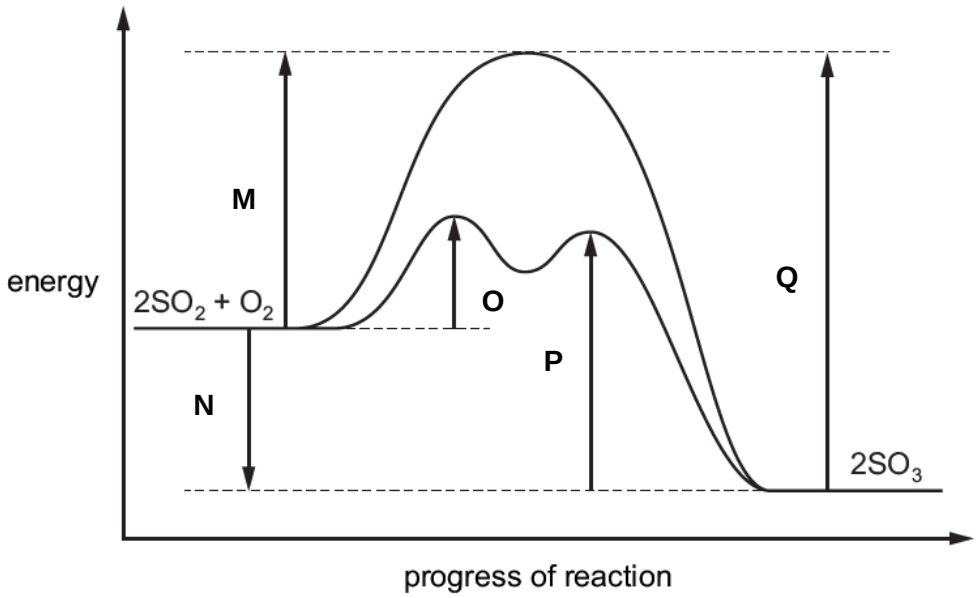
.....
[2]

(v) A reaction pathway diagram for both the catalysed and uncatalysed reactions of stage one is shown.



The letters **M – Q** represent energy changes.

Complete the table by stating which letter, **M – Q**, represents the energy change described.

energy change	letter
the energy change for the production of SO_3	
the activation energy for the production of SO_3 in the absence of a catalyst	
the activation energy for the first step in the **decomposition** of SO_3 in the presence of a catalyst	

[3]

(b) Transition metal manganese present in strong oxidising agents such as potassium manganate(VII), are used in many organic chemistry applications.

Butan-2-ol was heated with acidified potassium manganate(VII) to produce **R**.

$$CH_3CH(OH)CH_2CH_3 \xrightarrow{\mathbf{I}} \underset{\mathbf{R}}{CH_3COCH_2CH_3}$$

(i) Write a balanced equation for reaction **I**.

.....

[1]

(ii) There are two constitutional isomers of **R**, which are also carbonyl compounds. In the boxes below, draw the skeletal formulae of the isomers of **R**.

[2]

(iii) Suggest an alternative reagent and condition for reaction **I**.

.....

[1]

(c) Mohr's salt, $(NH_4)_2Fe(SO_4)_2 \cdot xH_2O$, is a hydrated form of ammonium iron(II) sulfate, where ***x*** represents the number of moles of water in 1 mole of the salt.

A student wanted to determine the value of ***x***.

0.784 g of the hydrated salt was dissolved in water and 10 cm^3 of sulfuric acid was added. All of the solution was titrated with 0.0200 mol dm^{-3} potassium manganate(VII) where 20.00 cm^3 of potassium manganate(VII) solution was required for the complete reaction with the Fe^{2+} ions.

(i) Use changes in oxidation number, or otherwise, balance the equation for the reaction taking place.

MnO_4^- (aq) + ….Fe^{2+} (aq) + ….H^+ (aq) → ….Mn^{2+} (aq) + ….Fe^{3+} (aq) + ….H_2O (*l*)

[1]

(ii) Calculate the amount of Fe^{2+} in the sample of the salt.

[1]

(iii) Calculate the relative formula mass of $(NH_4)_2Fe(SO_4)_2 \cdot xH_2O$ and hence, determine the value of ***x***.

[2]

[Total: 20]

7 **(a)** Samples of 2-bromopropane were dissolved in dilute aqueous ethanol and reacted with potassium hydroxide solution. Several experiments were carried out at constant temperature. The initial rate of reaction was determined in each case.

Expt	$[(CH_3)_2CHBr]$ / mol dm^{-3}	$[OH^-]$ / mol dm^{-3}	Rate / mol dm^{-3} s^{-1}
1	0.015	0.015	13.5
2	0.015	0.030	13.5
3	0.030	0.045	27.0

(i) Determine the order of reaction with respect to 2-bromopropane and potassium hydroxide.

[2]

(ii) Hence, write the rate equation and determine the rate constant, indicating the units clearly.

[2]

(iii) In another experiment, 2-bromopropane was reacted **hot aqueous** potassium hydroxide solution instead.

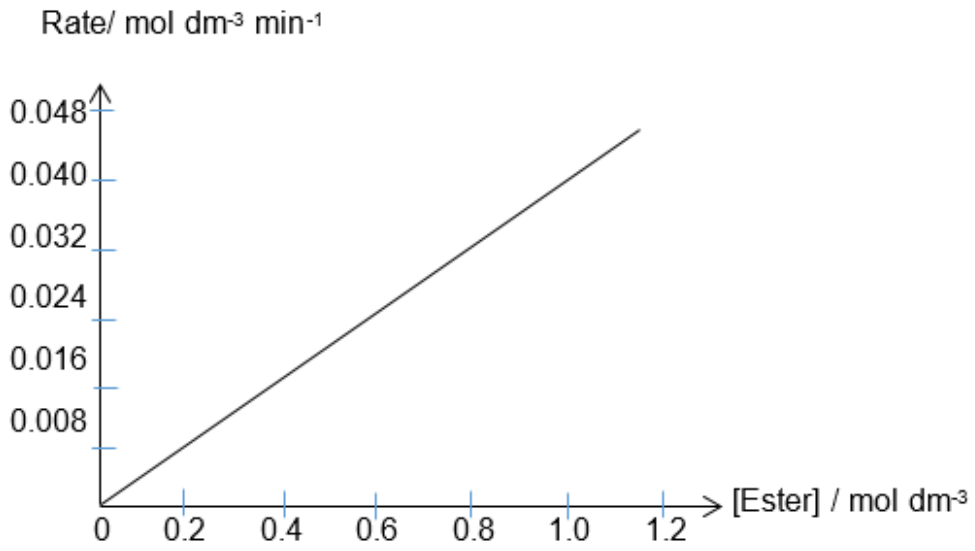
Write a balanced equation for the reaction that occurs.

.....

[1]

(b) A series of experiments was conducted to investigate the kinetics of the hydrolysis of an ester.

The graph below shows the results obtained when concentrations of the ester were varied with the addition of large quantity of water at 400 K. Order of reaction with respect to the ester was found to be one.



(i) Using the graph, determine the value of rate constant, *k*.

[1]

(ii) Predict how the gradient of the graph would change at 500 K. Explain your answer.

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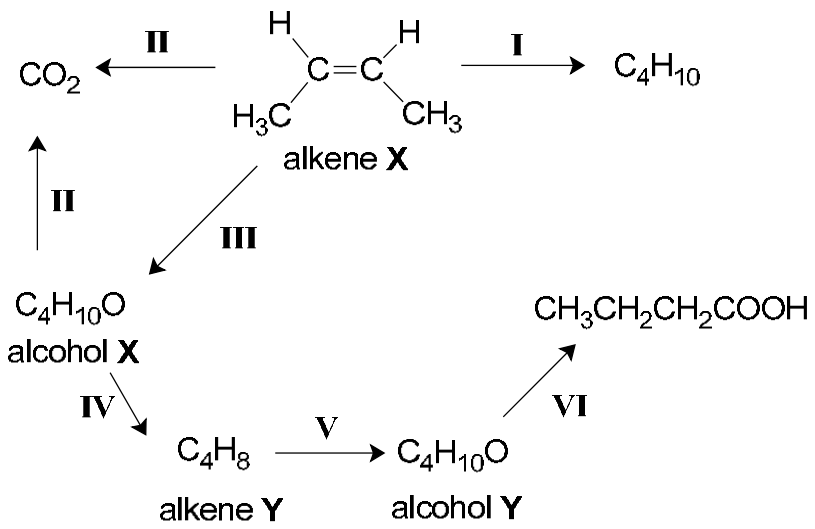
.....

.....

[3]

(c)



(i) Construct a balanced chemical equation for reaction **II** involving alkene **X.**

.....

[1]

(ii) When alkene **X** undergoes reaction with water in the presence of an acid catalyst, alcohol **X**, a secondary alcohol, is produced.

Draw the displayed formula of alcohol **X**. Hence, name the carbonyl compound that can be reduced to form this alcohol.

[2]

(iii) Draw the structural formula of alkene **Y** and alcohol **Y**.

[2]

(iv) Acidified potassium manganate(VII) was used in the oxidation process of alcohol **Y** to butanoic acid, as seen in reaction **VI**.

The oxidation half-equation for the reaction is shown below.

$$C_4H_{10}O + H_2O \rightarrow CH_3CH_2CH_2COOH + 4H^+ + 4e$$

With an aid of a *Data Booklet*, construct an overall balanced chemical equation for reaction **VI**, and determine the volume of 1.25 mol dm^{-3} potassium manganate(VII) required to oxidise 15 g of alcohol **Y**.

[3]

(v) Platinum acts as catalyst in reaction **I**. With an aid of a Maxwell-Boltzmann distribution diagram, explain how platinum increases the rate of reaction.

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.....

.....

[3]

[Total: 20]

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SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 1

CHEMISTRY 8873/01

JC2 Preliminary Examination **20 September 2018**
Paper 1 Multiple Choice **1 hour**

1	B	**6**	B	**11**	A	**16**	C	**21**	A	**26**	D
2	B	**7**	A	**12**	B	**17**	B	**22**	A	**27**	C
3	D	**8**	A	**13**	D	**18**	B	**23**	D	**28**	A
4	C	**9**	C	**14**	D	**19**	B	**24**	A	**29**	D
5	D	**10**	A	**15**	B	**20**	C	**25**	B	**30**	A

WORKED SOLUTIONS

1 Use of the *Data Booklet* is relevant to this question.

What is the number of atoms in 800 cm^3 of hydrogen gas under room temperature conditions?

	A	2.0×10^{22}
	B	4.0×10^{22}
	C	2.0×10^{25}
	D	4.0×10^{25}

Ans: **B**

$n_H = \frac{0.8}{24} \times 2$

number of H atoms = $\frac{0.8}{24} \times 2 \times 6.02 \times 10^{23} = 4.0 \times 10^{22}$

2 Use of the *Data Booklet* is relevant to this question.

The relative abundances of the isotopes of a sample of carbon are shown in the table below.

relative isotopic mass	12	13	14
relative abundance	100	1.08	0.01

What is the relative atomic mass of carbon in this sample?

A	12.00	**B**	12.01	**C**	12.10	**D**	12.15	

Ans: **B**

Relative atomic mass = $\frac{(12 \times 100)+(13 \times 1.08)+(14 \times 0.01)}{100+1.08+0.01}$ = 12.01

3 Four substances **E**, **F, G** and **H** have physical properties as shown.

substance	melting point/ °C	boiling point/ °C	electrical conductivity	
			of solid	of liquid
E	17	45	Poor	Poor
F	64	759	Good	Good
G	1132	1950	Poor	Good
H	3550	3825	Good	Unknown

What could be the identities of **E**, **F, G** and **H**?

	E	**F**	**G**	**H**
A	PCl_5	SO_3	Na_2O	Al_2O_3
B	PCl_5	Al_2O_3	K	Na_2O
C	SO_3	PCl_5	C (graphite)	Na_2O
D	SO_3	K	Na_2O	C (graphite)

Ans: **D**

substance	melting point/ °C	boiling point/ °C	electrical conductivity		Structure
			of solid	of liquid	
E	17	45	Poor	Poor	SMS PCl_5 / SO_3
F	64	759	Good	Good	GMLS K
G	1132	1950	Poor	Good	GILS Na_2O
H	3550	3825	Good	Unknown	GMS Graphite

4	10 cm^3 of hydrogen peroxide was diluted to 250 cm^3 using a standard flask. 25.0 cm^3 of the diluted solution was reacted with 10 cm^3 of concentrated potassium iodide in the presence of dilute sulfuric acid. The resulting mixture was then titrated with 0.10 mol dm^{-3} sodium thiosulfate. It was found that 21.00 cm^3 of thiosulfate was required to reach end-point. The following shows the reactions described above. $H_2O_2 + 2I^- + 2H^+ \rightarrow I_2 + 2H_2O$ $I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$ What is the initial concentration of the hydrogen peroxide used?	
	A	0.04 mol dm^{-3}
	B	0.08 mol dm^{-3}
	C	1.05 mol dm^{-3}
	D	2.10 mol dm^{-3}
	Ans: **C** Mole ratio $2S_2O_3^{2-}$: 1 I_2 : $1H_2O_2$ n $S_2O_3^{2-}$ = $\frac{21.00}{1000} \times 0.10$ = 2.10×10^{-3}mol n H_2O_2in 25 cm^3 = 1.05×10^{-3} mol n H_2O_2in 250 cm^3 = 1.05×10^{-2} mol initial concentration of H_2O_2 = 1.05×10^{-2} / (10/1000) = **<u>1.05 mol dm^{-3}</u>**	

5	Which of the following is a redox reaction?	
	A	$NaOH + HBr \rightarrow NaBr + H_2O$
	B	$FeCl_3 + 6H_2O \rightarrow [Fe(H_2O)_6]^{3+} + 3Cl^-$
	C	$H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2H_2O$
	D	$Cu + NH_3 + O_2 + H_2O \rightarrow [Cu(NH_3)_4](OH)_2$
	Ans: **D** There are no change in oxidation numbers of any species for options A, B and D. Option C: Cu is oxidised from 0 to +2 O is reduced from 0 to –2	

6	Which of the following statements is **untrue** about the second ionisation energies of Period 2 elements?	
	A	The general trend is similar to that of first ionisation energies.
	B	Increase in shielding effect outweighs the increase in nuclear charge.
	C	The anomalies lie between group 13 and 14, and between 16 and 17 elements.
	D	There is increasing electrostatic forces of attraction between the nucleus and valance electrons.
	Ans: **B** Across the period, shielding effect is similar as electrons are added to the same quantum shell. Thus, **B** is untrue.	

7	When $_4He$ nuclei was pass through an electric field, it was deflected 4°. Which of the following ions would be deflected half as much as the $_4He$ nuclei in the opposite direction?	
	A	C^{3-}
	B	N^{3-}
	C	Na^{+}
	D	Mg^{2+}
	Ans: **A** **Concept:** $\frac{e}{m}$ α angle of deflection $\frac{e}{m}$ of $_4He$ nuclei is +½ (You need to know that the **nucleus** is **positively** charged) Thus, only options **A** and **B** are possible, as they will deflect in the opposite direction. $\frac{e}{m}$of $C^{3-}$is –¼ Hence, will be deflected half as much as the $_4He$ nuclei in the opposite direction.	

8	Which of the following statements is true for Al^{3+}?	
	A	There are no d orbitals occupied.
	B	There are a total of five subshells occupied.
	C	There are a total of three s orbitals occupied.
	D	The last electron removed to obtain Al^{3+} came from the 3p orbital.

Ans: **A**

Al^{3+} : $1s^2 2s^2 2p^6$

- No d orbitals is occupied.
- There are 3 subshells occupied.
- There are two s orbitals occupied.
- The first 3 electrons removed obtain Al^{3+} came from the the 3p orbital first, followed by 3s orbital.

9	A chloride and an oxide of the elements in the third period of the Periodic Table were dissolved in two separate portions of water to form aqueous solutions. Both of the resulting solutions could dissolve Al_2O_3 but only one of the two could dissolve P_4O_{10}. Which of the following pairs could be the chloride and the oxide used?		
	1	$NaCl$	SO_3
	2	$MgCl_2$	MgO
	3	$SiCl_4$	Na_2O
	A	**2** only	
	B	**1** and **3**	
	C	**2** and **3**	
	D	**1, 2** and **3**	

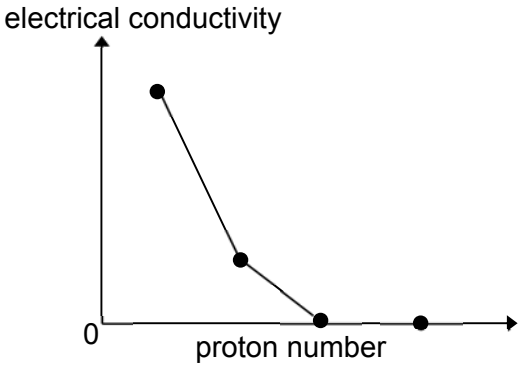
Ans: **C**

You should work these out first:

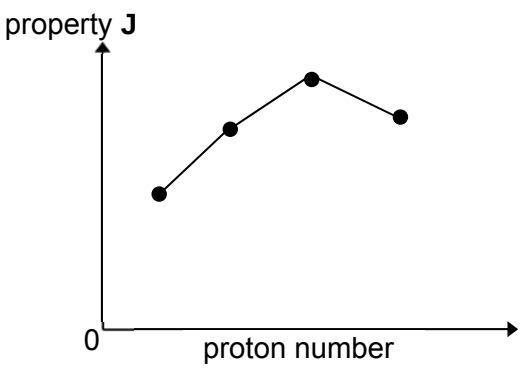
	Compound	pH	Compound	pH
In aqueous solution	NaCl	7 (neutral)	SO_3	3 (acidic)
	$MgCl_2$	6.5 (slightly acidic)	MgO	12 (basic)
	$SiCl_4$	2 (acidic)	Na_2O	13 (basic)

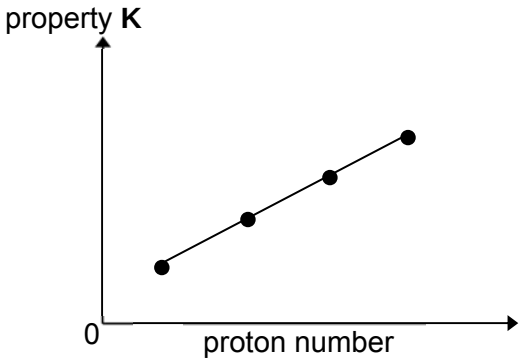
Since **both** of the resulting solutions can be used to dissolve **Al_2O_3 (amphoteric)** but only **one** of the two can be used to dissolve P_4O_{10}, **<u>one of the solution has to be acidic</u>** while **<u>the other basic.</u>** Only options **2** and **3** gives both an acidic and basic solution.

10 The diagram represents the melting points of four consecutive elements in the third period of the Periodic Table.



The sketches below represent another two properties of the elements.





What are properties **J** and **K**?

	property **J**	property **K**
A	first ionisation energy	electronegativity
B	number of valence electrons	melting point
C	ionic radius	nuclear charge
D	boiling point	atomic radius

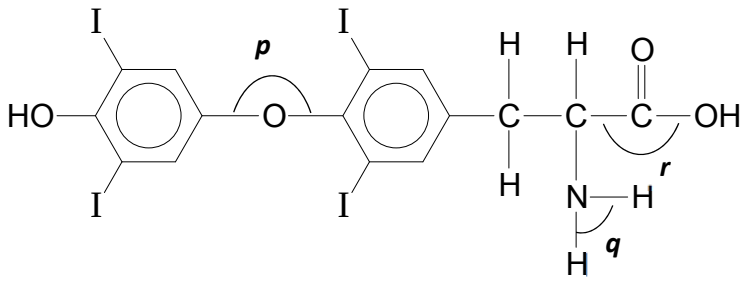
Ans: **A**

The four consecutive elements are aluminium (conductor), silicon (semiconductor), phosphorus (non-conductor) and sulphur (non-conductor) respectively.

Hence, property **J** can represent the 1st IE trend **only** and **K** can represent electronegativity or nuclear charge.

11	Which one of the following **cannot** be explained using hydrogen bonding?	
	A	CH_3CHO has a higher boiling point than C_2H_6.
	B	CH_3COOH has a M_r of 120 in benzene.
	C	HF has a higher boiling point than HCl.
	D	CH_3COCH_3 is miscible with water.
	Ans: A Intermolecular H-bonds form btw molecules with N, O or F atoms directly bonded to H atom. Aldehyde groups such as CH_3CHO do not have intermolecular H-bonds. CH_3CHO has **intermolecular pd-pd forces of attraction**, while C_2H_6 has intermolecular id-id forces of attraction. H-bond does not account for this difference.	

12 The thyroid gland concentrates iodine and uses it to produce thyroxine, which is a hormone that controls the metabolic rate.

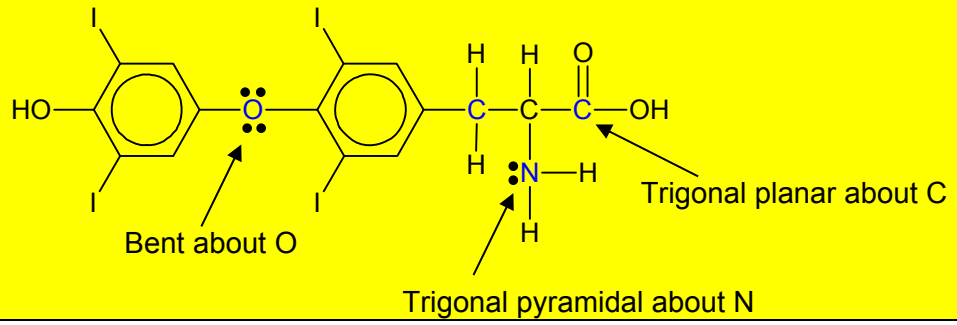


Thyroxine

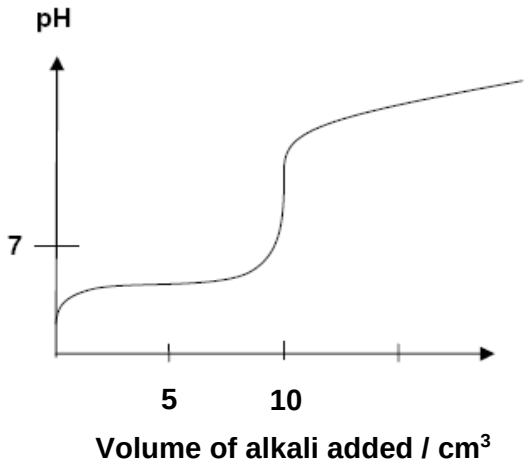
What are the values of the bond angles ***p***, ***q*** and ***r***?

	p	***q***	***r***
A	105°	107°	180°
B	105°	107°	120°
C	109°	120°	180°
D	109°	120°	120°

Ans: B



13 The following graph shows the changes in pH of 20.0 cm^3 of 1.0 mol dm^{-3} CH_3COOH when excess 1.0 mol dm^{-3} alkali solution is added gradually.



Which one of the following alkali solution with a suitable indicator could have resulted in the graph below?

	Alkali	Indicator
A	NaOH	Methyl orange
B	NaOH	Phenolphthalein
C	$Ba(OH)_2$	Methyl orange
D	$Ba(OH)_2$	Phenolphthalein

Ans: D

From the graph, equivalence volume = 10 cm^3
This shows that 1 mol base reacts with 2 mol of CH_3COOH.
Thus, the base **<u>$Ba(OH)_2$ and cannot be NaOH.</u>**

Since it is a **strong base and weak acid neutralisation**, end point **pH will be >7**. **Phenolphthalein** is used.

14	Which of these mixtures will form a buffer solution?	
	A	20 cm^3 sodium hydroxide and 10 cm^3 sulfuric acid of the same concentration
	B	Equal volumes of 1.0 mol dm^{-3} sodium hydroxide and 2.0 mol dm^{-3} ammonia
	C	Equal volumes of 1.0 mol dm^{-3} ethanoic acid and 1.0 mol dm^{-3} ammonia
	D	10 cm^3 ethanoic acid and 20 cm^3 sodium ethanoate of the same concentration
	Ans: D Buffer solution consists of weak acid and salt of its conjugate base. Option A is wrong – NaOH is strong base, H_2SO_4 is strong acid. Option B is wrong – NaOH is strong base, NH_3 is weak base. No rxn as well. Option C is wrong – both CH_3COOH and NH_3 in the context will completely neutralise to form salt and water. Option D consist of weak acid and salt of its conjugate base – acidic buffer.	

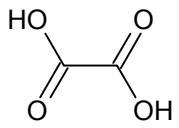
15	Given the following data, determine the enthalpy of hydrogenation of ethene, $CH_2{=}CH_2$ to ethane, CH_3CH_3.	

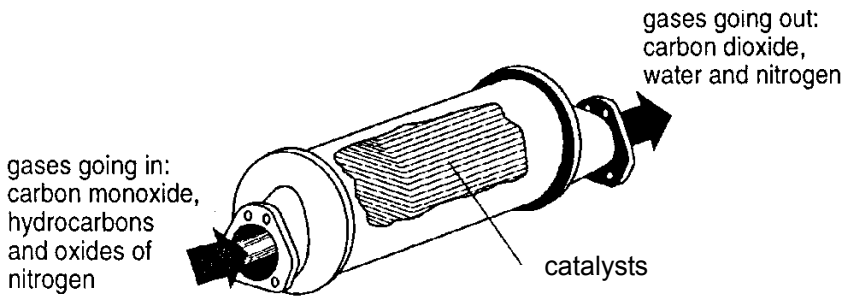
compound	enthalpy change of combustion ΔH_c^θ
$CH_2{=}CH_2$ (g)	–1411
H_2 (g)	–286
CH_3CH_3 (g)	–1560

$$CH_2{=}CH_2\ (g) + H_2\ (g) \xrightarrow{\Delta H^\theta_{hydrogenation}} CH_3CH_3\ (g)$$

	A	+137 kJ mol^{-1}
	B	–137 kJ mol^{-1}
	C	+1084 kJ mol^{-1}
	D	–1084 kJ mol^{-1}
	Ans: B $\Delta H^\theta_{hydrogenation} = \sum\Delta H^\theta_c$ (rxt) - $\sum\Delta H^\theta_c$ (pdt) = (-1411 – 286) – (-1560) = **<u>–137 kJ mol^{-1}</u>**	

16	Which of these statements account for the lower melting point of aluminium oxide as compared to magnesium oxide?	
	A	Aluminium oxide is a simple molecular structure.
	B	Aluminium oxide has weaker intermolecular forces of attraction.
	C	Aluminium oxide has a greater covalent character than magnesium oxide.
	D	Aluminium oxide has a larger magnitude of lattice energy than magnesium oxide.
	Ans: C **C** and **D** are wrong as aluminium oxide is a giant ionic compound. **A** is wrong as a larger magnitude of lattice energy is proportional to strength of ionic bond.	

17	Which statement best explains the reason why the reaction between 10 cm^3 of 0.1 mol dm^{-3} sodium hydroxide with 5 cm^3 of oxalic acid 0.1 mol dm^{-3} is more exothermic than between sodium hydroxide with hydrochloric acid of the same respective volumes and concentrations?  **Oxalic acid**	
	A	Some energy is required to further dissociate the weak acid.
	B	More molecules of water are produced in the first reaction.
	C	Both acids are limiting reagents.
	D	Heat loss to the surrondings.
	Ans: B **A** is wrong as the question stated that the weak acid reaction is more exo than the strong acid reaction. **B** is right as the amount of base is the same for both reactions but oxalic acid dissociates two H^+ per mol hence more H^+ has been neutralised. **C** is wrong as oxalic acid is not a limiting reagent. **D** is wrong as both reactions would have heat lost to surroundings and it should not have an impact as to why oxalic acid reaction is more exo.	

18	The diagram shows the structure of a catalytic converter as fitted into the exhaust system of a car. It also describes the substances involved in the exhaust gases.  Which processes take place in the catalytic converter?	
	1	Platinum and cobalt catalyse redox reactions.
	2	Carbon monoxide and oxides of nitrogen react together.
	3	Carbon monoxide and hydrocarbons react together.
	4	Hydrocarbons and oxides of nitrogen react together.
	A	1 and 2
	B	2 and 3
	C	2 and 4
	D	1 and 3
	Ans: B Catalytic converters use <u>3 types of catalysts</u>: Pt, Pd, Rh, **not Co**. <u>2 main reactions take place</u>: NO is reduced to N_2 by the excess CO present. $2NO\ (g) + 2CO\ (g) \rightarrow 2CO_2\ (g) + N_2\ (g)$ Unburnt hydrocarbons are oxidized to CO_2 and H_2O while CO is oxidized to CO_2, with Pt as the catalyst. $C_xH_y\ (g) + (x + y/4)O_2\ (g) \rightarrow xCO_2\ (g) + y/2\ H_2O\ (g)$ $2CO\ (g) + O_2\ (g) \rightarrow 2CO_2\ (g)$	

19 The following graph was obtained for the decomposition of 0.75 mol dm^{-3} H_2O_2, given by the equation below.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

What would be the half-life of H_2O_2 when the experiment was repeated with 1.5 mol dm^{-3} of $H_2O_2(aq)$?

A	3.5 min	**C**	14 min
B	7 min	**D**	28 min

Ans: B

You should first find out that **order of rxn wrt H_2O_2 is one** from the constant half-life.

When concentration is doubled (1.5 mol dm^{-3} is 2 times the original concentration at 0.75 mol dm^{-3}), the rate of reaction is doubled.

Half-life at 0.75 mol dm^{-3} is about 14 min, thus half-life at 1.5 mol dm^{-3} is 7 min.

20 A piece of bone from an archaeological dig was found to contain 6.25 x 10^{-4} mol of C^{14} atoms. Given that the estimated original amount of C^{14} in that piece was supposed to be 0.01 mol, calculate how old this piece of bone is.
(half-life of C^{14} = 5730 years)

A	16 years
B	8267 years
C	22 920 years
D	91 680 years

Ans: C

<u>Method 1</u>

6.25 x 10^{-4} /0.01 = $(1/2)^n$, where n = no. of half-lives elapsed

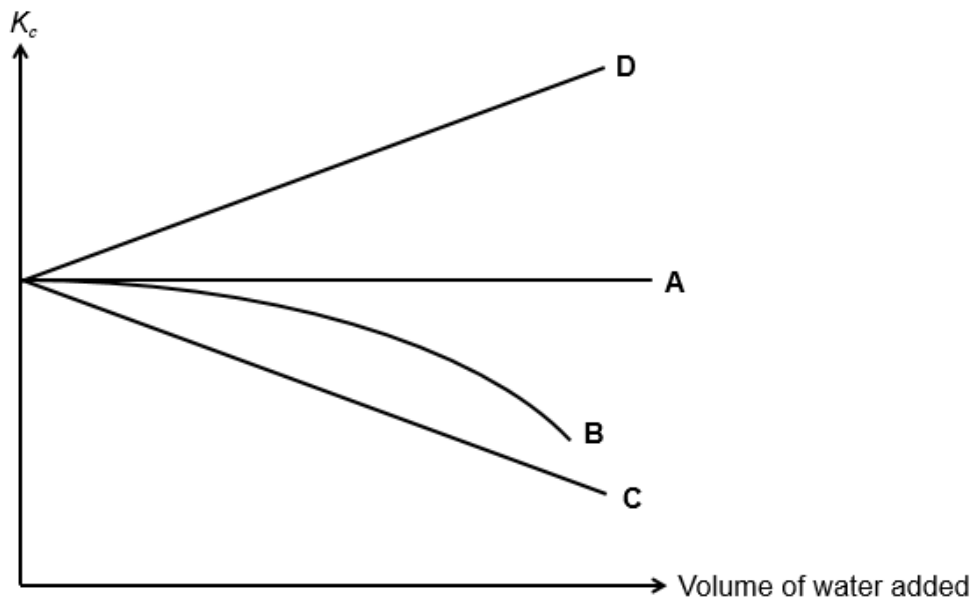
n = 4

<u>Method 2</u>

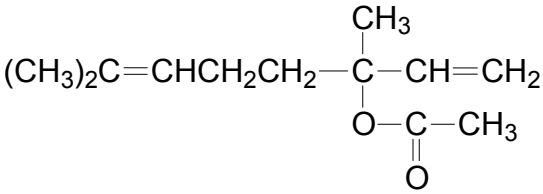
0.01→0.005→0.0025→0.00125→0.000625 (4 half-lives have passed)

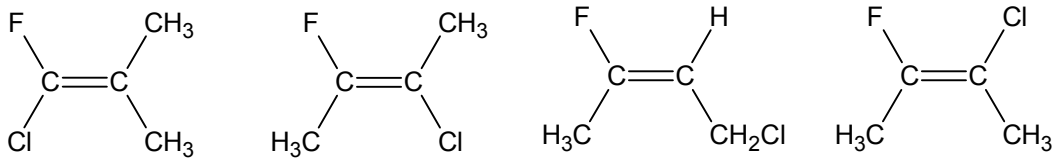
Thus, time elapsed = 4 x 5730 = **<u>22920 years</u>**

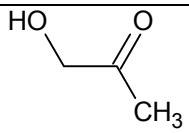
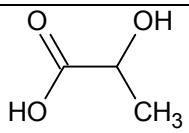
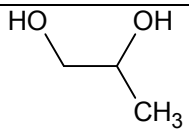
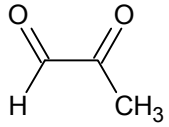
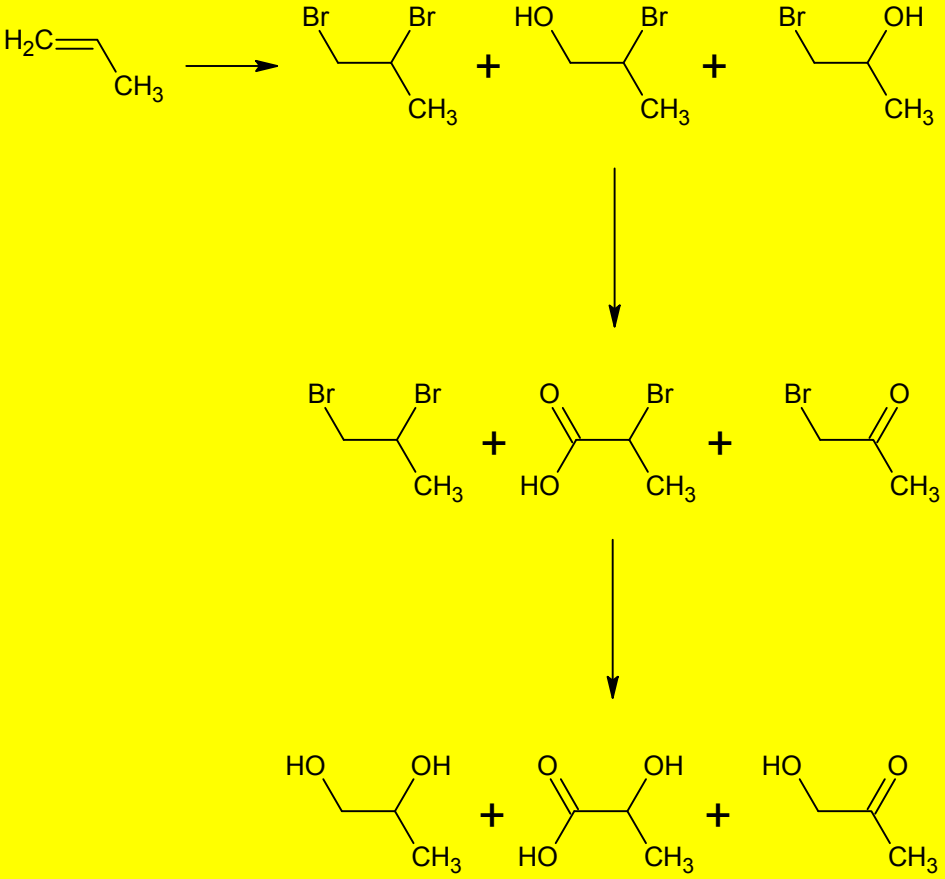
21	At 35°C, K_c = 1.6 x 10^{-5} mol dm^{-3} for the following reaction $2\ NOCl\ (g) \rightleftharpoons 2\ NO\ (g) + Cl_2\ (g) \qquad \Delta H > 0$ Which one of the following statements is correct?	
	A	[NO] < [NOC*l*] at equilibrium
	B	K_c will decreases when temperature increases.
	C	Addition of catalyst will cause more Cl_2 to be formed.
	D	Position of equilibrium will shift to the right when total pressure of the system increases.
	Ans: A $K_c = \frac{[products]}{[reactants]}$ Since K_c <1, equilibrium position lies to the left, signifying [reactants] > [products]. Thus, A is true. **B, C** and **D** are incorrect: When temperature increases, eqm position shifts to the right, forming more product. Thus, K_c should increase. Addition of catalyst does not affect yield. When pressure increases, eqm position shifts to the left, to form fewer number of mol of gas.	

22	Which of these graphs is correct for the equilibrium shown below? A (aq) + B (aq) ⇌ C (s) + D (aq) 
	Ans: A K_c is temperature dependent and does not change with concentration.

23	Which of the following compounds on reaction will produce ethanoic acid?	
	1	$CH_3CH{=}CH_2$ and steam
	2	CH_3COOCH_3 and dilute HC*l*, reflux
	3	CH_3CH_2CHO and acidified $KMnO_4$, reflux
	4	CH_3CH_2OH and acidified $K_2Cr_2O_7$, reflux
	A	1 and 2
	B	2 and 3
	C	3 and 4
	D	2 and 4
	Ans: D Option 1 produces CH_3CH_2CHOH Option 2: Hot acid causes –COO ester linkage to be hydrolysed, forming **<u>CH_3COOH</u>**. Option 3: Oxidation of aldehyde, propanal, CH_3CH_2CHO, forms **propanoic** acid instead Option 4: Oxidation of primary alcohol, ethanol, forms **<u>CH_3COOH</u>**	

24	Linalyl acetate is a naturally-occurring compound and it is a principal component of the essential oils of lavender.  **Linalyl acetate** Which one of the statements is **not** true about linalyl acetate?	
	A	It is a condensation polymer.
	B	It cannot exhibit cis-trans isomerism.
	C	It reacts with hot sulfuric acid.
	D	It reacts with 2 mol of hydrogen gas.
	Ans: A Option A is **not true**. This is not a polymer, as there are no repeat units / polyester linkages present. Option B is true. No cis-trans isomerism in the compound as both C=C has same type of substituents attached to one of the C atoms. Option C is true, as the ester linkage will be hydrolysed in the presense of hot NaOH. Options D is true, as 2 mole of C=C is present, thus 2 mol H_2 is needed for hydrogenation.	

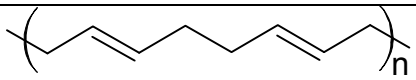
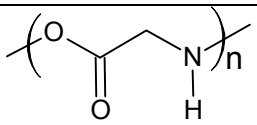
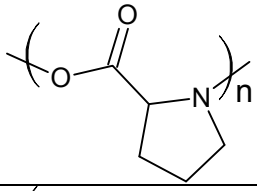
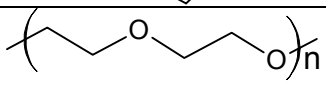
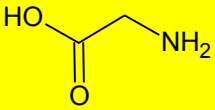
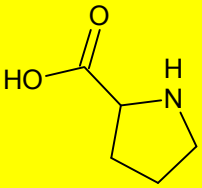
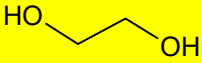
25	Which of the molecular structures below will have the smallest overall dipole?  **A** **B** **C** **D**
	Ans: B The **C-F bond and C-Cl bond** in option **B** are on **<u>opposite</u>** sides, thus the dipole moment almost cancels each other out, resulting in the smallest overall dipole.

26	Propene reacts with aqueous bromine. The product was collected and subsequently reacted with hot potassium manganate(VII), followed by hot sodium hydroxide. Which of this is **not** a possible correct structure of the final product?	
	A	
	B	
	C	
	D	
	Ans: D  Only option **D** is not a possible compound.	

27	Which of these statements is incorrect for a sheet of graphene?	
	A	It is able to conduct electricity.
	B	It has a giant molecular structure.
	C	It is a nanoparticle.
	D	It is a planar molecule.
	Ans: C The best answer is **C** as no details about the dimension is given, hence we do not know if it is a nanoparticle or nanomaterial.	

28	Which of these statements are correct?	
	A	Nanomaterials have one of its dimensions within 10 nm to 100 nm.
	B	Lizards are able to climb on wet surfaces due to hydrogen bonding.
	C	The vivid pink colour of flamingo feathers are due to nanostructures.
	D	Picoscopic (10^{-12}) volcanic dust pose no threat when inhaled.
	Ans: A Picoscopic (10^{-12}) volcanic dust is a nanoparticle and can cause damage to our internal organs when inhaled.	

29	Which of these statements are inconsistent with the properties of a polyamide shirt?	
	A	It is able to absorb water well.
	B	It is prone to creasing.
	C	It is a condensation polymer.
	D	It is resistant to basic hydrolysis.
	Ans: D Polyamides are prone to hydrolysis.	

30	Which of these shows an example of an addition polymer?	
	A	
	B	
	C	
	D	
	Ans: A Monomers A: Addition B:  Condensation C:  Condensation D:  Condensation	

END

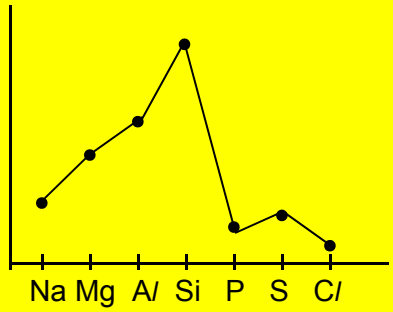
SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 1

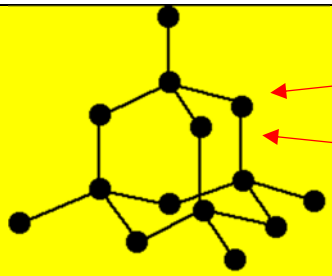
CHEMISTRY 8873/02

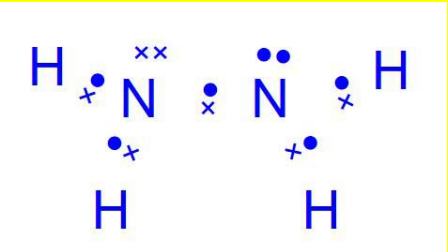
JC2 Preliminary Examination **12 September 2018**
Paper 2 Structured Questions **2 hours**

Section A

1	Combustion data can be used to calculate the empirical formula, molecular formula and relative molecular mass of many organic compounds.		
	(a)	Define the term *relative molecular mass.* [1]	
		Relative molecular mass is the **average mass of one molecule of the substance compared to $\frac{1}{12}$ the mass of an atom of carbon-12.** [1]	
	(b)	**B** is an alcohol, C_xH_yO. A 20 cm^3 gaseous sample of **B** was completely burnt in 200 cm^3 of oxygen (an excess). The final volume, measured under the same conditions as the gaseous sample, was 250 cm^3. Under these conditions, all water present was vaporised. Removal of the water vapour from the gaseous mixture decreased the volume to 170 cm^3. The remaining gaseous mixture was treated with concentrated alkali, and the eventual volume was decreased to 110 cm^3. Given the equation for the complete combustion of **B**, answer the questions below. $C_xH_yO + zO_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$	
		(i)	Calculate the value of ***x*** and ***y***. [2]
			Volume of CO_2 = 170 – 110 = 60 cm^3 Using Avogadro's Law, $\frac{CxHyO}{CO2} = \frac{20}{60} = \frac{1}{x}$ ***x*** = 3 [1] Volume of water vapour = 250 – 170 = 80 cm^3 $\frac{CxHyO}{H2O} = \frac{20}{80} = \frac{1}{y/2}$ ***y*** = 8 [1]
	(c)	Period 3 elements also react with oxygen to form oxides. Sodium oxide and sulfur dioxide are two such oxides.	

		(i)	Write chemical equations, with state symbols, when each of the above oxides react with water. [2]
			$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$ **[1]** $SO_2(g) + H_2O(l) \rightleftharpoons H_2SO_3(aq)$ **[1]**
		(ii)	State and explain the pattern of change of oxidation number which occurs to both oxygen and the Period 3 elements (sodium to silicon) when they react together. [2]
			• The oxidation number of O does not change (-2 throughout). • Oxidation number of Na to Si increases from +1 to +4. • The number of oxygen attached to the element matches the respective group numbers **[2] for 2 points**
	(d)	The first ionisation energies of elements across Period 3 show a general increase. Aluminium and sulfur do **not** follow this general trend.	
		(i)	Write an equation to define the first ionisation energy of aluminium. [1]
			$Al (g) \rightarrow Al^+ (g) + e$ **[1] with state symbols**
		(ii)	Explain the general increase in ionisation energy across Period 3. [2]
			Across period 3, **<u>nuclear charge increases</u>** while **<u>shielding effect is similar</u>**. **[1]** Thus, overall effective nuclear charge increases, resulting in **<u>stronger electrostatic forces of attraction between nucleus</u>** and valence **<u>electrons</u>**. **<u>More energy is needed to remove the electron</u>** **[1]** across Period 3.
		(iii)	Explain why aluminium has a lower first ionisation energy than magnesium. [1]
			Al: $[Ne]3s^2 3p^1$; Mg: $[Ne]3s^2$ Electron is **<u>removed from the outer 3p subshell for Al</u>**, which is **<u>further</u>** away from the attraction of the nucleus. Thus, less energy is needed to do so. **[1]**
	(e)	Silicon is an element in Period 3 displaying unique properties such as electrical conductivity at high temperatures and high melting point.	
		(i)	Complete the sketch of the melting point trend for Period 3 elements in **Figure 1.1**. [1]
			Melting point / °C  **[1]**

		(ii)	With the aid of a well-labelled diagram, explain the abnormally high melting point of silicon, using concepts of structure and bonding. [3]
			 **[1] for labelled diagram** Silicon has a **giant covalent structure [1] with strong covalent bonds between Si atoms**. **A lot of energy** is needed to overcome these strong bonds, hence high melting point is observed. **[1]**
		(ii)	When silicon reacts with magnesium, Mg_2Si forms. Mg_2Si is thought to contain the Si^{4-} ion. State the full electronic configuration of Si^{4-}. [1]
			$1s^22s^22p^63s^23p^6$ **[1]**
		(iii)	Solid Mg_2Si reacts with dilute hydrochloric acid to form gaseous SiH_4 and a solution of magnesium chloride. Write an equation to show the reaction described above. Include state symbols. [1]
			Mg_2Si (s) + 4HCl (aq) → SiH_4 (g) + 2 $MgCl_2$ (aq) **[1] with correct S.S.**
			[Total: 17]

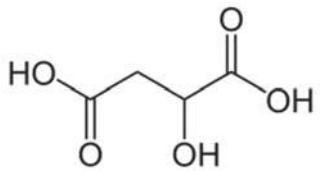
2	Hydrazine has many industrial uses such as rocket fuel, pesticides and to prepare gas precursors used in air bags. Liquid hydrazine undergoes combustion according to the following equation: $N_2H_4\,(l) + O_2\,(g) \rightarrow N_2\,(g) + 2H_2O\,(l)$ A chemist conducted an experiment to determine the standard enthalpy change of combustion of hydrazine where 0.420 g of hydrazine was burnt to heat up a beaker containing 200 cm^3 of water. The temperature of water in the beaker was recorded as follows: Initial temperature /ºC: 29.3 Final temperature / ºC: 37.4			
	(a)	**(i)**	Draw the dot-and-cross diagram of hydrazine.	[1]
			 **[1]**	

		(ii)	Explain what is meant by standard *enthalpy change of combustion of hydrazine.*	[1]
			Standard enthalpy change of combustion (ΔH_c^{θ}) of hydrazine is the **energy released** when **one mole of the hydrazine** is **completely burnt in oxygen** at **(standard conditions) 298K and 1 atm**. **[1]**	
		(iii)	Calculate the standard enthalpy change of combustion of hydrazine. You may assume the process has 80 % efficiency	[2]
			Q = 200 x (37.4 – 29.3) x 4.18 = 6771.6 J Amount of heat released by reaction, Q' = Q / 0.8 = 8464.5 J **[1]** No of moles of N_2H_4 = 0.420 / 32 = 1.313 x 10^{-2} mol $\Delta H_c(N_2H_4)$ = − 6771.6 / 1.313 x 10^{-2} = − 644914 J mol^{-1} = **−645 kJ mol^{-1}** **[1]**	
		(iv)	Given the following data: enthalpy change of formation of steam = −242 kJ mol^{-1} enthalpy change of vapourisation of water = +44 kJ mol^{-1} Using the value you have calculated in **(iii),** complete the following energy cycle to determine the standard enthalpy of formation of hydrazine.	
			N_2 (g) + $2H_2$ (g) → N_2H_4 (*l*) ↓ ↓ N_2 (g) + $2H_2O$ (g) ← N_2 (g) + $2H_2O$ (*l*)	[2]
			$\Delta H_f(N_2H_4$ (l) N_2 (g) + $2H_2$ (g) → N_2H_4 (l) 2 x$\Delta H_f(H_2O$ (g)) ↓ ↓ $\Delta H_c(N_2H_4$ (l) 2 x$\Delta H_v(H_2O$ (l)) N_2 (g) + $2H_2O$ (g) ← N_2 (g) + $2H_2O$ (l) **M[1]** By Hess' law, ΔH_f (N_2H_4(*l*)) = 2(−242) – (−645) – 2(+44) = **+ 73.0 kJmol^{-1}** **[1]**	

	(b)	**(i)**	The standard enthalpy change of formation of hydrazine gas is +235 kJ mol^{-1}. Using appropriate data from the *Data Booklet*, calculate the bond energy of N−H in hydrazine gas.	[2]
			ΔH_f (N_2H_4) = [944 + 2(436)] – [(160) + 4 x B.E(N−H)] + 235 +(+160) + 4 x B.E(N−H) = +944 + 2(+436) [M1] B.E (N−H) = +**355 kJ mol^{-1}** [1]	
		(ii)	Suggest a reason for the difference in the N−H bond energy value obtained from **(b)(i)** with the value given in the *Data Booklet*.	[1]
			The bond energy values obtained from the Data Booklet are **average values** and would differ from the experimental values. [1]	
				[Total: 9]

3	This question is about nanoparticles and its applications.		
	(a)	Finely divided nanoparticles of nickel is found to be an extremely good heterogeneous catalyst for many organic synthesis reactions.	
		(i)	Define the term *catalyst*. **[1]**
			a substance that **increases the rate of a chemical reaction by providing an alternative pathway with a lower activation energy, itself being chemically unchanged.** [1]
		(ii)	State the difference between a *nanoparticle* and a *nanomaterial*. **[1]**
			Nanoparticles **ALL dimensions 1 to 100 nm on the nanoscale** Nanomaterial (**at least) one dimension 1 to 100 nm on the nanoscale**. [1]
		(iii)	Briefly explain how nickel **nanoparticles** operate as a **catalyst**. **[2]**
			Nanoparticles have **higher surface area to volume ratio**, total surface energy increases with overall surface area. **More nickel atoms are exposed** to the reactants. **[1]** **Frequency of effective collisions** between the reactants and catalyst **increases**. **Rate of reaction increases**. [1]
	(b)	One study found that 85 % of sunscreens available in Singapore are likely to contain titanium dioxide nanoparticles due to its ability to block UV radiation while remaining transparent on the skin.	
		(i)	Although the health risk posed by these sunscreen creams is minimal, this is not so for aerosol spray sunscreens. Suggest a reason why aerosol spray sunscreens pose a greater health risk. **[2]**
			Aerosol cans release the nanoparticles in the form of vapour/mist, which are easily inhaled. [1]

	(c)	Geckoes and many insects have adopted nanoscale fibrillary structures on their feet as adhesion devices. Many have the remarkable ability to run at any orientation on just about any smooth or rough, wet or dry, clean or dirty surface.
		Using your understanding of molecular forces, suggest why a gecko can support its own weight and stick to the wall. **[3]**
		On coming in contact with any surface, the nanostructure (spatula) on the gecko legs deforms to enable maximum contact with the wall surface, **forming instantaneous dipole-induced dipole interaction**. **[1]** As the spatula possesses **high surface to volume ratio** and there are billions of spatula per gecko, this creates a **huge collective surface area of contact**. **[1]** The cumulative spatula-wall forces of attraction generated is therefore translated into **enormous attractive (adhesive) forces** capable of supporting many times the animal's body weight. **[1]**
		[Total: 8]

4	Acids are an important component in both winemaking and the finished product of wine. They have a direct influence on the colour and taste of the wine. The measure of the amount of acid in wine is known as the "total acidity". A label on a bottle of wine describes it as having a "total acidity" of 5.8 g dm^{-3}.			
	(a)	**(i)**	The acids found in wine behave as *Brønsted-Lowry acids*. Define a *Brønsted-Lowry acid*.	[1]
			proton donors **[1]**	
		(ii)	One of the most common acid present in wine is malic acid.  **malic acid** M_r = 134.0 K_a = 3.98 x 10^{-4} mol dm^{-3} Assuming that malic acid behaves effectively as a monobasic acid, RCOOH. Write an equation to show the dissociation of malic acid.	[1]
			RCOOH ⇌ $RCOO^-$ + H^+ **[1]**	
		(iii)	Calculate the concentration in, mol dm^{-3}, of malic acid and the pH of the wine.	[2]
			[ROOH] = $\frac{5.8}{134}$ = 0.04328 mol dm^{-3} **[1]**	

$K_a = \frac{[H^+][ROO^-]}{[RCOOH]}$

$K_a = \frac{[H^+]^2}{[RCOOH]}$

$[H^+] = \sqrt{K_a \times [RCOOH]} = \sqrt{3.98 \times 10^{-4} \times 0.04328}$

$= 0.004150 \text{ mol dm}^{-3}$

pH = **2.38** **[1]**

(iv) The dissociation of malic acid is endothermic. Explain the impact on its pH **and** K_a when temperature increases. [3]

The dissociation of malic acid is an endothermic process. By LCP, the **equilibrium position** will **shift right** to favour the endothermic forward reaction to **absorb heat**.**[1]** **[H^+] increases**, [RCOOH] decreases. Thus, **pH decreases**. **[1]**

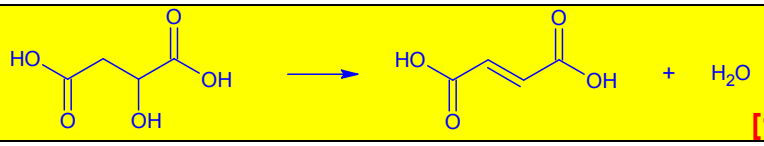
K_a will increase **[1]** as well.

(v) During the ingestion of wine, mouth saliva interacts with it through a buffering action involving CO_3^{2-} / HCO_3^-. Use an equation to illustrate how the buffer system in saliva maintains pH when wine is consumed. [1]

$CO_3^{2-} + H^+ \rightarrow HCO_3^-$ **[1]**

(b) Malic acid undergoes elimination with concentrated sulfuric acid.

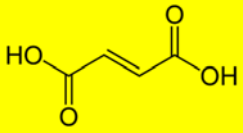
(i) Write a balanced equation for the reaction that took place. [1]



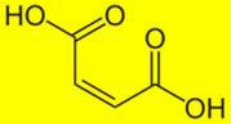
[1]

(ii) Draw two possible isomers formed in **(b)(i)** and state the type of isomerism. [2]

Cis-trans [1] isomerism

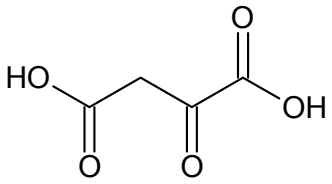


Trans



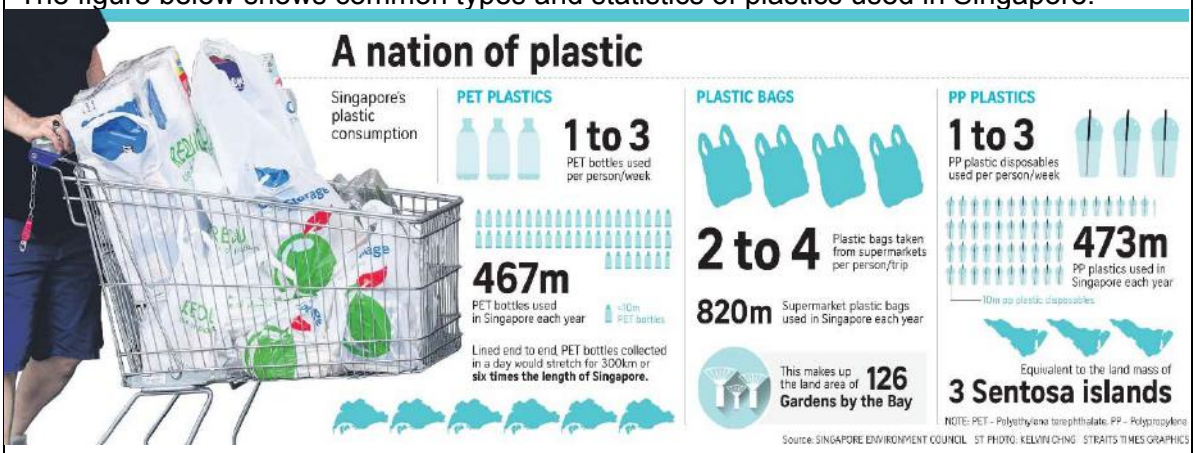
Cis

[1] for both structures

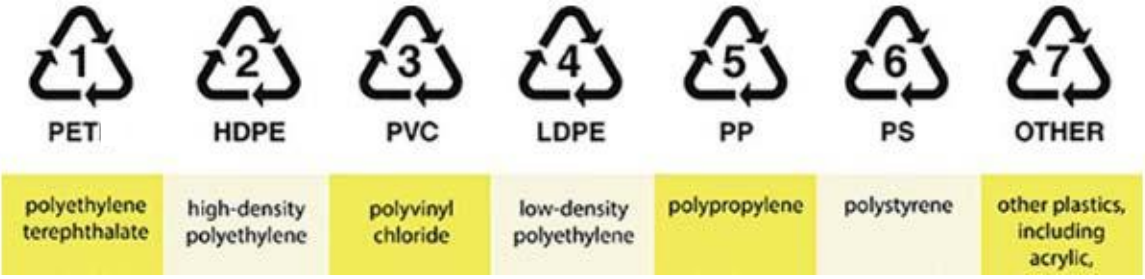
	(d)	Suggest the reagent required for the synthesis of malic acid from the following compound.  [1]
		$NaBH_4$ in ethanol or H_2, Ni catalyst and heat [1] Note: Cannot use $LiAlH_4$ as –COOH group will be reduced as well
		[Total: 12]

5 Singapore uses almost one plastic item per person per day, but fewer than 20% of these are recycled, according to the Singapore Environment Council (SEC). According to the National Environment Agency (NEA), only 6% by mass of plastics are recycled.

The figure below shows common types and statistics of plastics used in Singapore:



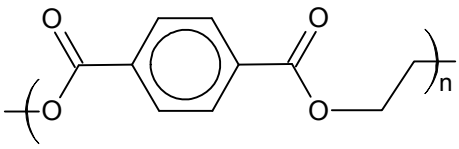
The ASTM International Resin Identification Coding System, often abbreviated as the RIC, is a set of symbols appearing on plastic products that identify the plastic resin out of which the product is made. Understanding the seven plastic codes will make it easier to choose plastics and to know which plastics to recycle:



The methods to reduce on waste in Singapore follows the three "Rs" – Reduce, Reuse and Recycle. However, not all plastics can be reused or recycled.

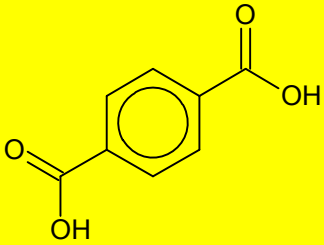
According to some environmental watch groups, in order for a material to be reused, especially with applications on food and drink, it should not leach compounds that are toxic to human consumption (e.g. benzene derivatives). In order for a material to be recycled, it must be able to be melted and remoulded under high heat, and not decompose or char.

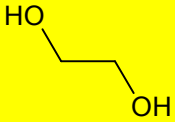
(a) (i) PET polymers are thermoplastics and are observed to have the repeat unit shown below.



Draw the monomer of PET and suggest the classification of this polymerisation.

[2]

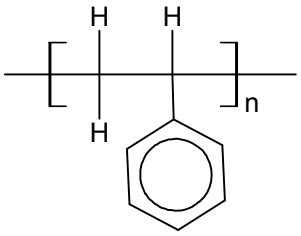




[1] for both

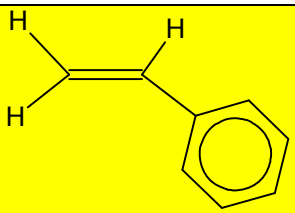
Condensation polymer **[1]**

(ii) PS polymers are thermosets and are observed to have the repeat unit shown below.



Draw the monomer of PS and suggest the classification of this polymerisation.

[2]

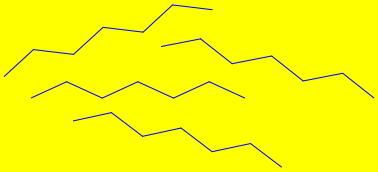


[1]

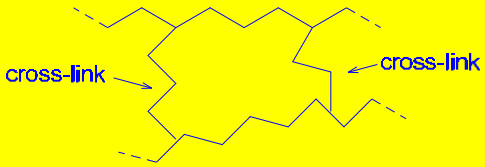
Addition polymer **[1]**

(iii) With the aid of a simple well-labelled diagram, explain how thermoplastics differ from thermosets in their bonding between polymer chains.

[2]



Thermoplastic **[1]**



Thermoset

			[1] Thermoplastic polymer has little or **no cross links between chains** and have **weak instantaneous dipole – induced dipole interactions between its chains** [1] while thermosetting polymers are **highly cross linked by strong covalent bonds formed between chains**. [1]
		(iv)	State if PET and PS can be recycled or reused. **[1]**
			PET can be recycled, but not reused. PS can cannot be recycled nor reused. **[1] for both**
	(b)	Explain the relative rigidity and state possible uses of both LDPE and HDPE. **[3]**	
		LDPE has **branching** on the chains cannot be packed closely together thus creating space between polymer chains resulting in **weaker intermolecular forces of attraction.** HDPE has **straight chain** configuration, the chain of polymer are packed closely together. **Extensive intermolecular forces of attraction** between the chain. **[1]** Hence **HDPE is more rigid than LDPE** **[1]** HDPE is used in pipes or detergent bottles, while LDPE is used as plastic grocery bags. **[1]**	
	(c)	A school performed a survey on 1000 students and 200 staff members. The survey found that the average person in school would purchase a drink in a plastic cup, and use two pieces of plastic crockery, for lunch every day. Each of those items used had a symbol emblazoned at the base shown below. Identify the polymer used, and calculate the percentage waste contributed by this school in a year in relation to the type of polymer resin used. **[2]**	
		Poly(propene) Polypropylene/ PP **[1]** No. of plastic items used by each person = 3 (a plastic cup amd 2 pcs of crockery) Total number of plastics disposed in a year by 1200 students and staff = 3 x (1000 + 200) x 365 = 1314000 % waste = 1314000 / 473000000 x 100% = **0.278%** **[1]**	
		[Total: 14]	

Section B

6 (a) Transition metals are used in many commercial applications such as catalysts. The manufacture of sulfuric acid via the Contact process uses vanadium(V) oxide as catalyst.

Stage one of this process involves the conversion of sulfur dioxide into sulfur trioxide.

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \qquad \Delta H = -196\ \text{kJ mol}^{-1}$$

2.00 moles of SO_2(g) and 2.00 moles of O_2(g) are sealed in a 40 dm^3 container with the addition of catalyst, at constant temperature and pressure. The resulting equilibrium contains 1.98 moles of SO_3(g).

(i) Use the information above to calculate the K_c value for the reaction, stating its units clearly.

[3]

	$2SO_2$	O_2	$2SO_3$
I / mol	2.00	2.00	0
C / mol	-1.98	- (1.98 / 2)	+1.98
E / mol	0.02	1.01	1.98

[1] for working

$$K_c = \frac{[SO3]^2}{[SO2]^2[O2]} = \frac{\left(\frac{1.98}{40}\right)^2}{\left(\frac{0.02}{40}\right)^2\left(\frac{1.01}{40}\right)} = \underline{\mathbf{3.88 \times 10^5}}\ \mathbf{[1]}\ \underline{\mathbf{mol^{-1}\ dm^3}}\ \mathbf{[1]}$$

(ii) State and explain the effect of increasing pressure on the **rate** of production of SO_3.

[2]

When pressure is increased, there are **<u>more number of reactant particles per unit volume</u>**, resulting in **<u>more effective collisions</u>**. **[1]**

Since **<u>rate of reaction is proportionate to number of effective collisions, rate of production increases</u>**. **[1]**

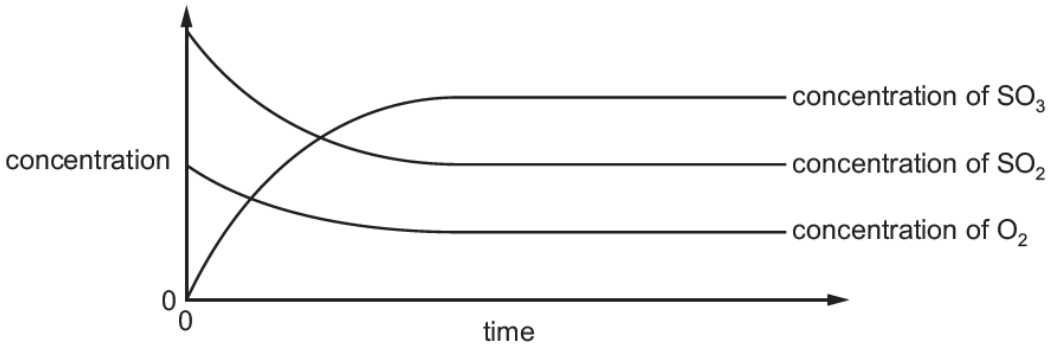
(iii) State and explain the effect of increasing pressure on the **yield** of SO_3.

[2]

By LCP, when pressure increases, **<u>position of equilibrium shifts to the right to product fewer molecules of gas,</u>** **[1]** to decrease pressure. Thus, **<u>yield of SO_3 increases.</u>** **[1]**

(vi) Another experiment of stage one was carried out.

The following graph showing how the concentrations of the three species in the system change with time was sketched.



Study the graph and explain the following:

(I) The gradients of the SO_2 and O_2 lines decrease with time

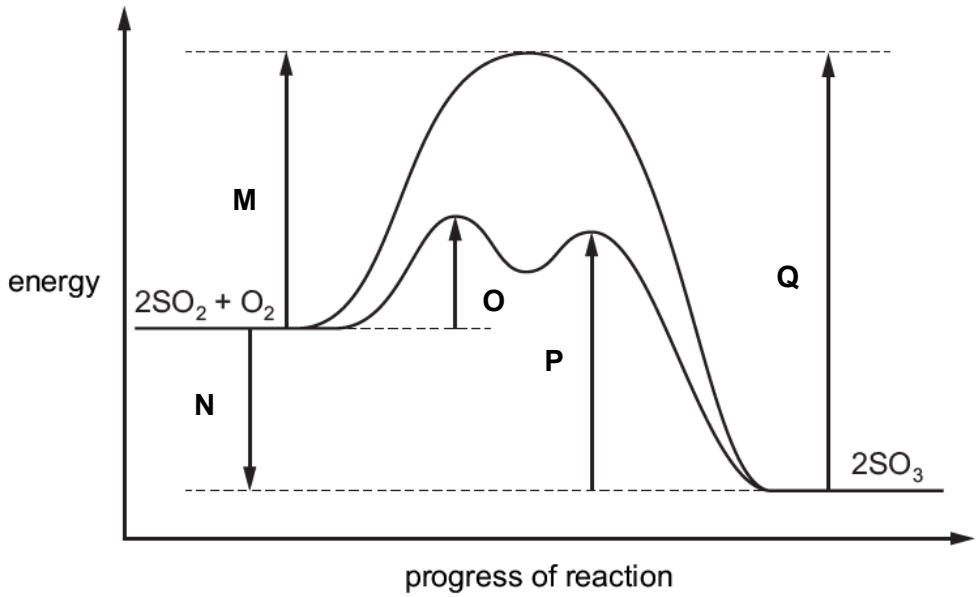
(II) The initial gradient of the SO_2 line is steeper than that of the O_2 line

[2]

(I) This is due to **decreasing concentrations** of the **reactants (or SO_2 and O_2)** as reaction progresses, so **rate of reaction decreases**. [1]

(II) The **mole ratio of SO_2 to O_2 is 2:1 / there is 2 times more mol of SO_2 than O_2**, thus **SO_2 is used up / reacted twice as fast** than O_2. [1]

(v) A reaction pathway diagram for both the catalysed and uncatalysed reactions of stage one is shown.



The letters **M – Q** represent energy changes.

Complete the table by stating which letter, **M – Q**, represents the energy change described.

energy change	letter
the energy change for the production of SO_3	
the activation energy for the production of SO_3 in the absence of a catalyst	
the activation energy for the first step in the **decomposition** of SO_3 in the presence of a catalyst	

[3]

N, M and P respectively **[1] each , total [3]**

(b) Transition metal manganese present in strong oxidising agents such as potassium manganate(VII), and used in many organic chemistry applications.

Butan-2-ol was heated with acidified potassium manganate(VII) to produce **R**.

$$CH_3CH(OH)CH_2CH_3 \xrightarrow{\mathbf{I}} \underset{\mathbf{R}}{CH_3COCH_2CH_3}$$

(i) Write a balanced equation for reaction **I**.

[1]

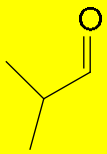
$CH_3CH(OH)CH_2CH_3 + 2[O] \rightarrow CH_3COCH_2CH_3 + H_2O$ **[1]**

(ii) There are two constitutional isomers of **R**, which are also carbonyl compounds. In the boxes below, draw the skeletal formulae of the isomers of **R**.

[2]

The 2 isomers are:
$CH_3CH_2CH_2CHO$ and $(CH_3)_2CHCHO$

Skeletal formulae (marks will only be awarded for this):

[1]	 **[1]**

(iii) Suggest an alternative reagent and condition for reaction **I**.

[1]

$K_2Cr_2O_7$ in H_2SO_4 (aq), heat / reflux **[1]**

	(c)		Mohr's salt, $(NH_4)_2Fe(SO_4)_2 \cdot xH_2O$, is a hydrated form of ammonium iron(II) sulfate, where ***x*** represents the number of moles of water in 1 mole of the salt. A student wanted to determine the value of ***x***. 0.784 g of the hydrated salt was dissolved in water and 10 cm^3 of sulphuric acid was added. All of the solution was titrated with 0.0200 mol dm^{-3} potassium manganate(VII) where 20.00 cm^3 of potassium manganate(VII) solution was required for the complete reaction with the Fe^{2+} ions.
		(i)	Use changes in oxidation number, or otherwise, balance the equation for the reaction taking place. MnO_4^- (aq) + ….Fe^{2+} (aq) + ….H^+ (aq) → ….Mn^{2+} (aq) + ….Fe^{3+} (aq) + ….H_2O (*l*) [1]
			MnO_4^- (aq) + 5Fe^{2+} (aq) + 8H^+ (aq) → 1Mn^{2+} (aq) + 5Fe^{3+} (aq) + 4H_2O (*l*) **[1]**
		(ii)	Calculate the amount of Fe^{2+} in the sample of the salt. [1]
			Amount of MnO_4^- = 20/1000 x 0.0200 = 0.0004 mol Amount of Fe^{2+} = 5 x 0.0004 = **<u>0.002 mol</u> [1] allow ecf**
		(iii)	Calculate the relative formula mass of $(NH_4)_2Fe(SO_4)_2 \cdot xH_2O$ and hence, determine the value of x. [2]
			Mole ratio: 1 $(NH_4)_2Fe(SO_4)_2 \cdot xH_2O$ ≡ 1 Fe^{2+} 0.002 $(NH_4)_2Fe(SO_4)_2 \cdot xH_2O$ ≡ 0.002 Fe^{2+} Using formula, n = $\frac{mass}{Mr}$ 0.002 = $\frac{0.784}{Mr}$ M_r = **<u>392.0</u> [1]** 392.0 = 2(14) + 8(1) + 55.8 + 2(32) + 8(16) + x(2+16) x = **<u>6</u> [1]**
			[Total: 20]

7 **(a)** Samples of 2-bromopropane were dissolved in dilute aqueous ethanol and reacted with potassium hydroxide solution. Several experiments were carried out at constant temperature. The initial rate of reaction was determined in each case.

Expt	$[(CH_3)_2CHBr]$ / mol dm^{-3}	$[OH^-]$ / mol dm^{-3}	Rate / mol dm^{-3} s^{-1}
1	0.015	0.015	13.5
2	0.015	0.030	13.5
3	0.030	0.045	27.0

(i) Determine the order of reaction with respect to 2-bromopropane and potassium hydroxide.

[2]

Comparing Expt 1 and 2,
By **keeping $[(CH_3)_2CHBr]$ constant and doubling $[OH^-]$, rate was constant**.
Hence, order of reaction wrt to $[OH^-]$ is **ZERO**. **[1]**

Comparing Expt 1 and 3,
By **tripling $[OH^-]$, rate remains constant.**
By doubling $[(CH_3)_2CHBr]$, rate was doubled.
Hence, order of reaction wrt to $[(CH_3)_2CHBr]$ is **ONE**. **[1]**

(ii) Hence, write the rate equation and determine the rate constant, indicating the units clearly.

[2]

Rate = k $[(CH_3)_2CHBr]$ **[1]**

From Expt 1 data, 13.5 = k (0.015)
k = **900 s^{-1}** **[1]**

(iii) In another experiment, 2-bromopropane was reacted **hot aqueous** potassium hydroxide solution instead.

Write a balanced equation for the reaction that occurs.

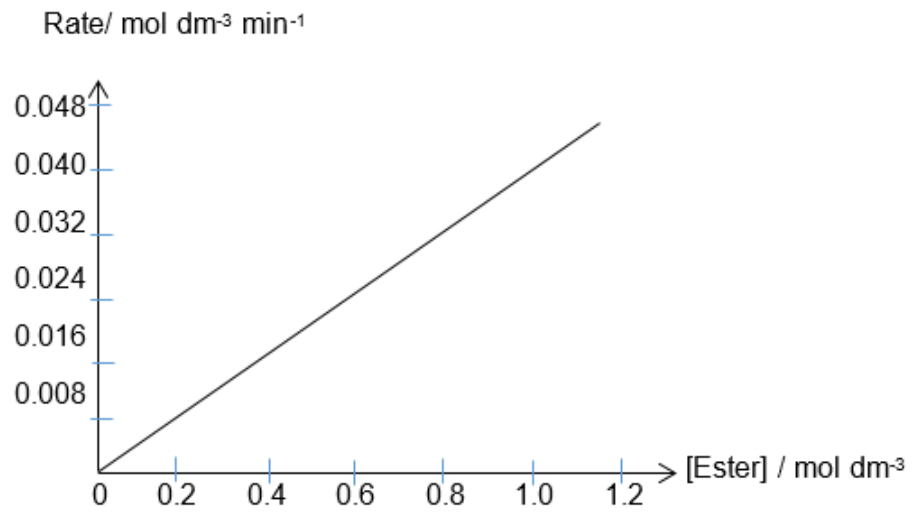
[1]

$CH_3CHBrCH_3$ + KOH → $CH_3CH(OH)CH_3$ + KBr **[1]**

nucleophilic substitution happens, instead of elimination

(b) A series of experiments was conducted to investigate the kinetics of the hydrolysis of an ester.

The graph below shows the results obtained when concentration of the ester were varied with the addition of large quantity of water at 400K. Order of reaction with respect to the ester is one.



(i) Using the graph, determine the value of rate constant, *k*. [1]

The **gradient** of the graph is the rate constant, *k*.

Rate constant, k = 0.032 / 0.8 = **0.0400** min^{-1} **[1] no need units**

(ii) Predict how the gradient of the graph would change at 500 K. Explain your answer. [3]

The gradient will become **steeper [1]**

When temperature of the reaction increases,

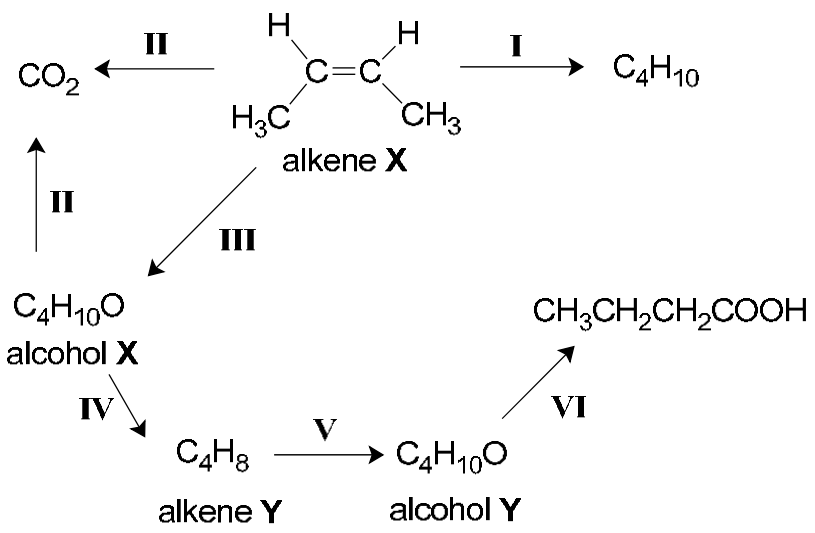
- **average kinetic energy** of the reactant particles **increases**
- **more reactant particles with energy ≥ E_a**

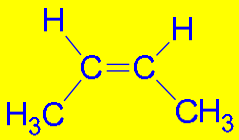
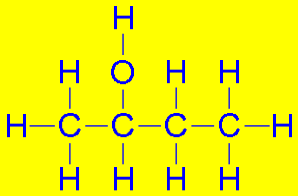
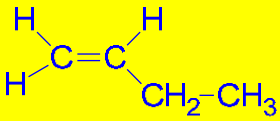
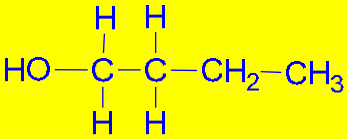
Above 2 points **[1]**

- **more effective collisions**
- Since rate of reaction is proportional to the frequency of effective collisions, **rate** of reaction **increases**

Above 2 points **[1]**

(c)



		(i)	Construct a balanced chemical equation for reaction **II.** [1]
			Combustion  $+ \; 6O_2 \longrightarrow 4CO_2 + 4H_2O$ **[1]**
		(ii)	When alkene **X** undergoes reaction with water in the presence of an acid catalyst, alcohol **X**, a secondary alcohol, is produced. Draw the displayed formula of alcohol **X**. Hence, name the carbonyl compound that can be reduced to form this alcohol [2]
			 **[1] displayed formula only** butanone **[1]**
		(iii)	Draw the structural formula of alkene **Y** and alcohol **Y**. [2]
			Alkene Y:  [1] Alcohol Y:  [1] FYI: • Alkene **Y** is a positional isomer of alkene **X** • alcohol **Y** is **primary ROH**, since alcohol **X** is secondary alcohol
		(iv)	Acidified potassium manganate(VII) was used in the oxidation process of alcohol **Y** to butanoic acid, as seen in reaction **VI.** The oxidation half-equation for the reaction is shown below. $C_4H_{10}O + H_2O \longrightarrow CH_3CH_2CH_2COOH + 4H^+ + 4e$ With an aid of a *Data Booklet*, construct an overall balanced chemical equation for reaction **VI** and determine the volume of 1.25 mol dm^{-3} potassium manganate(VII) required to oxidise 15 g of alcohol **Y**. [3]
			oxidation : $C_4H_{10}O + H_2O \longrightarrow CH_3CH_2CH_2COOH + 4H^+ + 4e$ (x5) reduction: $MnO_4^- + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O$ (x4) Overall equation: $5C_4H_{10}O + 4MnO_4^- + 12H^+ \longrightarrow 5CH_3CH_2CH_2COOH + 4Mn^{2+} + 11H_2O$ **[1]**

Amt of alcohol **Y** = 15/ (4(12) + 10(1) + 16) = 0.2027 mol

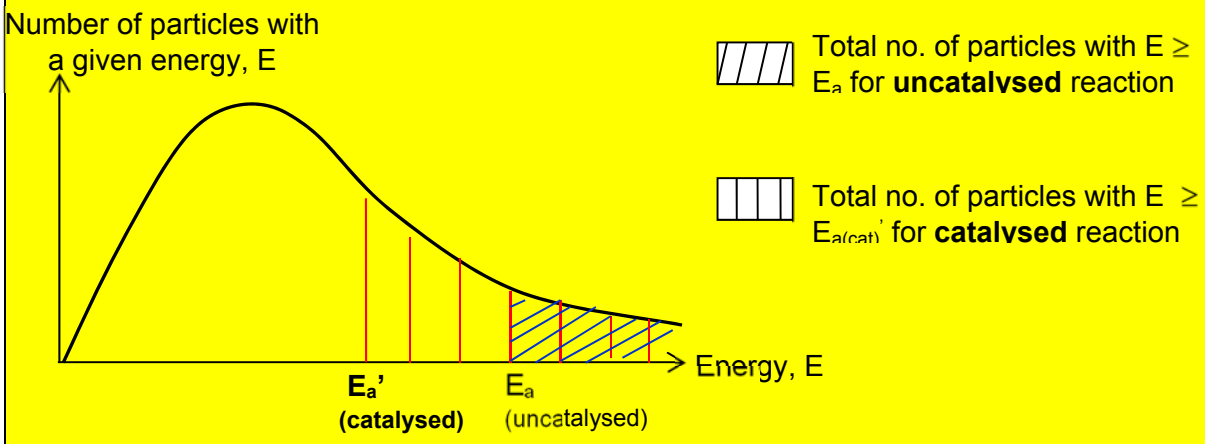
Since $5C_4H_{10}O \equiv 4MnO_4^-$,
Amt of MnO_4^- = (4/5) x 0.2027 = 0.1622 mol **[1]**

Volume of MnO_4^- required = 0.1622 / 1.25
= **0.130 dm^3 (or 130 cm^3)** **[1]**

(v) Platinum acts as catalyst in reaction **I**.

With an aid of a Maxwell Boltzmann distribution diagram, explain how platinum increases the rate of reaction.

[3]



Platinum is a catalyst with provide an alternative reaction pathway with lower activation energy.

When a catalyst is present,

- **more reactant particles with energy ≥ E_a'(catalysed)** leading to **more effective collisions**
- Since **rate of reaction is proportional to the frequency of effective collisions,**
- **rate of reaction increases**

any mistakes -1 mark, total [3]

[Total: 20]

END

TEMASEK
JUNIOR COLLEGE

CHEMISTRY 8873/01

Paper 1 Multiple Choice **17th September 2018**
1 hour

Additional materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.

1. Enter your NAME (as in NRIC). _____
2. Enter the SUBJECT TITLE. _____
3. Enter the TEST NAME. _____
4. Enter the CLASS. _____

Write your **name** and **Civics Group**

Write and shade your index number

WRITE		SHADE APPROPRIATE BOXES									
INDEX NUMBER		0	1	2	3	4	5	6	7	8	9
		0	1	2	3	4	5	6	7	8	9
		0	1	2	3	4	5	6	7	8	9
		0	1	2	3	4	5	6	7	8	9
		0	1	2	3	4	5	6	7	8	9
		A	B	C	D	E	F	G	H	I	

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **13** printed pages.

Section A

For each question there are four possible answers, **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the separate Answer Sheet (OMS).

1 Some isotopes are unstable and undergo nuclear (radioactive) reactions. In one type of reaction, an unstable nucleus assimilates an electron from an inner orbital of its electron cloud. The net effect is the conversion of a proton and an electron into a neutron.

Which of the following describes this type of reaction?

A $^{11}C \rightarrow {}^{12}C$

B $^{111}I \rightarrow {}^{111}Te$

C $^{76}Br \rightarrow {}^{75}Br$

D $^{76}Kr \rightarrow {}^{75}Br$

2 Sodium hydrogencarbonate can be prepared from sodium sulfate by a three-step process:

$Na_2SO_4(s) + 4C(s) \rightarrow Na_2S(s) + 4CO(g)$

$Na_2S(s) + CaCO_3(s) \rightarrow CaS(s) + Na_2CO_3(s)$

$Na_2CO_3(s) + H_2O(l) + CO_2(g) \rightarrow 2NaHCO_3(s)$

What is the mass of sodium hydrogencarbonate that could be formed from 100 kg of the sodium sulfate, assuming a 90% yield in each step?

A 106 kg **B** 96 kg **C** 86 kg **D** 43 kg

3 Which of the following reactions is a redox reaction?

A $2NO_2 \rightarrow N_2O_4$

B $6HCl + As_2O_3 \rightarrow 2AsCl_3 + 3H_2O$

C $SbF_3 + F_2 \rightarrow SbF_5$

D $Cr_2O_7^{2-} + 2OH^- \rightleftharpoons 2CrO_4^{2-} + H_2O$

4 When 2.6 g of a metal X are added to copper(II) sulfate solution 4.8 g of copper are obtained. The relative atomic mass of X is 52. Which one of the following cations of X is produced?

A X^{4+} **B** X^{3+} **C** X^{2+} **D** X^{+}

5 20.0 cm^3 of 0.02 mol dm^{-3} bromate(V), BrO_3^-, was found to react completely with 80.0 cm^3 of 0.01 mol dm^{-3} hydroxylamine, NH_2OH. BrO_3^- ions are reduced as follows:

$$BrO_3^- + 6e^- + 6H^+ \rightarrow Br^- + 3H_2O$$

Which of the following could be the half-equation for the oxidation of hydroxylamine?

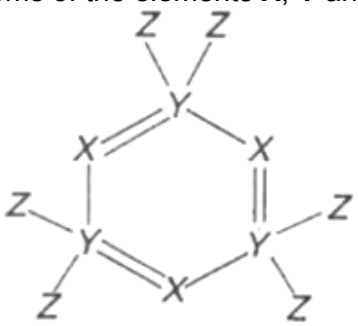
A $NH_2OH \rightarrow ½\ N_2O + 2H^+ + ½\ H_2O + 2e^-$

B $NH_2OH + H_2O \rightarrow NO_2^- + 5H^+ + 4e^-$

C $NH_2OH \rightarrow NO + 3H^+ + 3e^-$

D $NH_2OH + 2H_2O \rightarrow NO_3^- + 7H^+ + 6e^-$

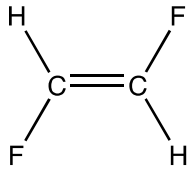
6 A stable molecule containing atoms of the elements **X**, **Y** and **Z** has the following structure.

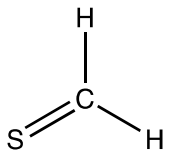


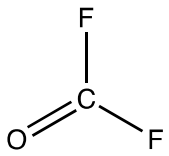
Which one of the following is a possible combination of elements?

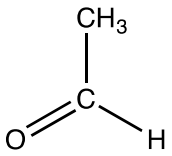
	X	**Y**	**Z**
A	P	As	H
B	P	N	C*l*
C	B	C	H
D	O	N	F

7 Which molecule has the largest dipole?

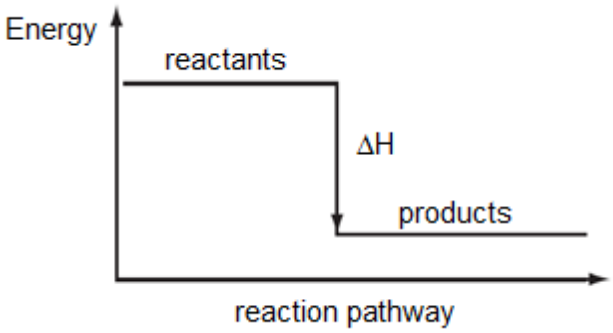
A 

B 

C 

D 

8 Which enthalpy change could **not** be correctly represented by the enthalpy diagram shown?



A Bond energy

B Lattice energy

C Standard enthalpy change of combustion

D Standard enthalpy change of neutralisation

9 Phosphorus pentachloride reacts with limited amount of water to give a liquid and white fumes as shown in the equation below.

$$PCl_5(s) + H_2O(l) \rightarrow POCl_3(l) + 2HCl(g) \qquad \Delta H^{\ominus} = -640 \text{ kJ mol}^{-1}$$

The following enthalpy changes are given:

$\Delta H_f^{\ominus}$ $PCl_5(s)$ = – 444 kJ mol^{-1}
$\Delta H_f^{\ominus}$ $HCl(g)$ = – 92 kJ mol^{-1}
$\Delta H_c^{\ominus}$ $H_2(g)$ = – 286 kJ mol^{-1}

What is the standard enthalpy change of formation of $POCl_3(l)$?

A – 1278 kJ mol^{-1} **B** – 1186 kJ mol^{-1} **C** + 94 kJ mol^{-1} **D** + 274 kJ mol^{-1}

10 Compound **M**, $CH_3CH{=}CHCHC\mathit{l}CH_3$, reacts readily with alcoholic KCN according to the following equation:

$$CH_3CH{=}CHCHC\mathit{l}CH_3 + CN^- \rightarrow CH_3CH{=}CHCH(CN)CH_3 + C\mathit{l}^-$$

The following kinetics data were collected:

Experiment	[M] / mol dm^{-3}	[CN$^-$] / mol dm^{-3}	Relative Rate
1	0.1	0.1	1
2	0.2	0.1	2
3	0.3	0.3	3

Which conclusion can be drawn from this information?

A The overall order of reaction is 2.

B Increasing the concentration of CN^- ions leads to the increase in the rate of reaction.

C The reaction is an addition reaction as it involves the two reactant molecules combining to form the product.

D Replacing the chlorine atom in **M** with bromine atom will require a shorter time for the reaction to be completed

11 The radioactive decay of isotopes **P** and **Q** follow first-order kinetics.

Isotope **P** decreases from 1800 counts per minute to 450 counts per minute in six months. Isotope **Q** decreases from 5400 counts per minute to 1350 counts per minute in four months.

In a separate experiment, a sample containing a mixture of the two isotopes was left to decay, and the molar ratio of **P** : **Q** was found to be 1 : 1 after six months.

What is the molar ratio of **P** : **Q** at the beginning?

A 1 : 2 **B** 1 : 4

C 2 : 1 **D** 4 : 1

12 Which of the following statements are correct?

1 From silicon to sulfur, the melting points of phosphorous and silicon are the lowest and highest respectively.

2 The maximum oxidation number of the element in the oxides increase continuously from sodium to chlorine.

3 The first ionisation energies of the elements in Period 3 increase continuously from sodium to chlorine.

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3

13 **X**, **Y** and **Z** are elements in Period 3 of the Periodic Table. The following statements were made about the properties of **X**, **Y** and **Z**, and their compounds.

1 The oxide of **Z** does not dissolve in excess dilute NaOH(aq).
2 When a sample containing equimolar quantities of each oxide is mixed with water, the solution obtained is highly acidic.
3 Only the chlorides of **Y** and **Z** give an acidic solution with water.

Based on the statements above, identify elements **X**, **Y** and **Z**.

	X	**Y**	**Z**
A	Na	S	Mg
B	Mg	P	Si
C	Na	P	Si
D	Al	S	Mg

14 Astatine (At) is an element in Group 17. Which of the following statements is correct?

A Astatine exists as a dark brown liquid at room temperature.

B HAt(aq) is a weaker acid than HC*l*(aq).

C Astatine reacts with aqueous sodium chloride to form sodium astatide and chlorine.

D The enthalpy change of formation of hydrogen astatide is less exothermic than that of hydrogen chloride.

15 A sample of 0.300 mol of HBr was decomposed in a sealed container at temperature T. The resulting equilibrium mixture was found to contain 0.015 mol of Br_2.

$$2HBr(g) \rightleftharpoons H_2(g) + Br_2(g) \qquad \Delta H \text{ is positive}$$

Which of the following statements are true for the reaction?

1 The total number of moles of gas at equilibrium is 0.30 mol.

2 The equilibrium constant $K_c = 3.09 \times 10^{-3}$

3 The K_c will increase if reaction is carried out at higher temperature.

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 1 only

16 Which statements about indicators are always correct?

1 The pH working range is greater for indicators with higher pK_a values.

2 The pK_a value of an indicator is within its pH working range.

3 The mid-point of an indicator's colour change is at pH = 7.

4 The colour red indicates an acidic solution.

A 1 and 2 only

B 2 only

C 1 and 3 only

D 3 and 4 only

17 One enzyme operates at maximum efficiency when in an aqueous solution buffered at pH 5. Which combination of substances, when dissolved in 4 dm^3 of water, would give the necessary buffer solution?

A 1 mol of HC*l* and 1 mol of CH_3CO_2Na

B 2 mol of NaOH and 1 mol of CH_3CO_2H

C 2 mol of NH_3 and 1 mol of $CH_3CO_2NH_4$

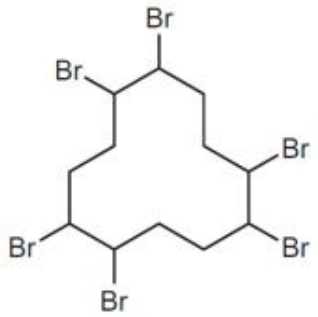
D 2 mol of CH_3CO_2H and 1 mol of NaOH

18 The alkynes are a series of hydrocarbons containing one C≡C triple bond per molecule. They have the general formula C_nH_{2n-2}.

How many structural isomers are there for the alkyne containing six carbon atom per molecule?

A 3 **B** 5 **C** 6 **D** 7

19 The compound shown is used as flame retardant.



Which statement about this molecule is **not** correct?

A The carbon atom ring is planar.

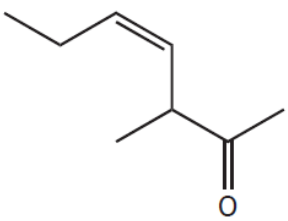
B It is immiscible in water.

C Its empirical formula is C_2H_3Br.

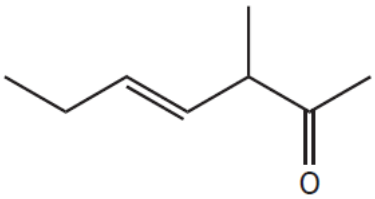
D The compound reacts with ethanolic sodium hydroxide to form $C_{12}H_{12}$.

20 5-methylhept-3-ene-2-one is an aroma molecule found in some types of tea. Which of the following shows a structural formula for the *trans*-isomer of 5-methylhept-3-ene-2-one?

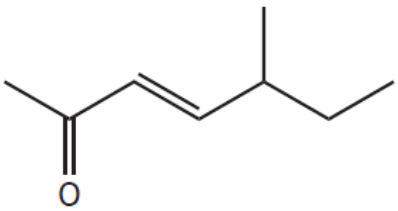
A



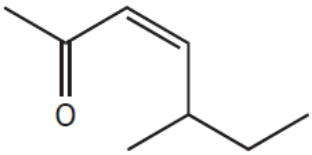
B



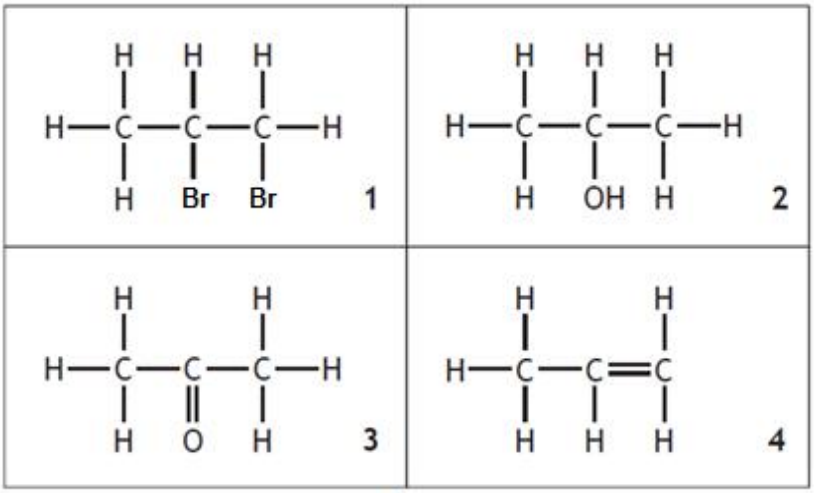
C



D



21



Which line in the table correctly identifies **W**, **X**, **Y** and **Z** in the reaction sequence?

$$W \xrightarrow{\text{reduction}} X \xrightarrow{\text{elimination}} Y \xrightarrow{\text{addition}} Z$$

	W	X	Y	Z
A	1	4	2	3
B	3	2	1	4
C	3	2	4	1
D	4	1	2	3

22 2-methylbuta-1,3-diene, $CH_2{=}C(CH_3){-}CH{=}CH_2$, is used as a monomer in the manufacture of synthetic rubbers.

Which compound would **not** produce this monomer on treatment with excess concentrated sulfuric acid at 170°C?

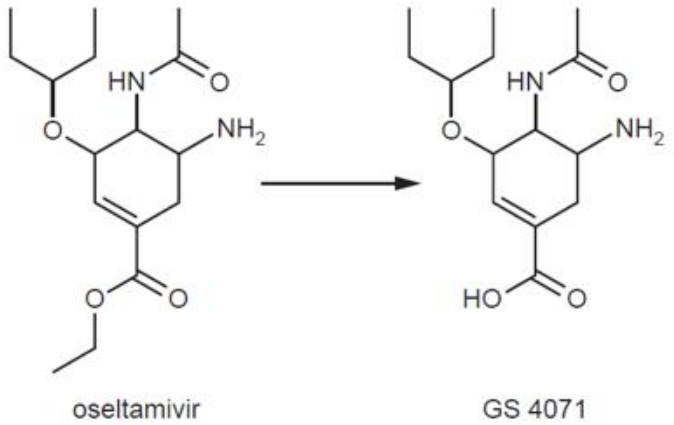
A $(CH_3)_2C(OH)CH(OH)CH_3$

B $HOCH_2CH(CH_3)CH_2CH_2OH$

C $HOCH_2CH(CH_3)CH(OH)CH_3$

D $HOCH_2C(CH_3)(OH)CH_2CH_3$

23 Oseltamivir is an anti-viral drug that is converted to its active form, GS 4071, in the body a being administered. Assume that R-O-R is an inert functional group.



Which of the following statements are correct?

1 The reaction shown above is an elimination reaction.

2 There are three single C-C σ bonds formed by sp^2 - sp^2 overlap in oseltamir and GS 4071.

3 When oseltamir is hydrolysed by aqueous HC*l*, 3 products are obtained.

4 The common functional groups found in oseltamir and GS 4071 are amine, alkene and ketone groups.

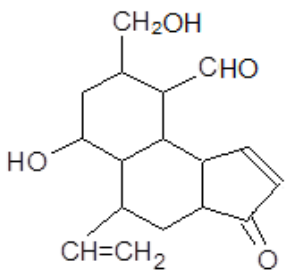
A 1, 2, 3 and 4 only

B 2, 3 and 4 only

C 1 and 4 only

D 3 only

24 What is the correct number of hydrogen atoms incorporated per molecule of compound **Y** when it is reacted with each of the following reducing agents?



Compound **Y**

	Reducing agent	Number of hydrogen atoms incorporated per molecule of **Y**
1	H_2 / Ni	8
2	LiA/H_4 in dry ether	8
3	$NaBH_4$ in ethanol	4

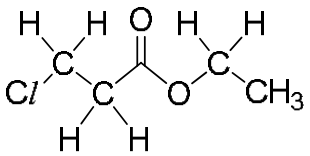
A 1 and 2 only

B 1 and 3 only

C 1 only

D 2 and 3 only

25 What would be the products formed when the following compound is boiled with aqueous sodium hydroxide?



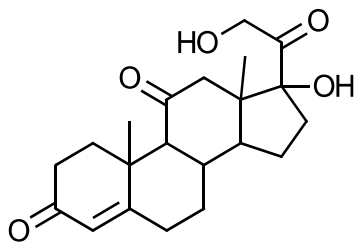
A CH_3CH_2OH and $HOCH_2CH_2CO_2^-Na^+$

B CH_3CH_2OH and $Cl/CH_2CH_2CO_2^-Na^+$

C $CH_3CH_2O^-Na^+$ and $Cl/CH_2CH_2CO_2^-Na^+$

D $CH_3CH_2O^-Na^+$ and $HOCH_2CH_2CO_2^-Na^+$

26 Cortisone is one of the main hormones that are released in response to stress.



cortisone

Which statement about this compound is **incorrect**?

A It does not exhibit cis-trans isomerism.

B It will decolourise hot acidified $Cr_2O_7^{2-}$ ions.

C It can undergo reaction with an amine in presence of dicyclohexylcarbodiimide to form an amide.

D It can undergo esterification with ethanoic acid, in the presence of H^+ ions.

27 What is the maximum size of a nanoparticle?

A 1×10^{-5} cm

B 1×10^{-7} cm

C 1×10^{-9} cm

D 1×10^{-11} cm

28 Which statement best explains that geckos are able to stick on walls?

A The millions of tiny setae on its feet can be attached on the rough surface of the wall.

B The bending of the tiny setae on the surface of the wall causes surface area of contact to increase.

C Its body weight on the wall causes a reactive force from the wall to itself which is sufficient to support its own body weight.

D The millions of tiny setae on the wall have a large surface area to volume ratio to generate extensive hydrogen bonds to support its own body weight.

29 Which of the following statements are correct for a thermosetting plastic?

1 strong covalent bonds formed between the polymer chains

2 carbon-carbon covalent bonds joining the monomers together

3 it can be recycled

4 it is rigid and has high tensile strength

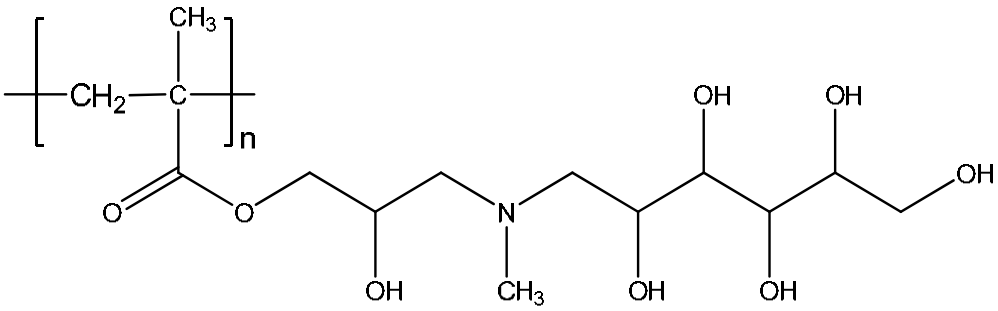
A 1 and 2 only

B 1, 3 and 4 only

C 1 and 3 only

D 1, 2 and 4 only

30 The structure below is that of a polymer based on N-methyl-D-glucamine.



Which statements correctly describe the above polymer?

1 It is able to form hydrogen bonds with water.

2 It can be classified as a condensation type of polymer.

3 The polymer has no reaction with hot aqueous base.

4 The monomer cannot exhibit cis trans isomerism.

A 1 and 2 only

B 1 and 4 only

C 2 and 4 only

D 2 and 3 only

TEMASEK JUNIOR COLLEGE

PRELIMINARY EXAMINATIONS

HIGHER 1

CANDIDATE NAME										
CIVICS GROUP			/							
CENTER NUMBER	S					INDEX NUMBER				

CHEMISTRY **8873/02**

Paper 2 Structured Questions **23 August 2018**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Civics Group, centre number, index number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	/ 60
1	/ 16
2	/ 13
3	/ 7
4	/ 8
5	/ 6
6	/ 10
Section B	/ 20
7	/ 20
8	/ 20
Paper 1	/ 30
Total	

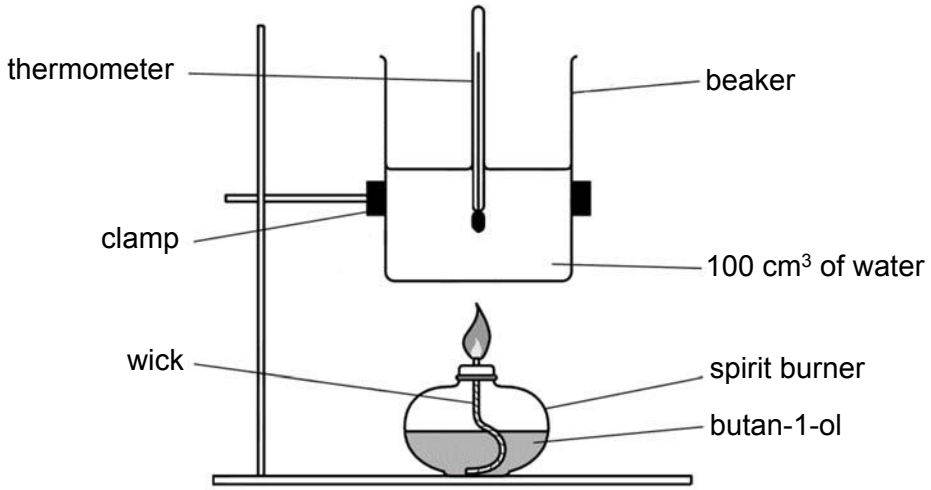
This document consists of **29** printed pages.

Section A

Answer **all** the questions in this section in the spaces provided.

1 **(a)** For many compounds, the enthalpy change of formation cannot be calculated directly. An indirect method based on enthalpy change of combustion can be used.

The enthalpy change of combustion of butan-1-ol can be found by a calorimetry experiment in which the heat given off during combustion is used to heat a known mass of water and the temperature change recorded.



temperature of water before heating = 25.0 °C

temperature of water after heating = 66.1 °C

mass of spirit burner and butan-1-ol before heating = 80.44 g

mass of spirit burner and butan-1-ol after heating = 79.70 g

(i) The heat transfer from the spirit burner to water is known to be only 70% efficient. From the data provided above, determine the enthalpy change of combustion of butan-1-ol.

[3]

(ii) Write the chemical equation that represents the standard enthalpy change of combustion of butan-1-ol, including the state symbols.

..... [1]

(iii) Use the bond energies given in the Data Booklet to calculate another value for the standard enthalpy change of combustion of butan-1-ol.

[2]

(iv) Suggest a reason for the discrepancy between this value and that calculated in **(a)(i)**.

.....

.....

..... [1]

(b) The table below gives some data on four fuel sources: methanol, ethanol, hydrogen and octane. Octane can serve as a rough approximation of petrol.

name	formula	molar mass/ g mol^{-1}	density/ g cm^{-3}	$\Delta H_c^{\ominus}$ (298K)/ kJ mol^{-1}
methanol	CH_3OH	32	0.793[a]	-726.0
ethanol	CH_3CH_2OH	46	0.789[a]	-1367.3
liquid hydrogen	H_2	2	0.0711[b]	-285.8[#]
octane	C_8H_{18}	114	0.703[a]	-5470.2

[a] At 298K and 1 bar pressure

[b] At 20K and 1 bar pressure

[#] standard enthalpy change of combustion of hydrogen **gas**

(i) Calculate the density of gaseous hydrogen at 298 K and 1 bar pressure. Assume 1 mol of any gas occupies 24.7 dm^3 at 298 K and 1 bar pressure. Give your answers in g cm^{-3}.

[1]

(ii) An important property of a fuel, especially when the fuel has to be lifted such as in aviation, is the energy released on combustion per gram of fuel.

Calculate the enthalpy change of combustion per gram of fuel at 1 bar pressure and 298K for methanol.

[1]

(iii) Another important characteristic of a fuel, especially when there is a fuel tank of limited size, is the energy released on combustion per cm^3 of fuel.

Calculate the enthalpy change of combustion per cm^3 of fuel for octane.

[1]

(iv) Explain why, given the data in the question, it is not strictly possible to make a fair comparison of the energy released per cm^3 of liquid hydrogen with other fuels.

……

……

…… [1]

(c) Carbon monoxide and steam are products of incomplete combustion of hydrocarbons. An equilibrium mixture of carbon monoxide and steam is also produced when carbon dioxide is mixed with hydrogen gas.

$$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$$

(i) 0.0100 mol of CO_2 and 0.0200 mol of H_2 were mixed and allowed to reach equilibrium at a temperature T. The final mixture contained 6.93×10^{-3} mol of H_2O.

Calculate the value of K_c at this temperature

[2]

(ii) The numerical value of equilibrium constant is 0.08 at 400 °C and 0.40 at 600 °C. Explain whether the reaction between carbon dioxide and hydrogen is exothermic or endothermic.

……..

……..

……..

…… [2]

(iii) State and explain the effect of increasing pressure on the position of this equilibrium.

……..

……..

…… [1]

[Total: 16]

2 **(a)** What do you understand by the *Brønsted–Lowry* theory of acids and bases?

…… [1]

(b) The following is a list of compounds that react with or dissolve in water:

Sodium chloride, hydrogen bromide, silicon tetrachloride, ammonia, methanol.

Water can react as either an acid or a base. Choose a compound from the above list with which water acts as

- a *Bronsted* base
- a *Bronsted* acid

Construct a balanced equation for each reaction.

• water as a Bronsted base

• water as a Bronsted acid

[2]

(c) Lactic acid is a monoprotic acid which is an important flavouring component of many foods such as cheese, yoghurt and pickled cabbage. A solution of lactic acid in water containing 0.10 moldm^{-3} has a pH of 2.43.

(i) Is lactic acid a strong or weak acid? Explain your answer.

……..

……..

…… [1]

(ii) Use the data given to calculate the value of K_a for lactic acid.

[2]

(iii) Suggest a suitable indicator for the titration of lactic acid with aqueous barium hydroxide.

…… [1]

(iv) A sample of lactic acid was extracted from a blood sample. It was dissolved in water and titrated with 0.250 mol dm^{-3} barium hydroxide. It was found that 22.3 cm^3 of hydroxide was required for neutralisation.
Calculate the mass of lactic acid in the blood sample.
(M_r of lactic acid = 90.0)

[2]

(v) The mass composition of carbon, hydrogen and oxygen in lactic acid is 40.0%, 6.7% and 53.3% respectively. Determine the molecular formula of lactic acid.

[1]

(vi) When lactic acid is strongly oxidised, it gives an organic product with the same number of oxygen atoms. State the reagent and condition for the strong oxidation to occur.

Write a balanced equation for the oxidation reaction showing clearly the structural formula of lactic acid and its oxidation product.

Reagent and condition: …….

Equation:

[2]

(d) Explain, using an equation why an aqueous mixture of lactic acid and sodium lactate can act as a buffer solution on addition of alkali.

You may represent lactic acid as HA and sodium lactate as Na^+A^-.

……..……..

……..……..……..

……..……..… [1]

[Total: 13]

3 **(a)** Outline the principles of the Valence Shell Electron Pair Repulsion (VSEPR) theory.

……

……..

……..

…… [2]

(b) Predict and draw the shapes of the following molecules or ions.

(i) F_2O

[1]

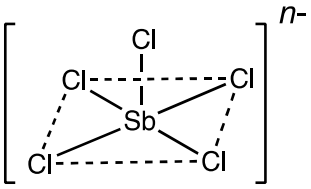
(ii) H_3O^+

[1]

(iii) ClF_4^-

[1]

(c) Antimony, Sb, is in Group 15 of the Periodic Table. It forms a series of salts which contain the $SbCl_5^{n-}$ anion, the structure of which is square pyramidal.



Deduce the total number of electrons around the antimony atom, the value of *n* and the oxidation number of Sb in this ion.

……

……..

……..

…… [2]

[Total: 7]

4 **(a)** Ammonium chloride, NH_4Cl, is a salt which has covalent bonding, dative bonding and ionic bonding. It is very soluble in water and can be used to maintain the urine at an acidic pH in the treatment of some urinary-tract disorders.

(i) What is a dative bond?

……

……

…… [1]

(ii) Draw a "dot-and-cross" diagram to show the bonding in NH_4Cl.

[1]

(iii) In terms of structure and bonding, explain why NH_4Cl is highly soluble in water.

……

……

……

……

…… [2]

(b) **(i)** Research in nanotechnology is growing and many new nanomaterials are being produced with ever more uses.

Suggest what is meant by the term nanomaterials.

……

…… [1]

(ii) Describe the structure of graphene. Explain how this structure gives graphene the properties of high strength and high electrical conductivity.

You may find it useful to include a labelled diagram in your answer.

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……

…… [3]

[Total: 8]

5 Period 3 elements react with oxygen to form oxides.

(a) Write equations for the reactions, if any, of the following three oxides with water. In each case, describe the effect of the resulting solutions on Universal Indicator solution.

(i) Na_2O

……

…… [1]

(ii) Al_2O_3

……

…… [1]

(iii) P_4O_6

……

…… [1]

(b) The oxides MgO, Al_2O_3 and SiO_2 are all used as refractory materials due to their high melting points. The last two are major constituents of gemstones, such as rubies, sapphires and amethysts.
If a sample of one of the oxides was provided as a white powder, describe the reactions you could carry out on the powder to determine which of the three oxides it was.

……

……

……

……

……

……

……

…… [3]

[Total:6]

6 **(a)** Some of the most commonly used polymers are formed by the polymerisation of ethene, C_2H_4.The presence of side-chains affects the bulk properties of an addition polymer.

Poly(ethene) exists in two different forms LDPE (low density poly(ethene)) which has lots of side-chains, and HDPE (high density poly(ethene)) in which there are fewer and shorter side-chains.

(i) Explain with the aid of sketches why the presence of side-chains causes a difference in density in poly(ethene).

……..……..

……..……..……..……..

……

……..…… [2]

(ii) By reference to the type of bonding between the poly(ethene) chains, explain why LDPE has a lower melting point that HDPE.

……..……..

……..……..……..……..

……

……..…… [1]

(b) Poly(vinyl alcohol), PVA, is a synthetic polymer used in papermaking, textiles, eye drops (such as artificial tears for dry eyes) and a variety of coatings. The monomer of PVA is vinyl alcohol, CH_2CHOH.
Poly(vinyl chloride), PVC, is a synthetic water-resistant polymer used for producing water pipes, textiles and clothings such as raincoats. The monomer of PVC is vinyl chloride, CH_2CHCl.

(i) Draw a section of the PVA and PVC molecules containing at least 2 monomer molecules, and identify clearly the repeat units with [ ].

A section of the PVA:

A section of the PVC:

[2]

(ii) What type of polymerisation reaction is likely to have produced these polymers?

…….. [1]

(iii) With reference to the structure and bonding, explain why PVA is commonly used in eye drops while PVC is used in producing clothings such as raincoats.

……

……

……

……

…… [2]

(iv) Suggest a reason why PVC might break down when exposed to concentrated aqueous sodium hydroxide whereas poly(ethene) does not.

……

……

…… [2]

[Total:10]

Section B

Answer **one** questions from this section, in the spaces provided

7 **(a)** Hydrogen peroxide is a mild antiseptic used on the skin to prevent infection of minor cuts, scarpes and burns.

A stock solution of H_2O_2 was diluted by adding 40.0 cm^3 of the solution into a standard flask which was filled with distilled water to make a 250 cm^3 standard solution. 25.0 cm^3 of the standard solution was titrated with 0.200 mol dm^{-3} of acidified $KMnO_4$ solution. 22.50 cm^3 of $KMnO_4$ solution was required to reach the end point and oxygen gas was produced at the end of reaction.

(i) Write a balanced equation for the reaction between hydrogen peroxide and acidified $KMnO_4$ solution, showing your working clearly

……

……

……

…… [1]

(ii) Determine the amount of H_2O_2, in moles, that reacted with $KMnO_4$.

[1]

(iii) Hence, determine the concentration of H_2O_2 in the stock solution.

[2]

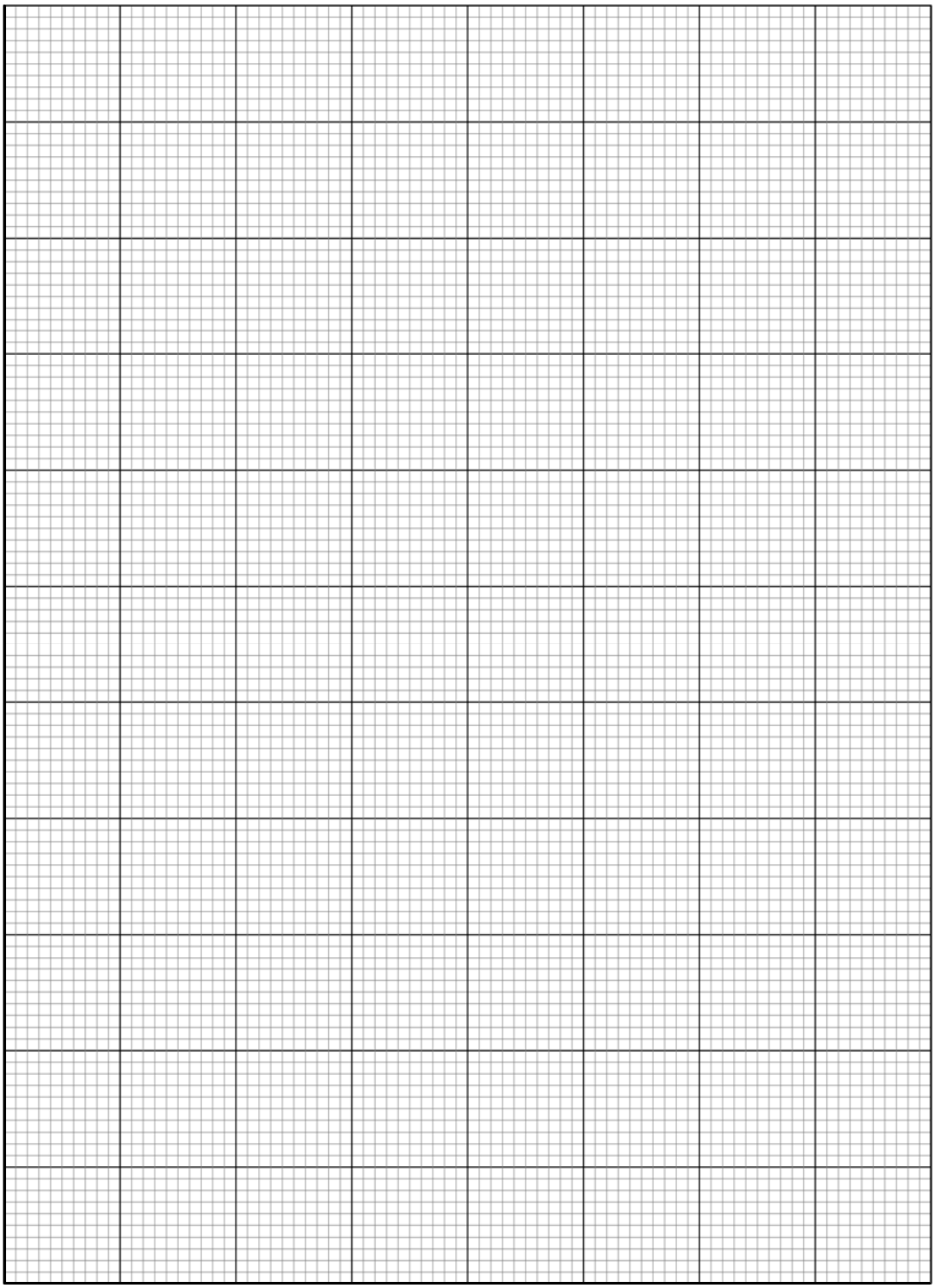
(b) Hydrogen peroxide reacts with acidified iodide ions to liberate iodine according to the following reaction:

$$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow 2H_2O(l) + I_2(aq)$$

The rate for the reaction between iodide and aqueous H_2O_2 was studied using two solutions of different initial concentrations of H_2O_2 and the same initial concentration of iodide. The results are as shown below:

Time / s	Experiment 1	Experiment 2
	$[I^-]$ / mol dm^{-3} when $[H_2O_2]$ = 0.20 mol dm^{-3}	$[I^-]$ / mol dm^{-3} when $[H_2O_2]$ = 0.30 mol dm^{-3}
0	0.0100	0.0100
40	0.0079	0.0070
80	0.0062	0.0049
120	0.0049	0.0034
160	0.0038	0.0024
200	0.0030	0.0017

(i) Plot a graph of these results, putting all the data on the same axes. Label each curve clearly.



[2]

(ii) From the graphs, deduce the order of reaction with respect to iodide and aqueous hydrogen peroxide.

[4]

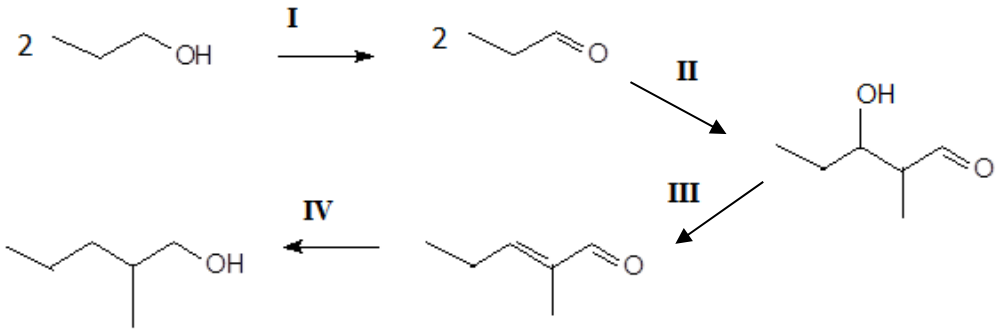
(iii) The order of reaction with respect to H^+ is zero. Hence, write the rate equation for the reaction.

……. [1]

(iv) Calculate the rate constant for **experiment 2**, stating its units.

[1]

(c) A four–step process to convert propanol into 2-methylpentan–1–ol could be an important step for production of renewable energy.



Compound G

(i) State the reagents and conditions required for steps **I** and **IV**.

Step I : ……

……

Step IV : ……

……

[2]

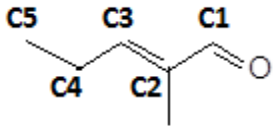
(ii) By considering the change in molecular formulae shown in steps **II** and **III**, suggest the types of reaction that occurred in both steps.

- **step II:** ……
- **Step III:** …… [2]

(iii) Draw the skeletal formula of the other stereoisomer of compound **G**.

[1]

(iv) By considering the hybridisation of the carbon atoms labelled **C1**, **C2**, **C4** and **C5** in compound **G** below, predict which sigma bond, **C1-C2** or **C4-C5,** will be shorter and explain your answer.



Compound **G**

……

……

……

…… [2]

(v) Draw the hybrid orbitals around the carbon atom labelled **C4**.

[1]

[Total: 20]

8 **(a)** Describe the thermal decomposition of the hydrogen halides HC*l*, HBr and HI and explain any variation in their thermal stabilities.

……

……

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……

……

…… [3]

(b) Halogenoalkanes can be made by the reaction of the corresponding halogen with alkanes.

When propane is treated with a small quantity of chlorine in the presence of ultraviolet light, two mono-substituted products are produced.

The order of reactivity of tertiary, secondary and primary hydrogen atoms follows a 5:4:1 ratio.

Draw the structural formula of the two mono-substituted products, and state the approximate ratio in which they are formed.

……

……

……

…… [2]

(c) Compound **A** (M_r=116) is a sweet smelling substance. Acid hydrolysis of compound **A** yields two products, compounds **B** and **C**. **C** reacts with Na_2CO_3 to give CO_2.

A series of tests were performed on compound **B**.

(i) **B** has the molecular formula $C_4H_{10}O$. Reacting **B** with acidified potassium manganate(VII) decolourises the solution and produces compound **D**, $C_4H_8O_2$. Heating **B** with excess concentrated sulfuric acid produces compound **E**, which does not show cis-trans isomerism. Reaction of **E** with hydrogen gas forms 2-methylpropane.

Suggest structures for **B, D** and **E** and explain the reactions involved.

……

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……

Compound	Structure
B	
D	

E	

[5]

(ii) Hence, deduce a possible structure for compound **A**.

……

……

……

……

……

Structure of compound A	

[2]

(d) A student wishes to investigate the kinetics of the acid-catalysed hydrolysis of compound **A** described in **(c)**.

(i) A number of experiments at a constant pressure of 101 kPa and temperature of 90 ^{o}C were performed in which the concentrations of compound **A** and hydrogen ions were varied. The results are shown below:

Experiment	**[H^+] / moldm^{-3}**	**[compound A] / moldm^{-3}**	**Initial rate/ mol dm^{-3}s^{-1}**
1	0.0100	0.120	1.8 x 10^{-4}
2	0.0050	0.240	1.8 x 10^{-4}
3	0.0050	0.480	3.6 x 10^{-4}

Using the above data, deduce the order of reaction with respect to compound **A** and hydrogen ions.

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……..…….…… [2]

(ii) Hence, construct a rate equation and use it to calculate a value of the rate constant, k, including its units, for the acid-catalysed hydrolysis of compound **A**.

……

……

……

……..……

……..…….…… [2]

(iii) With reference to a diagram where necessary, state and explain how the rate of reaction would change when the experiment was conducted:

- in the absence of hydrogen ions

……

……

……

……

……

……

……

- at a pressure of 121 kPa

……

……

……

……

…… [4]

[Total: 20]

2018 TJC JC2 H1 Chemistry Prelim MCQ Solutions

1	2	3	4	5	6	7	8	9	10
B	**C**	**C**	**B**	**C**	**A**	**D**	**A**	**B**	**D**
11	12	13	14	15	16	17	18	19	20
A	**A**	**C**	**D**	**A**	**B**	**D**	**D**	**A**	**C**
21	22	23	24	25	26	27	28	29	30
C	**D**	**D**	**B**	**A**	**C**	**A**	**B**	**D**	**B**

TEMASEK JUNIOR COLLEGE

PRELIMINARY EXAMINATIONS

HIGHER 1

CANDIDATE NAME										
CIVICS GROUP			/							
CENTER NUMBER	S					INDEX NUMBER				

CHEMISTRY **8873/02**

Paper 2 Structured Questions **23 August 2018**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Civics Group, centre number, index number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	/ 60
1	/ 16
2	/ 13
3	/ 7
4	/ 8
5	/ 6
6	/ 10
Section B	/ 20
7	/ 20
8	/ 20
Paper 1	/ 30
Total	

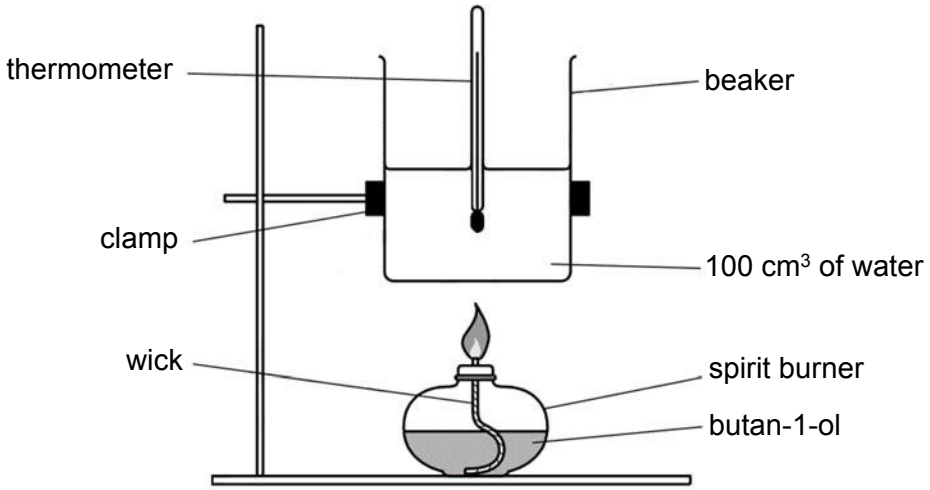
This document consists of **22** printed pages.

Section A

Answer **all** the questions in this section in the spaces provided.

1 **(a)** For many compounds, the enthalpy change of formation cannot be calculated directly. An indirect method based on enthalpy change of combustion can be used.

The enthalpy change of combustion of butan-1-ol can be found by a calorimetry experiment in which the heat given off during combustion is used to heat a known mass of water and the temperature change recorded.



temperature of water before heating = 25.0 °C

temperature of water after heating = 66.1 °C

mass of spirit burner and butan-1-ol before heating = 80.44 g

mass of spirit burner and butan-1-ol after heating = 79.70 g

(i) The heat transfer from the spirit burner to water is known to be only 70% efficient. From the data provided above, determine the enthalpy change of combustion of butan-1-ol.

mass of butan-1-ol reacted = 80.44 – 79.70 = 0.74 g

No. of moles of butan-1-ol reacted = 0.74 / 74 = 0.0100 mol

amount of heat taken in by water = mcΔT

= 100 x 4.18 x (66.1 – 25.0)

• = 17.2 kJ

• Heat provided by butan-1-ol = 100 x 17.2 / 70 = 24.6 kJ

enthalpy change of combustion of butan-1-ol = - 24.6/ 0.0100

• = - 2460 kJ mol^{-1}

[3]

(ii) Write the chemical equation that represents the standard enthalpy change of combustion of butan-1-ol, including the state symbols.

$CH_3CH_2CH_2CH_2OH$ (l) + $6O_2$(l) → $4CO_2$(g) + $5H_2O$(l)

[1]

(iii) Use the bond energies given in the Data Booklet to calculate another value for the standard enthalpy change of combustion of butan-1-ol.

Bonds broken: 3 C-C bonds, 9 C-H bonds, 1 C-O bond, 1 O-H bond
6 O=O bonds

Bonds formed: 8 C=O bonds, 10 O-H bonds

- Energy required to break bonds = (3 x 350) + (9 x 410) + (1 x 360) + (1 x 460) + (6 x 496) = 8536 kJ

  Energy released from bonds formed = (8 x 805) + 10 (460) = 11 040 kJ

- $\Delta H_c^{\ominus}$ of butan-1-ol = -11040 + 8536 = - 2504 kJ mol^{-1}

[2]

(iv) Suggest a reason for the discrepancy between this value and that calculated in **(a)(i)**.

- The bond energies given in the data booklet are only averages and would not apply to the exact compounds in the reaction.

Or

The $\Delta H_c^{\ominus}$ calculated applies for the reactants and products in the gaseous phase but the standard enthalpy change of combustion is defined in terms of the formation of liquid H_2O rather than gaseous H_2O.

Reject: heat loss to surrounding in (a)(ii), as that is accounted by the 70% efficiency

[1]

(b) The table below gives some data on four fuel sources: methanol, ethanol, hydrogen and octane. Octane can serve as a rough approximation of petrol.

name	formula	molar mass/ g mol^{-1}	density/ g cm^{-3}	$\Delta H_c^{\ominus}$ (298K)/ kJ mol^{-1}
methanol	CH_3OH	32	0.793[a]	-726.0
ethanol	CH_3CH_2OH	46	0.789[a]	-1367.3
liquid hydrogen	H_2	2	0.0711[b]	-285.8[#]
octane	C_8H_{18}	114	0.703[a]	-5470.2

[a] At 298K and 1 bar pressure

[b] At 20K and 1 bar pressure

[#] standard enthalpy change of combustion of hydrogen **gas**

(i) Calculate the density of gaseous hydrogen at 298 K and 1 bar pressure. Assume 1 mol of any gas occupies 24.7 dm^3 at 298 K and 1 bar pressure. Give your answers in g cm^{-3}.

Molar mass of H_2 = 2.0 g

Volume of 1 mol of H_2 = 24.7 dm^3 = 24 700 cm^3

Density of gaseous hydrogen = mass/ volume

= 2.0/ 24700

• = 8.10×10^{-5} g cm^{-3}

[1]

(ii) An important property of a fuel, especially when the fuel has to be lifted such as in aviation, is the energy released on combustion per gram of fuel.

Calculate the enthalpy change of combustion per gram of fuel at 1 bar pressure and 298K for methanol.

-726 / 32 = -22.7 kJ g^{-1}

[1]

(iii) Another important characteristic of a fuel, especially when there is a fuel tank of limited size, is the energy released on combustion per cm^3 of fuel.

Calculate the enthalpy change of combustion per cm^3 of fuel for octane.

-5470.2/ (114/0.703) = -33.7 kJ cm^{-3}

[1]

(iv) Explain why, given the data in the question, it is not strictly possible to make a fair comparison of the energy released per cm^3 of liquid hydrogen with other fuels.

vaporisation of hydrogen not accounted for

OR

the value of the density of liquid hydrogen is unsuitable for the calculation of energy per unit volume for gaseous hydrogen

Or enthalpy change of combustion value for hydrogen is for standard conditions, and so relates to **gaseous hydrogen**, not to liquid hydrogen.

[1]

(c) Carbon monoxide and steam are products of incomplete combustion of hydrocarbons. An equilibrium mixture of carbon monoxide and steam is also produced when carbon dioxide is mixed with hydrogen gas.

$$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$$

(i) 0.0100 mol of CO_2 and 0.0200 mol of H_2 were mixed and allowed to reach equilibrium at a temperature T. The final mixture contained 6.93×10^{-3} mol of H_2O.

Calculate the value of K_c at this temperature

	$CO_2(g)$ +	$H_2(g)$	⇌	$CO(g)$	+ $H_2O(g)$
initial amount/ mol	0.0100	0.0200		0	0
change in amount/ mol	-6.93×10^{-3}	-6.93×10^{-3}		$+6.93 \times 10^{-3}$	$+6.93 \times 10^{-3}$
eqm amount/ mol	1.31×10^{-2}	3.07×10^{-3}		6.93×10^{-3}	6.93×10^{-3}

- working

$$Kc = \frac{\left(\frac{6.93\times10^{-3}}{V}\right)\left(\frac{6.93\times10^{-3}}{V}\right)}{\left(\frac{1.31\times10^{-2}}{V}\right)\left(\frac{3.07\times10^{-3}}{V}\right)}$$

- = 1.20

[2]

(ii) The numerical value of equilibrium constant is 0.08 at 400 °C and 0.40 at 600 °C. Explain whether the reaction between carbon dioxide and hydrogen is exothermic or endothermic.

- The **position of equilibrium shifts right** when temperature increases.
- By Le Chatelier's Principle, this indicates that forward reaction absorbs heat to counteract the change exerted on the system, hence the reaction is **endothermic**.

[2]

(iii) State and explain the effect of increasing pressure on the position of this equilibrium.

- The position of equilibrium **does not change** since there are **equal number of moles of gases** on each side of the equation.

[1]

[Total: 16]

2 **(a)** What do you understand by the *Brønsted–Lowry* theory of acids and bases.

Bronsted-Lowry acids are proton donors and bases are proton acceptors.

[1]

(b) The following is a list of compounds that react with or dissolve in water:

Sodium chloride, hydrogen bromide, silicon tetrachloride, ammonia, methanol.

Water can react as either an acid or a base. Choose a compound from the above list with which water acts as

- a *Bronsted* base
- a *Bronsted* acid

Construct a balanced equation for each reaction.

• water as a Bronsted base

$$\underset{\text{acid}}{HBr} + \underset{\text{base}}{H_2O} \rightarrow Br^- + H_3O^+$$

• water as a Bronsted acid

$$\underset{\text{base}}{NH_3} + \underset{\text{acid}}{H_2O} \rightarrow NH_4^+ + OH^-$$

[2]

(c) Lactic acid is a monoprotic acid which is an important flavouring component of many foods such as cheese, yoghurt and pickled cabbage. A solution of lactic acid in water containing 0.10 moldm^{-3} has a pH of 2.43.

(i) Is lactic acid a strong or weak acid? Explain your answer.

• Weak acid.
$[H^+] = 10^{-2.43} = 3.72 \times 10^{-3}$ mol dm^{-3} < 0.1 mol dm^{-3}. Hence, lactic acid is partially dissociated. [1]

(ii) Use the data given to calculate the value of K_a for lactic acid.

$K_a = [H^+]^2 / [HA]_{initial} = (3.72 \times 10^{-3})^2 / (0.1) = 1.38 \times 10^{-4}$ mol dm^{-3}

Or	**HA**	**⇌**	**H^+**	**+**	**A^-**
Equil conc/ mol dm^{-3}	**$0.1 - 3.72 \times 10^{-3}$**		**3.72×10^{-3}**		**3.72×10^{-3}**

$K_a = [H^+]^2 / [HA]_{equilibrium} = 1.43 \times 10^{-4}$ mol dm^{-3} [2]

(iii) Suggest a suitable indicator for the titration of lactic acid with aqueous barium hydroxide.

• Phenolphthalein or thymol blue [1]

(iv) A sample of lactic acid was extracted from a blood sample. It was dissolved in water and titrated with 0.250 mol dm^{-3} barium hydroxide. It was found that 22.3 cm^3 of hydroxide was required for neutralisation.
Calculate the mass of lactic acid in the blood sample.
(M_r of lactic acid = 90.0)

Amount of $Ba(OH)_2$ reacted = 0.250 x 22.3/1000 = 5.575 x 10^{-3} mol
• Amount of lactic acid = 2 x 5.575 x 10^{-3} = 0.0112 mol
• mass of lactic acid = 0.0112 x 90.0 = 1.008 or 1.01 g [2]

(v) The mass composition of carbon, hydrogen and oxygen in lactic acid is 40.0%, 6.7% and 53.3% respectively. Determine the molecular formula of lactic acid.

	C	H	O
Mass /g	40.0	6.7	53.3
No. of moles	40.0/12 = 3.3	6.7	53.3/16 = 3.3
Ratio	1	2	1

Empirical formula is CH_2O
n[12.0 + 2(1.0) + 16.0] = 90.0
n = 3
Molecular formula is $C_3H_6O_3$ [1]

(vi) When lactic acid is strongly oxidised, it gives an organic product with the same number of oxygen atoms. State the reagent and condition for the strong oxidation to occur.

Write a balanced equation for the oxidation reaction showing clearly the structural formula of lactic acid and its oxidation product.

Reagent and condition: **acidified $K_2Cr_2O_7$, heat Or acidified $KMnO_4$, heat**

Equation: $CH_3CH(OH)CO_2H + [O] \rightarrow CH_3C(=O)-CO_2H + H_2O$ [2]

(d) Explain, using an equation why an aqueous mixture of lactic acid and sodium lactate can act as a buffer solution on addition of alkali.

You may represent lactic acid as HA and sodium lactate as Na^+A^-.

On addition of an alkali, HA will react with added OH^- resulting in no significant change in pH.

• $HA + OH^- \longrightarrow A^- + H_2O$ [1]

[Total: 13]

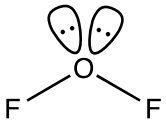
3 **(a)** Outline the principles of the Valence Shell Electron Pair Repulsion (VSEPR) theory.

- **Electron pairs (lone and bond pairs) in the <u>outer shell</u> of the central atom will arrange themselves as far apart as possible so as to <u>minimise repulsion</u> and maximise stability.**
- **The lone pair- lone pair repulsion is greater than lone pair-bond pair repulsion which in turn is greater than bond pair-bond pair repulsion.**

[2]

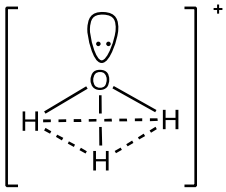
(b) Predict and draw the shapes of the following molecules or ions.

(i) F_2O

- **Bent shape**
- 

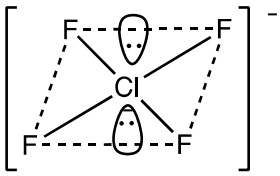
[1]

(ii) H_3O^+

- **Trigonal pyramidal shape**
- 

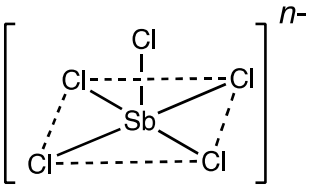
[1]

(iii) ClF_4^-

- **Square planar shape**
- 

[1]

(c) Antimony, Sb, is in Group 15 of the Periodic Table. It forms a series of salts which contain the $SbCl_5^{n-}$ anion, the structure of which is square pyramidal.



Deduce the total number of electrons around the antimony atom, the value of *n* and the oxidation number of Sb in this ion.

- **Total no of electrons around Sb atom = 10 + 2 = 12 (there is a lone pair on Sb since it is square-pyramidal)**

Since Sb is in Group 15 it has acquire an additional 2 electrons.

- **Hence n = 2 and oxidation number of Sb is +3**

[2]

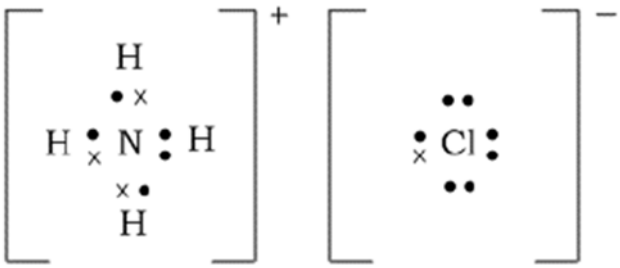
[Total: 7]

4 **(a)** Ammonium chloride, NH_4Cl, is a salt which has covalent bonding, dative bonding and ionic bonding. It is very soluble in water and can be used to maintain the urine at an acidic pH in the treatment of some urinary-tract disorders.

(i) What is a dative bond? [1]

Dative / Co-ordinate bond is a covalent bond in which a <u>pair of electrons is shared between 2 atoms</u> but <u>ONLY ONE</u> of them <u>provides both electrons</u> that make up the bond.

(ii) Draw a "dot-and-cross" diagram to show the bonding in NH_4Cl. [1]



(iii) In terms of structure and bonding, explain why NH_4Cl is highly soluble in water.

[2]

- **NH_4Cl has a <u>giant ionic structure</u> and water has a <u>simple molecular structure.</u>**
- **<u>Ion-dipole interactions</u> formed between the ions present in NH_4Cl and polar water molecules <u>releases sufficient energy</u> to overcome the <u>ionic bonds</u> in NH_4Cl *and* <u>hydrogen bonds</u> between water molecules.**

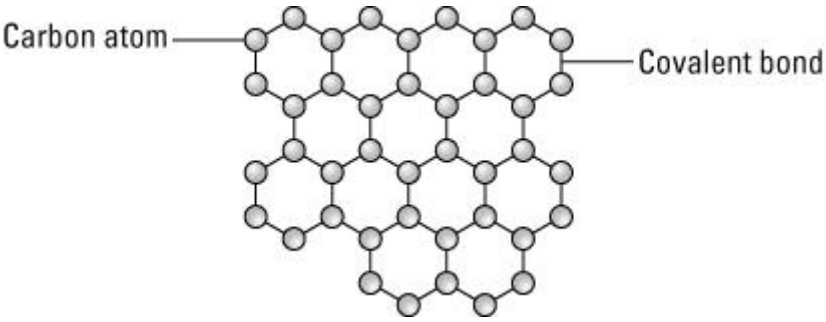
(b) **(i)** Research in nanotechnology is growing and many new nanomaterials are being produced with ever more uses.

Suggest what is meant by the term nanomaterials. [1]

A nanomaterial is a material will at least one dimension on the nanoscale (length ≤ 100nm).

(ii) Describe the structure of graphene. Explain how this structure gives graphene the properties of high strength and high electrical conductivity.

You may find it useful to include a labelled diagram in your answer. [3]



- **The structure of graphene is a giant covalent structure and it is a <u>single layer of hexagons</u> (graphite) where every atom is on the surface of the structure.**
- **<u>Each carbon atom has strong covalent bonds with three other carbon atoms</u> and a lot of energy is needed to break the bonds hence it has <u>high tensile strength</u>.**
- **<u>One p electron per carbon atom is delocalised</u> over the graphene layer and is able to act as a mobile charge carrier. Hence it has <u>high electrical conductivity.</u>**

[Total: 8]

5 Period 3 elements react with oxygen to form oxides.

(a) Write equations for the reactions, if any, of the following three oxides with water. In each case, describe the effect of the resulting solutions on Universal Indicator solution.

(i) Na_2O [1]

- **$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$;**
  The Universal Indicator solution will turn violet or indigo in the solutions.

(ii) Al_2O_3 [1]

- **No reaction**
  The Universal Indicator solution will turn green in the solutions.

(iii) P_4O_6 [1]

- **$P_4O_6(s) + 6H_2O(l) \rightarrow 4H_3PO_3(aq)$;**
  The Universal Indicator solution will turn red in the solutions.

(b) The oxides MgO, Al_2O_3 and SiO_2 are all used as refractory materials due to their high melting points. The last two are major constituents of gemstones, such as rubies, sapphires and amethysts.
If a sample of one of the oxides was provided as a white powder, describe the reactions you could carry out on the powder to determine which of the three oxides it was.

[3]

- **I will add HC*l* to a small amount of the powder. If it is soluble in the acid, it could be either MgO or Al_2O_3.**
- **Then I will add NaOH to another small portion of the powder. If it is soluble, then it is Al_2O_3, if not, then it is MgO.**
- **If the powder is not soluble in acid or base, it is SiO_2.**

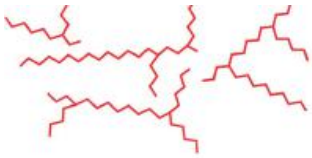
[Total:6]

6 **(a)** Some of the most commonly used polymers are formed by the polymerisation of ethene, C_2H_4.The presence of side-chains affects the bulk properties of an addition polymer.

Poly(ethene) exists in two different forms LDPE (low density poly(ethene)) which has lots of side-chains, and HDPE (high density poly(ethene)) in which there are fewer and shorter side-chains.

(i) Explain with the aid of sketches why the presence of side-chains causes a difference in density in poly(ethene).

[2]



LDPE

HDPE

- Minimum of 2 chains suitable sketches
- LDPE has more space between the chain/polymers, hence, low density or HDPE less empty space and more closely packed between the chains, hence, high density.

(ii) By reference to the type of bonding between the poly(ethene) chains, explain why LDPE has a lower melting point that HDPE.

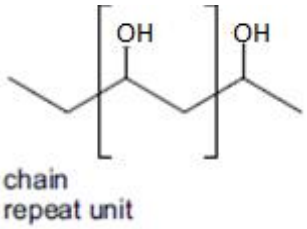
[1]

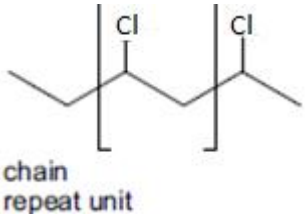
- LDPE has a less closely packed structure. It has less surface area of contact and weaker instantaneous dipole-induced dipole (id-id) attractions between polymer chains. Hence less energy is required to overcome the weak id-id attractions & melting point is lower.

(b) Poly(vinyl alcohol), PVA, is a synthetic polymer used in papermaking, textiles, eye drops (such as artificial tears for dry eyes) and a variety of coatings. The monomer of PVA is vinyl alcohol, CH_2CHOH.
Poly(vinyl chloride), PVC, is a synthetic water-resistant polymer used for producing water pipes, textiles and clothings such as raincoats. The monomer of PVC is vinyl chloride, CH_2CHCl.

(i) Draw a section of the PVA and PVC molecules containing at least 2 monomer molecules, and identify clearly the repeat units with [ ].

[2]





(allow displayed, structural or skeletal formulae)

(ii) What type of polymerisation reaction is likely to have produced these polymers?

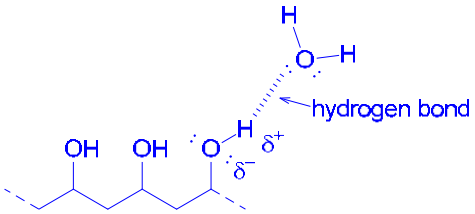
[1]

- Addition polymerisation

(iii) With reference to the structure and bonding, explain why PVA is commonly used in eye drops while PVC is used in producing clothings such as raincoats.

[2]

- PVA is soluble in water. The **-OH group** in PVA forms **hydrogen bonds** between the chains and the water molecules. The water trap in the polymers is used to relieve eye dryness and soreness as it lubricates the surface of the eye.



- Raincoats made from PVC are water-resistant/repellent because PVC consist of id-id & pd-pd. It cannot absorb water.

(iv) Suggest a reason why PVC might break down when exposed to concentrated aqueous sodium hydroxide whereas poly(ethene) does not.

- PVC reacts with NaOH, undergoes substitution reaction to form alcohol, bonds are disrupted and structure broken down.
- Poly(ethene) is non-polar and inert. It would not react and affect by NaOH.

[2]

[Total:10]

Section B

Answer **one** questions from this section, in the spaces provided

7 **(a)** Hydrogen peroxide is a mild antiseptic used on the skin to prevent infection of minor cuts, scarpes and burns.

A stock solution of H_2O_2 was diluted by adding 40.0 cm^3 of the solution into a standard flask which was filled with distilled water to make a 250 cm^3 standard solution. 25.0 cm^3 of the standard solution was titrated with 0.200 mol dm^{-3} of acidified $KMnO_4$ solution. 22.50 cm^3 of $KMnO_4$ solution was required to reach the end point and oxygen gas was produced at the end of reaction.

(i) Write a balanced equation for the reaction between hydrogen peroxide and acidified $KMnO_4$ solution, showing your working clearly.

$MnO_4^- + 5e^- + 8H^+ \rightarrow Mn^{2+} + 4H_2O$ x 2
$H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$ x 5

- **$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$**

[1]

(ii) Determine the amount of H_2O_2, in moles, that reacted with $KMnO_4$.

no of moles of MnO_4^- = (22.50 ÷ 1000) × 0.200 = 4.50×10^{-3} mol

- **no of moles of H_2O_2 = 4.50×10^{-3} × 5/2 = 0.01125 mol**

[1]

(iii) Hence, determine the concentration of H_2O_2 in the stock solution.

- **no of moles of H_2O_2 in 250 cm^3 standard solution = 0.01125 × 10 = 0.1125 mol**

- **[H_2O_2] in stock solution = 0.1125 ÷ 40/1000 = 2.81 mol dm^{-3}**

[2]

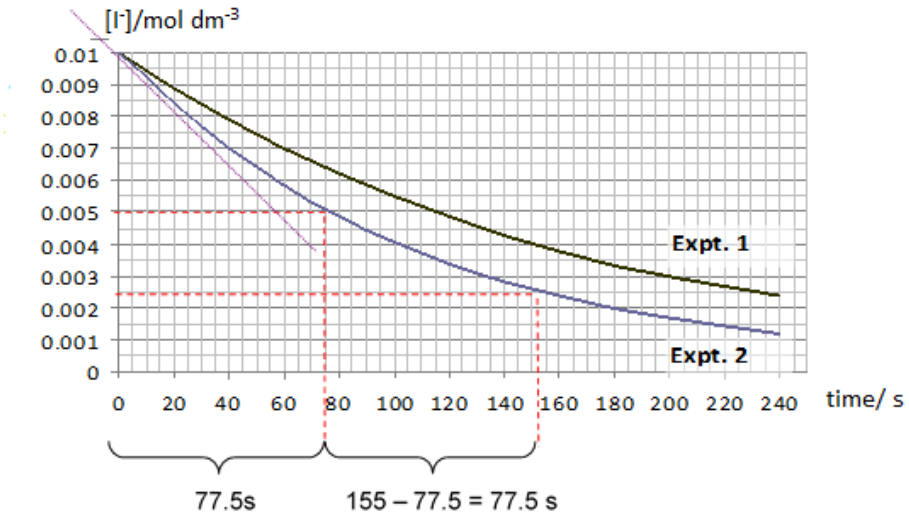
(b) Hydrogen peroxide reacts with acidified iodide ions to liberate iodine according to the following reaction:

$$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow 2H_2O(l) + I_2(aq)$$

The rate for the reaction between iodide and aqueous H_2O_2 was studied using two solutions of different initial concentrations of H_2O_2 and the same initial concentration of iodide. The results are as shown below:

Time / s	Experiment 1	Experiment 2
	$[I^-]$ / mol dm^{-3} when $[H_2O_2]$ = 0.20 mol dm^{-3}	$[I^-]$ / mol dm^{-3} when $[H_2O_2]$ = 0.30 mol dm^{-3}
0	0.0100	0.0100
40	0.0079	0.0070
80	0.0062	0.0049
120	0.0049	0.0034
160	0.0038	0.0024
200	0.0030	0.0017

(i) Plot a graph of these results, putting all the data on the same axes. Label each curve clearly.



[1m for correct label of axis and best fit smooth curves
1m for correct points plotted]

[2]

(ii) From the graphs, deduce the order of reaction with respect to iodide and aqueous hydrogen peroxide.

- **constant t½ of 77.5 s**
  (construction lines for at least 2 half-lives must be shown on graph)
- **thus first order with respect to iodide.**

Expt 1: 0.20 mol dm^{-3} H_2O_2,

initial rate = $\frac{0.01-0.005}{85-0}$ **= 5.88 x 10^{-5} mol dm^{-3} s^{-1}**

Expt 2: 0.30 mol dm^{-3} H_2O_2,

initial rate = $\frac{0.01-0.004}{70-0}$ **= 8.57 x 10^{-5} mol dm^{-3} s^{-1}**

- **When [H_2O_2] increases 1.5 x, initial rate increases** $\frac{8.57x10^{-5}}{5.88x10^{-5}}$ **= 1.46 x**
- **1st order w.r.t. H_2O_2.**

[4]

(iii) The order of reaction with respect to H^+ is zero. Hence, write the rate equation for the reaction.

- **rate = k[H_2O_2][I^-]**

[1]

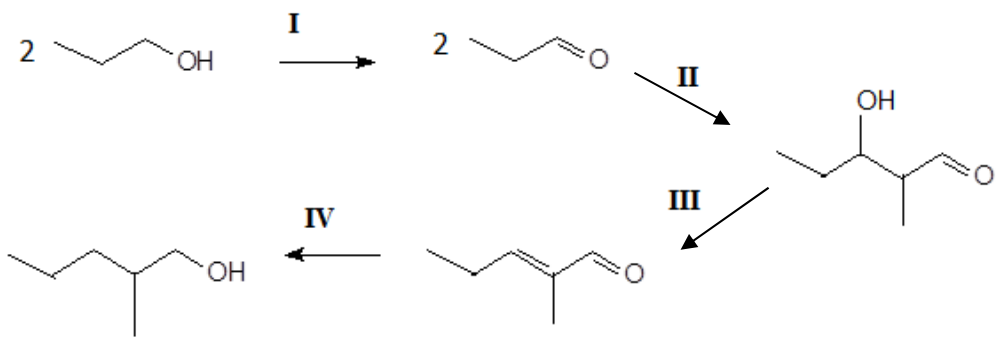
(iv) Calculate the rate constant for **experiment 2**, stating its units.

- **k =** $\frac{8.57x10^{-5}}{(0.30)(0.01)}$ **= 0.0286 mol^{-1} dm^3 s^{-1}**

or k = $\frac{ln\ 2}{77.5\ x\ 0.3}$ **= 0.0298 mol^{-1} dm^3 s^{-1}**

[1]

(c) A four–step process to convert propanol into 2-methylpentan–1–ol could be an important step for production of renewable energy.



Compound G

(i) State the reagents and conditions required for steps **I** and **IV**.

- **step I: $K_2Cr_2O_7$, dilute H_2SO_4, warm with immediate distillation**
- **step IV: H_2, Pt / Pd, room temperature (accept Ni, with elevated temp and pressure)**

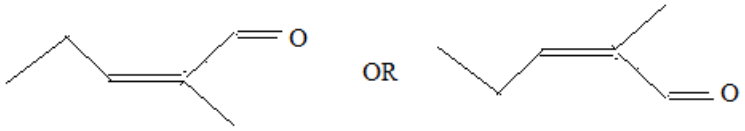
[2]

(ii) By considering the change in molecular formulae shown in steps **II** and **III**, suggest the types of reaction that occurred in both steps.

- **step II: addition**
- **Step III: elimination**

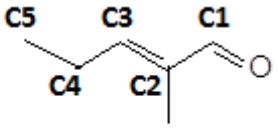
[2]

(iii) Draw the skeletal formula of the other stereoisomer of compound **G**.

- 

[1]

(iv) By considering the hybridization of the carbon atoms labelled **C1**, **C2**, **C4** and **C5** in compound **G** below, predict which sigma bond, **C1-C2** or **C4-C5,** will be shorter and explain your answer.

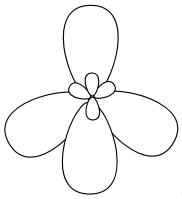


Compound **G**

- **The C1-C2 bond is shorter**
- **C1-C2 is sp^2-sp^2 orbital overlap, while C4-C5 is sp^3-sp^3 orbital overlap. sp^2 orbital has more s character, resulting in more effective orbital overlap and stronger bond.**

[2]

(v) Draw the hybrid orbitals around the carbon atom labelled **C4**.

-  **around C4**

[1]

[Total: 20]

8 **(a)** Describe the thermal decomposition of the hydrogen halides HC*l*, HBr and HI and explain any variation in their thermal stabilities.

• Hydrogen halides decompose thermally to from H_2 gas and halogen, X_2.

•Thermal stability <u>decreases</u> down the group: HC*l* > HBr > HI

•This is because the <u>atomic radius increases</u> down the group, resulting in <u>decreasing degree of effective overlap of orbitals</u> and <u>covalent bond strength and hence bond energy of HX decreases</u> down the group.

(alternative ans: quote bond energy values from Data Booklet and recognise that H-X bond strength decreases in the order HC*l* > HBr > HI)

[3]

(b) Halogenoalkanes can be made by the reaction of the corresponding halogen with alkanes.

When propane is treated with a small quantity of chlorine in the presence of ultraviolet light, two mono-substituted products are produced.

The order of reactivity of tertiary, secondary and primary hydrogen atoms follows a 5:4:1 ratio.

Draw the structural formula of the two mono-substituted products, and state the approximate ratio in which they are formed.

- **$CH_3CH_2CH_2CCl$: $CH_3CHClCH_3$**

6 x 1 : 2 x 4

6 : 8

- **3 : 4**

[2]

(c) Compound **A** (M_r=116) is a sweet smelling substance. Acid hydrolysis of compound **A** yields two products, compounds **B** and **C**. **C** reacts with Na_2CO_3 to give CO_2.

A series of tests were performed on compound **B**.

(i) **B** has the molecular formula $C_4H_{10}O$. Reacting **B** with acidified potassium manganate(VII) decolourises the solution and produces compound **D**, $C_4H_8O_2$. Heating **B** with excess concentrated sulfuric acid produces compound **E**, which does not show cis-trans isomerism. Reaction of **E** with hydrogen gas forms 2-methylpropane.

Suggest structures for **B, D** and **E** and explain the reactions involved.

•B

Compound	•••Structure
E	$CH_3-C(CH_3)=CH_2$
B	$CH_3-CH(CH_3)-CH_2-OH$
D	$CH_3-CH(CH_3)-COOH$

undergoes <u>oxidation</u> with acidified $KMnO_4$ to form D.

→ From B to D, there is an increase in 1 oxygen atom per molecule

→ B is a <u>primary alcohol</u> (contains $-CH_2OH$ group) and D is a carboxylic acid.

•B undergoes <u>elimination</u> when heated with excess conc. sulfuric to form E.

→ presence of C=C bond in E

[5]

(ii) Hence, suggest a possible structure for compound **A**.

M_r of C = M_r of A – M_r of B + M_r of H_2O

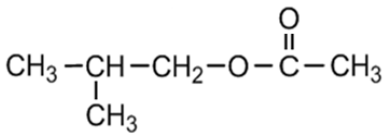
= 116 – [4(12)+10(1)+16] + 18

= 60

•C undergoes acid-carbonate reaction with Na_2CO_3 to give CO_2

→presence of <u>–COOH group</u> in C

→structure of C is most likely CH_3COOH

• **A is** 

[2]

(d) A student wishes to investigate the kinetics of the acid-catalysed hydrolysis of compound **A** described in **(c)**.

(i) A number of experiments at a constant pressure of 101 kPa and temperature of 90 °C were performed in which the concentrations of compound **A** and hydrogen ions were varied. The results are shown below:

Experiment	**[H^+] / moldm^{-3}**	**[compound A] / moldm^{-3}**	**Initial rate/ mol dm^{-3}s^{-1}**
1	0.0100	0.120	1.8 x 10^{-4}
2	0.0050	0.240	1.8 x 10^{-4}
3	0.0050	0.480	3.6 x 10^{-4}

Using the above data, deduce the order of reaction with respect to compound **A** and hydrogen ions.

From experiments 2 and 3,

•When <u>[A] doubles and [H^+] remains constant</u>, the initial rate doubles. Hence, the reaction is <u>first order</u> with respect to A.

•Let the order of reaction with respect to H^+ be x.

$$\frac{\text{rate 1}}{\text{rate 2}} = \frac{[H^+]^x[A]}{[H^+]^x[A]}$$

$$\frac{1.8 \times 10^{-4}}{1.8 \times 10^{-4}} = \frac{[0.0100]^x[0.120]}{[0.0050]^x[0.240]}$$

$$x = 1$$

Hence, the reaction is <u>first order</u> with respect to H^+.

[2]

(ii) Hence, construct a rate equation and use it to calculate a value of the rate constant, k, including its units, for the acid-catalysed hydrolysis of compound **A**.

Rate = k [H^+][A]

•$1.8 \times 10^{-4} = k(0.0100)(0.120)$

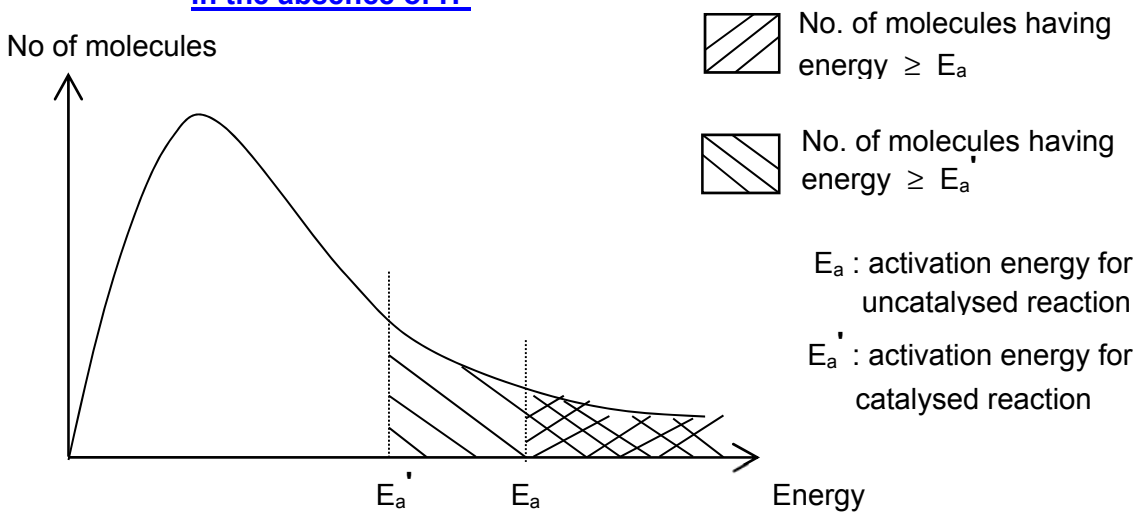
•$k = 0.15\ mol^{-1}dm^3s^{-1}$ *(1m working, 1m correct ans & units)*

[2]

(iii) With reference to a diagram where necessary, state and explain how the rate of reaction would change when the experiment was conducted:

- in the absence of hydrogen ions
- at a pressure of 121 kPa

In the absence of H^+



•diagram

• A catalyst increases the rate of reaction by providing an alternative pathway which involves a lower activation energy than that of an uncatalysed reaction.

• In the absence of the catalyst H^+, the number of reactant molecules having energy greater than or equal to the lower activation energy, E_a' decreases significantly. Hence the frequency of effective collisions decreases and the rate decreases.

At a pressure of 121 kPa

•When the pressure of the reaction increases (temperature remaining the same), the rate of reaction remains the same as the reactants are in the aqueous state and are not affected by pressure.

[4]

[Total: 20]

VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CHEMISTRY **8873/01**

Paper 1 Multiple Choice **19 September 2018**

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your Exam Number, name and CT group on the Multiple Choice Answer Sheet.

There are **thirty** questions. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choices in **soft pencil** on the separate Multiple Choice Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. No mark will be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **8** printed pages.

1 The Avogadro constant is *L*. How many neutrons are present in 24 dm^3 of chlorine gas, measured at r.t.p?

A 17*L* **B** 18.5*L* **C** 37*L* **D** 71*L*

2 Which of the following elements does **not** have paired *p* electrons in its ground state?

A carbon **B** oxygen **C** magnesium **D** neon

3 Gallium has the electronic configuration $[Ar]3d^{10}4s^24p^1$, where [Ar] represents the electronic configuration of argon.

In which order are the electrons lost in forming the Ga^{3+} ion?

	1st	**2nd**	**3rd**
A	3d	4p	4s
B	3d	4s	4s
C	4p	4s	3d
D	4p	4s	4s

4 Sodium thiosulfate is used in the textile industry to remove excess chlorine from bleaches by reducing it to chloride ions.

$$S_2O_3^{2-} + 4Cl_2 + 5H_2O \rightarrow 2HSO_4^- + 8H^+ + 8Cl^-$$

In this reaction, how many moles of electrons are transferred by 1 mol of thiosulfate ions?

A 1 **B** 2 **C** 4 **D** 8

5 A carbon sample contains a mixture of ^{12}C and ^{14}C isotopes. When 1.000 g of this sample is burned completely in $^{16}O_2$. The mass of CO_2 formed is 3.629 g.

What is the percentage by mass of the ^{12}C isotope in this sample?

A 85.0% **B** 88.6% **C** 90.0% **D** 91.4%

6 When phosphoryl chloride, $POCl_3$, dissolves in water, it gives a mixture of phosphoric acid and hydrochloric acid. How many moles of sodium hydroxide would be needed to neutralise the solution formed by adding one mole of $POCl_3$ to excess water?

A 3 **B** 4 **C** 5 **D** 6

7 Which of the elements exists as discrete molecules in the solid state?

A aluminium **B** silicon **C** iodine **D** argon

8 Which of the following pairs have similar shapes and the first species has a smaller bond angle than the second species?

1 $SiCl_4$, PF_4^+

2 PH_3, NH_3

3 SO_3^{2-}, CO_3^{2-}

A 1 only

B 2 only

C 1 and 2 only

D 2 and 3 only

9 But-2-enedioic acid, $HC(CO_2H)=C(CO_2H)H$, exists as a pair of *cis*-*trans* isomers. The *cis* isomer has a lower melting point than the *trans* isomer.

Which of the following statements is correct about but-2-enedioic acid?

1 In the solid state, both the *cis* and *trans* isomers have the same density.

2 Intramolecular hydrogen bonding is present in the *cis* isomer.

3 The *cis* isomer is less polar than the *trans* isomer.

A 2 only

B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

10 Which of the following statements about prop-1,2-diene, $H_2C=C=CH_2$, is **not** correct?

A Only two of the carbon atoms have the shape of trigonal planar.

B The two π-bonds in prop-1,2-diene are perpendicular to each other.

C There are only six σ-bonds in a prop-1,2-diene molecule.

D Prop-1,2-diene is a planar molecule.

11 When aqueous ammonia is added to a solution containing hexaaquairon(III) ions, a red-brown precipitate is formed as shown below.

$$[Fe(H_2O)_6]^{3+}(aq) + 3NH_3(aq) \rightleftharpoons Fe(OH)_3(H_2O)_3(s) + 3NH_4^+(aq)$$

What is the role of ammonia in this reaction?

A Brønsted-Lowry base

B Brønsted-Lowry acid

C Lewis acid

D Reducing agent

12 An enzyme, found in the stomach, operates at maximum efficiency when in an aqueous solution buffered at pH 5.

Which of the following combinations of substances would give the necessary buffer solution?

A 2 mol of HC*l* and 1 mol of CH_3CO_2H

B 2 mol of NaOH and 1 mol of CH_3CO_2H

C 2 mol of HC*l* and 1 mol of CH_3CO_2Na

D 2 mol of CH_3CO_2H and 1 mol of NaOH

13 Which of the following statements concerning the chlorine-containing compounds of period 3 elements is correct?

A PCl_3 and Cl_2O_7 are both acidic in nature due to their reactions with water.

B NaC*l* dissolves easily in water due to the favourable ion-dipole interactions and the compounds with the highest electrical conductivity in molten state is $AlCl_3$.

C The low boiling points of PCl_3 and Cl_2O_7 are due to the weak P–C*l* and C*l*–O bond energies.

D Both CCl_4 and $SiCl_4$ can dissolve in excess water completely to give an acidic solution.

14 Which of the following statements about Group 1 and Group 17 elements is correct?

A Caesium is a stronger oxidising agent as compared to lithium.

B Caesium is a stronger reducing agent as compared to lithium.

C Chloride is a stronger oxidising agent as compared to iodide.

D Chlorine is a stronger reducing agent as compared to iodine.

15 HI can decompose into H_2 and I_2 in the presence of heat. However, HF cannot decompose even under strong heating.

Which of the following statements correctly explains the above observation?

A The intermolecular forces of attraction between HI molecules are stronger as compared to that between HF molecules because HI molecules have more electrons.

B The intermolecular forces of attraction between HI molecules are weaker as compared to that between HF molecules because I atom is less electronegative.

C H–I bond is weaker than H–F bond due to less effective overlap of orbitals.

D I–I bond is weaker than F–F bond due to less effective overlap of orbitals.

16 The lattice energies of the compounds, magnesium oxide, magnesium bromide, sodium oxide and sodium bromide are given below.

Which of the following values corresponds to the lattice energy of magnesium bromide?

A –752 kJ mol^{-1}

B –2440 kJ mol^{-1}

C –2481 kJ mol^{-1}

D –3790 kJ mol^{-1}

17 The standard enthalpy change of combustion of but-1-ene, $C_4H_8(g)$ is x kJ mol^{-1}.

The standard enthalpy change of the reaction $2C_2H_4(g) \rightarrow C_4H_8(g)$ is y kJ mol^{-1}.

What is the standard enthalpy change of combustion of ethene, $C_2H_4(g)$?

A $\frac{x}{2} + y$ kJ mol^{-1}

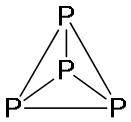
B $x + y$ kJ mol^{-1}

C $\frac{x+y}{2}$ kJ mol^{-1}

D $y - x$ kJ mol^{-1}

18 *The use of the Data Booklet is relevant to this question.*

Nitrogen exists as the N≡N, whereas phosphorus has the structure as shown below.



What is the enthalpy change for the following reaction, if nitrogen were to form a similar molecule N_4?

$$2N_2(g) \rightarrow N_4(g)$$

A –928 kJ mol^{-1}

B –16 kJ mol^{-1}

C +16 kJ mol^{-1}

D +928 kJ mol^{-1}

19 Three experiments are conducted to determine the rate equation for a reaction between sulfuric acid and sodium thiosulfate. The volumes used and the time taken for the precipitate to form are shown below.

Experiment	Volume of H_2SO_4 / cm^3	Volume of $Na_2S_2O_3$ / cm^3	Volume of water / cm^3	Time / s
1	20	20	20	30
2	40	20	0	15
3	x	20	0	15

What could be a suitable value for x?

A 5 **B** 10 **C** 20 **D** 30

20 Lead is the final product formed by a series of changes in which the rate-determining stage is the radioactive decay of uranium-238. This radioactive decay is a first-order reaction with a half-life of 4.5×10^9 years.

What would be the age of a rock sample, originally lead-free, in which the molar ratio of uranium to lead is now 1:7?

A 1.5×10^9 years

B 2.25×10^9 years

C 9.0×10^9 years

D 1.35×10^{10} years

21 A reversible reaction is catalysed.

Which of the following statements about this reaction are correct?

1 The catalyst alters the pathway of the reaction.
2 The catalyst reduces the activation energy for both the forward and the backward reaction.
3 The catalyst alters the composition of the equilibrium mixture.

A 1, 2 and 3 **B** 1 and 2 only
C 2 and 3 only **D** 1 only

22 During the Haber process, the following three gases are in equilibrium as shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Which of the following will increase when the pressure is increased at constant temperature?

A activation energy
B enthalpy change of reaction
C rate constant for the forward reaction
D amount of NH_3 formed

23 1.6 mol of pure nitrosyl chloride gas, NOC*l*, was heated at 320 °C in a 2.0 dm^3 vessel. At equilibrium, 40% of the NOC*l* gas has dissociated according to the equation below.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

What is the numerical value of the equilibrium constant, K_c?

A 0.071 **B** 0.142 **C** 0.213 **D** 0.427

24 The length, width and height of four clusters of metal atoms are shown below.

Which cluster of metal atoms is a nanomaterial but not a nanoparticle?

	length / m	width / m	height / m
A	2.0×10^{-8}	2.0×10^{-8}	2.0×10^{-8}
B	2.0×10^{-10}	2.0×10^{-10}	2.0×10^{-10}
C	2.0×10^{-8}	2.0×10^{-6}	2.0×10^{-11}
D	2.0×10^{-6}	2.0×10^{-6}	2.0×10^{-6}

25 In 1933, Gibson and Fawcett maintained ethene at a temperature of 170 °C under a pressure of 200 atm in the presence of a trace of amount oxygen catalyst for several days. What was the major product discovered in the reaction vessel when it was cooled and opened?

A artificial diamond **B** poly(ethene)
C graphene **D** carbon nanotube

26 Which of the following statements about nanomaterials is **not** correct?

A Nanomaterials could be a good catalyst due to its high surface area to volume ratio.

B Nanomaterials could be a good catalyst because some atoms at the edge are not fully bonded.

C Nanomaterials can be used in cosmetic products because it has no potential harmful effects on human health.

D Nanomaterials can lead to environment hazard if not disposed properly.

27 Which of the following statements about the two alkenes, $CH_3CH_2CH{=}CH_2$ and $CH_3CH{=}CHCH_3$, is correct?

A Only one of them exhibits *cis-trans* isomerism.

B Only one of them may be polymerised.

C Only one of them reacts with hydrogen to form butane.

D Only one of them reacts with bromine to give 1,3-dibromobutane.

28 Which of the following molecules can react with both acidified potassium dichromate(VI) and sodium borohydride?

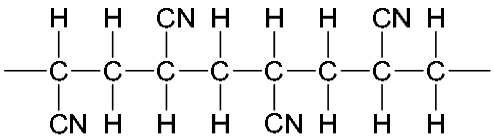
A $C_6H_5CH_2OH$

B C_6H_5CHO

C $C_6H_5COCH_3$

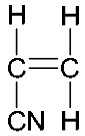
D $C_6H_5CH(OH)CH_3$

29 Acrylic fibre is an addition polymer. Part of this polymer chain is shown below.

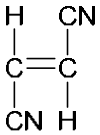


Which of the following monomers would form this polymer?

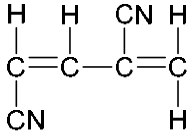
A



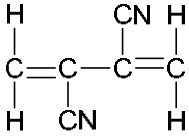
B



C

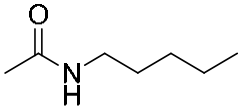


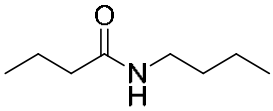
D

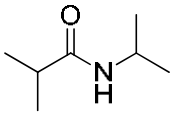


30 An amide, **M**, has the empirical formula $C_7H_{15}ON$. When **M** is hydrolysed by heating under reflux with dilute hydrochloric acid, a carboxylic acid with empirical formula C_2H_4O is obtained as one of the products.

What could be the skeletal formula of **M**?

1 

2 

3 

A 1, 2 and 3

B 1 only

C 2 and 3 only

D 3 only

End of Paper

Qn	Answer
1	**C**
2	**A**
3	**D**
4	**D**
5	**C**
6	**D**
7	**C**
8	**B**
9	**A**
10	**D**
11	**A**
12	**D**
13	**A**
14	**B**
15	**C**
16	**B**
17	**C**
18	**D**
19	**B**
20	**D**
21	**B**
22	**D**
23	**A**
24	**C**
25	**B**
26	**C**
27	**A**
28	**B**
29	**A**
30	**D**

VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME .....

CT GROUP .....

CHEMISTRY **8873/02**

Paper 2 **11 September 2018**

Candidates answer on the Question Paper. **2 hours**

Additional Materials: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

Write your name and CT group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

The number of marks is given in brackets [ ] at the end of each question or part question.

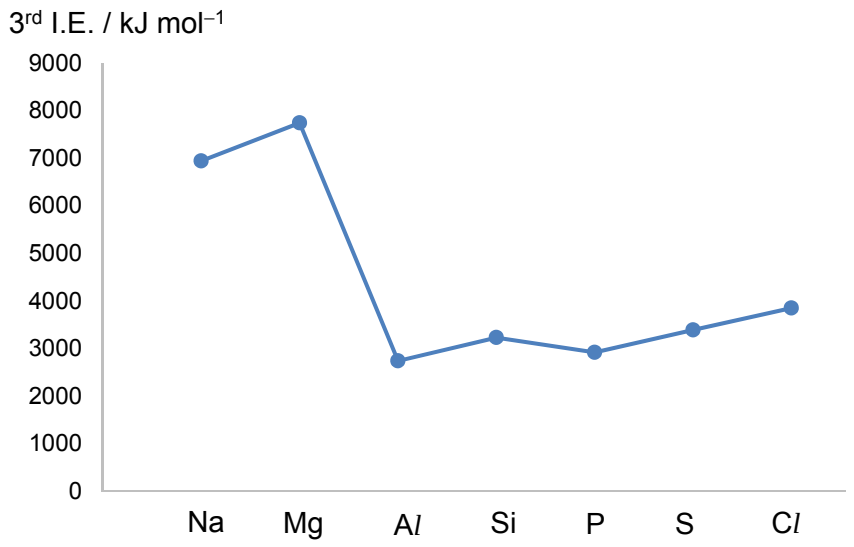
For Examiner's Use		
Section A	1	/ 20
	2	/ 12
	3	/ 8
	4	/ 20
Section B	5 / 6	/ 20
Total		/ 80

This document consists of **23** printed pages and **1** blank page.

Section A

Answer **all** the questions in this section, in the spaces provided.

1 **(a)** The graph below shows the third ionisation energies of the Period 3 elements from Na to C*l*.



(i) With the aid of an equation, define the 3rd ionisation energy of phosphorous.

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…… [2]

(ii) Explain why there is a general increase in the 3rd ionisation energies from phosphorous to chlorine.

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…… [2]

(iii) Give the full electronic configuration of P^{2+}.

…… [1]

(iv) With reference to your answer from **(a)(iii)**, explain why the 3rd ionisation energy of Si is higher than that of P.

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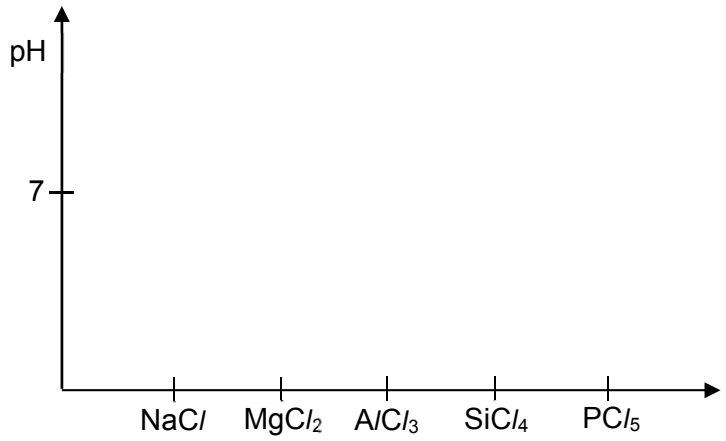
…… [2]

(b) **(i)** Sketch a graph on the axes provided to show the pH of the solutions produced when the Period 3 chlorides (from Na to P) are added to excess water.



[2]

(ii) Nitrogen is in the same group as phosphorous in the Periodic Table. Suggest whether NCl_5 is able to exist.

……..

…… [1]

(iii) Arsenic is in the same group as phosphorous in the Periodic Table. With the aid of an equation, suggest the pH of the solution obtained when arsenic trichloride is added to excess water.

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……..

…… [2]

(c) The boiling points of the two chlorides of phosphorous are shown in the table below.

compound	boiling point / °C
PCl_3	76.1
PCl_5	166.8

(i) Explain the difference in boiling points between the two chlorides of phosphorous.

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…… [2]

(ii) PCl_3 is able to react with BF_3. State the type of bond formed and draw a diagram to illustrate the shape of the product obtained.

[2]

(d) In the solid state, PCl_5 exists as an ionic lattice with the formula $[PCl_4]^+[PCl_6]^-$.

(i) State the shapes and bond angles of the $[PCl_4]^+$ and $[PCl_6]^-$ ions.

ion	shape	bond angle
$[PCl_4]^+$		
$[PCl_6]^-$		

[2]

(ii) Compare the lattice energy of $[PCl_4]^+[PCl_6]^-$ with that of $NaCl$. Explain your reasoning.

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…… [2]

[Total: 20]

2 **(a)** 3–chloropropanoic acid, $CH_2ClCH_2CO_2H$, is a weak Bronsted acid. Solution **A** is a 0.100 mol dm^{-3} $CH_2ClCH_2CO_2H$ solution. It has a pH of 2.49.

(i) Write the expression for the K_a of 3–chloropropanoic acid, including the units.

[1]

(ii) Hence, calculate the pK_a of 3–chloropropanoic acid.

[2]

(iii) When 25 cm^3 of 0.0500 mol dm^{-3} KOH was added to 25.0 cm^3 of solution **A**, a buffer solution is formed. With the aid of two equations, explain how the buffer solution is able to maintain a relatively constant pH.

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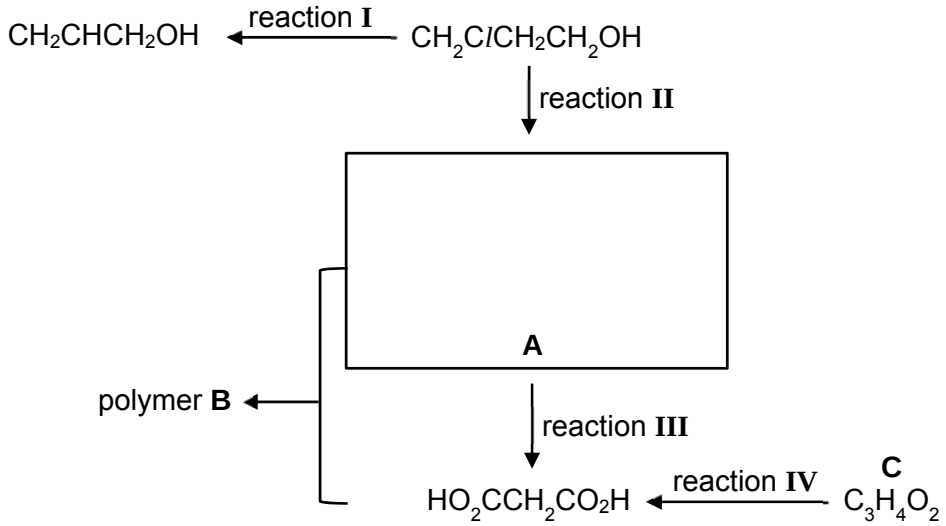
…… [3]

(b) 3–chloropropanoic acid can undergo a series of reactions as shown below.



(i) Draw the full structural formula of compound **A** in the box. [1]

(ii) State the reagents and conditions required for reactions **I**, **II** and **III**.

Reaction **I**:

reagents ……

condition ……

Reaction **II**:

reagents ……

condition ……

Reaction **III**:

reagents ……

condition ……

[3]

(iii) Draw the structure of one repeat unit of the polymer **B**.

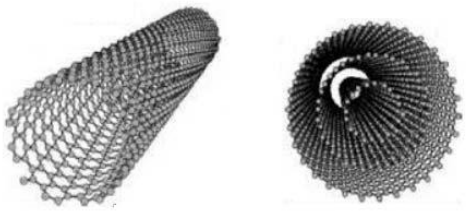
[1]

(iv) Suggest the structural formula of compound **C**.

[1]

[Total: 12]

3 **(a)** Single–walled carbon nanotubes behave like cylindrical graphene. Multi–walled carbon nanotubes consist of multiple–rolled layers of graphene.



Single-walled carbon nanotube Multi-walled carbon nanotube

(i) Plastic is a good replacement for steel because of its low cost. The insertion of carbon nanotubes into plastic has made it at least 10 times stronger than steel.

Describe the structure and bonding of a carbon nanotube. Hence, explain whether a single–walled carbon nanotube or a multi–walled carbon nanotube has higher tensile strength.

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…… [2]

(ii) Similar to graphene, carbon nanotubes conduct electricity. They can be 'unzipped' to form sheets of oxidised graphene as shown in **Figure 1**.

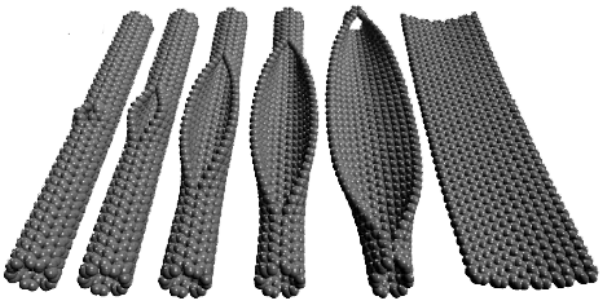

Figure 1

The 'unzipping' of a carbon nanotube to form oxidised graphene at the molecular level is shown in **Figure 2** below.

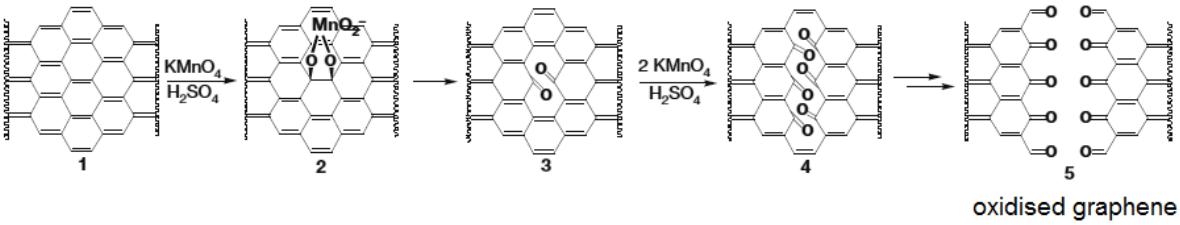

Figure 2

With reference to **Figures 1** and **2**, explain whether sheets of oxidised graphene can conduct electricity.

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…… [2]

(iii) We can obtain a sheet of graphene by reduction of oxidised graphene, only if the width is less than 50 nm.

Currently, it is not possible to produce very large sheets of graphene. Suggest how the edges of the graphene sheet pose difficulties to the production of large sheets of graphene.

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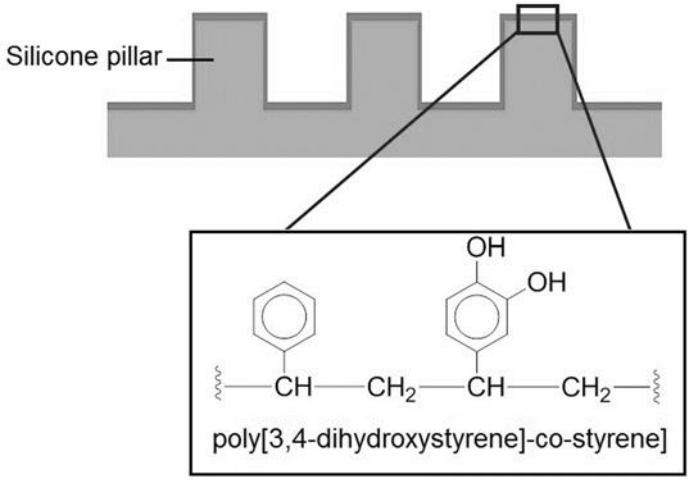
……..

…… [1]

(b) Geckos are lizards with the remarkable ability to scamper up walls. A shortcoming of synthetic gecko–inspired fibres is that it cannot operate on both wet and dry surfaces.

Researchers have created 'geckel' which is an array of high silicone pillars sitting on a solid substrate. Each cylindrical pillar has dimensions of 400 nm in diameter and 600 nm in height. The surfaces of the pillars are coated with a synthetic adhesive polymer, poly[3,4–dihydroxystyrene]–co–styrene], as shown below. 'Geckel' can be used to create wall–climbing robots.



(i) Explain whether each silicone pillar can be considered as a nanomaterial.

……..

……..

…… [1]

(ii) A wall has been painted with a paint comprising of a mixture of hydrocarbons while another wall has been painted with a paint comprising of a polymer, poly(ethylene oxide).

$$H\left[OCH_2CH_2\right]_nOH$$

poly(ethylene oxide)

Explain how the silicone pillars and synthetic adhesive polymer of 'Geckel' enable a wall–climbing robot to support its own weight on both types of paint surfaces.

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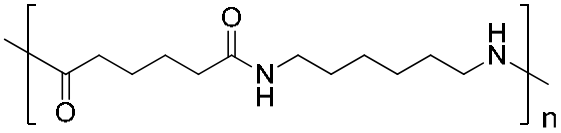
……..

…… [2]

[Total: 8]

4 **(a)** The two most common types of nylons used in textile and plastic industries are nylon−6 and nylon−6,6. The structure of nylon−6,6 is shown below.



nylon-6,6

(i) Define the term *polymer*.

……..

……..

…… [1]

(ii) Ropes made of nylon−6,6 are chosen for its high tensile strength. Ropes made from polyesters such as poly(ethylene terephthalate) (PET) are about 90% as strong as that of nylon−6,6.

With the aid of a diagram, showing relevant interactions, explain why nylon−6,6 is stronger than polyester.

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…… [3]

(iii) Rust or grout on toilet tiles can be removed by spraying the tiles with a rust remover (**Figure 3**) before scrubbing the tiles with a brush. Explain whether a brush with nylon bristles or high density poly(ethene) bristles should be used for the scrubbing.

Figure 3

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……

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…… [2]

(iv) State whether nylon−6,6 is classified as a thermoplastic or thermoset. Hence, explain whether it can be recycled.

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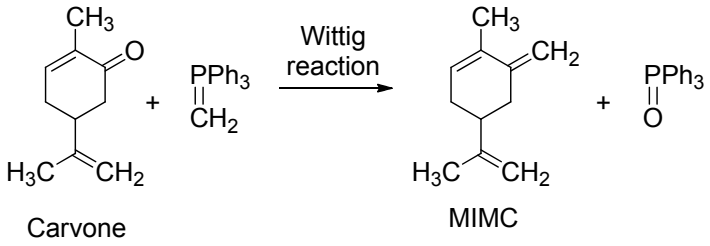
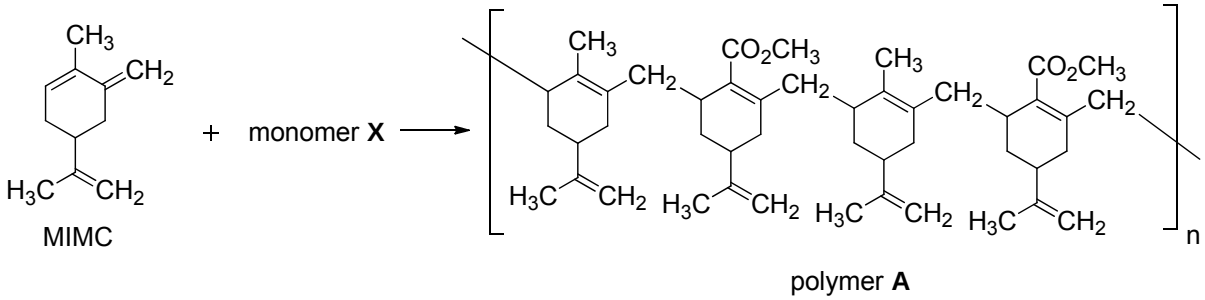
…… [2]

(b) Cavone is found in the oils of spearmint. It undergoes a Wittig reaction to yield the monomer, MIMC, which could undergo polymerisation with monomer **X** to form polymer **A**.





(i) State the type of polymerisation that has occurred to form polymer **A**. Hence, draw the constitutional formula of monomer **X**.

[2]

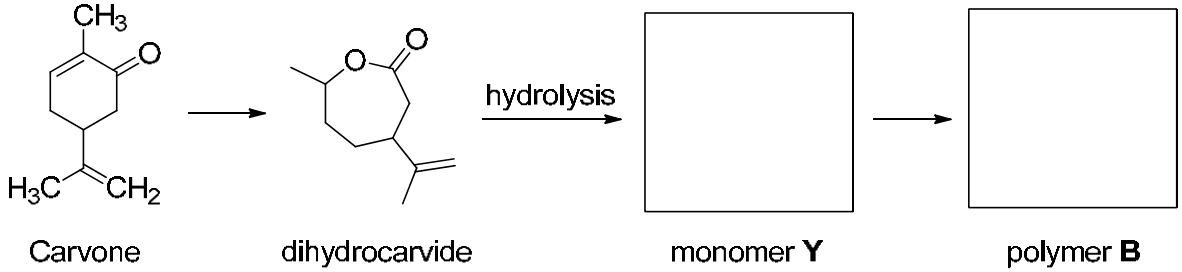
(ii) Explain why polymer **A** has a more rigid structure as compared to nylon−6,6 in **(a)**.

……..

……..

…… [1]

Carvone can also be transformed into dihydrocarvide which undergoes a series of steps to form polymer **B**.



(iii) Write an equation for the base hydrolysis of dihydrocarvide.

[1]

(iv) Infra–red spectroscopy can be used to identify functional groups present in organic compounds. For example, the ketone functional group of carvone shows an absorption signal at 1670–1740 cm^{-1}.

Polymer **B** shows the following infra-red absorption signals at 1635–1690 cm^{-1}, 1050–1330 cm^{-1} and 1730–1750 cm^{-1}.

With reference to the *Data Booklet*, identify the bonds that correspond to the above infrared absorptions.

1635–1690 cm^{-1} …….

1050–1330 cm^{-1} …….

1730–1750 cm^{-1} …….

[1]

(v) With the aid of an equation, define the *enthalpy change of combustion* of carvone, $C_{10}H_{14}O$.

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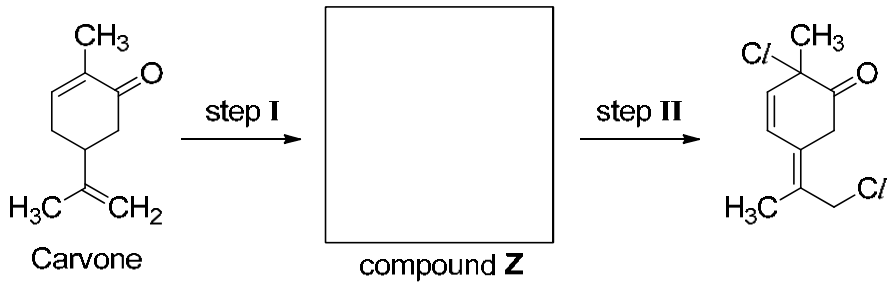
……..

Equation:

[2]

(vi) Draw the structure of compound **Z** in the box for the following synthesis. State the reagents and conditions for step **I** and step **II**.



Step **I**:

reagents ……

condition ……

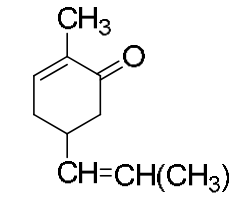
Step **II**:

reagents ……

condition ……

[3]

(vii) Only one of the C=C bonds in the isomer of carvone exhibits *cis–trans* isomerism. Draw the skeletal structures of the *cis–trans* isomers.



isomer of carvone

[2]

[Total: 20]

Section B

Answer **one** question from this section, in the spaces provided.

5 (a) Phosphine has the chemical formula PH_3. The kinetics of the reaction between phosphine and sodium chlorate(I) can be investigated by the following method.

$$PH_3 + 2NaClO \rightarrow H_3PO_2 + 2NaCl$$

Experiment	Initial concentrations of reactants / mol dm^{-3}		Initial rate of disappearance of PH_3 / mol dm^{-3} s^{-1}
	PH_3	NaC*l*O	
1	0.24	3.50	3.68
2	0.14	5.70	3.58
3	0.48	3.50	7.36

(i) Determine the order of reaction with respect to PH_3 and NaC*l*O.

[2]

(ii) Write the rate equation for this reaction.

…… [1]

(iii) Determine the rate constant for experiment 1 and state its units.

[2]

(iv) Calculate the initial rate of formation of NaC*l* when the initial concentrations of PH_3 and NaC*l*O are 0.36 mol dm^{-3} and 2.50 mol dm^{-3} respectively.

[1]

(v) Determine the concentration of NaC*l* produced after two half-lives for experiment 1.

[2]

(b) The Appel reaction is used to convert alcohols to alkyl halides while triphenylphosphine, PPh_3, is oxidised to triphenylphosphine oxide, $O{=}PPh_3$.

Ph in PPh_3 and $O{=}PPh_3$ is a phenyl group, which remains unchanged after the reaction.

$$PPh_3 + CBr_4 + CH_3CH_2OH \rightarrow O{=}PPh_3 + CHBr_3 + CH_3CH_2Br$$

(i) With reference to the *Data Booklet*, calculate the enthalpy change for this reaction.

[2]

(ii) Using bond energy values from the *Data Booklet*, explain why the rate of reaction is slower when CCl_4 is used in place of CBr_4.

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…… [2]

(iii) Triphenylphosphine. PPh_3 can also be oxidised by oxygen to form triphenylphosphine oxide, $O{=}PPh_3$ with the use of a catalyst $[MoO_2Cl_2(DMSO)_2]$.

With the aid of a Maxwell–Boltzmann distribution diagram, explain how the addition of a catalyst speeds up the rate of reaction.

……..

……..

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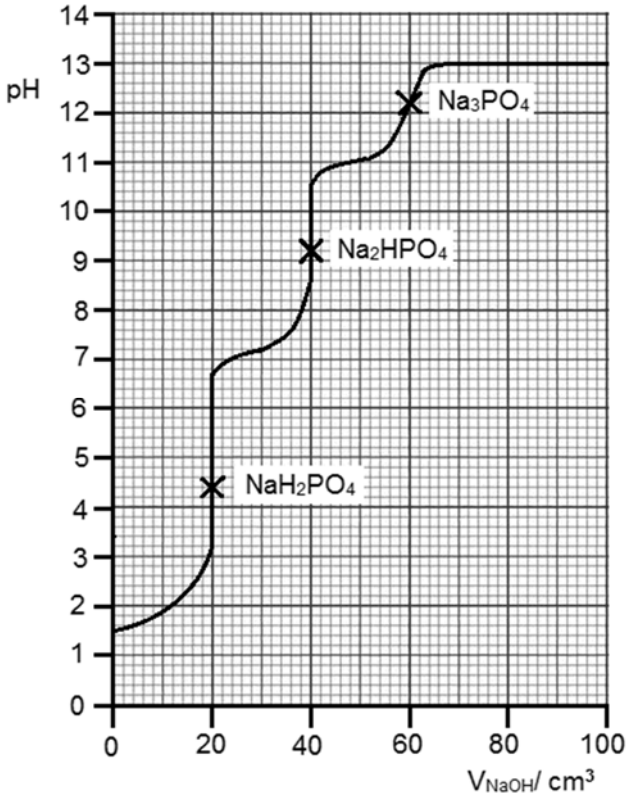
……..

…… [2]

(c) In a titration experiment, 0.100 mol dm^{-3} NaOH was added to 15.0 cm^3 of phosphoric acid as shown below.



Phosphoric acid is a tribasic acid, and it dissociates into PO_4^{3-} in three steps as shown below.

Step 1: $H_3PO_4 \rightleftharpoons H_2PO_4^- + H^+$ K_{a1}
Step 2: $H_2PO_4^- \rightleftharpoons HPO_4^{2-} + H^+$ K_{a2}
Step 3: $HPO_4^{2-} \rightleftharpoons PO_4^{3-} + H^+$ K_{a3}

(i) Calculate the concentration of the phosphoric acid.

[1]

(ii) With reference to the titration curve and **(c)(i)**, suggest whether phosphoric acid is a weak or strong acid.

[2]

(iii) Arrange the three K_a values of phosphoric acid in decreasing order of acidity. Explain your answer.

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…… [2]

(iv) The table below lists some common indicators found in the college laboratory. With reference to the given titration curve for phosphoric acid, suggest an indicator to detect the second end–point. Hence, state the colour change of your chosen indicator at the second end-point of the titration.

indicator	pH range for colour change	colour in acidic pH	colour in basic pH
methyl orange	3–5	red	yellow
bromothymol blue	6–8	yellow	blue
phenolphthalein	8–10	colourless	pink
thymolphthalein	9.3–10.5	colourless	blue
trinitrobenzoic acid	12–13.4	colourless	orange–red

……..

…… [1]

[Total: 20]

6 **(a)** During an experiment, a student added 3.00 g of solid KOH to 100 cm^3 of 1.00 mol dm^{-3} HNO_3 solution. The initial temperature of the HNO_3 solution was 29.2 °C and the highest temperature recorded was 36.5 °C.

(i) Define the *standard enthalpy change of neutralisation,* $\Delta H^{\ominus}_{neut}$.

……..

……..

…… [1]

(ii) Calculate the ΔH_{neut} of this reaction. You may assume that 4.18 J of energy is required to raise the temperature of 1 g of the solution by 1 °C.

[2]

(b) Compressed Natural Gas (CNG) has been used as a fuel for vehicles in Singapore since 2001 because it releases less air–borne pollutants. Together with the mandatory catalytic converters installed in vehicles, this helps to maintain the high air quality that Singapore enjoys.

The reaction below takes place in the catalytic converter and it is catalysed by a rhodium catalyst.

$$2CO(g) + 2NO(g) \rightarrow N_2(g) + 2CO_2(g) \qquad \Delta H < 0$$

(i) Draw energy profile diagrams for both the catalysed and uncatalysed reactions on the axes below. Label on the diagrams the axes, ΔH, activation energies for both the catalysed (E_a(cat)) and uncatalysed (E_a) reactions.

[2]

(ii) Explain in terms of collision theory, how the addition of a catalyst increases the rate of reaction.

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…… [1]

(iii) Explain the mode of action of the rhodium catalyst in this reaction.

……..

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……..

…… [3]

(c) Natural gas has many impurities such as CH_4 and H_2S, which can react according to the following equilibrium.

$$CH_4(g) + 2H_2S(g) \rightleftharpoons CS_2(g) + 4H_2(g)$$

2.0 mol of CH_4, 4.0 mol of H_2S, 2.0 mol of CS_2 and 6.8 mol of H_2 were allowed to reach equilibrium in a 250 cm^3 vessel at 800 ^oC. The equilibrium concentration of CH_4 was found to be 3.4 mol dm^{-3}.

(i) Calculate the value of K_c, include the units in your answer.

[2]

(ii) Define *Le Chatelier's Principle*.

……..

……..

…… [1]

(iii) Explain how the position of equilibrium would be affected if the volume of the vessel is changed to 500 cm^3.

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……..

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……..

…… [2]

(iv) Explain how the position of equilibrium would be affected if a catalyst was introduced into the vessel.

……..

……..

…… [1]

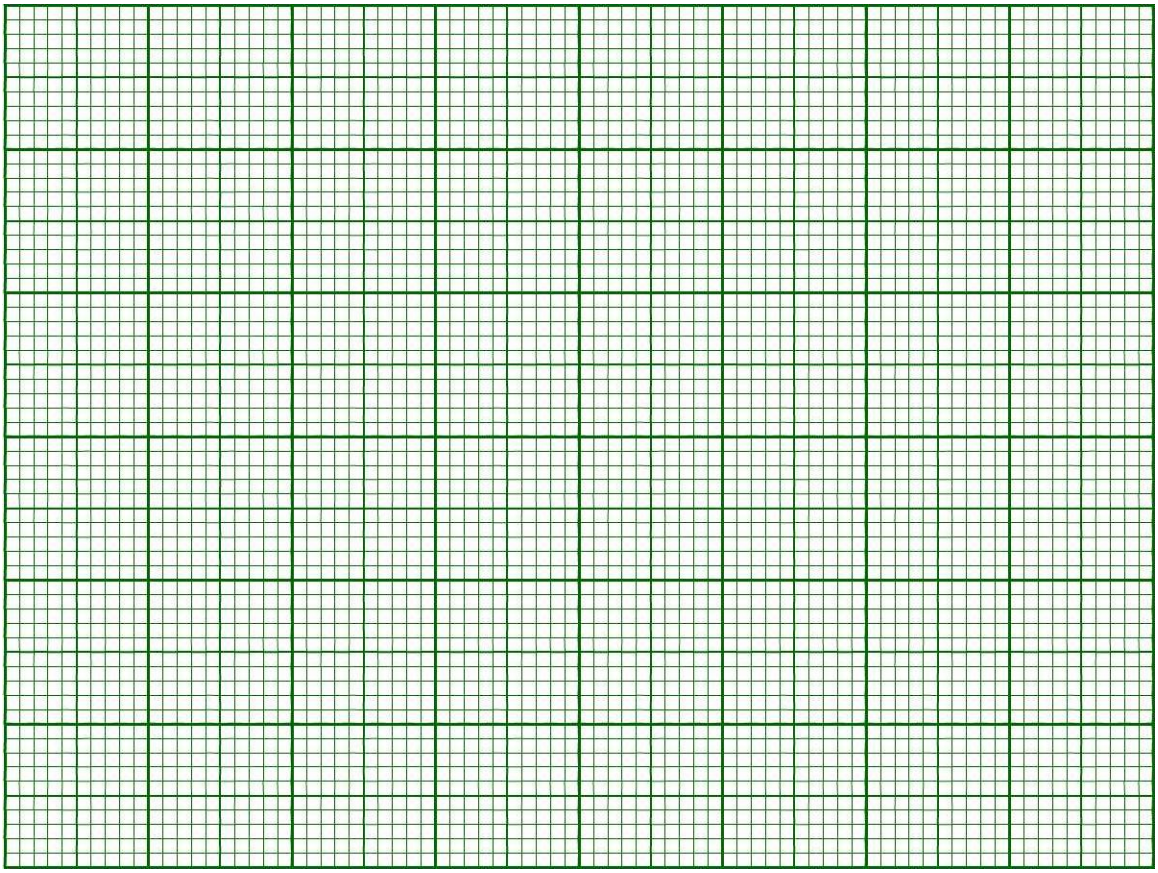
(d) Hydrogen peroxide and iodide ions react in an acidic medium to form water and iodine as shown below.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow 2H_2O + I_2$$

The rate of reaction is monitored by measuring the amount of iodine produced with time. The concentration of H_2O_2 remaining is then calculated as shown in the table below.

Time / s	$[H_2O_2]$ / mol dm^{-3}
0	0.0200
80	0.0167
180	0.0135
315	0.0103
490	0.0070
760	0.0038

(i) Plot a graph of $[H_2O_2]$ against time on the axes below. Hence, determine the order of reaction with respect to $[H_2O_2]$.



[3]

(ii) Use the graph to determine the initial rate of the reaction.

[2]

[Total: 20]

End of Paper

VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME .....

CT GROUP .....

CHEMISTRY **8873/02**

Paper 2 **11 September 2018**

Candidates answer on the Question Paper. **2 hours**

Additional Materials: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

Write your name and CT group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

The number of marks is given in brackets [ ] at the end of each question or part question.

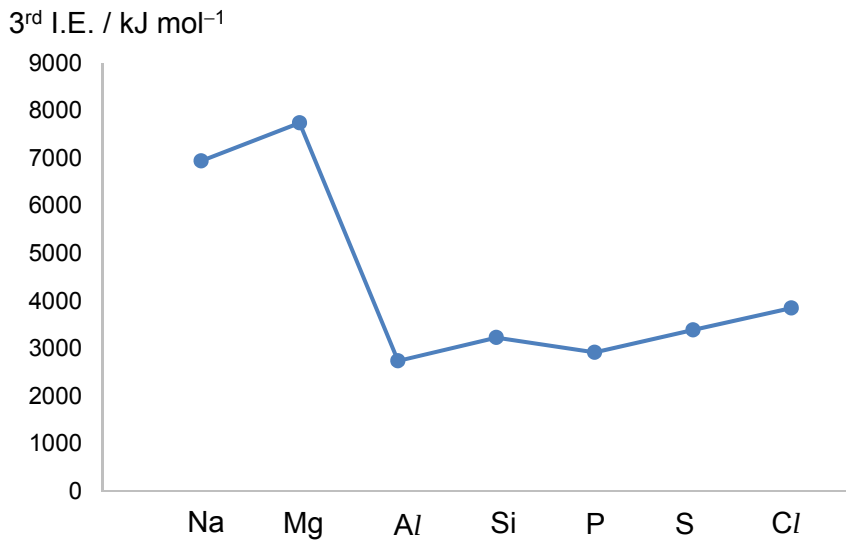
For Examiner's Use		
Section A	1	/ 20
	2	/ 12
	3	/ 8
	4	/ 20
Section B	5 / 6	/ 20
Total		/ 80

This document consists of **23** printed pages and **1** blank page.

Section A

Answer **all** the questions in this section, in the spaces provided.

1 (a) The graph below shows the third ionisation energies of the Period 3 elements from Na to C*l*.



(i) With the aid of an equation, define the 3rd ionisation energy of phosphorous.

It is the energy required to remove 1 mol of electrons from 1 mol of gaseous P^{2+} ions to form 1 mol of gaseous P^{3+} ions.

$P^{2+}(g) \rightarrow P^{3+}(g) + e^-$

[2]

(ii) Explain why there is a general increase in the 3rd ionisation energies from phosphorous to chlorine.

Nuclear charge increases from phosphorous to chlorine due to an increase in number of protons.
Shielding effect remains relatively constant from phosphorous to chlorine due to the same number of inner shell electrons.
Hence, effective nuclear charge increases from phosphorous to chlorine.
More energy is required to remove the 3rd electron that is more strongly held by the nucleus.

[2]

(iii) Give the full electronic configuration of P^{2+}.

P^{2+}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

[1]

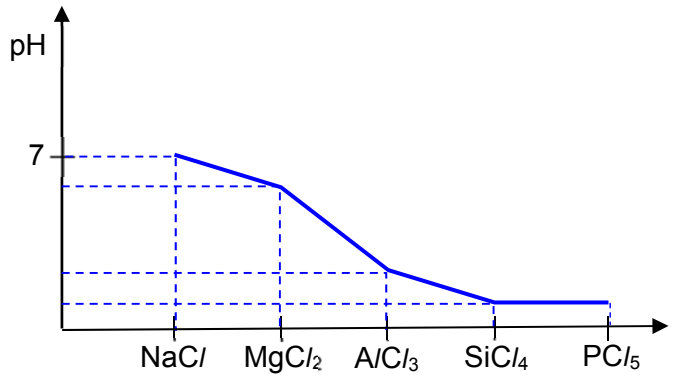
(iv) With reference to your answer from **(a)(iii)**, explain why the 3rd ionisation energy of Si is higher than that of P.

Si^{2+}: $1s^2\ 2s^2\ 2p^6\ 3s^2$
P^{2+}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

The removal of the 3rd electron from P is from the 3p subshell compared to the removal from the 3s subshell for Si.
Since the 3p subshell is further away from the nucleus / is of higher energy, less energy is required to remove the 3rd electron from P^{2+}.

[2]

(b) **(i)** Sketch a graph on the axes provided to show the pH of the solutions produced when the Period 3 chlorides (from Na to P) are added to excess water.



[2]

(ii) Nitrogen is in the same group as phosphorous in the Periodic Table. Suggest whether NCl_5 is able to exist.

NCl_5 does not exist.
N atom does not have energetically accessible vacant orbitals to expand its octet.

[1]

(iii) Arsenic is in the same group as phosphorous in the Periodic Table. With the aid of an equation, suggest the pH of the solution obtained when arsenic trichloride is added to excess water.

$AsCl_3 + 3H_2O \rightarrow H_3AsO_3 + 3HCl$

pH <u>2</u>
$AsCl_3$ undergoes complete <u>hydrolysis</u> in water to produce a strong acid, HCl.
[*Accept pH 1–3*]

[2]

(c) The boiling points of the two chlorides of phosphorous are shown in the table below.

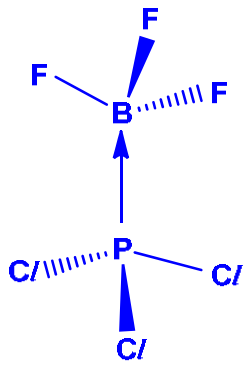
compound	boiling point / °C
PCl_3	76.1
PCl_5	166.8

(i) Explain the difference in boiling points between the two chlorides of phosphorous.

Due to the greater number of electrons in PCl_5, more energy is required to overcome the stronger instantaneous dipole–induced dipole interactions in PCl_5 compared to the permanent dipole–permanent dipole interactions in PCl_3.

[2]

(ii) PCl_3 is able to react with BF_3. State the type of bond formed and draw a diagram to illustrate the shape of the product obtained.



[2]

(d) In the solid state, PCl_5 exists as an ionic lattice with the formula $[PCl_4]^+[PCl_6]^-$.

(i) State the shapes and bond angles of the $[PCl_4]^+$ and $[PCl_6]^-$ ions.

ion	shape	bond angle
$[PCl_4]^+$	tetrahedral	109.5°
$[PCl_6]^-$	octahedral	90°

[2]

(ii) Compare the lattice energy of $[PCl_4]^+[PCl_6]^-$ with that of $NaCl$. Explain your reasoning.

Since lattice energy $\propto \left|\frac{q^+q^-}{r^+ + r^-}\right|$ and all the ions are singly charged while the radii of $[PCl_4]^+$ and $[PCl_6]^-$ are larger than that of Na^+ and Cl^-, the lattice energy will be less exothermic for $[PCl_4]^+[PCl_6]^-$.

[2]

[Total: 20]

2 (a) 3–chloropropanoic acid, $CH_2ClCH_2CO_2H$, is a weak Bronsted acid. Solution **A** is a 0.100 mol dm^{-3} $CH_2ClCH_2CO_2H$ solution. It has a pH of 2.49.

(i) Write the expression for the K_a of 3–chloropropanoic acid, including the units.

$CH_2ClCH_2CO_2H \rightleftharpoons CH_2ClCH_2CO_2^- + H^+$

$K_a = \frac{[CH_2ClCH_2CO_2^-][H^+]}{[CH_2ClCH_2CO_2H]}$ mol dm^{-3}

[1]

(ii) Hence, calculate the pK_a of 3–chloropropanoic acid.

Since pH = 2.49, $[H^+] = 10^{-2.49}$

$K_a = \frac{[CH_2ClCH_2CO_2^-][H^+]}{[CH_2ClCH_2CO_2H]}$

$= \frac{[10^{-2.49}][10^{-2.49}]}{[0.100]}$
$= 1.05 \times 10^{-4}$

$pK_a = -\lg(1.05 \times 10^{-4})$
$= 3.98$

[2]

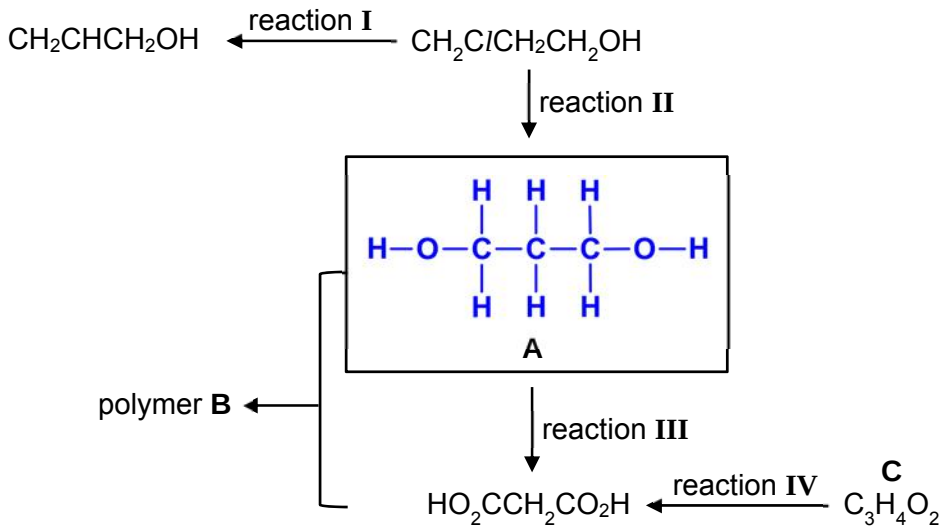
(iii) When 25 cm^3 of 0.0500 mol dm^{-3} KOH was added to 25.0 cm^3 of solution **A**, a buffer solution is formed. With the aid of two equations, explain how the buffer solution is able to maintain a relatively constant pH.

When a small amount of acid is added, a large reservoir of $CH_2ClCH_2CO_2^-$ neutralises the acid to maintain a fairly constant pH.
$CH_2ClCH_2CO_2^- + H^+ \rightarrow CH_2ClCH_2CO_2H$

When a small amount of base is added, a large reservoir of $CH_2ClCH_2CO_2H$ neutralises the base to maintain a fairly constant pH.
$CH_2ClCH_2CO_2H + OH^- \rightarrow CH_2ClCH_2CO_2^- + H_2O$

[3]

(b) 3–chloropropanoic acid can undergo a series of reactions as shown below.



(i) Draw the full structural formula of compound **A** in the box. [1]

(ii) State the reagents and conditions required for reactions **I**, **II** and **III**.

Reaction **I**:

reagents NaOH(alc)

condition reflux

Reaction **II**:

reagents NaOH(aq)

condition reflux

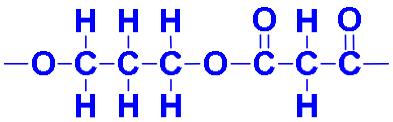
Reaction **III**:

reagents $KMnO_4(aq)$ or $K_2Cr_2O_7(aq)$, $H_2SO_4(aq)$

condition reflux
[*Allow heat*]

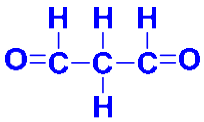
[3]

(iii) Draw the structure of one repeat unit of the polymer **B**.



[1]

(iv) Suggest the structural formula of compound **C**.

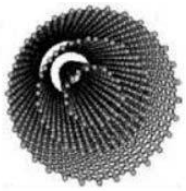


[1]

[Total: 12]

3 (a) Single–walled carbon nanotubes behave like cylindrical graphene. Multi–walled carbon nanotubes consist of multiple–rolled layers of graphene.

Single-walled carbon nanotube



Multi-walled carbon nanotube

(i) Plastic is a good replacement for steel because of its low cost. The insertion of carbon nanotubes into plastic has made it at least 10 times stronger than steel.

Describe the structure and bonding of a carbon nanotube. Hence, explain whether a single–walled carbon nanotube or a multi–walled carbon nanotube has higher tensile strength.

Single–walled carbon nanotube is made up of a single layer of carbon atoms, arranged in a hexagonal network with each carbon atom covalently bonded to three other carbon atoms.
Multi–walled carbon nanotube has higher tensile strength as it has more covalent bonds that need to be broken due to the multiple walls of cylindrical graphene.

[2]

(ii) Similar to graphene, carbon nanotubes conduct electricity. They can be ‘unzipped’ to form sheets of oxidised graphene as shown in **Figure 1**.

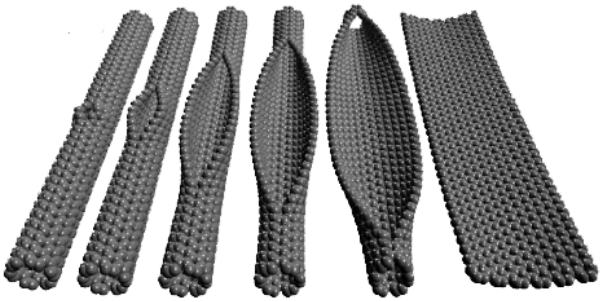


Figure 1

The 'unzipping' of a carbon nanotube to form oxidised graphene at the molecular level is shown in **Figure 2** below.

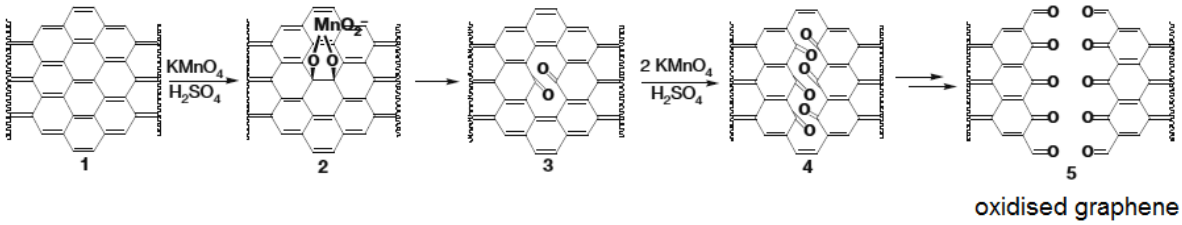


Figure 2

With reference to **Figures 1** and **2**, explain whether sheets of oxidised graphene can conduct electricity.

The p–orbitals on the carbon atoms in oxidised graphene overlap sideways to form a continuous pi–electron cloud / allow delocalisation of pi–electrons, where the electrons act as mobile charge carriers.

[2]

(iii) We can obtain a sheet of graphene by reduction of oxidised graphene, only if the width is less than 50 nm.

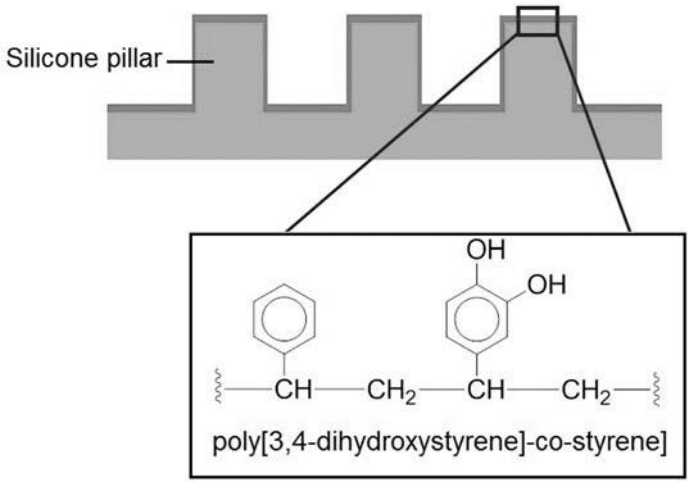
Currently, it is not possible to produce very large sheets of graphene. Suggest how the edges of the graphene sheet pose difficulties to the production of large sheets of graphene.

Edges have carbon atoms that are not fully bonded / edges may curve upwards or downwards causing areas of graphite / multilayer structure formed.

[1]

(b) Geckos are lizards with the remarkable ability to scamper up walls. A shortcoming of synthetic gecko–inspired fibres is that it cannot operate on both wet and dry surfaces.

Researchers have created 'geckel' which is an array of high silicone pillars sitting on a solid substrate. Each cylindrical pillar has dimensions of 400 nm in diameter and 600 nm in height. The surfaces of the pillars are coated with a synthetic adhesive polymer, poly[3,4–dihydroxystyrene]–co–styrene], as shown below. 'Geckel' can be used to create wall–climbing robots.



(i) Explain whether each silicone pillar can be considered as a nanomaterial.

No, since each cylindrical pillar has dimensions of 400 nm in diameter and 600 nm in height.
Nanomaterials have at least one dimension within the range of 1 nm to 100 nm.

[1]

(ii) A wall has been painted with a paint comprising of a mixture of hydrocarbons while another wall has been painted with a paint comprising of a polymer, poly(ethylene oxide).

$$H\left[OCH_2CH_2\right]_nOH$$

poly(ethylene oxide)

Explain how the silicone pillars and synthetic adhesive polymer of 'Geckel' enable a wall–climbing robot to support its own weight on both types of paint surfaces.

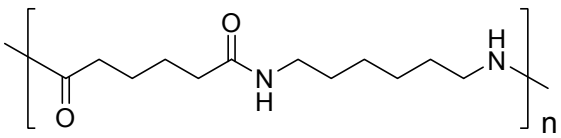
The silicone pillars of 'Geckel' have large surface areas that are able to come into close contact with the wall surface.

The molecules of the synthetic adhesive polymer are able to stick to the wall surface through instantaneous dipole–induced dipole interactions for the wall painted with hydrocarbons and hydrogen bonding for the wall painted with poly(ethylene oxide).

[2]

[Total: 8]

4 (a) The two most common types of nylons used in textile and plastic industries are nylon−6 and nylon−6,6. The structure of nylon−6,6 is shown below.



nylon-6,6

(i) Define the term *polymer*.

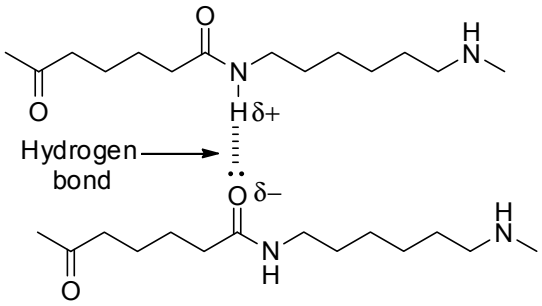
Polymer is a macromolecule made from monomers with average molecular mass of at least 1000 or at least 100 repeat units.

[1]

(ii) Ropes made of nylon−6,6 are chosen for its high tensile strength. Ropes made from polyesters such as poly(ethylene terephthalate) (PET) are about 90% as strong as that of nylon−6,6.

With the aid of a diagram, showing relevant interactions, explain why nylon−6,6 is stronger than polyester.

There are stronger hydrogen bonds in between nylon polymer chains as compared to permanent dipole–permanent dipole interactions in polyester chain.



[3]

(iii) Rust or grout on toilet tiles can be removed by spraying the tiles with a rust remover (**Figure 3**) before scrubbing the tiles with a brush. Explain whether a brush with nylon bristles or high density poly(ethene) bristles should be used for the scrubbing.

Figure 3

A brush with high density poly(ethene) bristles should be used.
The acid would cause hydrolysis of the amide linkage in nylon bristles while poly(ethene) bristles are unaffected.

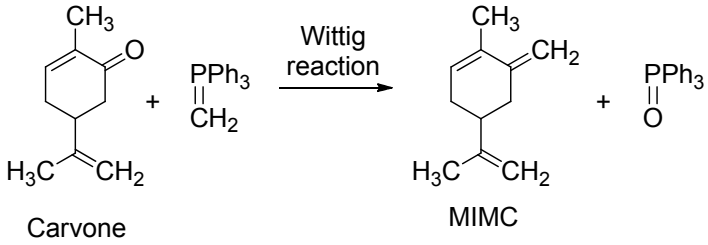
[2]

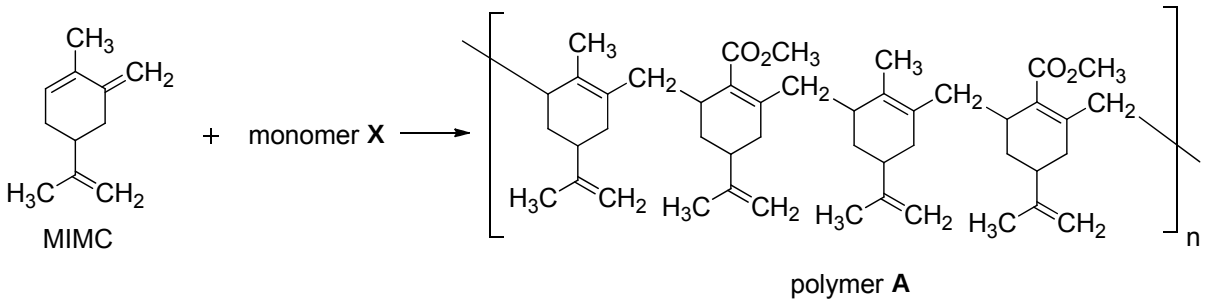
(iv) State whether nylon−6,6 is classified as a thermoplastic or thermoset. Hence, explain whether it can be recycled.

Nylon–6,6 is a thermoplastic which is recyclable.
It melts upon heating as the hydrogen bonds between the chains can be broken.

[2]

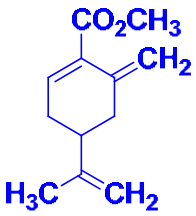
(b) Cavone is found in the oils of spearmint. It undergoes a Wittig reaction to yield the monomer, MIMC, which could undergo polymerisation with monomer **X** to form polymer **A**.





(i) State the type of polymerisation that has occurred to form polymer **A**. Hence, draw the constitutional formula of monomer **X**.

Addition polymerisation



monomer X

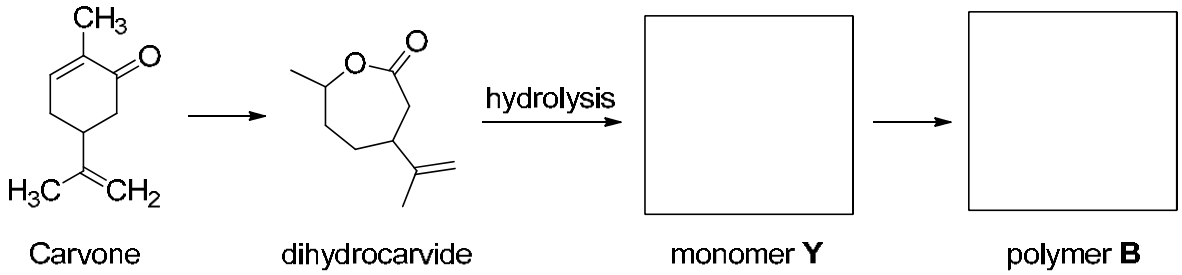
[2]

(ii) Explain why polymer **A** has a more rigid structure as compared to nylon−6,6 in **(a)**.

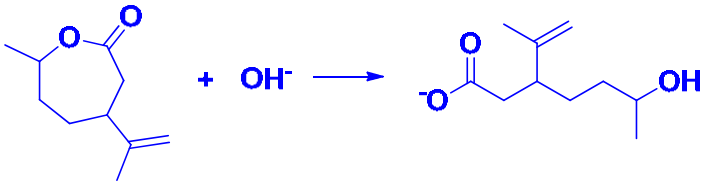
Polymer A contains C=C double bonds which can crosslink between the polymer chains through covalent bond formation.

[1]

Carvone can also be transformed into dihydrocarvide which undergoes a series of steps to form polymer **B**.



(iii) Write an equation for the base hydrolysis of dihydrocarvide.



[1]

(iv) Infra–red spectroscopy can be used to identify functional groups present in organic compounds. For example, the ketone functional group of carvone shows an absorption signal at 1670–1740 cm^{-1}.

Polymer **B** shows the following infra-red absorption signals at 1635–1690 cm^{-1}, 1050–1330 cm^{-1} and 1730–1750 cm^{-1}.

With reference to the *Data Booklet*, identify the bonds that correspond to the above infrared absorptions.

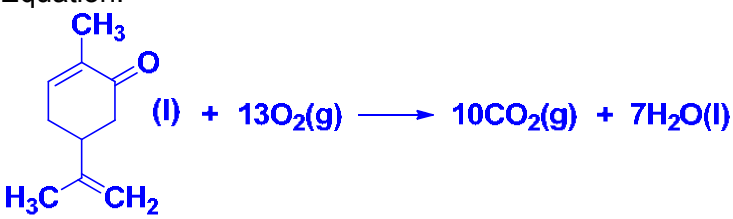
1635–1690 cm^{-1}	C=C
1050–1330 cm^{-1}	C−O of ester
1730–1750 cm^{-1}	C=O of ester

[1]

(v) With the aid of an equation, define the *enthalpy change of combustion* of carvone, $C_{10}H_{14}O$.

The enthalpy change of combustion is the energy released when one mole of carvone
is completely burnt in excess oxygen under standard conditions of 298 K and 1 bar.

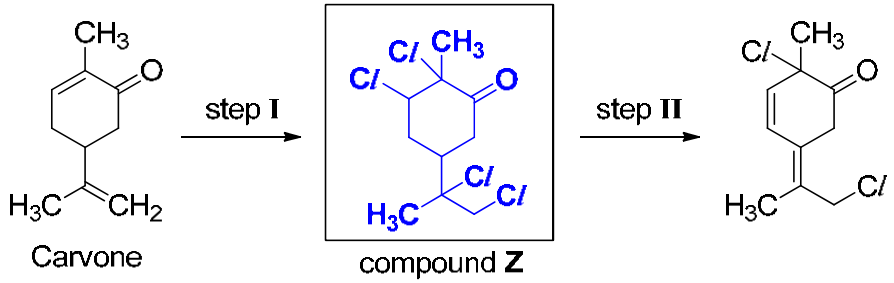
Equation:



[Accept $C_{10}H_{14}O$ used in the balanced equation]

[2]

(vi) Draw the structure of compound **Z** in the box for the following synthesis. State the reagents and conditions for step **I** and step **II**.



Step **I**:

reagents Cl_2(g)

condition room temperature

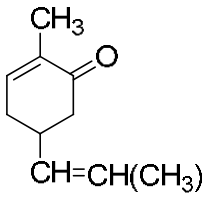
Step **II**:

reagents NaOH(alc)

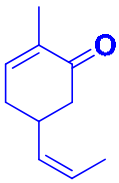
condition heat under reflux

[3]

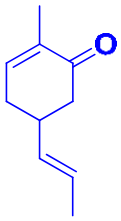
(vii) Only one of the C=C bonds in the isomer of carvone exhibits *cis–trans* isomerism. Draw the skeletal structures of the *cis–trans* isomers.



isomer of carvone



cis



trans

[2]

[Total: 20]

Section B

Answer **one** question from this section, in the spaces provided.

5 (a) Phosphine has the chemical formula PH_3. The kinetics of the reaction between phosphine and sodium chlorate(I) can be investigated by the following method.

$$PH_3 + 2NaClO \rightarrow H_3PO_2 + 2NaCl$$

Experiment	Initial concentrations of reactants / mol dm^{-3}		Initial rate of disappearance of PH_3 / mol dm^{-3} s^{-1}
	PH_3	NaC*l*O	
1	0.24	3.50	3.68
2	0.14	5.70	3.58
3	0.48	3.50	7.36

(i) Determine the order of reaction with respect to PH_3 and NaC*l*O.

Comparing experiments 1 and 3,
when the concentration of PH_3 is doubled, the rate of reaction is also doubled.
Hence, the order of reaction with respect to PH_3 is 1.

Comparing experiments 2 and 3,

$$\frac{rate_2}{rate_3} = \frac{[PH_3]^1[NaClO]^x}{[PH_3]^1[NaClO]^x}$$

$$\frac{3.58}{7.36} = \frac{(0.14)^1(5.70)^x}{(0.48)^1(3.50)^x}$$

Hence, the order of reaction with respect to NaC*l*O is 1.

[2]

(ii) Write the rate equation for this reaction.

Rate = $k[PH_3][NaClO]$

[1]

(iii) Determine the rate constant for experiment 1 and state its units.

Rate = $k[PH_3][NaClO]$
$3.68 = k(0.24)(3.50)$
$k = 4.38$
Unit = mol^{-1} dm^3 s^{-1}

[2]

(iv) Calculate the initial rate of formation of NaC*l* when the initial concentrations of PH_3 and NaC*l*O are 0.36 mol dm^{-3} and 2.50 mol dm^{-3} respectively.

Initial rate of formation of NaC*l*
= 2 × initial rate of disappearance of PH_3
= 2 × 4.38(0.36)(2.50)
= 7.88 mol dm^{-3} s^{-1}

[1]

(v) Determine the concentration of NaC*l* produced after two half-lives for experiment 1.

$[NaCl]_{max}$
$= 0.24 \times 2$
$= 0.480$ mol dm^{-3}

[NaC*l*] after two half-lives
$= 0.75 \times 0.480$
$= 0.360$ mol dm^{-3}

[2]

(b) The Appel reaction is used to convert alcohols to alkyl halides while triphenylphosphine, PPh_3, is oxidised to triphenylphosphine oxide, $O{=}PPh_3$.

Ph in PPh_3 and $O{=}PPh_3$ is a phenyl group, which remains unchanged after the reaction.

$$PPh_3 + CBr_4 + CH_3CH_2OH \rightarrow O{=}PPh_3 + CHBr_3 + CH_3CH_2Br$$

(i) With reference to the *Data Booklet*, calculate the enthalpy change for this reaction.

$\Delta H = \Sigma BE(\text{reactant}) - \Sigma BE(\text{product})$
$= [BE(C–Br) + BE(C–O) + BE(O–H)] – [BE(P=O) + BE(C–H) + BE(C–Br)]$
$= (280 + 360 + 460) – (540 + 410 + 280)$
$= –130$ kJ mol^{-1}

[2]

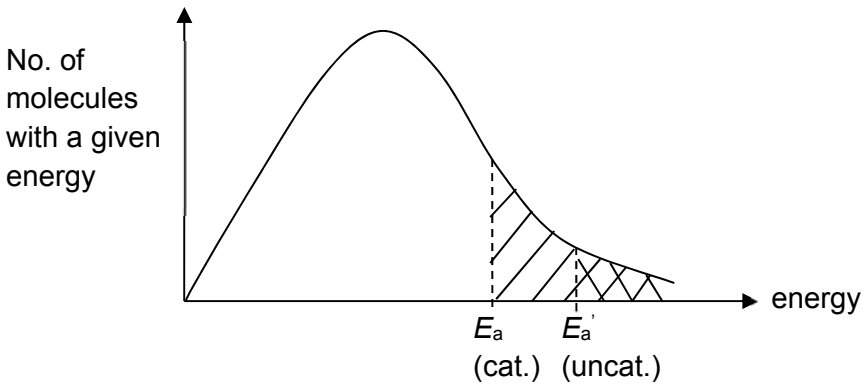
(ii) Using bond energy values from the *Data Booklet*, explain why the rate of reaction is slower when CCl_4 is used in place of CBr_4.

B.E.(C–C*l*) = 340 kJ mol^{-1} > B.E.(C–Br) = 280 kJ mol^{-1}
Thus, more energy is needed to break the C–Br bond leading to larger E_a and slower rate of reaction.

[2]

(iii) Triphenylphosphine. PPh_3 can also be oxidised by oxygen to form triphenylphosphine oxide, $O{=}PPh_3$ with the use of a catalyst $[MoO_2Cl_2(DMSO)_2]$.

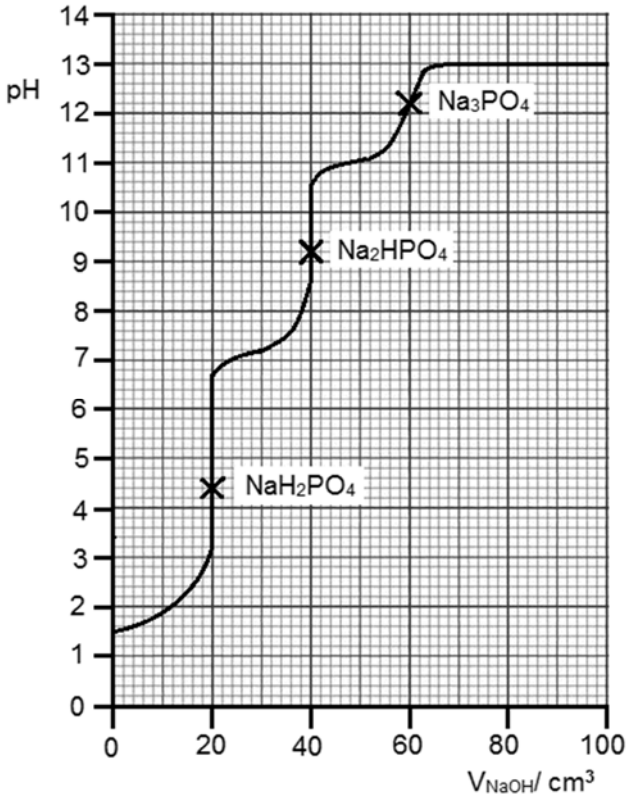
With the aid of a Maxwell–Boltzmann distribution diagram, explain how the addition of a catalyst speeds up the rate of reaction.



A catalyst provides an alternative pathway with a lower activation energy (E_a) for the reaction, thus leading to more molecules with energy ≥ E_a (catalysed), causing a greater frequency of effective collisions.

[2]

(c) In a titration experiment, 0.100 mol dm^{-3} NaOH was added to 15.0 cm^3 of phosphoric acid as shown below.



Phosphoric acid is a tribasic acid, and it dissociates into PO_4^{3-} in three steps as shown below.

Step 1: $H_3PO_4 \rightleftharpoons H_2PO_4^- + H^+$ K_{a1}
Step 2: $H_2PO_4^- \rightleftharpoons HPO_4^{2-} + H^+$ K_{a2}
Step 3: $HPO_4^{2-} \rightleftharpoons PO_4^{3-} + H^+$ K_{a3}

(i) Calculate the concentration of the phosphoric acid.

Amount of phosphoric acid required
$= 0.100 \times 20 \times 10^{-3}$
$= 0.00200$ mol

$[H_3PO_4]$
$= 0.00200 \div (15.0 \times 10^{-3})$
$= 0.133$ mol dm^{-3}

[1]

(ii) With reference to the titration curve and **(c)(i)**, suggest whether phosphoric acid is a weak or strong acid.

For $H_3PO_4 \rightleftharpoons H_2PO_4^- + H^+$
From the graph, initial pH = 1.5.

$[H^+] = 10^{-1.5} = 0.0316$ mol dm^{-3}
$[H^+] < [H_3PO_4]$

H_3PO_4 is a weak acid as it dissociates partially.

[2]

(iii) Arrange the three K_a values of phosphoric acid in decreasing order of acidity. Explain your answer.

$K_{a1} > K_{a2} > K_{a3}$
It is more difficult to remove a positively charged proton from an ion of increasing negative charge, leading to a lower extent of dissociation.

OR The H^+ ion produced from the first dissociation suppress the subsequent dissociation, leading to a lower extent of dissociation.

[2]

(iv) The table below lists some common indicators found in the college laboratory. With reference to the given titration curve for phosphoric acid, suggest an indicator to detect the second end–point. Hence, state the colour change of your chosen indicator at the second end-point of the titration.

indicator	pH range for colour change	colour in acidic pH	colour in basic pH
methyl orange	3–5	red	yellow
bromothymol blue	6–8	yellow	blue
phenolphthalein	8–10	colourless	pink
thymolphthalein	9.3–10.5	colourless	blue
trinitrobenzoic acid	12–13.4	colourless	orange–red

Thymolpthalein
Colour changes from colourless to blue.

[1]

[Total: 20]

6 (a) During an experiment, a student added 3.00 g of solid KOH to 100 cm^3 of 1.00 mol dm^{-3} HNO_3 solution. The initial temperature of the HNO_3 solution was 29.2 °C and the highest temperature recorded was 36.5 °C.

(i) Define the *standard enthalpy change of neutralisation,* $\Delta H^{\ominus}_{neut}$.

The energy released when one mole of water is formed when an acid neutralises a base, under standard conditions of 298 K and 1 bar.

[1]

(ii) Calculate the ΔH_{neut} of this reaction. You may assume that 4.18 J of energy is required to raise the temperature of 1 g of the solution by 1 °C.

$KOH + HNO_3 \rightarrow KNO_3 + H_2O$

Amount of KOH
= 3.0 ÷ (39.1 + 16.0 + 1.0)
= 0.0535 mol

Amount of HNO_3
= $1.00 \times 100 \times 10^{-3}$
= 0.100 mol

Amount of water formed
= 0.0535 mol

Heat evolved
= mcΔT
= (100)(4.18)(36.5 – 29.2)
= 3051.4 J

ΔH_{neut}
= –(3051.4) ÷ 0.0535
= –57004 J mol^{-1} (negative sign and units)
= –57.0 kJ mol^{-1}

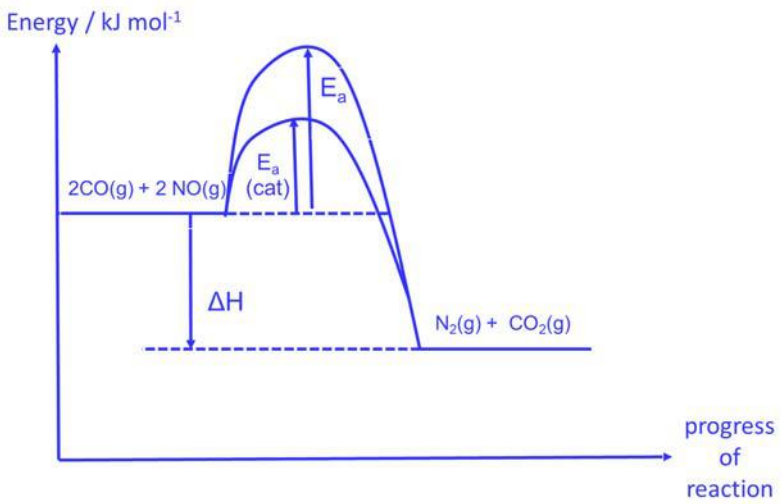
[2]

(b) Compressed Natural Gas (CNG) has been used as a fuel for vehicles in Singapore since 2001 because it releases less air–borne pollutants. Together with the mandatory catalytic converters installed in vehicles, this helps to maintain the high air quality that Singapore enjoys.

The reaction below takes place in the catalytic converter and it is catalysed by a rhodium catalyst.

$$2CO(g) + 2NO(g) \rightarrow N_2(g) + 2CO_2(g) \qquad \Delta H < 0$$

(i) Draw energy profile diagrams for both the catalysed and uncatalysed reactions on the axes below. Label on the diagrams the axes, ΔH, activation energies for both the catalysed (E_a(cat)) and uncatalysed (E_a) reactions.



[2]

(ii) Explain in terms of collision theory, how the addition of a catalyst increases the rate of reaction.

A catalyst provides an alternative pathway with a lower activation energy for the reaction.
There are more molecules with energy greater than E_a(cat), leading to a greater frequency of effective collisions.

[1]

(iii) Explain the mode of action of the rhodium catalyst in this reaction.

The type of catalysis is heterogeneous catalysis.
Adsorption of reactant molecules by forming weak bonds with active sites.
This weakens the covalent bonds in the molecules.
The surface concentration of reactants increases and reactants have the correct orientation for reaction to occur.
After reaction, the products desorb from the surface.

[3]

(c) Natural gas has many impurities such as CH_4 and H_2S, which can react according to the following equilibrium.

$$CH_4(g) + 2H_2S(g) \rightleftharpoons CS_2(g) + 4H_2(g)$$

2.0 mol of CH_4, 4.0 mol of H_2S, 2.0 mol of CS_2 and 6.8 mol of H_2 were allowed to reach equilibrium in a 250 cm^3 vessel at 800 °C. The equilibrium concentration of CH_4 was found to be 3.4 mol dm^{-3}.

(i) Calculate the value of K_c, include the units in your answer.

	$CH_4(g)$ +	$2H_2S(g)$ ⇌	$CS_2(g)$ +	$4H_2(g)$
Initial / mol dm^{-3}	8.0	16.0	8.0	27.2
Change / mol dm^{-3}	−4.6	−9.2	+4.6	+18.4
Equilibrium / mol dm^{-3}	3.4	6.8	12.6	45.6

$$K_c = \frac{[CS_2][H_2]^4}{[CH_4]H_2S]^2}$$
$$= \frac{(12.6)(45.6)^4}{(3.4)(6.8)^2}$$
$$= 3.47 \times 10^6 \text{ mol}^2 \text{ dm}^{-6}$$

[2]

(ii) Define *Le Chatelier's Principle*.

Le Chatelier's Principle states that when a system at equilibrium is disturbed, the system will counteract the change imposed by shifting the position of equilibrium
in a direction that tends to reduce that change, so as to re–establish the equilibrium.

[1]

(iii) Explain how the position of equilibrium would be affected if the volume of the vessel is changed to 500 cm^3.

When the volume of the vessel is doubled, the total pressure is halved.
Hence, by Le Chatelier's Principle, the system will counteract the decrease in pressure by favoring the forward reaction to increase the total number of gaseous molecules. The position of equilibrium shifts to the right.

[2]

(iv) Explain how the position of equilibrium would be affected if a catalyst was introduced into the vessel.

A catalyst increases the rates of the forward and backward reactions to the same extent, there will be no shift in the position of equilibrium.

[1]

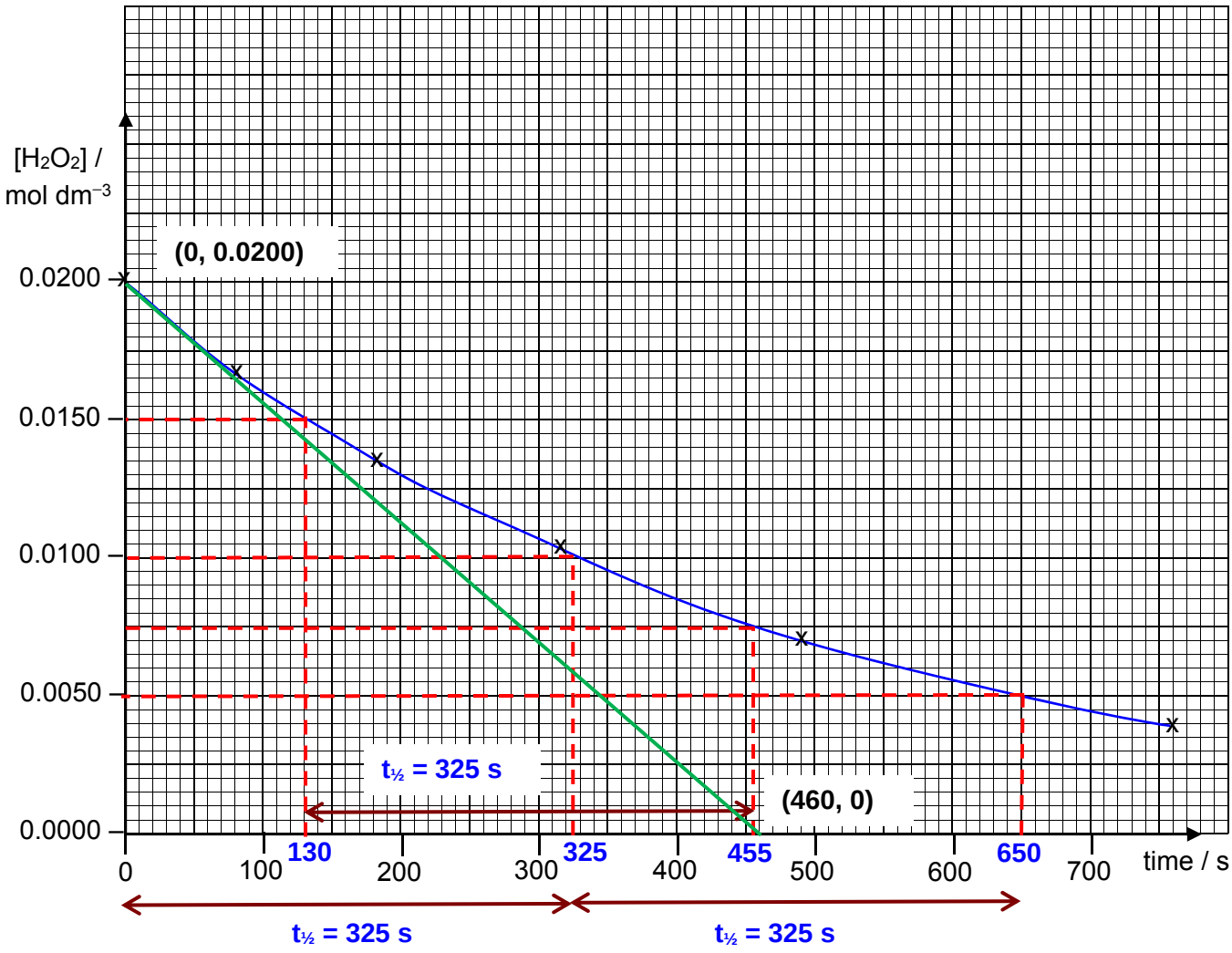
(d) Hydrogen peroxide and iodide ions react in an acidic medium to form water and iodine as shown below.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow 2H_2O + I_2$$

The rate of reaction is monitored by measuring the amount of iodine produced with time. The concentration of H_2O_2 remaining is then calculated as shown in the table below.

Time / s	$[H_2O_2]$ / mol dm^{-3}
0	0.0200
80	0.0167
180	0.0135
315	0.0103
490	0.0070
760	0.0038

(i) Plot a graph of $[H_2O_2]$ against time on the axes below. Hence, determine the order of reaction with respect to $[H_2O_2]$.



Since the three half–lives are approximately constant ≈ 325 s, the order of reaction with respect to $[H_2O_2]$ is one.

[3]

(ii) Use the graph to determine the initial rate of the reaction.

Initial rate
= –gradient of tangent at t = 0
$= \frac{0.0200 - 0}{0 - 460}$
$= 4.35 \times 10^{-5}$ mol dm^{-3} s^{-1}

[2]

[Total: 20]

End of Paper

CANDIDATE'S NAME: _____ **CTG:** _____

YISHUN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION 2018

CHEMISTRY **8873/01**
HIGHER 1 **13 September 2018**
Paper 1: Multiple-Choice Questions **1400hrs – 1500hrs**
1 hour

Additional materials:

Optical Mark Sheet
Data Booklet

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INSTRUCTIONS TO CANDIDATES

Multiple Choice Questions

Write in soft pencil.

Do not use paper clips, highlighters, glue or correction fluid.

Write your name and CTG on the Answer Sheet. Shade your NRIC number in the spaces provided in the Optical Mark Sheet.

There are thirty questions on this paper. Answer **all** questions. For each question, there are four possible answers **A**, **B**, **C**, and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

This question paper consists of 11 printed pages.

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 Nitrogen and phosphorus are both in Group 15 of the Periodic Table. Phosphorus forms a chloride with the formula PCl_5 but nitrogen does not form NCl_5.

Which statements help to explain this?

1 Nitrogen cannot have an oxidation state of +5.

2 Nitrogen is more electronegative than phosphorus.

3 Nitrogen's outer shell cannot contain more than eight electrons.

A 1 and 2 only **B** 1 and 3 only **C** 2 and 3 only **D** 3 only

2 When nuclear reactions take place, the elements produced are different from the elements that reacted. Nuclear equation, such as the one below, are used to represent the changes that occur.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3{}^{1}_{0}n$$

The nucleon (mass) number total is constant at 236 and the proton number total is constant at 92.

In another nuclear reaction, uranium-238 is reacted with deuterium atoms, $^{2}_{1}H$. An isotope of a new element, **G** is formed as well as two neutrons.

$$^{238}_{92}U + {}^{2}_{1}H \rightarrow G + 2{}^{1}_{0}n$$

What is isotope **G**?

A ^{238}Np **B** ^{238}Pu **C** ^{240}Np **D** ^{240}Pu

3 Two conversions are shown.

$$NH_4^+ \rightarrow NH_3$$
$$C_2H_4 \rightarrow C_2H_6$$

Which similar features do these conversions have?

A change in oxidation state of an element

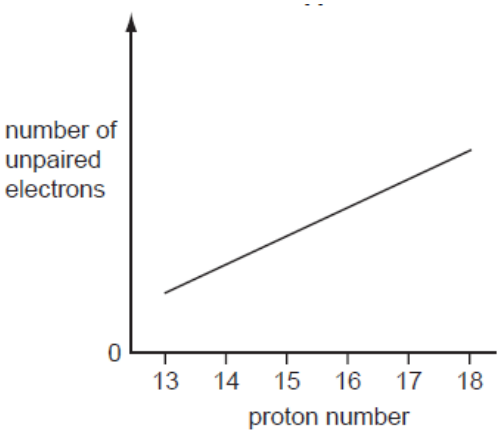
B decrease in bond angle

C formation of a lone pair of electrons

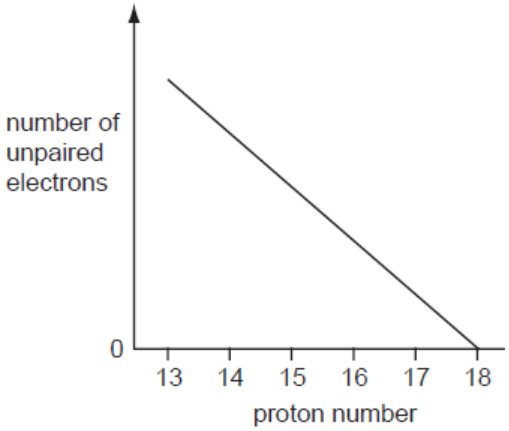
D loss of a π bond

4 Which graph represents the number of unpaired p orbital electrons for atoms with proton number 13 to 18?

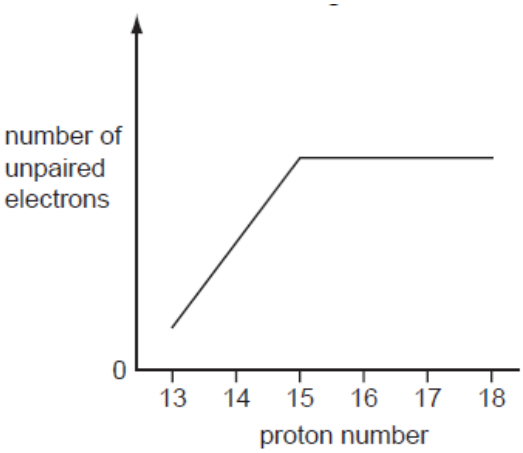
A



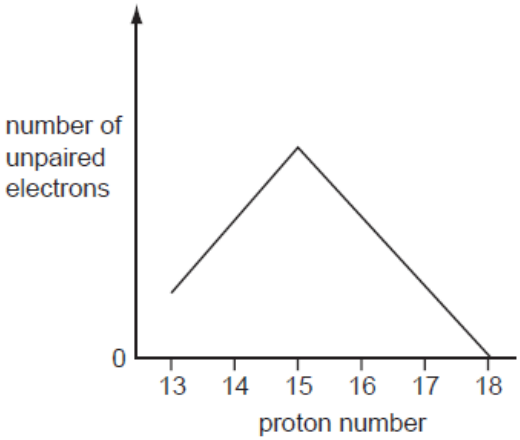
B



C



D



5 What is the correct number of bonds of each type in the Al_2Cl_6 molecule?

	covalent	co-ordinate (dative covalent)
A	6	1
B	6	2
C	7	0
D	7	1

6 Ethylene glycol, $HOCH_2CH_2OH$, is primarily used in antifreeze formulations and as a raw material in the manufacture of polyesters. It has a boiling point of 197 °C while ethanol boils at 79 °C.

Which statements help account for this difference in melting points?

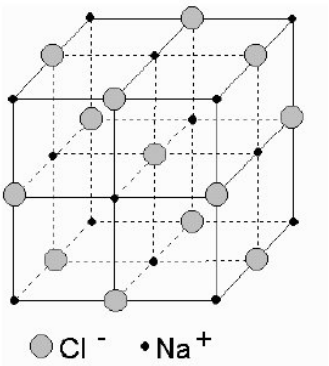
1 Ethylene glycol forms more hydrogen bonds per molecule than ethanol.

2 Ethylene glycol has a larger surface area than ethanol.

3 The covalent bonds in ethylene glycol are stronger than those in ethanol.

A 1 and 2 only **B** 1 and 3 only **C** 2 and 3 only **D** 1 only

7 In the sodium chloride lattice the number of chloride ions that surround each sodium ion is called the *co-ordination number* of the sodium ions.



Referring to the above diagram, what are the co-ordination numbers of the sodium ions and the chloride ions in the sodium chloride lattice?

	sodium ions	chloride ions
A	4	4
B	6	4
C	6	6
D	4	6

8 The pH of human blood is constant at about 7.40.

Which ion or molecule in the human body will remove contaminating $H^+(aq)$ ions from the blood to keep the pH constant?

A CO_3^{2-} **B** HCO_3^- **C** H_2CO_3 **D** PO_4^{3-}

9 What is the final pH of the solution formed by mixing equal volumes of two NaOH solutions, one with pH 11.0 and the other with pH 13.0?

A 11.7 **B** 12.0 **C** 12.7 **D** 13.0

10 **J**, **K** and **L** are three elements in the third period.

- **J** reacts with chlorine to give a liquid product.
- **K** reacts with chlorine to give a solid product that dissolves in water to give a solution of pH 7.
- **L** reacts with chlorine to give a solid product that dissolves in water to give a solution of pH 6.

Which elements are good conductors of electricity?

A **J** only **B** **J** and **K** **C** **K** only **D** **K** and **L**

11 The volatility of the Group 17 elements chlorine, bromine, and iodine, decreases down the group.

What is responsible for this?

A bond length in the halogen molecule

B bond strength in the halogen molecule

C electronegativity of the halogen

D number of electrons in the halogen molecule

12 This question refers to isolated gaseous species.

The species F^-, Ne and Na^+ are isoelectronic. This means that they have the same number of electrons.

In which order do their radii increase?

	smallest →		largest
A	Na^+	Ne	F^-
B	Na^+	F^-	Ne
C	F^-	Ne	Na^+
D	F^-	Na^+	Ne

13 A student makes sodium chloride by reacting 0.0125 mol of sodium carbonate with an excess of 0.50 mol dm^{-3} hydrochloric acid.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

Which statements about the quantities of substance are correct?

1 300 cm^3 of carbon dioxide is produced at room temperature and pressure.

2 25 cm^3 of the hydrochloric acid is needed to exactly neutralise the sodium carbonate.

3 1.46 g of sodium chloride is produced.

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

14 Shakudo is a Japanese alloy of copper and gold. The information in the table as obtained by mass spectrometry of a sample of shakudo.

mass number	63	65	197
% abundance	65	29	6

What is the A_r value for copper?

A 59.8 **B** 63.5 **C** 63.6 **D** 71.6

15 $Na_2S_2O_3$ reacts with HCl as shown.

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + SO_2(g) + S(s)$$

What is the oxidation number of sulfur in $Na_2S_2O_3$, SO_2 and S?

	$Na_2S_2O_3$	SO_2	S
A	+2	+2	+1
B	+2	+4	0
C	+4	+2	+1
D	+4	+4	0

16 Given the following half equations:

$$Cr_2O_7^{2-} + 14\ H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

$$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$$

What volume of 0.020 mol dm^{-3} of potassium dichromate, $K_2Cr_2O_7$, is required to oxidise 18 cm^3 of an acidified solution of 0.020 mol dm^{-3} of FeC_2O_4 ?

A 3.0 cm^3 **B** 6.0 cm^3 **C** 9.0 cm^3 **D** 18.0 cm^3

17 In a calorimetric experiment 1.60 g of a fuel are burnt. 45.0 % of the energy released is absorbed by 200 g of water. The temperature of the water rises from 18.0 °C to 66.0 °C.

Given that the specific heat capacity of water is 4.18 J g^{-1} K^{-1}, what is the total energy released per gram of fuel burnt (to 3 significant figures)?

A 11 300 J **B** 55 700 J **C** 89 200 J **D** 143 000 J

18 Which equation represents the standard enthalpy change of formation of water?

A $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)$

B $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$

C $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

D $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

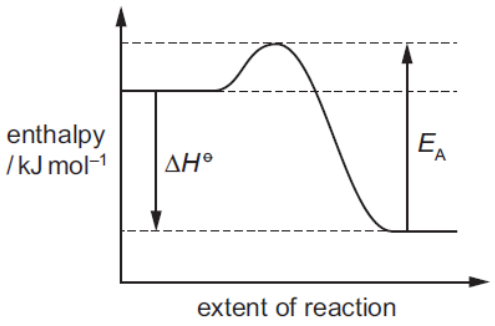
19 Nitric oxide, NO and bromine vapour react together according to the following equation.

$$2NO(g) + Br_2(g) \rightarrow 2NOBr\ (g) \qquad \Delta H^{\ominus} = -23\ kJ\ mol^{-1}$$

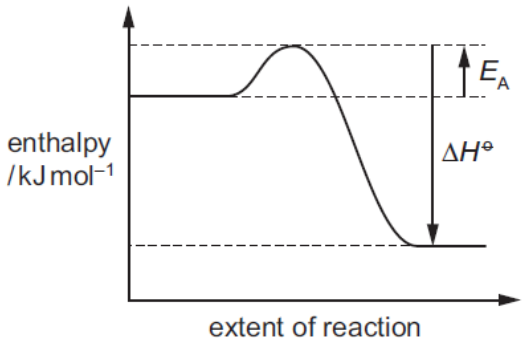
The reaction has an activation energy of +5.4 kJ mol^{-1}.

What is the correct reaction pathway diagram for this reaction?

A



B



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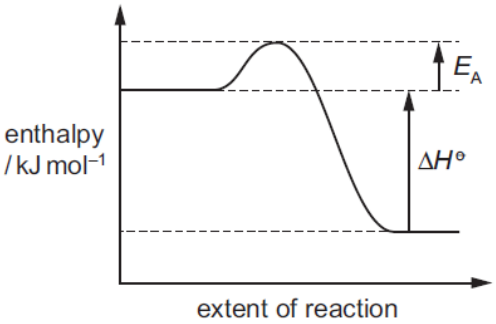
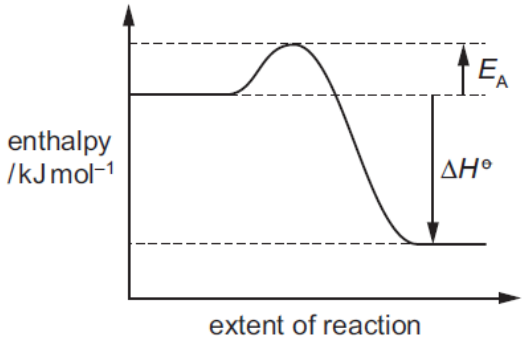


D



20 Enzymes are biological catalysts. Many enzymes show specificity. An example of an enzyme which shows specificity is glucokinase. Glucokinase is involved in the metabolism of glucose.

What does specificity mean in this context?

A Glucokinase is most effective as a catalyst over a narrow pH range.

B Glucokinase is most effective as a catalyst over a narrow range of temperatures.

C Glucokinase only operates on a narrow range of substrate molecules.

D Glucokinase provides an alternative route for the reactions it catalyses.

21 Methanol, CH_3OH, can be produced industrially by reacting CO with H_2.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

The process can be carried out at 4×10^3 kPa and 1150 K.

Which statements about the reaction are correct?

1 Increasing the temperature will increase the rate of the backward reaction.

2 Increasing the temperature will decrease the yield of methanol.

3 Increasing the pressure will increase the yield of methanol.

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

22 Two moles of **P** were placed in a sealed container. The container was heated and **P** was partially decomposed to produce **Q** and **R** only. A dynamic equilibrium between **P**, **Q** and **R** was established.

At equilibrium, *x* moles of **R** were present and the total number of moles present was $\left(2 + \frac{x}{2}\right)$.

What is the equation for this reversible reaction?

A $\mathbf{P} \rightleftharpoons 2\mathbf{Q} + \mathbf{R}$

B $2\mathbf{P} \rightleftharpoons 2\mathbf{Q} + \mathbf{R}$

C $2\mathbf{P} \rightleftharpoons \mathbf{Q} + \mathbf{R}$

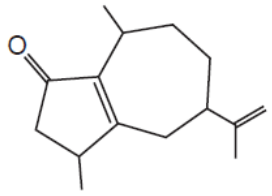
D $2\mathbf{P} \rightleftharpoons \mathbf{Q} + 2\mathbf{R}$

23 Researchers have attempted to create a synthetic material that sticks to surfaces, by imitating the mechanism that allows the gecko to climb a vertical surface.

Which statement explains how the synthetic material sticks to surfaces?

A It forms a glue that forms covalent bonds with surfaces.
B It forms a glue that forms van der Waals' forces with surfaces.
C It is a nanomaterial that has a high surface area to volume ratio.
D It is a nanomaterial that has a low surface area to volume ratio.

24 The compound rotundone is responsible for the peppery smell of pepper and is also found in some red wines.



rotundone

How many hydrogen atoms are in one molecule of rotundone?

A 15 **B** 19 **C** 22 **D** 24

25 *Melamine* and *acrylic* are both hard polymers. *Melamine* is used on worktop surfaces and it chars (becomes blackened) on heating. *Acrylic* is a sturdy substitute for glass and it melts on heating.

Which statements about *melamine* and *acrylic* are correct?

1 Both polymers can be recycled.
2 Heating does not break the crosslinks in *acrylic*.
3 Heating does not break the crosslinks in *Melamine.*

A 3 only **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

26 It is difficult to dispose PVC. Two possible methods are burying it in landfill sites and disposal by combustion.

Which option is correct?

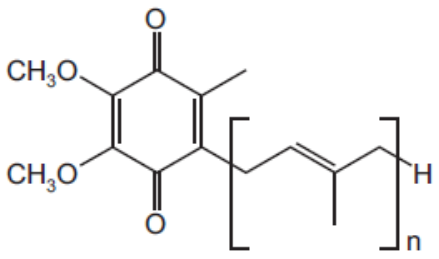
	rate of biodegradation of PVC in landfill sites	gases produced when PVC combusts
A	fast	CO_2, H_2O, HCl
B	fast	CO_2, H_2O, Cl_2
C	slow	CO_2, H_2O, HCl
D	slow	CO_2, H_2O, Cl_2

27 How many esters with the molecular formula $C_5H_{10}O_2$ can be made by reacting a **primary** alcohol with a carboxylic acid?

A 4 **B** 5 **C** 6 **D** 8

28 People who take statin drugs to control their blood cholesterol may also take 'coenzyme Q_{10}'.

The diagram shows a simplified structure of one form of this coenzyme.

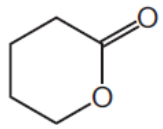


coenzyme Q_{10}

Which option describes this structure correctly?

	functional groups present	number of π bonds in one molecule
A	aldehyde and alkene	n + 2
B	aldehyde and alkene	n + 4
C	ketone and alkene	n + 2
D	ketone and alkene	n + 4

29 Cyclic esters are also known as lactones. *Delta* lactone is used as solvent and in the manufacture of polyesters.



delta lactone

Which compound could be used to produce *delta* lactone in a single reaction?

A $HOCH_2CH_2CH_2COCH_3$

B $HOCH_2CH_2CH_2CH_2CHO$

C $HOCH_2CH_2CH_2CH_2CO_2H$

D $HOCH_2CH_2CH_2CH_2CH_2OH$

30 Compound **X** is heated with a mild oxidising agent. One of the products of the reaction will react with hydrogen cyanide, forming 2-hydroxypentanenitrile.

What is compound **X**?

A butan-1-ol
B butan-2-ol
C pentan-1-ol
D pentan-2-ol

CANDIDATE'S NAME: _____ **Group:** _____

YISHUN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION 2018

CHEMISTRY **8873/02**
HIGHER 1 **27 August 2018**
Paper 2 **0800hrs – 1000hrs**
2 hours

Additional materials:
Data Booklet
Electronic calculator

YISHUN JUNIOR COLLEGE
FLORESCAT CONCORDIA

INSTRUCTIONS TO CANDIDATES

Write your name and group in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use paper clips, highlighters, glue or correction fluid.
The use of scientific calculator is expected, where appropriate.

Answer **all** the questions on the Question Paper.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 1	
Total	**/ 30**
Paper 2	
1	**/ 28**
2	**/ 12**
3	**/ 8**
4	**/ 6**
5	**/ 6**
6	**/ 20**
7	**/ 20**
Total	**/ 80**
Overall	**/110**

This question paper consists of **24** printed pages.

Section A

Answer **all** the questions in this section in the spaces provided.

1. The Earth's climate is changing. Temperatures are rising, snow and rainfall patterns are shifting, and more extreme climate events – like heavy rainstorms and record high temperatures – are already happening. Many of these observed changes are linked to the rising levels of carbon dioxide and other greenhouse gases (gases that trap heat) in our atmosphere, caused by human activities.

Gross calculation shows that while carbon dioxide accounts for 74% of the greenhouse gases, methane is the second most prevalent (14%) greenhouse gas emitted from human activities - natural gas (mainly methane) and petroleum systems activities such as incinerations, are the largest source of methane emission, accounting for 31%, while methane generated from landfills as waste decomposes, accounting for 16%.

Although methane's lifetime in the atmosphere is much shorter than carbon dioxide, but methane is more efficient at trapping radiation than carbon dioxide. Kilogram for kilogram, the comparative impact of methane is about 12 times greater than carbon dioxide.

A fossil fuel power station is a power station which burns a fossil fuel such as coal, natural gas, or petroleum to produce electricity. In an attempt to cut down carbon dioxide emissions during the production of electricity from such fuels, there has been a move in many countries to build more power stations burning natural gas rather than coal. The following table compares these two types of power station.

Type of power station	Overall efficiency of power station	Amount of by-product produced per MJ of electrical energy (1 MJ = 10^6 J)	
		SO_2	NO_2
coal	40%	0.31 g	0.64 g
natural gas	51%	0.0015 g	0.11 g

In your calculations, assume that coal consists of 95% of carbon, together with 5% of non-combustible ash.

(a) Write balanced equations for the complete combustion of

(i) methane

…… [1]

(ii) carbon

…… [1]

(b) The enthalpy changes of combustion of methane and carbon are :

$\Delta H_c(CH_4) = -890$ kJ mol^{-1}
$\Delta H_c(C) = -394$ kJ mol^{-1}

(i) Use these data to calculate how many moles of each of methane and carbon needed to be burned to produce 1 MJ of **heat** energy. [2]

Methane :

Carbon :

(ii) Using the efficiency figures given in the table, and your answers in **(b)(i)**, calculate how many moles of each of methane and carbon needed to be burned in the power stations, to produce 1 MJ of **electrical** energy. [4]

Methane :

Carbon :

(c) Hence, calculate the mass of the ash that would be produced per MJ of electrical energy in a coal-fired power station. Assume that the average relative molecular mass of the ash is 220.0. [2]

[Turn over

(d) Use the data in the table to suggest **two** environmental advantages of using a natural gas power station. Explain your answer. [3]

……..

……..

……

……

……

……

(e) Despite the advantages of operating a gas power station, use your answer in **b(ii)** and relevant data from the passage, explain why methane is more harmful to the environment than coal. [3]

……

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……

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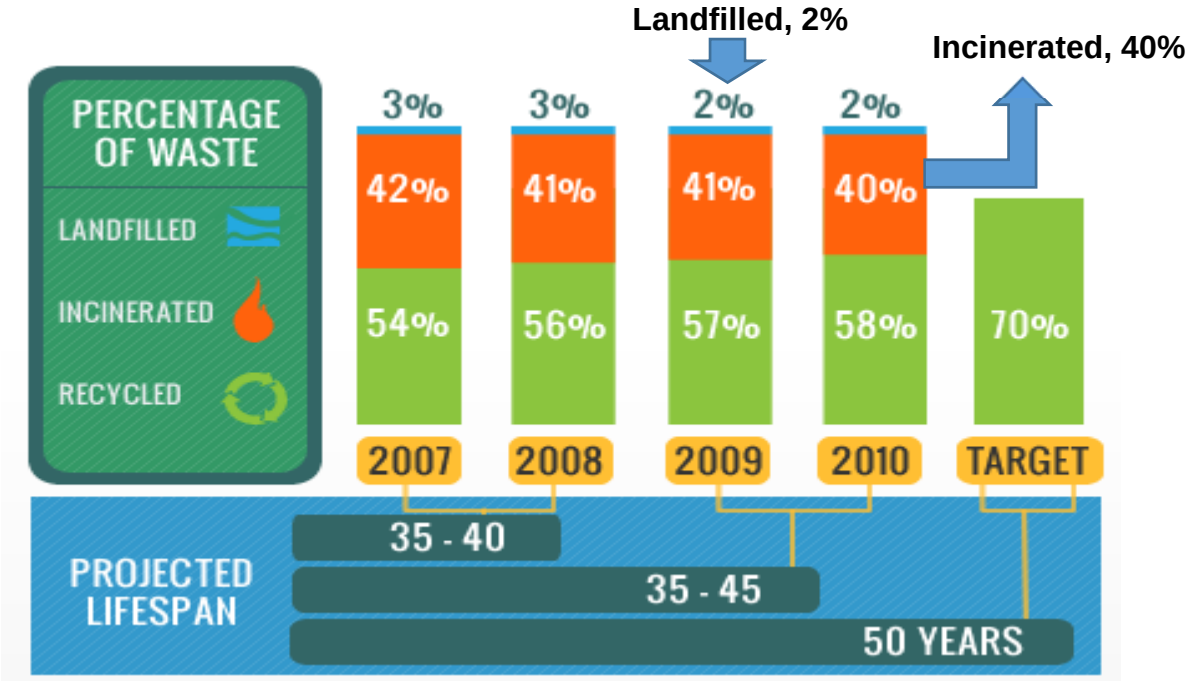
……...

……

(f) Locally, the National Environment Agency, NEA has released the following data on its refuse disposal :



Use relevant data from the passage, suggest one advantage and one disadvantage for NEA to increase the use of incineration for refuse disposal over landfill. [2]

……

……

……

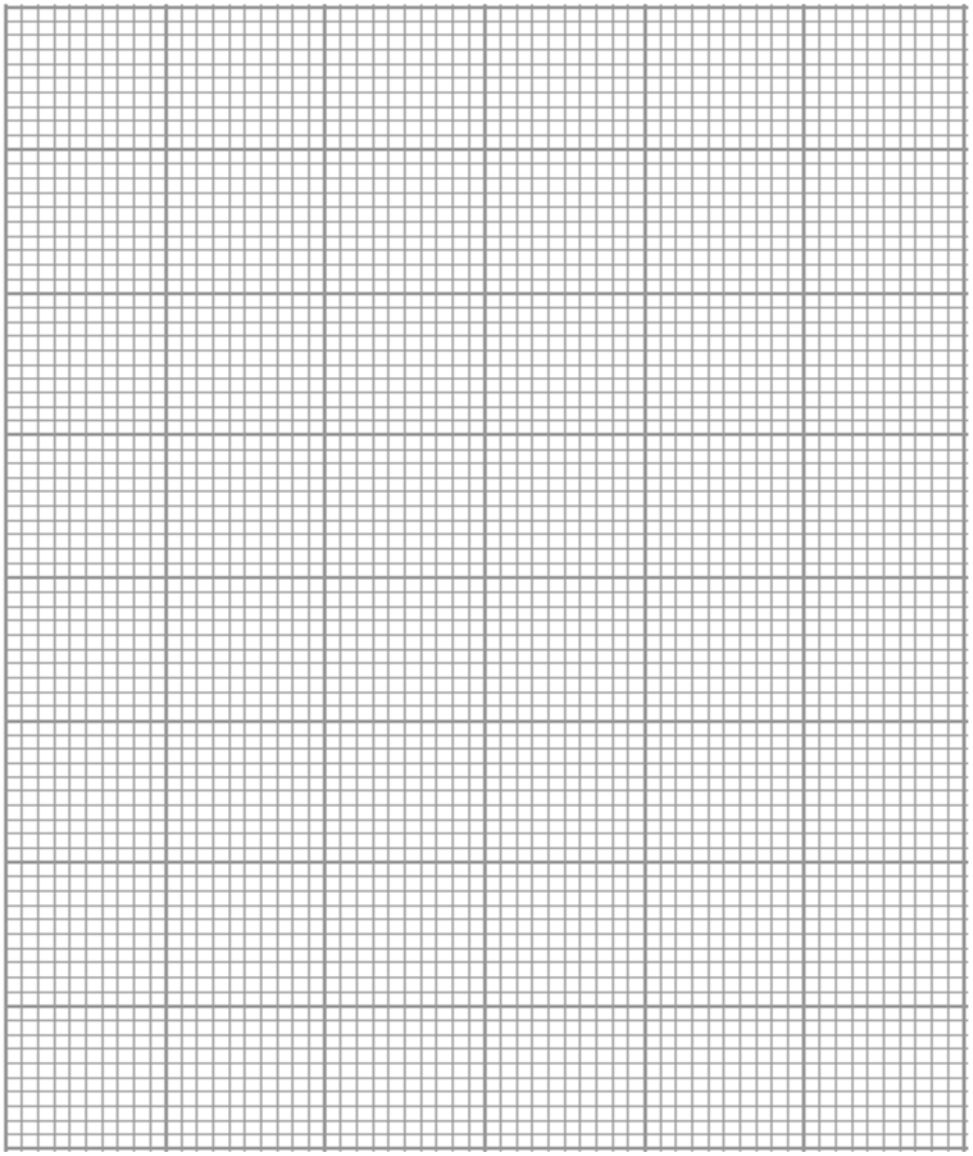
……

[Turn over

(g) Methane belongs to a family of organic compounds known as alkanes.
The standard enthalpy changes of combustion of five straight chain alkanes are given in the table below.

alkane	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}
$\Delta H_c^{\ominus}$/ kJ mol^{-1}	–890	–1560	–2230	–2920	–3570

On the grid below, plot a graph to show how the standard enthalpy changes of combustion vary for these five alkanes. [3]



Use the graph you have plotted above, determine

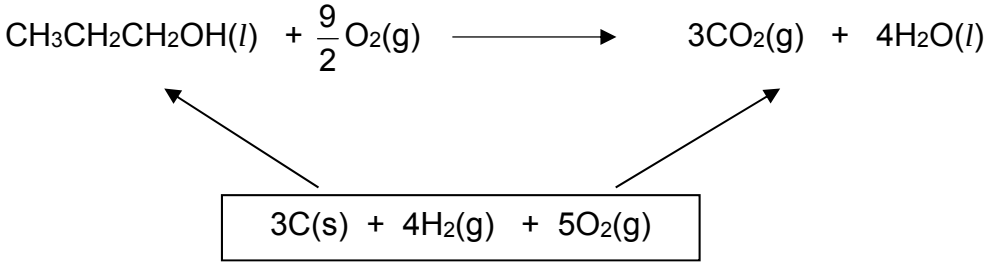
(i) the **average** standard enthalpy change of combustion of a "CH_2" group [2]

(ii) the standard enthalpy change of combustion of hydrogen gas [1]

(iii) the standard enthalpy change of combustion of hexane, C_6H_{14}. [2]

(h) Alcohols are also commonly used as fuels.

The diagram below shows an energy cycle involving propan-1-ol, $CH_3CH_2CH_2OH$.



Use the following data to calculate the standard enthalpy change of combustion of propan-1-ol. [2]

$\Delta H_f^{\ominus}(CO_2) = -393$ kJ mol^{-1}

$\Delta H_f^{\ominus}(H_2O) = -286$ kJ mol^{-1}

$\Delta H_f^{\ominus}(CH_3CH_2CH_2OH) = -303$ kJ mol^{-1}

[Total : 28]

[Turn over

2. The mass spectrometer made it possible to determine the masses of atoms very accurately, and it became clear that not all atoms of the same element had the same mass.
The accurate masses gave rise to the idea of the isotopes:
"Isotopes have the same atomic numbers, but different mass numbers."

(a) (i) Write the symbols showing the nucleon numbers, proton numbers and charges of the following three particles, **K, L** and **M**.
You may refer to the example given for the particle, **A** [3]

Particle	Protons	Neutrons	Electrons	Symbol
K	6	8	6	
L	7	7	10	
M	8	7	7	
A	**5**	**8**	**5**	$^{13}_{5}\mathbf{A}$

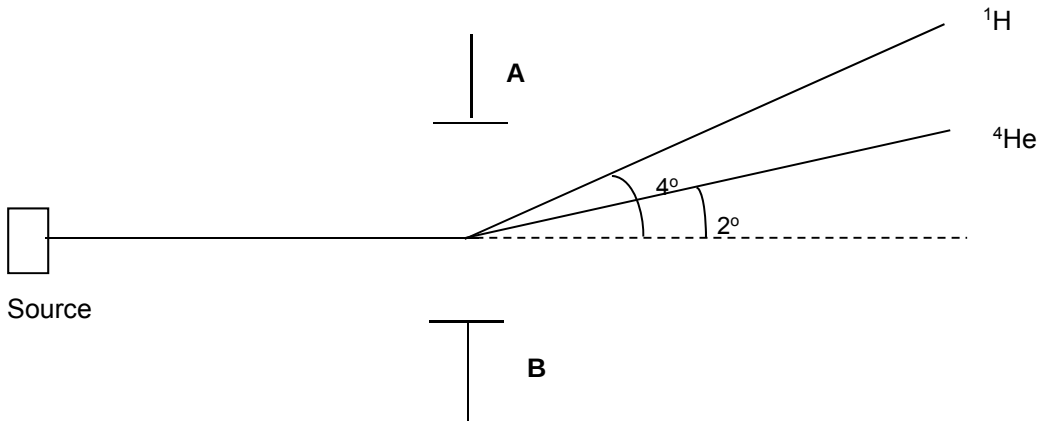
(ii) Using the data from the *Data Booklet*, write the symbols of the usual isotopes of the elements concerned. [3]

Particle **K** :

Particle **L** :

Particle **M** :

(b) A plasma is a gaseous mixture in which the atoms have been completely stripped of their electrons, leaving bare nuclei. Because of possible use in controlled nuclear fusion reactions, plasma behaviour has been extensively studied. When passed between two plates carrying a certain electric charge, ^{1}H and ^{4}He nuclei are deflected as follows.



Giving reason for your answer, suggest the polarity (+ or -) of plate **A**. [2]

……

……

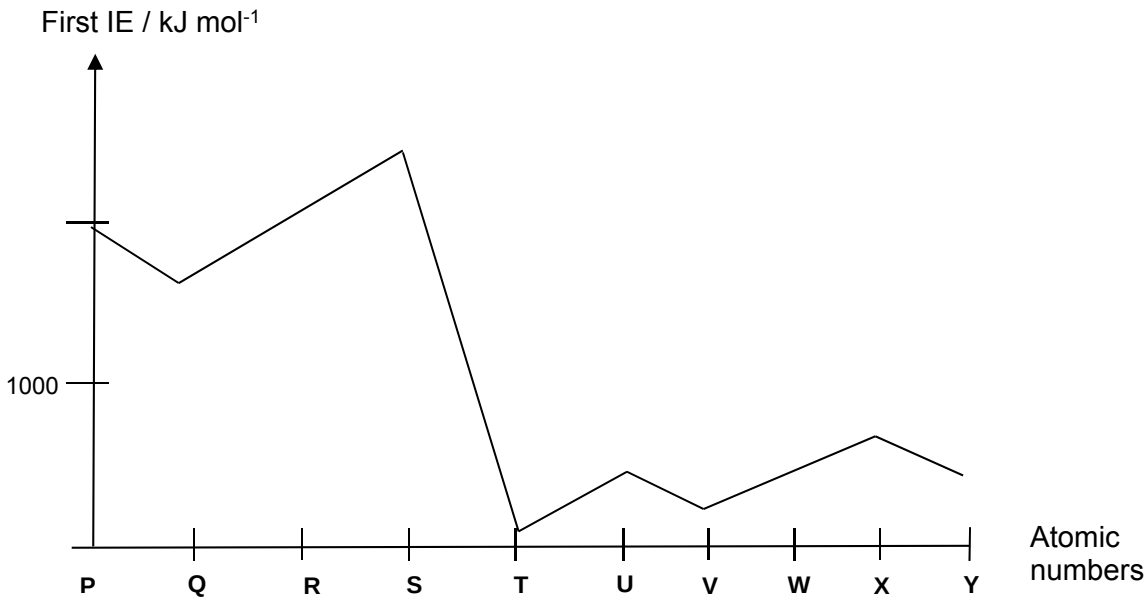
……

……

[Turn over

(c) In an analytical chemistry laboratory, the plasma torch is often used to ionise a variety of samples during their analyses.

In one series of analyses, samples of unknown elements **P** to **Y** were passed through the plasma torch and their first ionisation energies were recorded and plotted as shown.



P to **Y** are consecutive elements with atomic numbers below 20.

(i) Identify the group to which element **X** belongs to, and state its electronic configuration. [2]

Group : ……

Electronic configuration : ……..

(ii) Give the formula of the chloride of **X**, able to function as a Lewis base, and draw the dot-and-cross diagram of this chloride. [2]

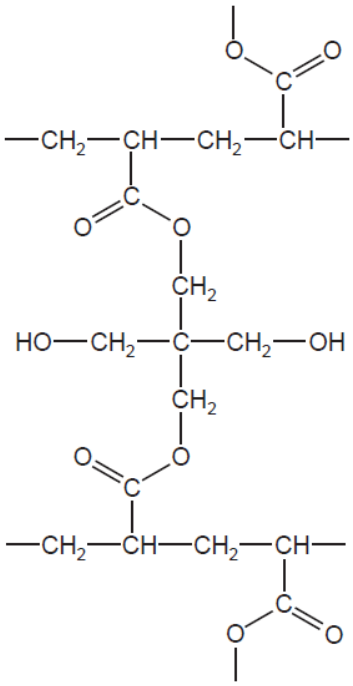
Chloride of **X** : ……

Dot–and–cross diagram of the chloride of **X**

[Total : 12]

3. In recent years there has been considerable interest in a range of polymers known as 'hydrogels'. These polymers are hydrophilic and can absorb large quantities of water.

(a) The diagram shows part of the structure of a hydrogel.



The hydrogel is formed from the chains of one polymer which are cross-linked using another molecule.

(i) Draw the structure of a possible monomer used in the polymer chains. [1]

(ii) State the type of polymerisation used to form these chains. [1]

.....

(iii) Draw the structure of the molecule used to cross-link the polymer chains. [1]

[Turn over

(b) Once a hydrogel has absorbed water, it can be dried and re-used many times.
Explain why this is possible, making reference to the structure shown on the previous page.
[2]

……

……

……

(c) Not every available side-chain in the polymer is cross-linked, and the amount of cross-linking affects the properties of the hydrogel.

(i) The amount of cross-linking has little effect on the ability of the gel to absorb water.
Suggest why this is the case. [1]

……

……

……

(ii) Suggest **one** property of the hydrogel that will change if more cross-linking takes place.
Explain how the increased cross-linking brings about this change. [2]

……

……

……

[Total: 8]

4. In search of the perfect hair dye, materials scientists conducted experiments whereby they coated hair with a graphene solution that included water, vitamin C and a polymer to improve adhesion. They reported that the new method stayed on after 30 washings, the number necessary for a hair dye to be considered permanent.

(a) State the difference between a nanomaterial and nanoparticle in terms of size. [1]

…….

…….

…….

(b) Graphene is a nanomaterial which is strong, thin and a good conductor of electricity.

(i) Describe the structure of graphene. Explain how this structure gives graphene the properties of high strength and high electrical conductivity.
You may find it useful to include a labelled diagram in your answer. [3]

…….

…….....

…….

…….

…….....

…….

…….

…….

[Turn over

(ii) Suggest why a solution of graphene makes a good coating material for hair. [2]

…….

…….

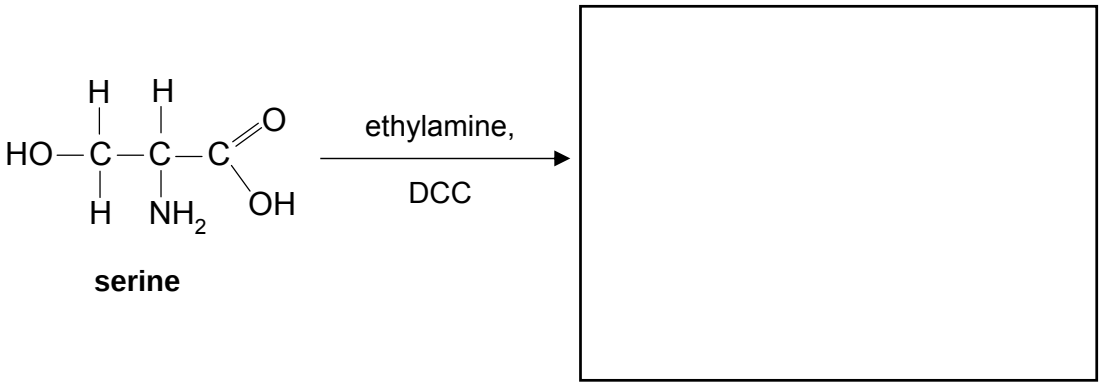
…….

[Total: 6]

5. Amino acids play central roles both as building blocks of protein and as intermediates in metabolism.

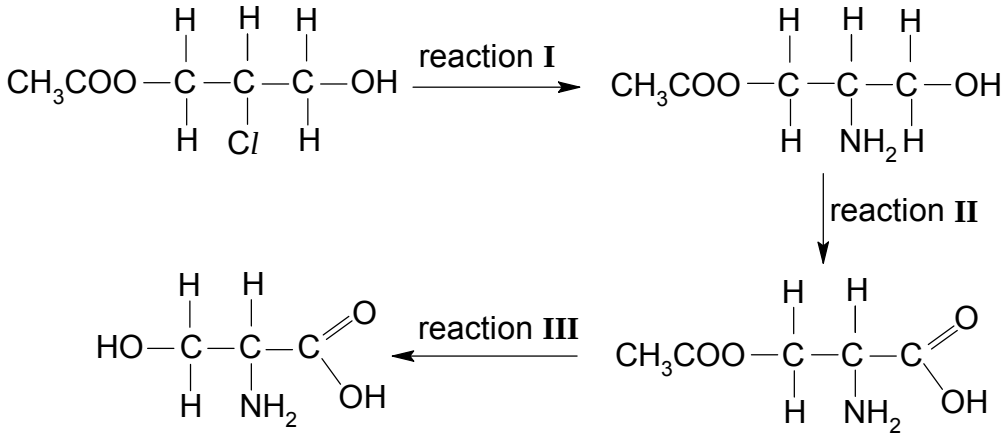
(a) Serine is a naturally-occurring amino acid.

(i) In the box below, draw the structure of the organic compound formed when serine reacts with ethylamine in the presence of dicyclohexylcarbodiimide, DCC. [1]



serine

One possible method of synthesising serine is shown below.



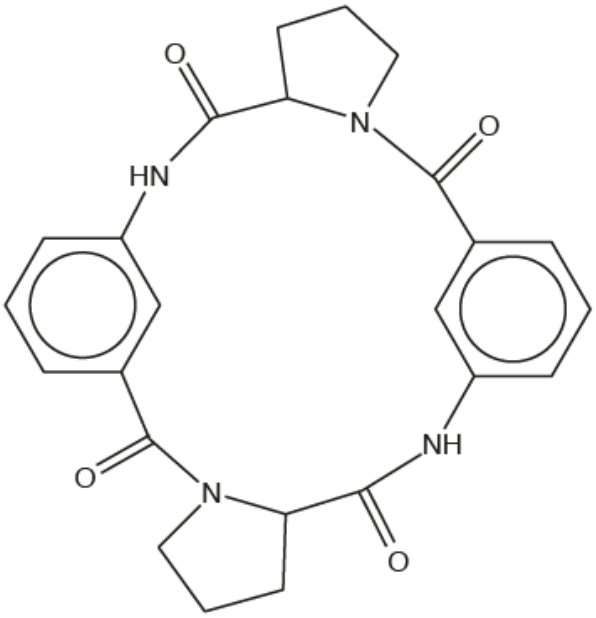
(ii) State the types of reaction for reactions **I** and **II**. [2]

reaction **I**: ……...

reaction **II**: ……...

[Turn over

(b) A cyclic tetrapeptide has been synthesised from 3-aminobenzoic acid and an amino acid.



cyclic tetrapeptide

The cyclic tetrapeptide was treated with hot aqueous sodium hydroxide.

Draw the structures of the **two** organic products formed from the reaction and state the type of reaction undergone. [3]

type of reaction: ……..

[Total:6]

Section B

Answer **one** question from this section on separate answer paper.

6. **(a)** Carboxylic acids are important organic compounds which are widely used as food flavourings. Carboxylic acids are usually *weak Brønsted acids*.

(i) Explain what is meant by a *weak Brønsted acid*. [2]

……

……

(ii) The K_a values for some organic acids are listed below.

acid	K_a / mol dm^{-3}
CH_3CO_2H	1.7×10^{-5}
$ClCH_2CO_2H$	1.3×10^{-3}
Cl_2CHCO_2H	5.0×10^{-2}

Explain the trend in K_a values in terms of the structure of these acids. [3]

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[Turn over

(b) Esters such as ethyl ethanoate can be formed by reacting carboxylic acids with alcohols.

$$CH_3CO_2H(l) + C_2H_5OH(l) \rightleftharpoons CH_3CO_2C_2H_5(l) + H_2O(l)$$

This reaction is allowed to proceed until a dynamic equilibrium is established.

(i) Explain what is meant by the term *dynamic equilibrium*. [1]

.....

.....

(ii) Write the expression for the equilibrium constant, K_c, for this reaction. [1]

(iii) For this equilibrium, the value of K_c is 4.0 at 298 K.

A mixture containing 0.5 mol ethanoic acid, 0.5 mol ethanol, 0.1 mol ethyl ethanoate and 0.1 mol water was set up and allowed to come to equilibrium at 298 K.

Calculate the amount, in moles, of each substance present at equilibrium. [3]

(iv) State and explain what would happen to the position of the equilibrium when 0.05 mol ethyl ethanoate is withdrawn from the equilibrium mixture in **(b)(iii)**. [2]

.....

.....

.....

.....

(c) **H** is a halogenoalkane with molecular formula C_4H_9Cl. When reacted with hot ethanolic NaOH, the product **J** is found to display cis-trans isomerism. When refluxed with aqueous NaOH, compound **K** is formed.

K undergoes oxidation to form product **L**. **L** does not react with Tollens' reagent.

(i) Using the information given above, suggest the structures of compounds **H, J, K** and **L**. [4]

(ii) Draw and name the two isomers of compound **J**. [2]

(iii) Compound **K** is found to have a higher boiling point as compared to compound **L**. With reference to structure and bonding, explain why this is so. [2]

……

……

……

[Total : 20]

[Turn over

7. Phosphorus, P, is an element found in the third period of the Periodic Table. The element was discovered by Hennig Brand when he experimented with urine in 1669.

(a) **(i)** Sketch a graph showing the variation of melting point of the elements across the third period of the Periodic Table. [2]

(ii) Explain qualitatively the shape of the graph you have drawn in **(a)(i)**. [2]

……

……

……

……

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……

Magnesium and aluminium are also elements from the third period of the Periodic Table. Both elements react with excess oxygen gas to form their respective oxides, MgO and Al_2O_3.

At room temperature, both MgO and Al_2O_3 are white crystalline solids. These compounds have useful applications in our daily lives – MgO is used as a drying agent to preserve books and Al_2O_3 is used as an abrasive in sandpapers.

(b) A sample of white powder is known to be either MgO or Al_2O_3. In order to determine its identity, **one** of the following reagents can be used.

- dilute hydrochloric acid
- aqueous sodium hydroxide
- aqueous hydrogen peroxide

(i) State the reagent you would use to determine the identity of the white powder. [1]

…….

(ii) Explain your choice in **(b)(i)**, and write balanced equation(s) for any chemical reactions that may occur. [3]

Equation(s) : …….

…….....

Explanation : ……

……

[Turn over

Arsenic, As, is in the same Group of the Periodic Table as phosphorus. The element burns in excess oxygen gas to form arsenic(III) oxide, As_2O_3. An acidified solution of vanadium(V) ions is able to gradually oxidise arsenic(III) oxide to arsenic(V) oxide, according to the following balanced equation.

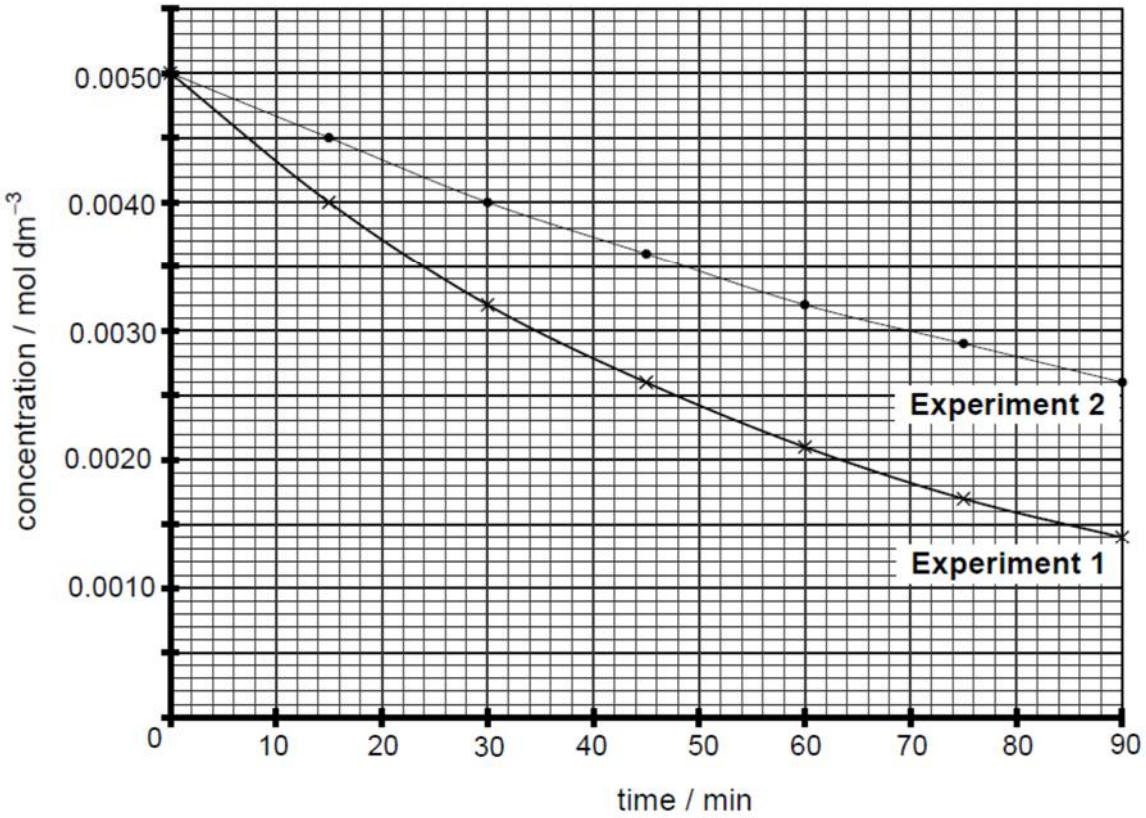
$$As_2O_3 + 4VO_2^+ + 4H^+ \rightarrow As_2O_5 + 4VO^{2+} + 2H_2O$$

(c) The rate of the reaction between acidified VO_2^+ ions and arsenic(III) oxide at 25°C was followed by measuring the concentration of remaining vanadium(V) ion after fixed time intervals. Two experiments were carried out, starting with different concentrations of arsenic(III) oxide.

Experiment 1: $[As_2O_3] = 0.10$ mol dm^{-3}

Experiment 2: $[As_2O_3] = 0.05$ mol dm^{-3}

The following graphs show the results of the two experiments.



(i) Define *order of reaction*. [1]

……

……

(ii) Use the graphs to determine the order of reaction with respect to arsenic (III) oxide, As_2O_3 and vanadium (V) oxide ion, VO_2^+ respectively. [4]

(iii) Write the rate equation for the reaction. [1]

……

(iv) Calculate the rate constant for the reaction, stating its units. [2]

[Turn over

(v) A third experiment involving the reaction between As_2O_3 and VO_2^+ is carried out at 40°C.

With the aid of a suitable diagram, state and explain how the rate of reaction at 40°C would compare with that at 25°C. [4]

……

……

……

……

……

[Total : 20]

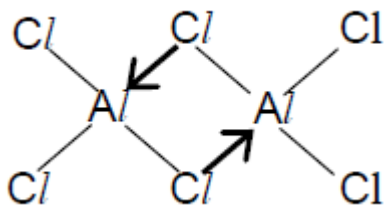
END OF PAPER

Yishun Junior College H1 Chemistry 8873 Preliminary Examinations 2018
Paper 1 Solutions

<table>
<tr><td>1</td><td>D</td><td>Option 1 – Incorrect. Nitrogen has a maximum oxidation state of +5.
Option 2 - Incorrect. Electronegativity does not explain why nitrogen is unable to expand octet configuration.
Option 3 – Correct. Nitrogen is from period 2 and so it does not have energetically accessible d orbitals to expand octet.

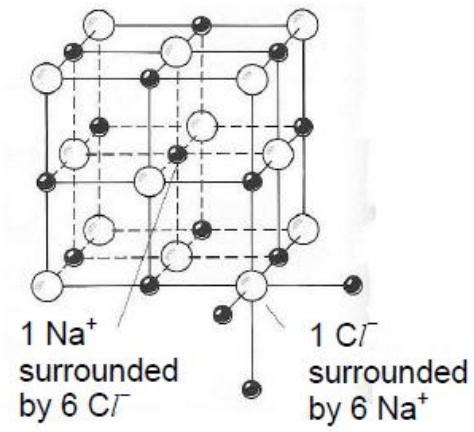
Hence, only option 3 is correct.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>2</td><td>A</td><td>Total nucleon mass = 238 + 2 = 240
Total proton no = 92 + 1 = 93

Nucleon mass of G = 240 – 2 = 238
Proton no = 93

From the Periodic Table, Np has a proton number of 93. Hence G is ^{238}Np.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>3</td><td>B</td><td>Option A – Oxidation number of N do not change while oxidation number of C changes.
Option B – Bond angle in NH_4^+, NH_3, C_2H_4 and C_2H_6 are 109.5°, 107°, 120° and 109.5° respectively.
Option C - There are no lone pairs of electrons in C_2H_6.
Option D – There are no π bonds in the conversion of $NH_4^+ \rightarrow NH_3$.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>4</td><td>D</td><td><table>
<tr><th>proton number</th><th>electronic configuration</th><th>no. of unpaired electrons</th></tr>
<tr><td>13</td><td>$3s^2\ 3p^1$</td><td>1</td></tr>
<tr><td>14</td><td>$3s^2\ 3p^2$</td><td>2</td></tr>
<tr><td>15</td><td>$3s^2\ 3p^3$</td><td>3</td></tr>
<tr><td>16</td><td>$3s^2\ 3p^4$</td><td>2</td></tr>
<tr><td>17</td><td>$3s^2\ 3p^5$</td><td>1</td></tr>
<tr><td>18</td><td>$3s^2\ 3p^6$</td><td>0</td></tr>
</table></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>5</td><td>B</td><td> 

Hence, there are 6 single covalent bonds and 2 dative bonds.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>6</td><td>A</td><td>Option 1 – Correct. Ethylene glycol can form 2 hydrogen bonds per molecule (due to the presence of 2 –OH groups) and ethanol forms 1 hydrogen bond per molecule (due to the presence of 1 –OH group).
Option 2 – Correct. Ethylene glycol has a larger electron cloud and so, a larger surface area, resulting in stronger intermolecular instantaneous dipole-induced dipole interactions.
Option 3 – Incorrect. Boiling points of simple molecular compounds is dependent on the strength of intermolecular forces of attraction. The strength of covalent bonds does not affect the boiling points of ethylene glycol and ethanol.

Hence, only options 1 and 2 are correct.</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

7	**C**	 Hence, coordination number of Na = 6 and coordination number of C*l* = 6.
8	**B**	Buffer in blood consists of H_2CO_3 and HCO_3^-. To remove the contaminating H^+ ions from the blood, the large reserve of HCO_3^- removes H^+. $HCO_3^- + H^+ \rightarrow H_2CO_3$
9	**C**	Total $[OH^-] = (10^{-3} + 10^{-1}) / 2 = 0.0505$ mol dm^{-3} pOH = −lg (0.0505) = 1.297 pH = 14 – 1.297 = 12.7
10	**D**	• The formation of a liquid product between **J** and chlorine indicates that the product is likely to be covalent. Hence, **J** is a non-metal and unable to conduct electricity. • For **K**, the chloride formed is a solid and dissolves in water to give a solution of pH 7, indicating that the chloride is likely to be sodium chloride. Hence, **K** is sodium, a metal and so, it is able to conduct electricity. • For **L**, the chloride formed is a solid that dissolves in water to give a solution of pH 6, indicating that the chloride is likely to be magnesium chloride. Hence, **L** is magnesium, a metal and so, it is able to conduct electricity. Hence, **K** and **L** are good conductors of electricity.
11	**D**	Down group 17, the volatility decreases as the boiling points of the elements increases. This is because the size of the electron cloud of the elements increases and the polarisability of the electron cloud increases down the group, leading to an increase in the strength of the intermolecular instantaneous dipole-induced dipole (id-id) interactions. Hence, the energy needed to overcome the id-id interactions increases down the group.
12	**A**	The nuclear charge increases from F^- to Ne to Na^+, and the number of electrons are the same. Hence the attraction between the nucleus and the valence electrons increases from F^- to Ne to Na^+, resulting in a decrease in radii from F^- to Ne to Na^+. Hence, the radii increases from Na^+ to Ne to F^-.

13	**C**	**1** No. of moles of CO_2 = $\frac{300}{24\,000}$ = 0.0125 mol Volume of CO_2 = 0.0125 x 24 000 = 300 cm^3 **2** No. of moles of HC*l* = 0.0125 x 2 = 0.025 mol Volume of HC*l* = 0.025 ÷ 0.50 = 0.05 dm^3 = 50 cm^3 **3** No. of moles of NaC*l* = 0.0125 x 2 = 0.025 mol Mass of NaC*l* = 0.025 x 58.5 = 1.46 g Hence, options 1 and 3 are correct.
14	**C**	$A_r = \frac{(63 \times 65)+(65 \times 29)}{94}$ = 63.6
15	**B**	Oxidation no. of S in $Na_2S_2O_3$ = $\frac{-[3(-2)+2(+1)]}{2}$ = +2 Oxidation no. of S in SO_2 = - [2(-2)] = +4 Oxidation no. of S in S = 0
16	**C**	No. of moles of FeC_2O_4 = 18 x 10^{-3} x 0.020 = 3.60 x 10^{-4} mol No. of moles of $Cr_2O_7^{2-}$ needed to oxidise Fe^{2+} = $\frac{1}{6}$ x 3.60 x 10^{-4} = 6.0 x 10^{-5} mol No. of moles of $Cr_2O_7^{2-}$ needed to oxidise $C_2O_4^{2-}$ = $\frac{1}{3}$ x 3.60 x 10^{-4} = 1.2 x 10^{-4} mol Total no. of moles of $Cr_2O_7^{2-}$ = 6.0 x 10^{-5} + 1.2 x 10^{-4} = 1.8 x 10^{-4} mol Volume of $K_2Cr_2O_7$ = 1.8 x 10^{-4} ÷ 0.02 = 9.0 x 10^{-3} dm^3 = 9 cm^3
17	**B**	heat absorbed by water = 200 x 4.18 x 48 = 40128 J heat evolved from combustion = $\frac{40128}{45} \times 100$ = 89173 J total energy released per gram of fuel burnt = 89173 ÷ 1.6 = 55733 = 55700 J
18	**B**	Enthalpy change of formation of water is the enthalpy change when **1 mole of $H_2O(l)$** is formed from its constituent elements at their standard states, i.e., **$H_2(g)$ and $O_2(g)$** under standard conditions of 298 K and 1 bar.
19	**D**	option **A** - Incorrect. Arrow representing E_a should start from the reactants. option **B** – Incorrect. Arrow representing ΔH should start from the reactants. option **C** – Incorrect. Direction of arrow representing ΔH should be pointing from reactants to products. option **D** – Correct!
20	**C**	Since the substrate must fit into the active site of the enzyme before catalysis can occur, only properly designed molecules can serve as substrates for a specific enzyme; in many cases, an enzyme will react with only one naturally occurring molecule.

21 **A**

option 1 – Correct. Increasing temperature increases rate of forward and backward reactions.
option 2 – Correct. Increasing the temperature will cause the position of equilibrium to shift to the left, favouring the endothermic backward reaction, so as to absorb heat. Hence, yield of methanol decreases.
option 3 - Correct. Increasing the pressure will cause the position of equilibrium to shift to the right, favouring the forward reaction that produces less amount of gases, so as to reduce the increased pressure. Hence, the yield of methanol increases.

All 3 options are correct.

22 **D**

A

	P	**2Q**	**R**
Initial amount / mol	2	0	0
Change in amount / mol	−x	+2x	+x
Equilibrium amount / mol	2−x	2x	x
Total no. of moles = 2 + 2x (incorrect)			

B

	2P	**2Q**	**R**
Initial amount / mol	2	0	0
Change in amount / mol	−2x	+2x	+x
Equilibrium amount / mol	2−2x	2x	x
Total no. of moles = 2 + x (incorrect)			

C

	2P	**Q**	**R**
Initial amount / mol	2	0	0
Change in amount / mol	−2x	+x	+x
Equilibrium amount / mol	2−2x	x	x
Total no. of moles = 2 (incorrect)			

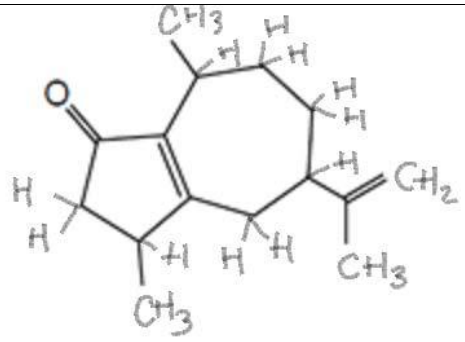
D

	2P	**Q**	**2R**
Initial amount / mol	2	0	0
Change in amount / mol	−x	$+\frac{x}{2}$	+x
Equilibrium amount / mol	2−x	$\frac{x}{2}$	x
Total number of moles = $2 + \frac{x}{2}$ (correct)			

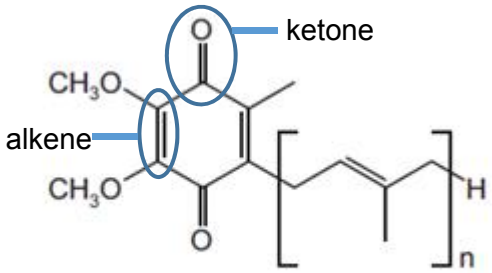
23 **C**

Geckos have arrays of millions of microscopic hairs, or setae, on the bottoms of their feet. Each seta ends in an array of **nanostructures**, called spatulae,that function as a dry adhesive. The **high surface area to volume ratio** results in the adhesive property.

24 **C**



Hence, there are 22 hydrogen atoms.

25	**A**	*Melamine* is a thermoset with strong covalent bonds holding the layers together and so, it does not melt. *Acrylic* is a thermoplastic whereby the chains are not cross-linked and the forces between the chains are weaker than the crosslinks in melamine. Hence, *acrylic* melts on heating. Option 1 – Incorrect. *Melamine* cannot be melted so, it cannot be recycled. Option 2 - Incorrect. *Acrylic* does not have crosslinks Option 3 – Correct. As the crosslinks are strong covalent bonds, heating does not break these crosslinks and so, *melamine* does not melt.
26	**C**	Rate of biodegradation of PVC is slow. PVC burns to produce CO_2,H_2O and HCl.
27	**C**	The esters are $HCO_2CH_2CH_2CH_2CH_3$, $HCO_2CH_2CH(CH_3)_2$, $CH_3CO_2CH_2CH_2CH_3$, $CH_3CH_2CO_2CH_2CH_3$, $CH_3CH_2CH_2CO_2CH_3$, $(CH_3)_2CHCO_2CH_3$. Hence, there are a total of 6 esters.
28	**D**	 coenzyme Q_{10} There are n π bonds in the brackets. There are 4 π bonds outside the brackets. Hence, there is a total of n + 4 π bonds in one molecule.
29	**C**	The functional group in delta lactone is ester which is formed from an alcohol and carboxylic acid. option **A** – incorrect. The functional groups present are alcohol and ketone. option **B** – incorrect. The functional groups present are alcohol and aldehyde. option **C** – correct. The functional groups present are alcohol and carboxylic acid. option **D** – correct. Both functional groups present are alcohols.
30	**A**	2-hydroxypentanenitrile is $CH_3CH_2CH_2CH(OH)CN$. $CH_3CH_2CH_2CH(OH)CN$ is formed from $CH_3CH_2CH_2CHO$, via addition reaction using HCN with NaCN catalyst, cold. The intermediate $CH_3CH_2CH_2CHO$ is formed from $CH_3CH_2CH_2CH_2OH$ (butan-1-ol), via oxidation reaction using acidified $K_2Cr_2O_7$, heat with immediate distillation.

8873 H1 Chemistry Preliminary Examination 2018 Answers
Section A

Answer **all** the questions in this section in the spaces provided.

1. The Earth's climate is changing. Temperatures are rising, snow and rainfall patterns are shifting, and more extreme climate events – like heavy rainstorms and record high temperatures – are already happening. Many of these observed changes are linked to the rising levels of carbon dioxide and other greenhouse gases (gases that trap heat) in our atmosphere, caused by human activities.

Gross calculation shows that while carbon dioxide accounts for 74% of the greenhouse gases, methane is the second most prevalent (14%) greenhouse gas emitted from human activities - natural gas (mainly methane) and petroleum systems activities such as incinerations, are the largest source of methane emission, accounting for 31%, while methane generated from landfills as waste decomposes, accounting for 16%.

Although methane's lifetime in the atmosphere is much shorter than carbon dioxide, but methane is more efficient at trapping radiation than carbon dioxide. Kilogram for kilogram, the comparative impact of methane is about 12 times greater than carbon dioxide.

A fossil fuel power station is a power station which burns a fossil fuel such as coal, natural gas, or petroleum to produce electricity. In an attempt to cut down carbon dioxide emissions during the production of electricity from such fuels, there has been a move in many countries to build more power stations burning natural gas rather than coal. The following table compares these two types of power station.

Type of power station	Overall efficiency of power station	Amount of by-product produced per MJ of electrical energy (1 MJ = 10^6 J)	
		SO_2	NO_2
coal	40%	0.31 g	0.64 g
natural gas	51%	0.0015 g	0.11 g

In your calculations, assume that coal consists of 95% of carbon, together with 5% of non-combustible ash.

(a) Write balanced equations for the complete combustion of

(i) methane

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$$

(ii) carbon

$$C(s) + O_2(g) \longrightarrow CO_2(g)$$

(b) The enthalpy changes of combustion of methane and carbon are :

$\Delta H_c (CH_4) = -\ 890\ kJ\ mol^{-1}$
$\Delta H_c (C) = -\ 394\ kJ\ mol^{-1}$

(i) Use these data to calculate how many moles of each of methane and carbon needed to be burned to produce 1 MJ of **heat** energy. [2]

Methane : 1×10^6 / 890 000 = 1.12 mol

Carbon : 1×10^6 / 394 000 = 2.54 mol

(ii) Using the efficiency figures given in the table, and your answers in **(b)(i),** calculate how many moles of each of methane and carbon needed to be burned in the power stations, to produce 1 MJ of electrical energy. [4]

Methane : 100/51 x 1.1236 = 2.20 mol

Carbon : 100/40 x 2.5381 = 6.35 mol

(c) Hence, calculate the mass of the ash that would be produced per MJ of electrical energy in a coal-fired power station. Assume that the average relative molecular mass of the ash is 220.0. [2]

Average mass of ash = 5/95 x 6.352 x 220.0 = 73.5 g

(d) Use the data in the table to suggest **two** environmental advantage of using a natural gas power station. Explain your answer. [3]

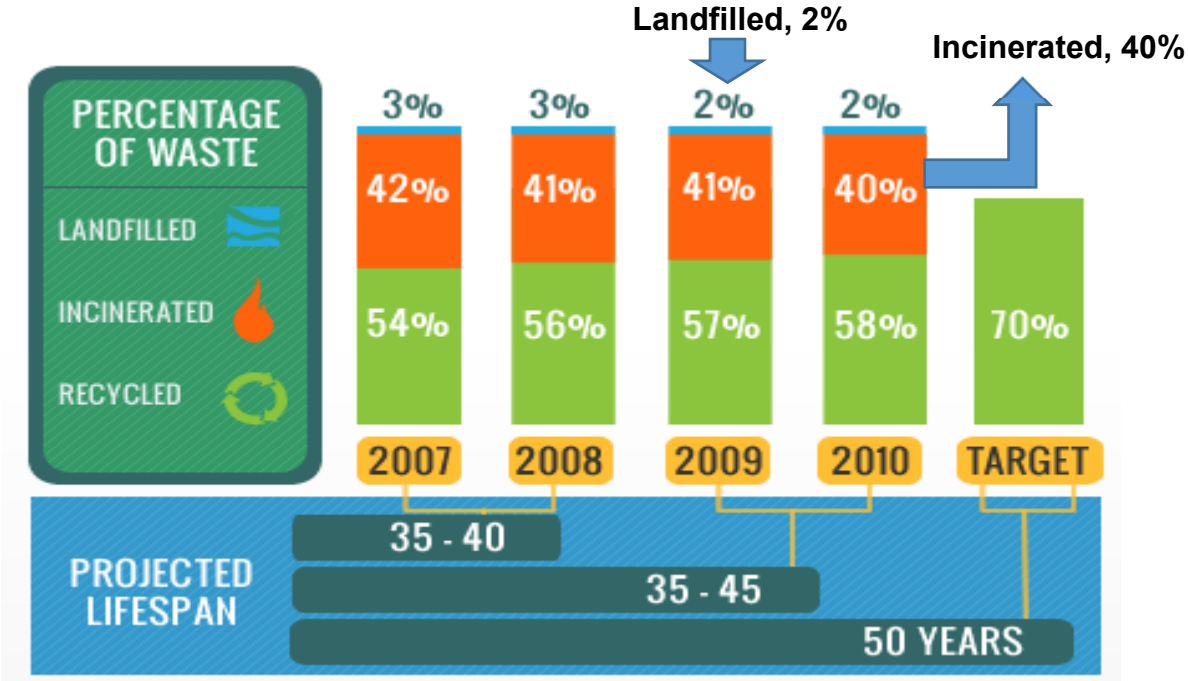
The use of natural gas in the power station produces less SO_2 and NO_2.

- **Both SO_2 and NO_2 are toxic chemicals which will cause respiratory problems**
- **Both SO_2 and NO_2 can contribute to acid rain that can cause damage to structures and harm aquatic live forms**

(e) Despite all the advantages of operating a gas power station, comment on any harmful threats behind this natural gas system. [3]

- **By the calculation in (b)(ii), 2.20 mol of methane can generate 1 MJ of electrical energy, compared to 6.35 mol of carbon**
- **As 1 mol carbon ≡ 1 mol CO_2, the use of methane is 6.35/2.20 = 2.88 times safer in terms of greenhouse gas emitted to the atmosphere**
- **However, the data given states that methane is 12 times more potent in trapping heat,**
  Hence, combining the advantage (2.88 times better in greenhouse gas emission) and disadvantage (methane is 12 times better in trapping heat),
  Methane is still about 4 times more potent in causing harm to the environment.

(f) Locally, the National Environment Agency, NEA has released the following data on its refuse disposal :



Use relevant data from the passage, suggest one advantage and one disadvantage for NEA to increase the use of incineration for refuse disposal over landfill. [2]

One disadvantage : **Landfill generates 16% , while incineration generates 31% of methane emission.**

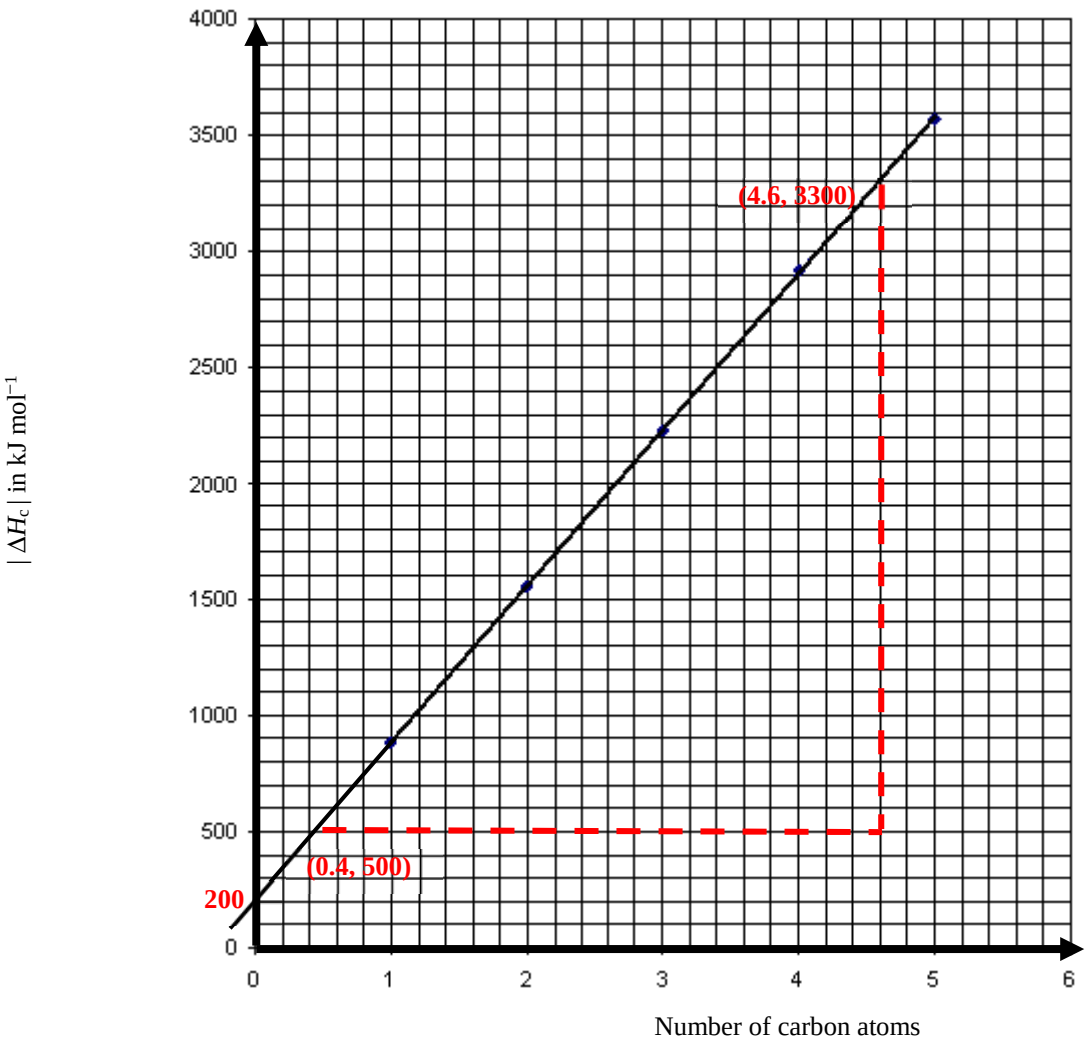
One advantage : **Incineration is favoured as Singapore is land-scarce.**

(g) Methane belongs to a family of organic compounds call Alkane.
The standard enthalpy changes of combustion of five straight chain alkanes are given in the table below.

alkane	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}
$\Delta H_c^{\ominus}$/ kJ mol^{-1}	–890	–1560	–2230	–2920	–3570

On the grid below, plot a graph to show how the standard enthalpy changes of combustion vary for these five alkanes. [3]

- **Either ΔH_c or $\lvert\Delta H_c\rvert$ can be plotted against number of carbon atoms in alkane, with the best fit line drawn through the data points**
- **Correctly labelled axes**
- **Straight line graph obtained**



Use the graph you have plotted above, determine

(i) the **average** standard enthalpy change of combustion of a "CH_2" group [2]

(ii) the standard enthalpy change of combustion of hydrogen gas [1]

(iii) the standard enthalpy change of combustion of hexane, C_6H_{14}. [2]

(g)

(i) Gradient of graph in (a) = $\frac{3300-500}{4.6-0.4}$ = 667 kJ mol^{-1}

So, the average enthalpy change of CH_2 group = –667 kJ mol^{-1}

(ii) Vertical intercept in (a) = 200 kJ mol^{-1}

So, $\Delta H_c^{\ominus}$ (H_2) = –200 kJ mol^{-1}

(iii) The equation of the graph is $y = 667x + 200$

When $x = 6$, [1m], $y = 4200$

$\Delta H_c^{\ominus}$ (hexane) = –4200 kJ mol^{-1}

(h) Alcohols are also commonly used as fuels.

The diagram below shows an energy cycle involving propan-1-ol, $CH_3CH_2CH_2OH$.

$$CH_3CH_2CH_2OH(l) + \frac{9}{2}O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(l)$$

$$\boxed{3C(s) + 4H_2(g) + 5O_2(g)}$$

Use the following data to calculate the standard enthalpy change of combustion of propan-1-ol. [2]

$\Delta H_f^{\ominus}(CO_2) = -393$ kJ mol^{-1}

$\Delta H_f^{\ominus}(H_2O) = -286$ kJ mol^{-1}

$\Delta H_f^{\ominus}(CH_3CH_2CH_2OH) = -303$ kJ mol^{-1}

ΔH_c + (–303) = 3(–393) + 4(–286) = –2323
ΔH_c propan-1-ol
= –2020 kJ mol^{-1}

[Total : 28]

2. The mass spectrometer made it possible to determine the masses of atoms very accurately, and it became clear that not all atoms of the same element had the same mass.

The accurate masses gave rise to the idea of the isotopes:

"Isotopes have the same atomic numbers, but different mass numbers."

(a) (i) Write the symbols showing the nucleon numbers, proton numbers and charges of the following three particles, **K, L** and **M**.

You may refer to the example given for the particle, **A** [3]

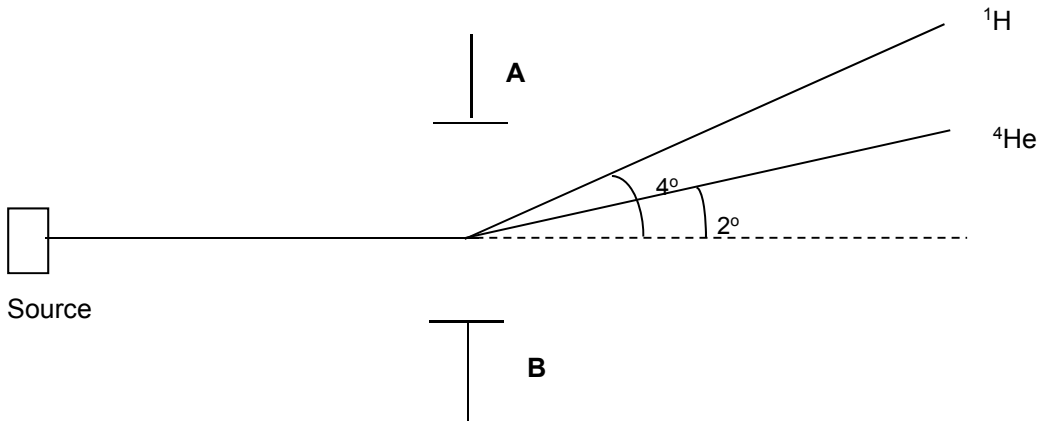
Particle	Protons	Neutrons	Electrons	Symbol
K	6	8	6	
L	7	7	10	
M	8	7	7	
A	**5**	**8**	**5**	$^{13}_{5}$**A**

(a) (i)
- **K:** $^{14}_{6}K$
- **L:** $^{14}_{7}L^{3-}$
- **M:** $^{15}_{8}M^{+}$

(ii) Using the data from the *Data Booklet*, write the symbols of the usual isotopes of the elements concerned. [3]

(ii)
- **Particle K:** $^{12}_{6}C$
- **Particle L:** $^{14}_{7}N$
- **Particle M:** $^{16}_{8}O$

(b) A plasma is a gaseous mixture in which the atoms have been completely stripped of their electrons, leaving bare nuclei. Because of possible use in controlled nuclear fusion reactions, plasma behaviour has been extensively studied. When passed between two plates carrying a certain electric charge, ^{1}H and ^{4}He nuclei are deflected as follows.

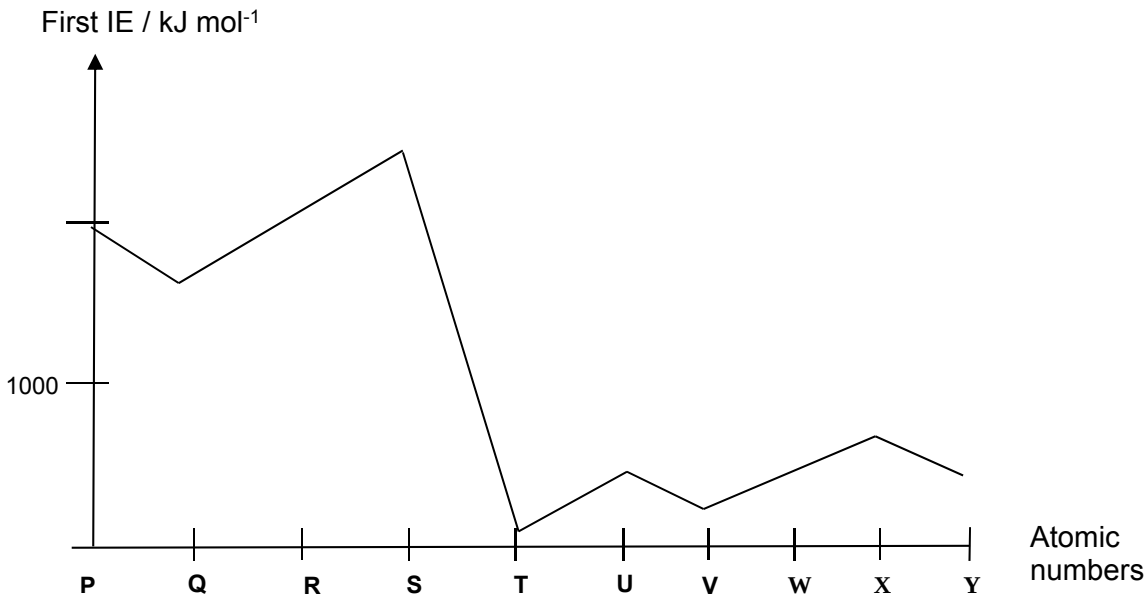


Giving reason for your answer, suggest the polarity (+ or -) of plate **A**. [2]

- **Plate A is negatively charged.**
- **As nuclei which are positively charged gets attracted to it.**

(c) In an analytical chemistry laboratory, the plasma torch is often used to ionise a variety of samples during their analyses.

In one series of analyses, samples of unknown elements **P** to **Y** were passed through the plasma torch and their first ionisation energies were recorded and plotted as shown.



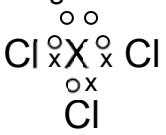
P to **Y** are consecutive elements with atomic numbers below 20.

(i) Identify the group to which element **X** belongs to, and state its electronic configuration [2]

Group : 15

Electronic configuration : $1s^2 2s^2 2p^6 3s^2 3p^3$

(ii) Give the formula of the chloride of **X**, able to function as a Lewis base and draw the dot-and-cross diagram of this chloride. [2]

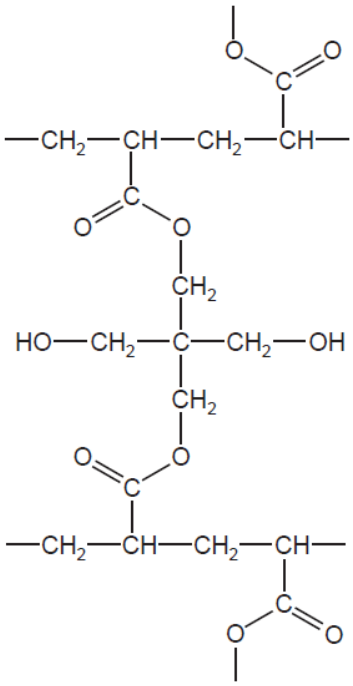


XCl_3

[Total : 12]

3. In recent years there has been considerable interest in a range of polymers known as 'hydrogels'. These polymers are hydrophilic and can absorb large quantities of water.

(a) The diagram shows part of the structure of a hydrogel.



The hydrogel is formed from the chains of one polymer which are cross-linked using another molecule.

(i) Draw the structure of a possible monomer used in the polymer chains. [1]

CH_2=CH-CO_2H <u>OR</u> CH_2=CHCO_2R <u>OR</u> CH_2=CH-COCl

(ii) State the type of polymerisation used to form these chains. [1]

Addition (polymerisation)

(iii) Draw the structure of the molecule used to cross-link the polymer chains. [1]

$C(CH_2OH)_4$

(b) Once a hydrogel has absorbed water, it can be dried and re-used many times.

Explain why this is possible, making reference to the structure shown on the previous page. [2]

Water is bonded to the polymer by <u>hydrogen bonding</u> when the hydrogel absorbs water.

<u>Hydrogen bonds are weak / easily broken</u> when the hydrogel is dried.

(c) Not every available side-chain in the polymer is cross-linked, and the amount of cross-linking affects the properties of the hydrogel.

(i) The amount of cross-linking has little effect on the ability of the gel to absorb water. Suggest why this is the case. [1]

cross-linking causes no reduction in the number of –OH groups
OR
cross-linking molecules have –OH groups

(ii) Suggest **one** property of the hydrogel that will change if more cross-linking takes place. Explain how the increased cross-linking brings about this change. [2]

property becomes harder / more rigid / less flexible / stronger / higher melting point
because the chains are more strongly / tightly held

[Total: 8]

4. In search of the perfect hair dye, materials scientists conducted experiments whereby they coated hair with a graphene solution that included water, vitamin C and a polymer to improve adhesion. They reported that the new method stayed on after 30 washings, the number necessary for a hair dye to be considered permanent.

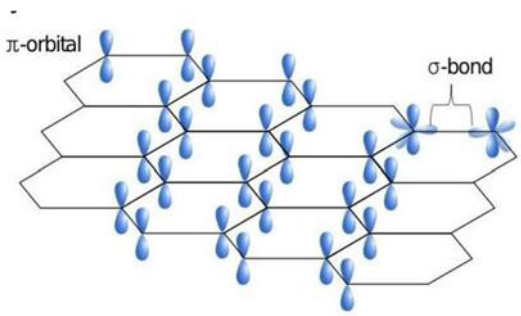
(a) State the difference between a nanomaterial and nanoparticle in terms of size. [1]

A nanomaterial is a material with at least one dimension from 1-100nm on the nanoscale while a nanoparticle is a cluster of atoms or molecules, with all three dimensions, in the range of 1–100 nm.

(b) Graphene is a nanomaterial which is strong, thin and a good conductor of electricity.

(i) Describe the structure of graphene. Explain how this structure gives graphene the properties of high strength and high electrical conductivity.

You may find it useful to include a labelled diagram in your answer. [3]



A single layer of carbon atoms arranged in hexagons whereby each carbon atom bonds to 3 other carbon atoms by a network of strong covalent bonds. In hexagonal lattice, each carbon has one partially filled p orbital in which the p electron is delocalised.

Description or clearly-labelled diagram

Immensely strong carbon–carbon covalent bonds produce an exceptionally high strength-to-weight ratio.

Presence of one p electron per carbon atom delocalised allows high electrical conductivity.

(ii) Suggest why a solution of graphene makes a good coating material for hair. [2]

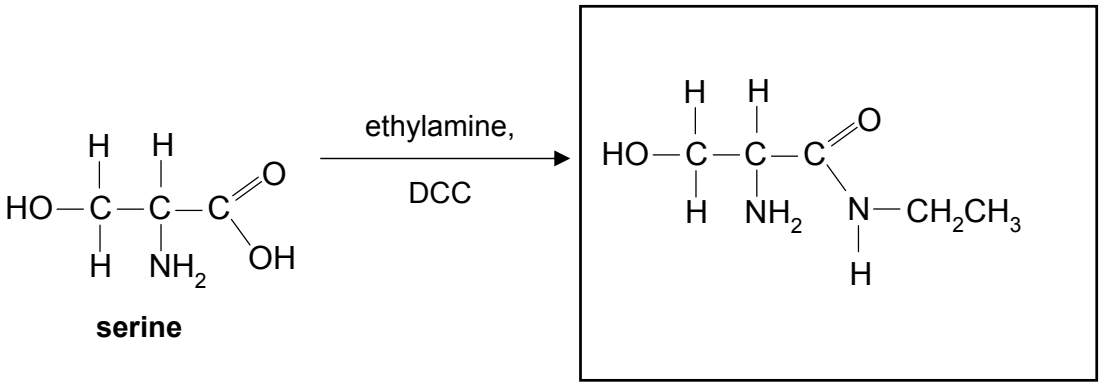
Its thin, flexible sheets can adapt to uneven surfaces. Also, the graphene flakes are too large to absorb through the skin, unlike other ingredients currently used in hair dyes.

[Total: 6]

5. Amino acids play central roles both as building blocks of protein and as intermediates in metabolism.

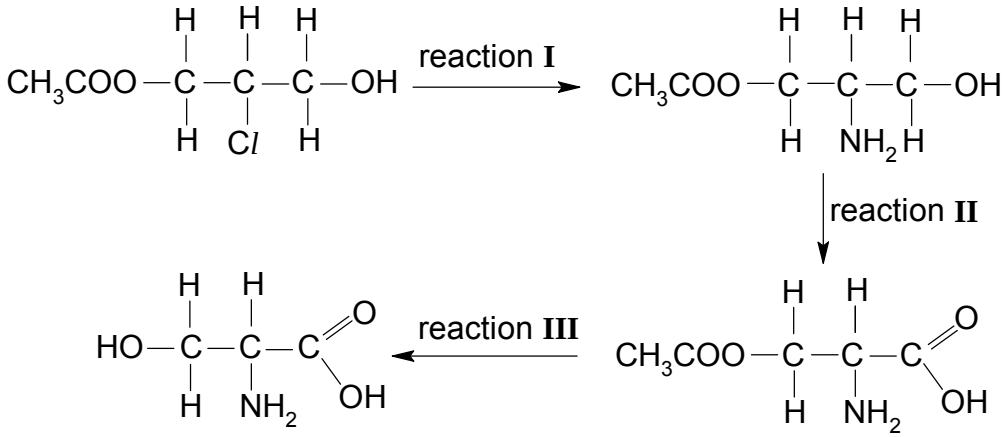
(a) Serine is a naturally-occurring amino acid.

(i) In the box below, draw the structure of the organic compound formed when serine reacts with ethylamine in the presence of dicyclohexylcarbodiimide, DCC. [1]



serine

One possible method of synthesising serine is shown below.

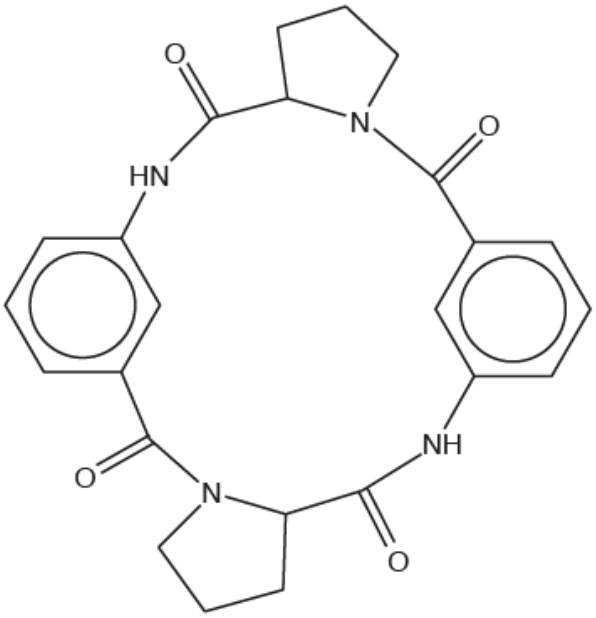


(ii) State the types of reaction for reactions **I** and **II**. [2]

reaction **I**: **substitution**

reaction **II**: **oxidation**

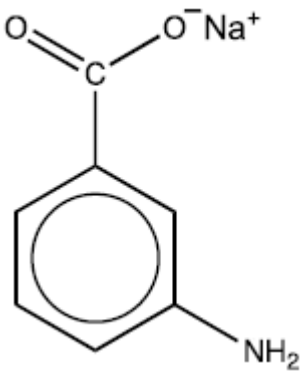
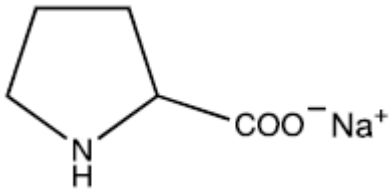
(b) A cyclic tetrapeptide has been synthesised from 3-aminobenzoic acid and an amino acid.



cyclic tetrapeptide

The cyclic tetrapeptide was treated with hot aqueous sodium hydroxide.

Draw the structures of the **two** organic products formed from the reaction and state the type of reaction undergone. [3]

type of reaction: **hydrolysis**

[Total:6]

Section B

Answer **one** question from this section on separate answer paper.

6. **(a)** Carboxylic acids are important organic compounds which are widely used as food flavourings. Carboxylic acids are usually *weak Brønsted acids*.

(i) Explain what is meant by a *weak Brønsted acid*. [2]

weak – dissociates partially in water

Brønsted acid – proton donor

(ii) The K_a values for some organic acids are listed below.

acid	K_a / mol dm^{-3}
CH_3CO_2H	1.7×10^{-5}
$ClCH_2CO_2H$	1.3×10^{-3}
Cl_2CHCO_2H	5.0×10^{-2}

Explain the trend in K_a values in terms of the structures of these acids.

[3]

- **electron-withdrawing C*l* atom disperses negative charge on $ClCH_2CO_2^-$ and $Cl_2CHCO_2^-$ ions**
- **greater number of C*l* atoms disperses negative charge on $Cl_2CHCO_2^-$ ion to a greater extent, and stabilise $Cl_2CHCO_2^-$ ion more**
- **Cl_2CHCO_2H dissociates more than $ClCH_2CO_2H$ and produces more H^+(aq)**

(b) Esters such as ethyl ethanoate can be formed by reacting carboxylic acids with alcohols.

$$CH_3CO_2H(l) + C_2H_5OH(l) \rightleftharpoons CH_3CO_2C_2H_5(l) + H_2O(l)$$

This reaction is allowed to proceed until a dynamic equilibrium is established.

(i) Explain what is meant by the term *dynamic equilibrium*. [1]

- **rate of forward reaction = rate of backward reaction**
- **both forward and backward reactions are on-going**

(ii) Write the expression for the equilibrium constant, K_c, for this reaction. [1]

$$K_c = \frac{[CH_3CO_2C_2H_5][H_2O]}{[CH_3CO_2H][C_2H_5OH]}$$

(iii) For this equilibrium, the value of K_c is 4.0 at 298 K.

A mixture containing 0.5 mol ethanoic acid, 0.5 mol ethanol, 0.1 mol ethyl ethanoate and 0.1 mol water was set up and allowed to come to equilibrium at 298 K.

Calculate the amount, in moles, of each substance present at equilibrium. [3]

$$CH_3CO_2H(l) + C_2H_5OH(l) \rightleftharpoons CH_3CO_2C_2H_5(l) + H_2O(l)$$

I	**0.5**	**0.5**	**0.1**	**0.1**
C	**-x**	**-x**	**+x**	**+x**
E	**0.5 – x**	**0.5 –x**	**0.1 + x**	**0.1 + x**

- **Let change in concentration be *x***
  At equilibrium, $[CH_3CO_2H] = [C_2H_5OH] = 0.5 - x$
  and $[CH_3CO_2C_2H_5] = [H_2O] = 0.1 + x$
- **So,** $\left(\frac{0.1+x}{0.5-x}\right)^2 = 4.0$ **i.e. $x = 0.30$**
- **equilibrium $[CH_3CO_2H] = [C_2H_5OH] = 0.20$ mol dm^{-3}**

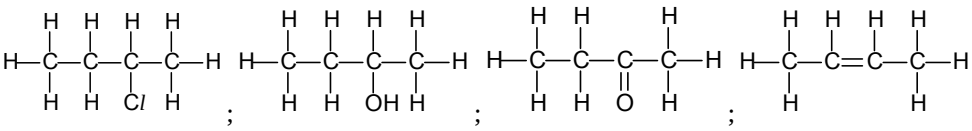
  equilibrium $[CH_3CO_2C_2H_5] = [H_2O] = 0.40$ mol dm^{-3}

(iv) State and explain what would happen to the position of the equilibrium when 0.05 mol ethyl ethanoate is withdrawn from the equilibrium mixture in **(iii)**. [2]

- **the equilibrium position shifts to the right**
- **to replenish $CH_3CO_2C_2H_5$**

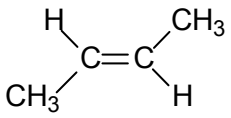
(c) **H** is a halogenoalkane with molecular formula C_4H_9Cl. When reacted with hot ethanolic NaOH, the product **J** is found to display cis-trans isomerism. When refluxed with aqueous NaOH, compound **K** is formed.
K undergoes oxidation to form product **L**. **L** does not react with Tollens' reagent.

(i) Using the information given above, suggest the structures of compounds **H,J,K** and **L.** [4]

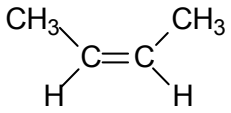


compound H **compound K** **compound L** **compound J**

(ii) Draw and name the two isomers of compound **J**. [2]



trans-but-2-ene



cis-but-2-ene

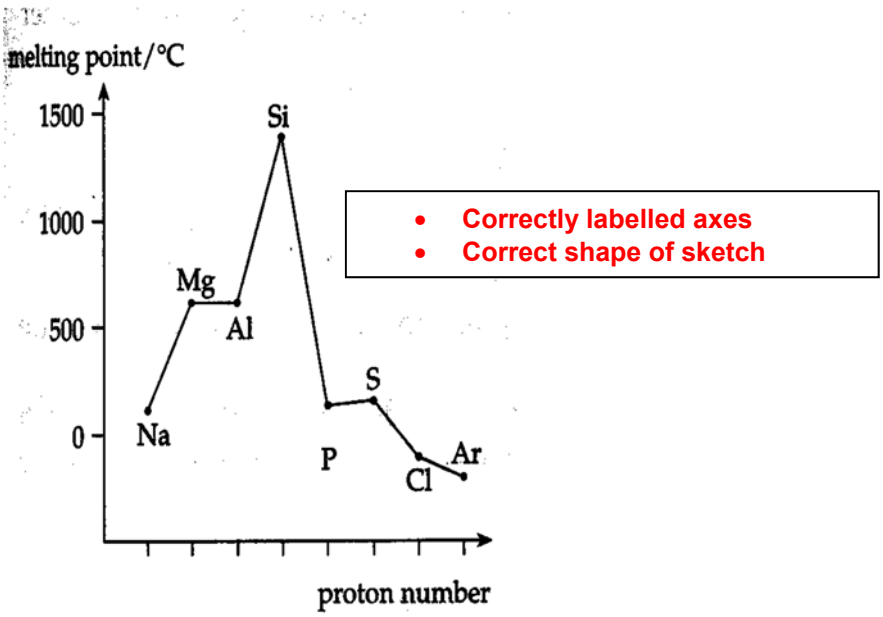
(iii) Compound **K** is found to have a higher boiling point as compared to compound **L**. With reference to structure and bonding, explain why this is so. [2]

- **Compound K has a <u>simple molecular structure</u> with <u>intermolecular hydrogen bonds</u>**
- **compound L has a simple molecular structure with <u>pd-pd attraction between molecules</u>**
- **<u>More energy</u> is needed to break the <u>stronger</u> hydrogen bonds between molecules of K compared to the <u>weaker</u> pd-pd forces of attraction between molecules of L . Hence, K has a higher boiling point than L**

[Total : 20]

7. Phosphorus, P, is an element found in the third period of the Periodic Table. The element was discovered by Hennig Brand when he experimented with urine in 1669.

(a) (i) Sketch a graph showing the variation of melting point of the elements across the third period of the Periodic Table. [2]



(ii) Explain qualitatively the shape of the graph you have drawn in **(a)(i)**. [2]

- **Na, Mg, A*l* : All have high mp. Giant metallic structures w/ strong electrostatic forces of attraction between metal cations and delocalized ē.**
- **Si : Very high mp. Giant molecular structure w/ numerous strong covalent bonds between atoms.**
- **P, S, C*l* : Low mp. <u>Simple molecular</u> structures w/ weak <u>id-id forces</u> between the molecules for P_4, S_8, Cl_2 , and <u>Simple atomic</u> structure w/ weak <u>id-id forces</u> between the atoms for Ar.**

  Strength of id-id forces of attraction α number of electrons.

  Order of melting point: $S_8 > P_4 > Cl_2$

Magnesium and aluminium are also elements from the third period of the Periodic Table. Both elements react with excess oxygen gas to form their respective oxides, MgO and Al_2O_3.

At room temperature, both MgO and Al_2O_3 are white crystalline solids. These compounds have useful applications in our daily lives – MgO is used as a drying agent to preserve books and Al_2O_3 is used as an abrasive in sandpapers.

(b) A sample of white powder is known to be either MgO or Al_2O_3. In order to determine its identity, **one** of the following reagents can be used.

- dilute hydrochloric acid
- aqueous sodium hydroxide
- aqueous hydrogen peroxide

(i) State the reagent you would use to determine the identity of the white powder. [1]

NaOH(aq)

(ii) Explain your choice in **(b)(i)**, and write balanced equations for any chemical reactions that may occur. [3]

- **Al_2O_3 is able to dissolve in NaOH(aq)**
- **but MgO will not**
- **$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4^-$**

Arsenic, As, is in the same Group of the Periodic Table as phosphorus. The element burns in excess oxygen gas to form arsenic(III) oxide, As_2O_3. An acidified solution of vanadium(V) ions is able to gradually oxidise arsenic(III) oxide to arsenic(V) oxide, according to the following balanced equation.

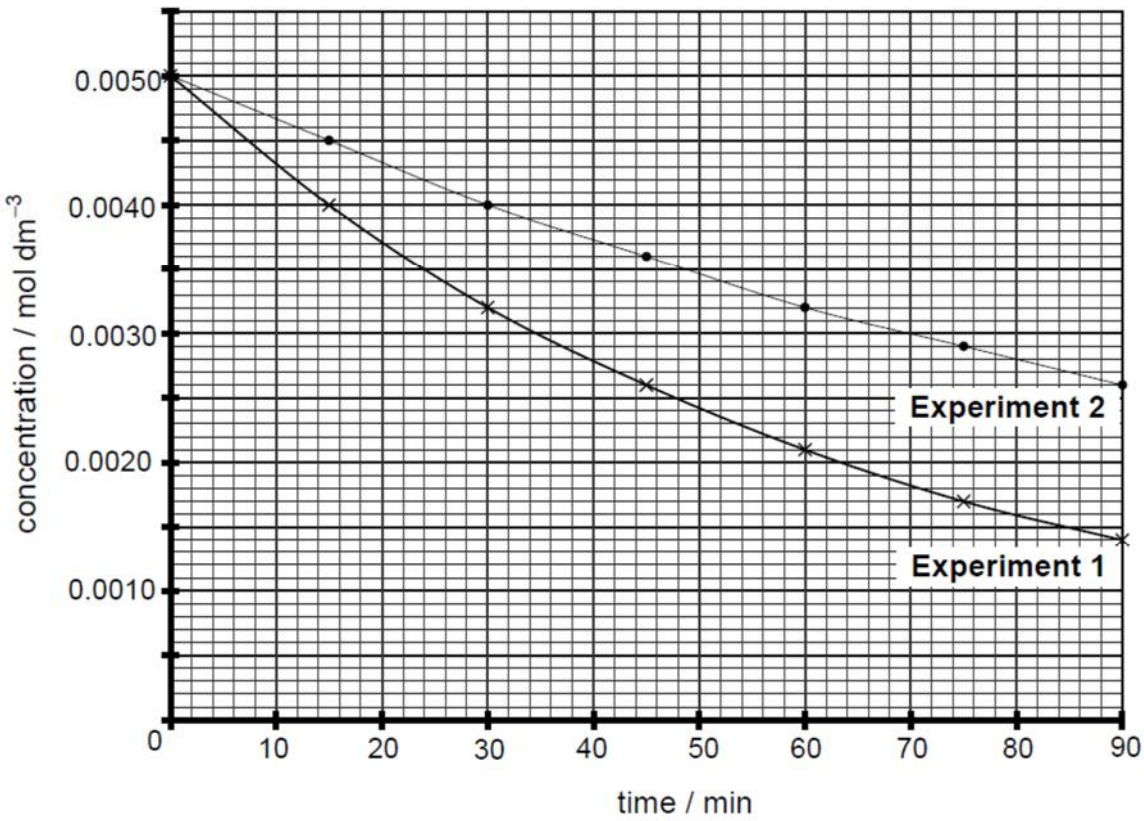
$$As_2O_3 + 4VO_2^+ + 4H^+ \rightarrow As_2O_5 + 4VO^{2+} + 2H_2O$$

(c) The rate of the reaction between acidified VO_2^+ ions and arsenic(III) oxide at 25°C was followed by measuring the concentration of remaining vanadium(V) ion after fixed time intervals. Two experiments were carried out, starting with different concentrations of arsenic(III) oxide.

Experiment 1: $[As_2O_3] = 0.10$ mol dm^{-3}

Experiment 2: $[As_2O_3] = 0.05$ mol dm^{-3}

The following graphs show the results of the two experiments.



(i) Define *order of reaction*. [1]

The order of reaction with respect to a particular reactant is the power to which the concentration of the reactant is raised to in the rate equation.

(ii) Use the graphs to determine the order of reaction with respect to arsenic (III) oxide, As_2O_3 and vanadium (V) oxide ion, VO_2^+ respectively. [4]

Let Rate = $k[VO_2^+]^m[As_2O_3]^n$

Since the reaction has a constant half-life ($t_{1/2}$ = 48 min) , the reaction is first order with respect to VO_2^+. i.e. m = 1

Rate = $k[VO_2^+]^1[As_2O_3]^n$

Initial rate of experiment 1 = $\left|\frac{0.0050-0.0022}{0-40}\right|$ **= 7.0×10^{-5} mol dm^{-3} min^{-1}**

Initial rate of experiment 2 = $\left|\frac{0.0050-0.0036}{0-40}\right|$ **= 3.5×10^{-5} mol dm^{-3} min^{-1}**

Experiment	Initial $[VO_2^+]$ / mol dm^{-3}	Initial $[As_2O_3]$ / mol dm^{-3}	Initial rate / mol dm^{-3} min^{-1}
1	0.0050	0.10	7.0×10^{-5}
2	0.0050	0.05	3.5×10^{-5}

[1m]

Comparing experiments 1 and 2:

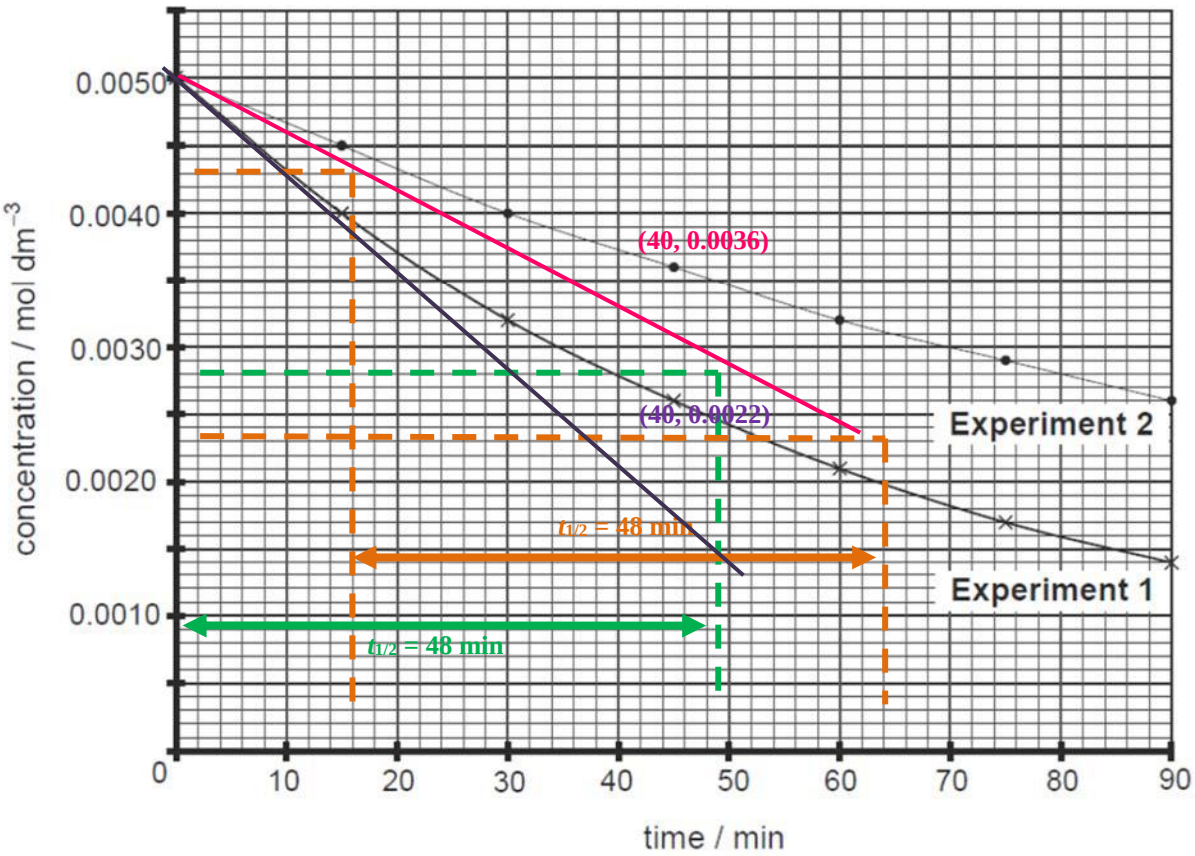
$$\frac{7.0\times\cancel{10^{-5}}}{3.5\times\cancel{10^{-5}}} = \frac{\cancel{k}(0.0050)(0.10)^n}{\cancel{k}(0.0050)(0.05)^n}$$

$$2 = \left(\frac{0.10}{0.05}\right)^n$$

$2 = 2^n$ i.e. $n = 1$

(iii) Write the rate equation for the reaction. [1]

Rate = $k[VO_2^+][As_2O_3]$



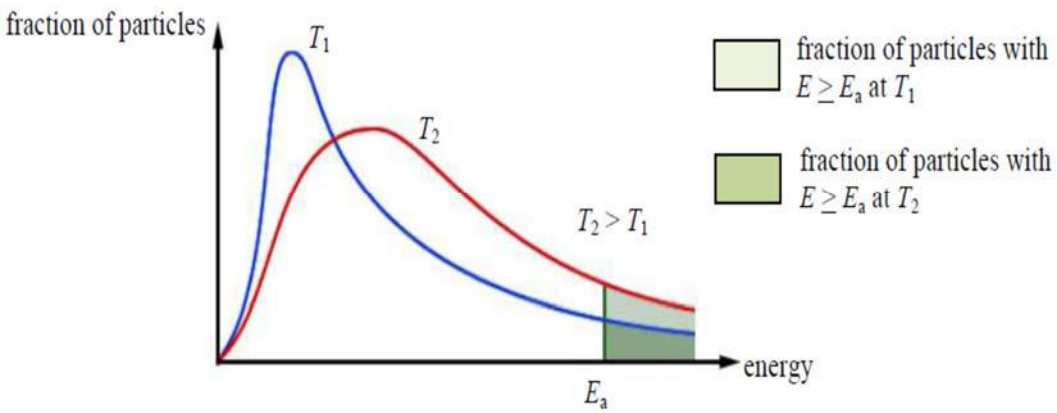
(iv) Calculate the rate constant for the reaction, stating its units. [2]

From experiment 1: $k = \dfrac{7.0\times10^{-5}}{0.0050\times0.10}$

= 0.14 mol^{-1} dm^{3} min^{-1}

(v) A third experiment involving the reaction between As_2O_3 and VO_2^+ is carried out at 40°C.

With the aid of a suitable diagram, state and explain how the rate of reaction at 40°C would compare with that at 25°C. [4]



- **When temperature increases, the reactant particles have higher kinetic energies. Hence, there will be a higher frequency of effective collisions.**

- **When temperature increases, a greater fraction of the particles will have energy greater or equal to the activation energy required for reaction.**
  Rate constant will increase at a higher temperature
- **Rate of reaction at 40^0C is greater than that at 25^0C**