2017

JC2 H1 Chemistry

1.	Anderson Junior College	
2.	Anglo Chinese Junior College	
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4.	Innova Junior College	
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ANDERSON JUNIOR COLLEGE

2017 JC 2 PRELIMINARY EXAMINATIONS

CHEMISTRY **8872/01**

Paper 1 Multiple Choice **18 September 2017**

50 minutes

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: 18/09/2017

This document consists of **14** printed pages.

Section A

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*.

How many atoms are present in 1 cm^3 of oxygen gas under room conditions?

A $\dfrac{2 \times 6.02 \times 10^{23}}{24000}$

B $\dfrac{1 \times 24000}{6.02 \times 10^{23}}$

C $\dfrac{1 \times 6.02 \times 10^{23}}{24000}$

D $\dfrac{6.02 \times 10^{23} \times 24000}{1 \times 1000}$

2 Cyanogen, a highly toxic gas, is composed of 46.2% carbon and 53.8% nitrogen by mass. At standard temperature and pressure, 1.16 g of cyanogen occupies 0.500 dm^3.

What is the molecular formula of cyanogen?

A CN **B** CN_2 **C** C_2N_2 **D** C_2N

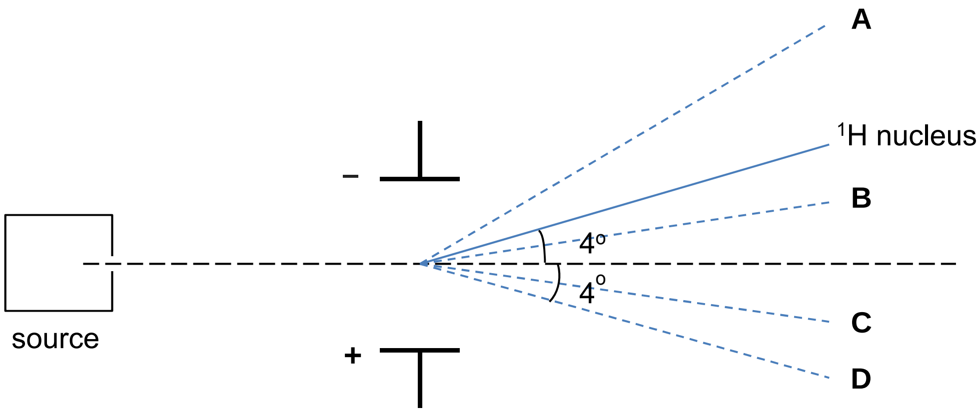
3 Gases given off during volcanic eruptions include CO, H_2S and CS_2.

A mixture of these gases was analysed by combustion in an excess of oxygen.

If the gases were in a $CO : H_2S : CS_2$, 1 : 3 : 1 mole ratio, what would be the $SO_2 : CO_2$ mole ratio in the mixture after combustion?

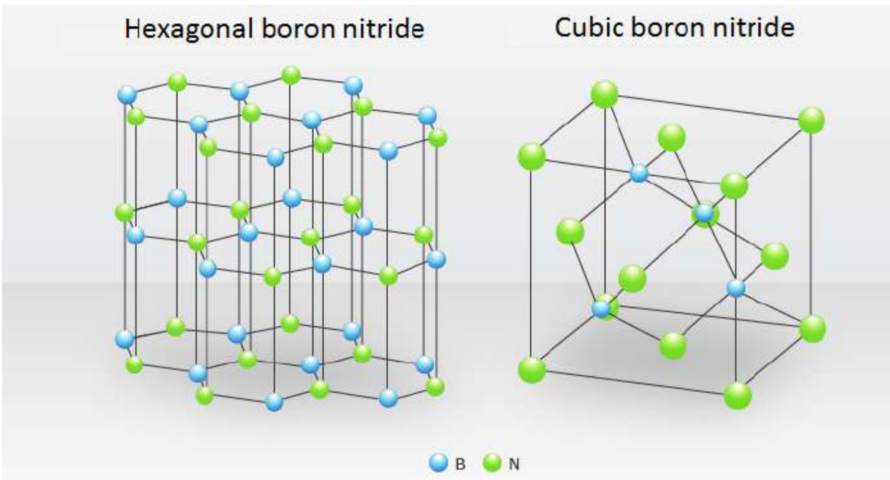
A 5 : 2 **B** 3 : 2 **C** 5 : 1 **D** 1 : 1

4 When passed through an electric field, the ^{1}H nucleus is deflected as shown below.



Which of the above beams represents the deflection for an ion $^{2}X^{2-}$?

5 Boron nitride is found to exist in two possible forms, hexagonal boron nitride and cubic boron nitride as shown below. Hexagonal boron nitride is found to be similar in structure and bonding to graphite.



Based on the structures of the two forms of boron nitride, which of the following statements about boron nitride is true?

A Hexagonal boron nitride has a giant covalent structure whereas cubic boron nitride has a simple covalent structure.

B Hexagonal boron nitride has strong covalent bonds between its layers of atoms.

C Both forms of boron nitride are soft and slippery.

D Only the hexagonal form of boron nitride is a good conductor of electricity.

6 Which of the following isomers is likely to have the highest boiling point?

A $CH_3CH_2CH_2CH_2CH_2CH_3$

B $(CH_3)_2CHCH_2CH_2CH_3$

C $(CH_3)_2CHCH(CH_3)_2$

D $(CH_3)_3CCH_2CH_3$

7 Which of the following pairs of compounds shows the same shape and similar bond angles?

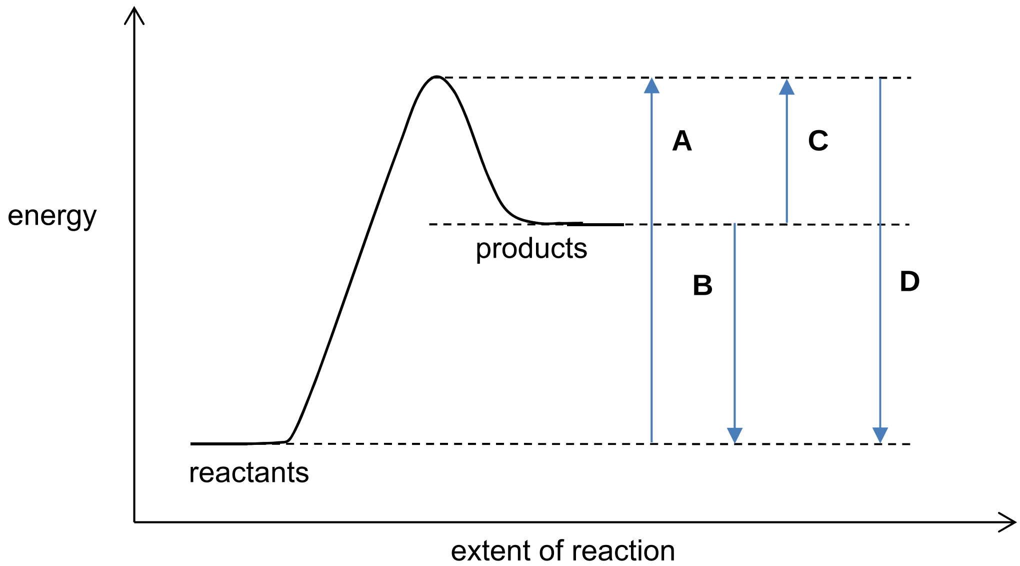
A $AlCl_3$ and PCl_5

B $BeCl_2$ and H_2O

C $POCl_3$ and CCl_4

D SO_2 and CO_2

8 Which arrow on the reaction pathway diagram shows the enthalpy change of reaction for the reverse reaction?



9 The values for the standard enthalpy changes of formation of hydrogen peroxide and of water are –187.8 kJ mol^{-1} and –285.8 kJ mol^{-1} respectively.

$$2H_2O_2(l) \longrightarrow 2H_2O(l) + O_2(g)$$

What is the enthalpy change of reaction for the decomposition of hydrogen peroxide?

A –98 kJ mol^{-1} **B** –196 kJ mol^{-1} **C** –398 kJ mol^{-1} **D** –451 kJ mol^{-1}

10 In an experiment to measure the enthalpy change of neutralisation of hydrochloric acid, 20 cm^3 of solution containing 0.04 mol of HC*l* was placed in a plastic cup of negligible heat capacity.

A 20 cm^3 sample of aqueous sodium hydroxide containing 0.04 mol of NaOH, at the same initial temperature, was added and the temperature rose by 15 °C.

If the heat capacity per unit volume of the final solution is 4.2 J K^{-1}cm^{-3}, what is the enthalpy change of neutralisation of hydrochloric acid?

A $40 \times 4.2 \times 288 \times 0.08$ J mol^{-1}

B $\dfrac{20 \times 4.2 \times 15}{0.04}$ J mol^{-1}

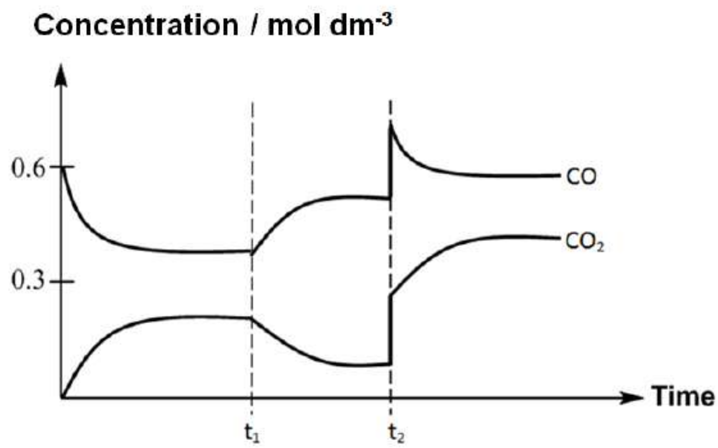
C $\dfrac{40 \times 4.2 \times 15}{0.04}$ J mol^{-1}

D $\dfrac{40 \times 4.2 \times 288}{0.08}$ J mol^{-1}

11 At a temperature T K, 0.60 mol dm^{-3} of CO and 0.30 mol dm^{-3} of O_2 were introduced into a 5 dm^3 vessel and allowed to reach equilibrium.

$$2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g) \qquad \Delta H < 0$$

The graph below shows the changes in the concentration of CO and CO_2 in the system with time. A change was made to the system at time, t_1 and t_2.



What were the changes made at time, t_1 and t_2?

	t_1	t_2
A	a catalyst was added	volume of the system is increased
B	more CO_2 was added	the temperature was decreased
C	the temperature was decreased	more O_2 was added
D	the temperature was increased	volume of the system is decreased

12 Pure carbon dioxide can be made to react with hot graphite, according to the following equation.

$$CO_2(g) + C(s) \rightleftharpoons 2CO(g) \qquad \Delta H > 0$$

A mixture containing 0.10 mol of carbon dioxide and 0.20 mol of graphite was placed in a sealed 0.10 dm^3 container and heated to a fixed temperature. At equilibrium, 69% of graphite remained unreacted.

What is the value of K_c for this reaction?

A 2.9 **B** 3.3 **C** 4.0 **D** 7.6

13 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 Water is not a neutral liquid at 62 °C.

B The ionic dissociation of water is an endothermic process.

C The ionic dissociation of water increases by a factor of 5 between 25 °C and 62 °C.

D The association of water molecules by hydrogen bonding increases as temperature rises.

14 The following equilibrium exists in a mixture of concentrated nitric acid and concentrated sulfuric acid.

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

Which of the statements is correct?

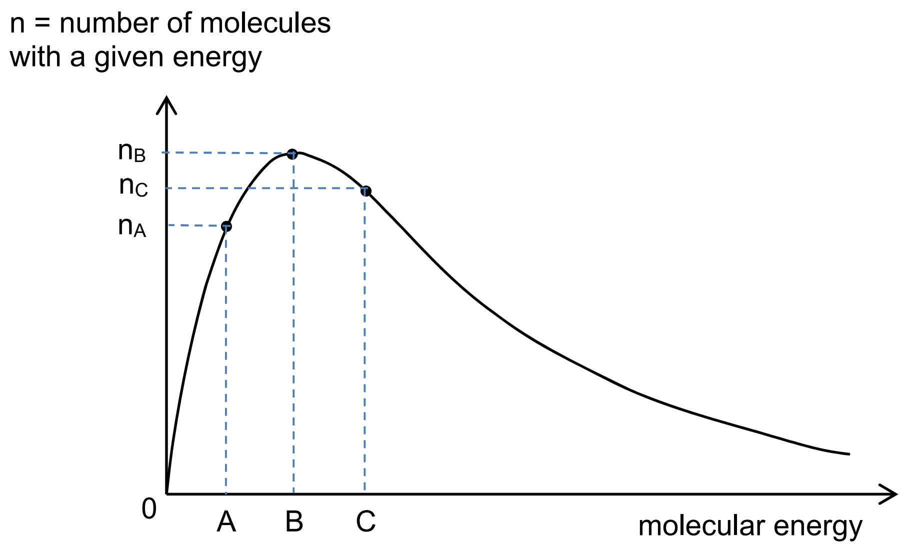
A HNO_3 is a stronger acid than H_2SO_4.

B The nitric acid acts as an oxidising agent.

C The sulfuric acid acts as a dehydrating agent.

D HNO_3 and $H_2NO_3^+$ are a conjugate acid–base pair.

15 The Maxwell–Boltzmann distribution for gas **E** at a given temperature is shown below.



Which statement is correct for the number of molecules with molecular energies A, B and C?

A n_C decreases when more gas **E** is added at the same temperature.

B n_A decreases when temperature is lowered.

C n_A and n_B increases when temperature is increased.

D Addition of catalyst at the same temperature has no effect on n_A, n_B and n_C.

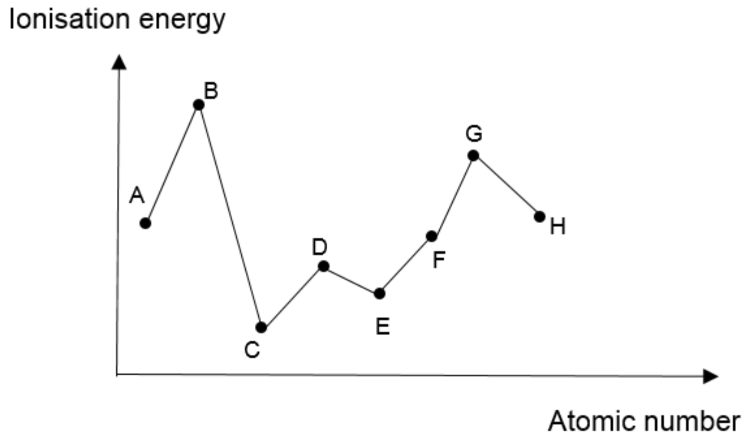
16 A radioactive element has two isotopes, **F** and **G**, with half–lives of 3 min and 9 min respectively.

An experiment starts with *h* times as many atoms of **F** as of **G**. After 9 min, the number of atoms of **F** and **G** are both equal.

Given that radioactive decay is a first order reaction, what is the value of *h*?

A 0.5 **B** 2 **C** 4 **D** 8

17 The following graph shows the first ionisation energy of eight consecutive elements, from **A** to **H** in the Periodic Table with atomic number between 3 and 20.



Which of the following statements is correct?

A The chloride of **D** does not conduct electricity in the molten state.

B **A** reacts with **C** to form a compound with giant ionic lattice structure.

C The melting points of **A** to **H** follow the trend as shown by the graph.

D The oxide of **H** gives a neutral pH when dissolved in water.

18 **X**, **Y** and **Z** are elements in Period 3 of the Periodic Table.

A mixture containing the oxides of **X**, **Y** and **Z** was dissolved in excess dilute sulfuric acid and filtered. The oxide of **Z** was collected as a residue. When excess dilute sodium hydroxide was added to the filtrate, only a white precipitate of the hydroxide of **Y** was formed.

What are the possible identities of **X**, **Y** and **Z**?

	X	**Y**	**Z**
A	A*l*	Mg	Si
B	A*l*	Mg	P
C	Mg	A*l*	Si
D	Mg	A*l*	P

19 When alkane **N**, C_7H_{16}, was reacted with bromine under ultraviolet light, it produced **six** isomeric monobromo compounds, with the formula $C_7H_{15}Br$.

What is the likely identity of alkane **N**?

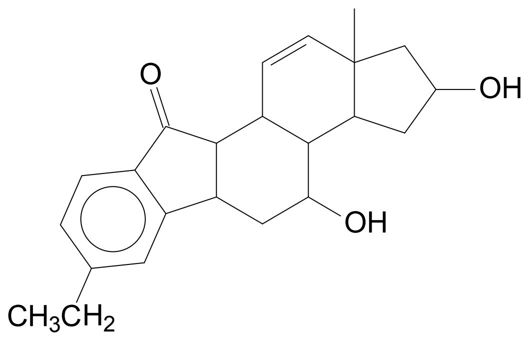
A $CH_3(CH_2)_5CH_3$

B $(CH_3)_2CH(CH_2)_3CH_3$

C $(CH_3)_3CCH_2CH_2CH_3$

D $(CH_3)_3CCH(CH_3)_2$

20



After heating the molecule above with steam and concentrated phosphoric acid, followed by subsequent heating with acidified potassium dichromate(VI), how many carboxylic acid groups are present in the resultant compound?

A 0 **B** 1 **C** 3 **D** 6

21 The compound, $CH_2{=}CHCH_2OH$, undergoes a sequence of reactions as follows:

$$CH_2{=}CHCH_2OH \xrightarrow{\textbf{X}} CH_2{=}CHCOOH \xrightarrow{\textbf{Y}} CH_3CH_2COOH$$

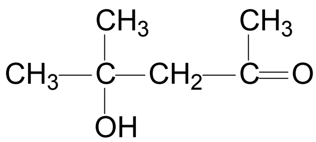
What could be the reagents for **X** and **Y**?

	X	**Y**
A	acidified $K_2Cr_2O_7$	$NaBH_4$
B	acidified $K_2Cr_2O_7$	H_2(g) with Ni catalyst
C	acidified $KMnO_4$	$LiAlH_4$ in dry ether
D	acidified $KMnO_4$	H_2(g) with Pt catalyst

22 In the presence of a dilute alkali, some aldehydes and ketones undergo the ‘aldol reaction’ where they dimerises to form a hydroxylcarbonyl compound (an aldol). For example, ethanal dimerises in this way to form 3–hydroxybutanal.

$$2\ CH_3CHO \xrightarrow{OH^-} CH_3CH(OH)CH_2CHO$$

Which of the following compounds will undergo the aldol reaction to produce the aldol shown below?



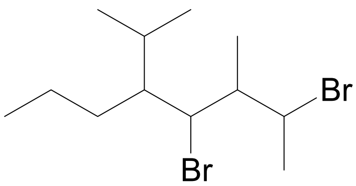
A CH_3COCH_3

B CH_3CH_2CHO

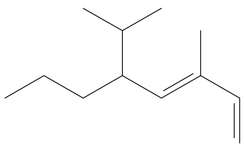
C $(CH_3)_2CHCHO$

D $CH_3CH_2COCH_3$

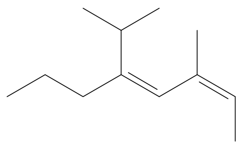
23 Which of the following will **not** be obtained when the molecule below is heated with NaOH in ethanol?



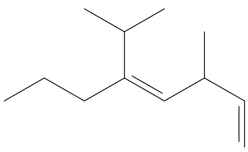
A



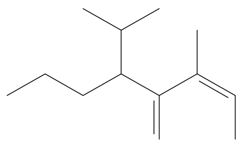
B



C



D



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24 **Q** gives a yellow precipitate on warming with alkaline aqueous iodine.

Which of the following could be **not** be **Q**?

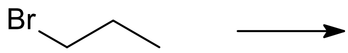
A ethanal

B ethanol

C butan–2–ol

D methyl ethanoate

25 Halogenoalkanes are very useful in making organic acids.



CH_3COOH

Which set of reagents, used in sequential order, would be the most suitable for this synthesis?

A aqueous KOH, acidified $KMnO_4$

B aqueous KOH, acidified $Na_2Cr_2O_7$

C ethanolic KOH, acidified $KMnO_4$

D ethanolic KCN, dilute H_2SO_4

Section B

For each of the question in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct.)

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 Orange dichromate(VI) ions, $Cr_2O_7^{2-}$ and yellow chromate(VI) ions, CrO_4^{2-}, exist in equilibrium in aqueous solution.

$$Cr_2O_7^{2-}(aq) + H_2O(l) \rightleftharpoons 2CrO_4^{2-}(aq) + 2H^+(aq)$$

Which of the following statement(s) about the equilibrium is correct?

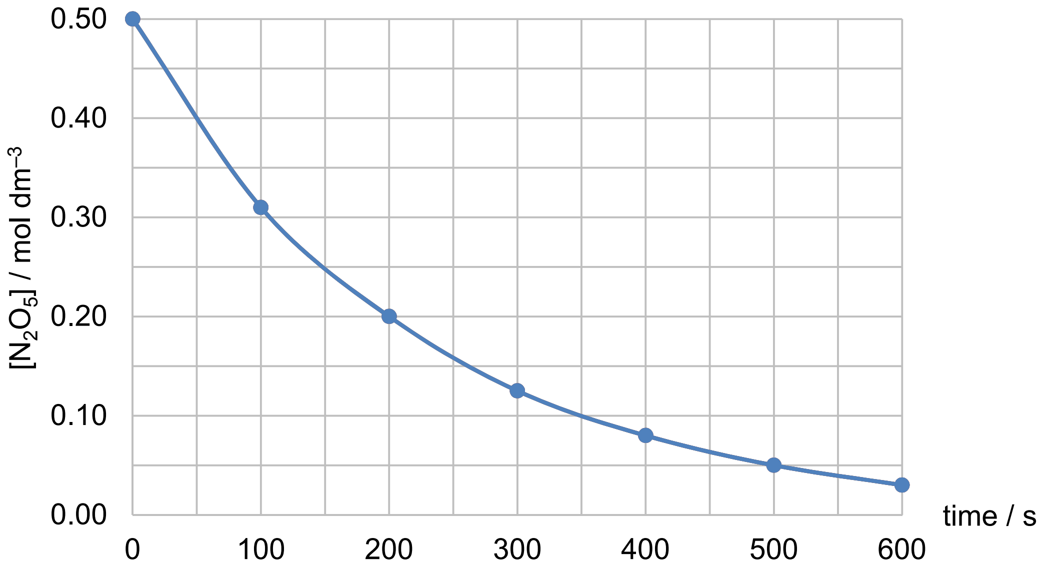
1 Addition of strong alkali will shift the position of equilibrium to the right.

2 Addition of K^+ (aq) will shift the position of equilibrium to the right.

3 This is a redox reaction.

27 The rate kinetics of decomposition of N_2O_5 is investigated by plotting the concentration of N_2O_5 with respect to time.

$$2N_2O_5(g) \longrightarrow 4NO_2(g) + O_2(g)$$



Which conclusions can be drawn from this result?

1 $[NO_2]$ is 0.60 mol dm^{-3} after 200 s.

2 The rate equation is rate = $k\,[N_2O_5]$.

3 The initial rate of production of O_2 is approximately 1×10^{-3} mol dm^{-3} s^{-1}.

28 Which of the following statement(s) about the chlorides of Period 3 elements is correct?

1 The pH of the solutions of chlorides generally decreases across the period.

2 When limited amount of water is added to the covalent chlorides, they give acidic white fumes.

3 Adding NaOH (aq) to a solution of $AlCl_3$ produces a white precipitate which is soluble in an excess of NaOH.

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

29 In a beehive, the queen bee secretes the substance below to cause worker bees to begin constructing royal colony cells.

$$CH_3CO(CH_2)_5CH{=}CHCO_2H$$

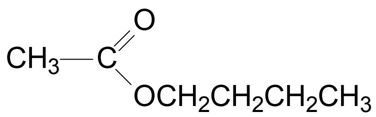
From the structure shown, which of the following statements are true?

1 It gives a brick red precipitate with alkaline Cu^{2+} solution.

2 It gives an orange precipitate with 2,4–dinitrophenylhydrazine solution.

3 It decolourises aqueous bromine solution.

30 An ester with a fruity odour has the following structural formula.



From the structure shown, which of the following statements are true?

1 The name of the ester is butyl ethanoate.

2 It has the same empirical formula as propanone.

3 The ester reacts with OH^- in 1 : 2 ratio in a complete reaction.

H1 Chemistry 8872 **AJC 2017 JC2 Prelim** **Paper 1 – 30 marks**

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

A	**8**
B	**7**
C	**7**
D	**8**

1 Under room conditions of 25°C and 1 atm, 1 mole of gas occupies 24 dm^3 of space. **A**

Moles of O_2 gas molecules = $\frac{1}{24000}$ mol

Moles of O atoms = $\frac{2}{24000}$ mol

No of O atoms = $\underline{\frac{2 \times 6.02 \times 10^{23}}{24000}}$ atoms

2 **C**

	C	N
Mole ratio	46.2 / 12 = 3.85	53.8 / 14 = 3.84
Simplest ratio	1	1

Empirical formula = CN

n(cyanogen) = $\frac{0.500}{22.4} = 0.0223$ mol

M_r of cyanogen = $\frac{1}{0.0223}$ x 1.16 = 52

n(14+12) = 52
n = 2
Hence, molecular formula = $\underline{C_2N_2}$

3 **A**

$CO + 1/2O_2 \longrightarrow \mathbf{CO_2}$
1 mol of CO produces **1 mol CO_2**

$H_2S + 3/2O_2 \longrightarrow H_2O + \mathbf{SO_2}$
3 mol H_2S produces **3 mol SO_2**

$CS_2 + 3O_2 \longrightarrow \mathbf{CO_2} + \mathbf{2\ SO_2}$
1 mol of CS_2 produces **1 mol CO_2** **2 mol of SO_2**

Total moles of SO_2 = 3 + 2 = 5 mol
Total moles of CO_2 = 1+1 = 2 mol
Therefore ratio of SO_2 : CO_2 = $\underline{5 : 2}$

4 **D**

angle of deflection α $\frac{\text{charge size}}{\text{mass}}$

for $^1H^+$, $\frac{z}{m} = +\frac{1}{1}$

for $^2X^{2-}$, $\frac{z}{m} = -\frac{2}{2}$

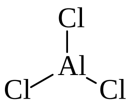
Hence, angle of deflection for $^2X^{2-}$ = $\underline{-4^o}$ (i.e. in the opposite direction)

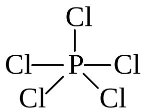
5 Hexagonal boron nitride resembles graphite, while cubic boron nitride resembles diamond. **D**

- Hence, both of them have giant molecular structures.
- Hexagonal boron nitride has strong covalent bonds between its atoms within the layer, but it has weak instantaneous dipole–induced dipole forces of attractions between its layers. Therefore, only hexagonal boron nitride is soft and slippery while cubic boron nitride is hard and rigid due to the strong, extensive covalent bonds between the B and N atoms.
- Hexagonal boron nitride resembles the structure of graphite as it also has a delocalized pi electron cloud system, which thus allows it to conduct electricity. Cubic boron nitride has no delocalised electrons to conduct electricity.

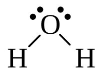
6 All molecules in the options have the same M_r and hence there is no difference in the number of electrons and the size of the electron cloud. **A**
Since $CH_3CH_2CH_2CH_2CH_2CH_3$ has an elongated shape as compared to other branched isomers, it has the greatest surface area of contact which allow for stronger id–id attractions between the molecules.

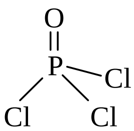
7 Considering that the shape and bond angle are dependent on the number of electron pairs around the central atom, **C**

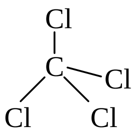
A

(3bp)
trigonal planar
120°

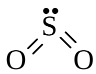

(5bp)
trigonal bipyramidal
90 and 120°

B
Cl—Be—Cl
(2bp)
linear
180°


(2bp + 2lp)
bent
105°

C

(4bp)
tetrahedral
109.5°


(4bp)
tetrahedral
109.5°

D

(2bp + 1lp)
bent
<120°

O=C=O
(2bp)
linear
180°

8 A represents E_a for forward reaction **B**
B represents enthalpy change of reaction for reverse reaction
C represents E_a for the reverse reaction
D has no significance

9 $\Delta H_r = [2\Delta H_f\,(H_2O) + \Delta H_f\,(O_2)] - 2\Delta H_f\,(H_2O_2)$ **B**
$= [2(-285.8) + 0] - 2(-187.8)$
$= \underline{-196\ \text{kJ mol}^{-1}}$

10 $\Delta H_{neut} = -\,Q / n_{H2O} = Vc\Delta T / n_{H2O}$ **C**
Volume of resultant solution of NaOH and HC*l* = 40 cm^3
n_{H2O} formed = n_{HCl} = 0.04 mol

Please note that the options given refer to the value of the ΔH_{neut}.

11 A. At t_1, catalyst increases the rate of the forward and backward reaction to the same extent such that there is no change to the concentration of the reactants and products. **D**
B. At t_1, addition of CO_2 would have caused an immediate increase in $[CO_2]$ followed by a decrease in $[CO_2]$ since POE shift left. This however is not shown in the diagram.
C. At t_1, when temperature decreases for an forward exothermic reaction, POE shifts to the right increasing the conc. of CO_2 but diagram shows a decrease in concentration of CO_2.
D. At t_1, an increase in temperature will cause POE to shift left, decreasing the [CO] and increasing the $[CO_2]$. When volume of the system is decreased at t_2, [CO] and $[CO_2]$ will increases. By LCP, POE will shift right hence decreasing [CO] and $[CO_2]$. All of these were reflected in the diagram.

12 **C**

$$K_c = \frac{[CO]^2}{[CO_2]}$$

	$CO_2(g)$ +	$C(s)$ $\rightleftharpoons$	$2CO(g)$
Initial (mol)	0.10	0.20	0
Change (mol)	–0.062	–(0.20 x 0.31) = –0.062	+0.062 x 2 = +0.124
Equilibrium (mol)	0.038	0.20 x 0.69 = 0.138	0.124
Equilibrium conc. (mol dm^{-3})	0.038 / 0.10 = 0.38	–	0.124 / 0.10 = 1.24

'ICE' table is not required

Equilibrium no. of moles of CO_2 = 0.10 – (0.20 x 0.31) = <u>0.038 mol</u>
Equilibrium no. of moles of CO = 0.062 x 2 = <u>0.124 mol</u>

$$K_c = \frac{[CO]^2}{[CO_2]} = \frac{(1.24)^2}{(0.38)} = \underline{4.0 \text{ mol dm}^{-3}}$$

13 **B** is the correct answer. **B**

$$2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

When temperature increases, the forward endothermic reaction is favoured. Thus, the position of equilibrium shifts to the right to absorb the excess heat.

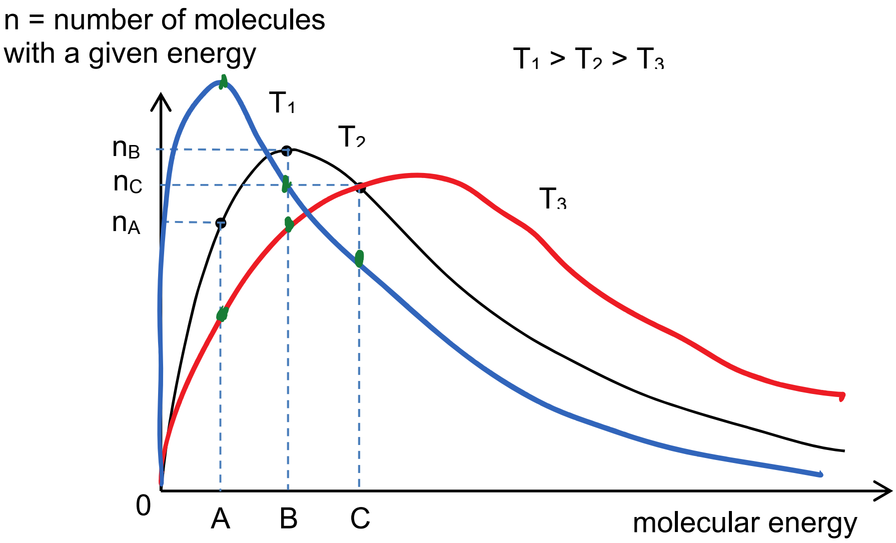
For **A**,
$K_w = [H^+][OH^-]$
$[H^+] = [OH^-] = \sqrt{10^{-13}} = 3.16 \times 10^{-7}$ mol dm^{-3}. Water is still a neutral liquid as the $[H^+] = [OH^-]$.

For **C**,
For T=25^{O}C, $[H^+] = 1.00 \times 10^{-7}$ mol dm^{-3}
For T=62^{O}C, $[H^+] = 3.16 \times 10^{-7}$ mol dm^{-3}
The ionic dissociation of water increases by a factor of <u>3.16</u> between 25 ^{O}C and 62 ^{O}C.

For **D**,
The association of water molecules by hydrogen bonding <u>decreases</u> as temperature rises. Molecules are moving at higher speeds, making it harder to form hydrogen bonds.

14 A. HNO_3 acts as a base here as H_2SO_4, being the stronger acid, has donated a proton to HNO_3, forming HSO_4^- and $H_2NO_3^+$, which will break down to H_2O and NO_2^+. **D**
B. The oxidation no. of N atom remained as +5.
C. Water is not eliminated in this reaction.
D. $H_2NO_3^+$ and HNO_3 forms a conjugate acid-base pair (differ by a H^+).

15 Area under the graph represents total number of molecules in sample. **D**
A is incorrect because when more gas is added to sample, no. of molecules at all energies will increase.
B is incorrect because when temperature decreases, curve shifts to the left and has a higher peak. i.e. n_a will increase. (check graph below)
C is incorrect because when temperature increases, curve shifts to the right and has a lower peak. i.e. n_a and n_b will decrease (check graph below)
D is correct because the presence of a catalyst does not shift the curve at all. It only provides an alternative pathway with a lowered E_a (E_a'). Hence there is no effect on n_a, n_b and n_c.



16 The easiest approach to answering this question is to start from the equimolar quantities of **F** and **G** after 9 min and work backwards. **C**
Since **F** has undergone 3 half–lives, its initial concentrations will be 8**F**.
Initial concentration of **G** will be 2**G** as it has undergone 1 half–lives.

8**F**	$\longrightarrow$	4**F**	$\longrightarrow$	2**F**	$\longrightarrow$	**F**
2**G**			$\longrightarrow$			**G**

∴ value of h = <u>4</u>

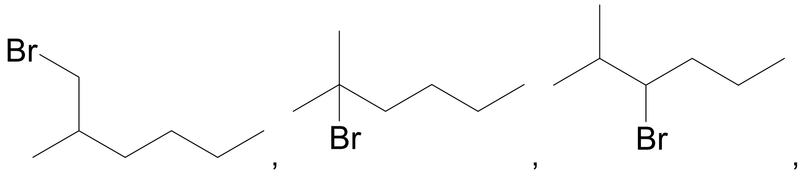
17 The big dip in IE shows that element C is in the next period since valence electron is further from the nucleus, resulting in lower IE. Since A to H has atomic number 3 to 20, B is Ne (period 2), C is Na (period 3). **B**

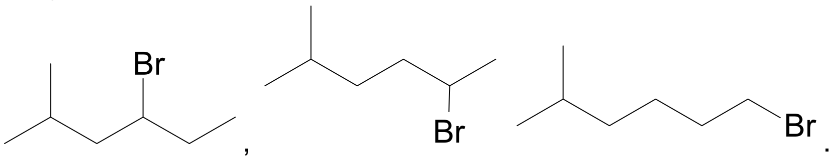
A. D is Mg and $MgCl_2$ being an ionic solid will conduct electricity in the molten state.
B. A which is F_2 which will react with C which is Na forms an ionic compound (NaF).
C. Ne exits as a gas and Na is a solid. Hence, trend of melting point is not in the trend above.
D. The oxide of H which is sulfur will give an acidic pH when dissolved in water.

18 MgO, Al_2O_3 are soluble in acid as they undergo acid–base reaction. Oxides of P are soluble in aq. acid. (Recall: Oxides of phosphorus can hydrolyse in water). **A**
SiO_2 is insoluble in acid. Thus **Z** is Si.

Filtrate contains Mg^{2+} or Al^{3+}.
When excess NaOH is added to the filtrate, $Mg(OH)_2$ is formed as white ppt.
$Al(OH)_3$ is amphoteric and reacts with excess NaOH to form salt and water.
$Al(OH)_3(s) + NaOH(aq) \rightarrow NaAl(OH)_4(aq)$
Hence, **X** is A*l* and **Y** is Mg.

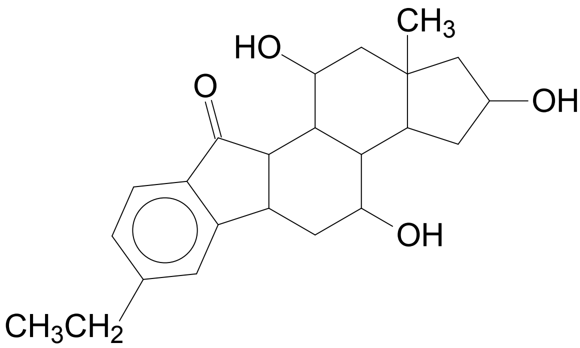
19 For structure B $(CH_3)_2CH(CH_2)_3CH_3$, there are **six different hydrogen environments** i.e. **6 different monobromo–substituted products** can be obtained. **B**

They are 



The other options give less than 6 isomeric monobromo compounds with the formula $C_7H_{15}Br$.

20 Subjecting the molecule to heating with steam and concentrated phosphoric acid results in (electrophilic) addition of water to the alkene functional group and you get this product. **A**

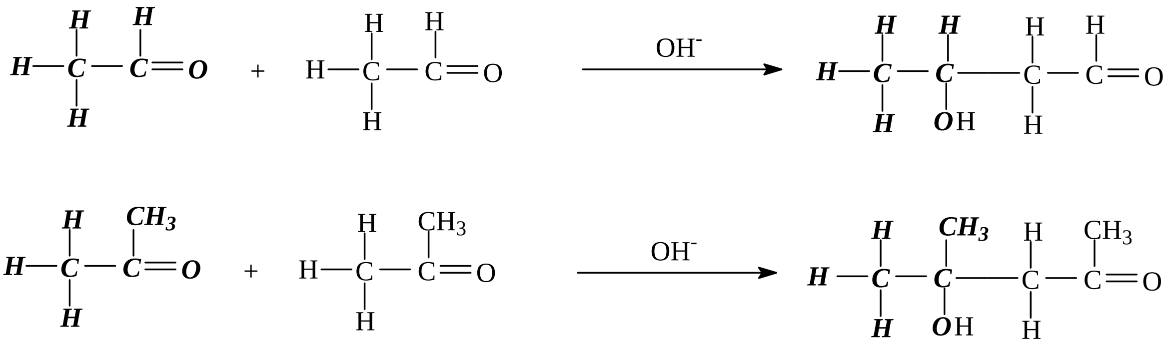


Upon heating with acidified potassium dichromate(VI), only the 3 secondary alcohols are oxidized to ketones. The ketone and the side–chain of the benzene ring does not undergo oxidation. As a result there are no carboxylic acid groups in the resultant product.

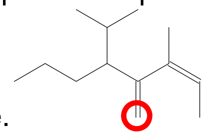
21 For **X**, acidified $KMnO_4$ is not suitable as it will cause oxidative cleavage of the double bond. **B**

For **Y**, $NaBH_4$ is unable to reduce the alkene double bond. $LiAlH_4$ will reduce the carboxylic acid to primary alcohol.

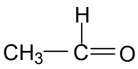
22 Making observations on the pattern in the given reaction, **A**

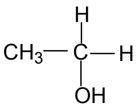


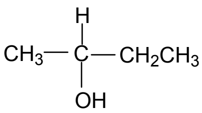
23 There are a few possible elimination products (Br eliminated together with a H atom on an adjacent carbon). Molecules in A – C are possible products upon elimination of 2 X H–Br. **D**

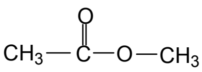
Only the molecule in D has an additional carbon i.e. 

24 **D**

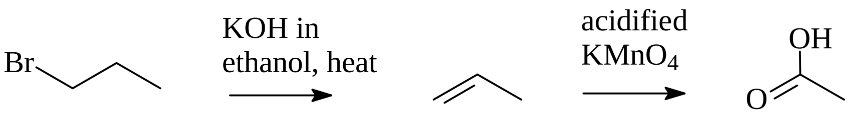
 gives yellow ppt in iodoform test

 gives yellow ppt in iodoform test

 gives yellow ppt in iodoform test

 does not give yellow ppt in iodoform test as the carbonyl carbon must be attached to only C or H

25 There is a loss of carbon atom in this reaction. **C**



26 Option 1 is correct because addition of strong alkali reduces the concentration of H^+, hence POE shifts to the right. **D**

Option 2 is incorrect because K^+ does not react with any of the species present. Hence there is no effect on the position of equilibrium.

Option 3 is incorrect because both $Cr_2O_7^{2-}$ and CrO_4^{2-} have the same oxidation no. of +6 despite having different colours ($Cr_2O_7^{2-}$ is orange in colour while CrO_4^{2-} is yellow). The equilibrium is known as an acid–base reaction instead of a redox reaction.

27 2. Graph shows half–life is constant at 150 s. Hence 1st order with respect to N_2O_5. **A**

3. Gradient of curve at t= 0 = $\frac{\Delta[NO_2]}{\Delta t}$ = *2.0 x 10*$^{-3}$ mol dm^{-3} s^{-1} .

$\frac{\Delta[O_2]}{\Delta t} = \frac{\Delta[O_2]}{2\Delta t}$ = *1.0 x10*$^{-3}$ mol dm^{-3} s^{-1}

1. After 200 s, the $[N_2O_5]$ is 0.20 mol dm^{-3}. This means that 0.30 mol dm^{-3} of N_2O_5 has been reacted, implying that 0.6 mol dm^{-3} of NO_2 and 0.5 mol dm^{-3} of O_2 are formed.

28 All 3 statements are true. **A**

Statement 1: pH of Na*Cl* (7)> Mg*Cl*$_2$ (6.5) > A*lCl*$_3$ (3) > Si*Cl*$_4$ and P*Cl*$_3$ or P*Cl*$_5$ (1 – 2)

Statement 2: $AlCl_3(s) + 3H_2O(l) \rightarrow Al(OH)_3(s) + 3HCl(g)$
Similarly for $SiCl_4$ and PCl_5

Statement 3: $Al^{3+} \rightleftharpoons Al(OH)_3 \rightleftharpoons Al(OH)_4^-$

Upon adding NaOH, white ppt of $Al(OH)_3$ is formed. In excess NaOH, white ppt dissolves to form complex ion $Al(OH)_4^-$.

29 It <u>will not</u> give a brick red precipitate with alkaline Cu^{2+} solution since there is <u>no</u> aldehyde group. **C**

It gives an orange precipitate with 2,4–dinitrophenylhydrazine solution since there is a carbonyl group (ketone).

It decolourises aqueous bromine solution since there is a C=C bond.

30 Option 1 is correct, as ethanoic acid and butan–1–ol react to give butyl ethanoate. **B**

Since it has a molecular formula of $C_6H_{12}O_2$, it has an empirical formula of C_3H_6O, like propanone, CH_3COCH_3.

Option 3 is incorrect as the expected products of base hydrolysis of the ester is sodium ethanoate ($CH_3COO^-Na^+$) and butan–1–ol.

ANDERSON JUNIOR COLLEGE

2017 JC 2 H1 PRELIMINARY EXAMINATIONS

NAME:___________________________ **PDG:**____ /16

CHEMISTRY **8872/02**

Paper 2 **13 September 2017**

2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Data Booklet
Writing paper

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.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** the questions.

Section B
Answer **two** questions on separate writing paper.
Start each question on a fresh sheet of paper.

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.

<table>
<tr><th colspan="8">For Examiner's Use</th></tr>
<tr><th rowspan="3">Paper 1 (33%)</th><th colspan="7">Paper 2 (67%)</th></tr>
<tr><th colspan="4">Section A</th><th colspan="2">Section B</th><th rowspan="2">Total</th></tr>
<tr><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th></th><th></th></tr>
<tr><td>/30</td><td></td><td></td><td></td><td></td><td></td><td></td><td>/ 80</td></tr>
<tr><td colspan="3"></td><td>Final marks</td><td colspan="4">/100</td></tr>
<tr><td colspan="3"></td><td>Grade</td><td colspan="4"></td></tr>
</table>

This document consists of **19** printed pages.

Section A

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

1 **(a)** *Use of the Data Booklet will be relevant to this question.*

Iron ore from different mines will contain different percentages by mass of iron. The percentage of iron in a sample of ore can be estimated by converting all of the iron present into Fe^{2+}(aq) ions and then using a redox titration.

The sample of ore is crushed, weighed and then dissolved in aqueous acid. The Fe^{3+}(aq) ions are then reduced to Fe^{2+}(aq) ions by reaction with an excess of aqueous tin(II) chloride, $SnCl_2$.

(i) Construct an ionic equation for the reduction of Fe^{3+}(aq) ions by Sn^{2+}(aq) ions.

……………………………………………………………………………………………..[1]

A sample of iron ore weighing 11.05 g was converted to Fe^{2+}(aq) ions using the method described above. The resultant solution was then made up to a volume of 250 cm^3 in a volumetric flask.

25.0 cm^3 portions of this solution were then titrated with 0.100 mol dm^{-3} of aqueous potassium dichromate(VI) using a suitable indicator. The results are shown below.

titration number	1	2	3
initial burette reading / cm^3	0.00	19.95	2.10
final burette reading / cm^3	19.95	39.95	22.15
titre / cm^3	19.95		

(ii) Complete the table above and use the results to determine the number of moles of potassium dichromate(VI) required to react with the Fe^{2+} ions in 25.0 cm^3 of the solution.

[2]

(iii) Write an ionic equation for the reaction of Fe^{2+} ions with acidified $Cr_2O_7^{2-}$ ions.

……………………………………………………………………………………………………..[1]

(iv) Calculate the total number of moles of Fe^{2+} in the original solution made up from the iron ore, and hence calculate the percentage by mass of iron in the sample of iron ore.

[2]

[Total: 6]

2 The Pollutant Standards Index (PSI) is an air quality indicator. It is based on five pollutants: particulate matter (PM10), sulfur dioxide, carbon monoxide, ozone and nitrogen dioxide.

To calculate the overall PSI, the PSI value is first determined, using the following table, for **each** of the five pollutants.

i	**PSI value, P_i**	**Concentration, C_i**				
		PM10 ($\mu g\ m^{-3}$)	**SO_2 ($\mu g\ m^{-3}$)**	**CO ($mg\ m^{-3}$)**	**Ozone ($\mu g\ m^{-3}$)**	**NO_2 ($\mu g\ m^{-3}$)**
1	50	50	80	5.0	118	–
2	100	150	365	10.0	157	–
3	200	350	800	17.0	235	1130
4	300	420	1600	34.0	785	2260
5	400	500	2100	46.0	980	3000
6	500	600	2620	57.5	1180	3750

[$1\ \mu g = 10^{-6}\ g$; $1\ mg = 10^{-3}\ g$]

Given the concentration of a pollutant (with units as stated in the table above), where C_{i+1} > concentration of pollutant > C_i ,

$$\text{PSI of pollutant} = [(\frac{P_{i+1} - P_i}{C_{i+1} - C_i})(\text{concentration of pollutant} - C_i)] + P_i$$

The overall PSI is then based on the maximum value out of the five calculated PSI pollutant values.

In Singapore, the 24–hr PSI is used by the National Environment Agency (NEA) to provide health advisory.

<table>
<tr><th>24−hr PSI</th><th>Healthy Persons</th><th>Elderly, Pregnant women, Children</th><th>Persons with chronic lung disease, heart disease, stroke</th></tr>
<tr><td>< 100</td><td colspan="3">Normal activities</td></tr>
<tr><td>101–200</td><td>Minimise prolonged or strenuous outdoor physical exertion.</td><td>Minimise prolonged outdoor activity.</td><td rowspan="3">Avoid all outdoor activities.
If outdoor activity is unavoidable, wear N95 mask.</td></tr>
<tr><td>201–300</td><td>Avoid prolonged or strenuous outdoor physical exertion.
If outdoor activity is unavoidable, wear N95 mask.</td><td rowspan="2">Avoid all outdoor activities.

If outdoor activity is unavoidable, wear N95 mask (for adults).</td></tr>
<tr><td>>300</td><td>Minimise all outdoor exposure.
If outdoor activity is unavoidable, wear N95 mask.</td></tr>
</table>

(a) **(i)** In a 1 m^3 sample of air, the mass of PM10 and carbon monoxide were found to be 320 μg and 20 mg respectively. Calculate the PSI values for each of the above pollutants, leaving your answers to **3 significant figures**.

[2]

(ii) Given that the PSI value of sulfur dioxide, ozone and nitrogen dioxide are 150, 112 and 133 respectively for the same sample of gas, use these values and your answers to **(a)(i)** to determine the overall PSI.

[1]

(iii) Assuming that the current overall PSI level is your answer in **(a)(ii)**, what advice would you give to a Physical Education (PE) teacher in Anderson Junior College who will be conducting a PE lesson soon?

…………………………………………………………………………………………………......

……………………………………………………………………………………………….....[1]

(b) The amount of sulfur dioxide in a sample of air can be determined by first reacting it with sodium iodate, $NaIO_3$. Iodine is one of the products in this reaction.

(i) Write an ionic equation for the reaction between sulfur dioxide and sodium iodate.

…………………………………………………………………………………………………..[1]

(ii) When a 1 m^3 sample of air was bubbled through a solution of sodium iodate, the resulting solution was neutralised by 10.0 cm^3 of 0.005 mol dm^{-3} sodium hydroxide solution.

Calculate the concentration of sulfur dioxide, in $\mu g\ m^{-3}$, in the sample of air.

[2]

(c) Some countries have set limits for particulates in the air. For example, the European Union has a daily average (24–hour) limit of 180 μg m^{-3} for PM10. Cities that violate this daily limit face a hefty financial penalty that is calculated with consideration of many factors such as the severity the violation has on the ecosystem, duration of the non–compliance and country's GDP etc.

(i) A collected sample of air from the German city of Leipzig contains 2 x 10^{-5} % by mass of PM10. Given that the density of air is 1 kg m^{-3}, calculate the concentration of PM10 in the sample collected.

[1]

(ii) Hence, deduce whether the German city of Leipzig will be faced with any financial penalty.

…………………………………………………………………………………………………….......

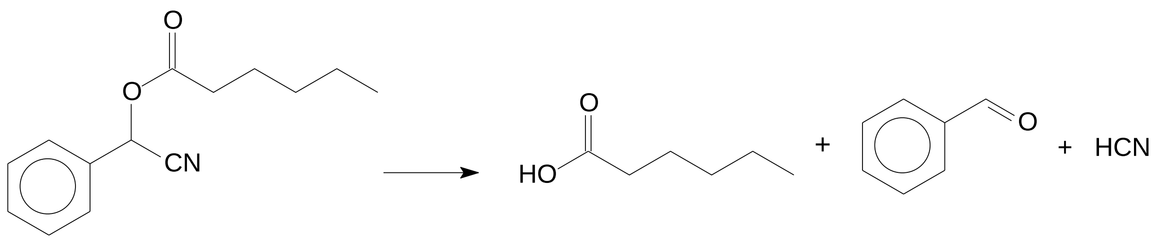
……………………………………………………………………………………………………..[1]

[Total: 9]

3 The *Oribatula tibialis* mite uses hydrogen cyanide, HCN, a highly volatile and toxic substance, to poison its predators.

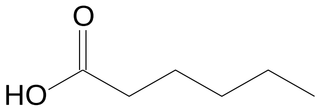
The HCN is stored in the form of mandelonitrile hexanoate, $C_{14}H_{17}NO_2$, in the mite's oil glands, to avoid poisoning itself. When attacked by predators, the mite secretes mandelonitrile hexanoate, which then release HCN, when in contact with the moisture, for example, from the predators' saliva.

(a) One of the possible reaction pathways of how mandelonitrile hexanoate secreted by *Oribatula tibialis* mite can release HCN is shown below.



mandelonitrile hexanoate $C_6H_{12}O_2$ C_7H_6O

(i) Name the functional group present, in addition to the hydrocarbon groups, in each of these compounds.



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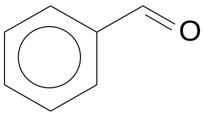


….……………………………………………………………

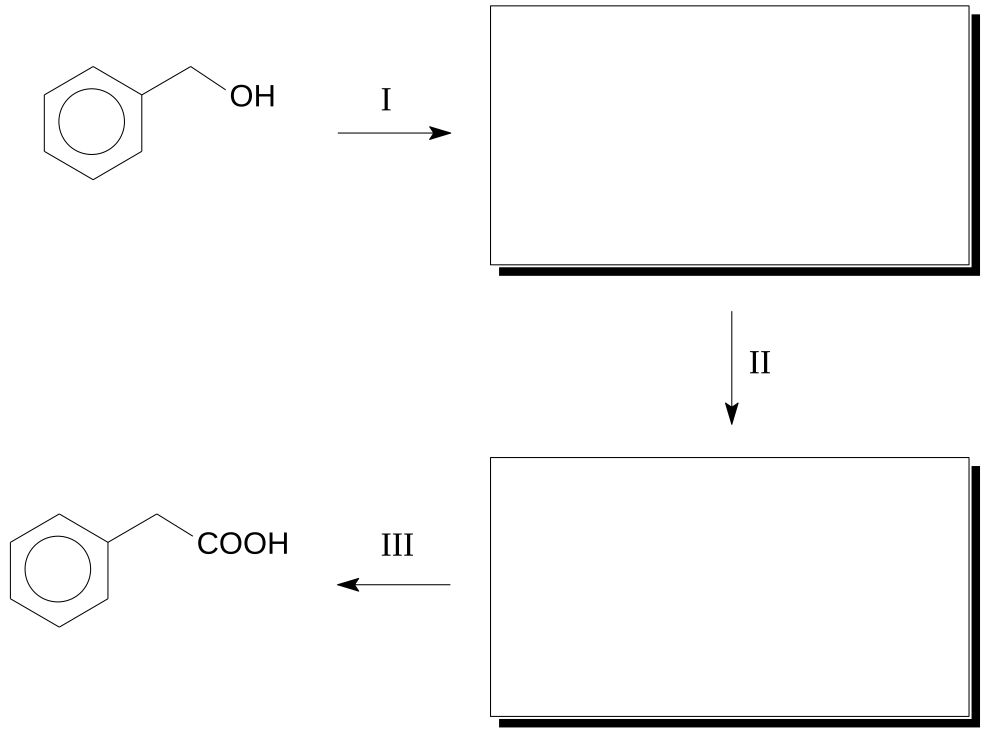
[1]

(ii) Describe a chemical test that would allow you to distinguish between the two organic products of the reaction. State what you would observe for each compound.

………………………………………………………………………………………………

………………………………………………………………………………………………[2]

(b) A sequence of reactions, starting from benzyl alcohol, is shown below.



(i) In the appropriate boxes, draw the structure of the two intermediates. [2]

(ii) State the reagents and conditions required for

stage I ……………………………………………………………….…………………...

stage II ……………………………………………………………….…………………...

stage III ……………………………………………………………….…………………...

[3]

(c) Benzoic acid, $C_7H_6O_2$, can be produced by the following reaction.

Reaction 1: $C_7H_6O(l) + C_7H_6O_3(s) \longrightarrow 2C_7H_6O_2(s)$

(i) Write an equation which represent the enthalpy change of combustion of benzoic acid.

……………………………………………………………………………………………………[1]

$$\begin{tikzcd}
C_7H_6O(l) + C_7H_6O_3(s) + 15O_2(g) \arrow[rr] & & 2C_7H_6O_2(s) + 15O_2(g) \arrow[d, "\Delta H_3^{\ominus}"] \\
14C(s) + 6H_2(g) + 17O_2(g) \arrow[u, "\Delta H_1^{\ominus}"] \arrow[rr, "\Delta H_2^{\ominus}"] & & 14CO_2(s) + 6H_2O(l)
\end{tikzcd}$$

(ii) Use the above energy cycle and the following data to calculate the value for $\Delta H_1^{\ominus}$, $\Delta H_2^{\ominus}$ and $\Delta H_3^{\ominus}$.

$\Delta H_c^{\ominus}$ carbon	=	–393.5 kJ mol^{-1}
$\Delta H_c^{\ominus}$ hydrogen	=	–285.8 kJ mol^{-1}
$\Delta H_f^{\ominus}$ $C_7H_6O(l)$	=	–87.0 kJ mol^{-1}
$\Delta H_f^{\ominus}$ $C_7H_6O_3(s)$	=	–367.0 kJ mol^{-1}
$\Delta H_c^{\ominus}$ $C_7H_6O_2(s)$	=	–3228 kJ mol^{-1}

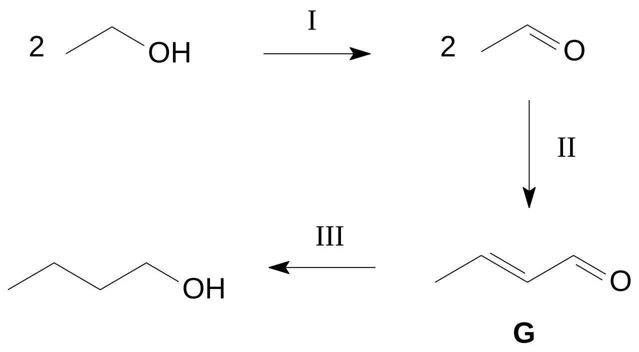
[3]

(iii) Hence, calculate the standard enthalpy change of reaction for reaction 1.

[1]

[Total: 13]

4 Scientists in the United States of America have come up with a simple 3–stage process to convert ethanol into butan–1–ol, in what could be an important step forward for renewable energy.



(a) (i) State the reagents and conditions required for stages I and III.

stage I ……………………………………………………………………………………………......

stage III ……………………………………………………………………………………………...

[2]

(ii) By considering the change in molecular formula shown in stage II, suggest the type of reaction occurred.

……………………………………………………………………………………………………[1]

(iii) Describe the type(s) of stereoisomerism shown by compound **G**.
Draw the displayed formula of the stereoisomers of **G**.

Type of isomerism …………………………………………………..

[2]

(iv) **G** reacts with a suitable reducing agent to give a compound **H**.

H effervesces with sodium metal and also decolourises aqueous bromine.

Suggest the structure of **H** and explain these observations.

………………………………………………………………………………………………………

………………………………………………………………………………………………………

……………………………………………………………………………………………………[2]

(b) Butan–1–ol has a number of structural isomers.

(i) Explain what is meant by *structural isomers.*

……

……[1]

(ii) Draw the structural formula of the other three alcohols with the same molecular formula as butan–1–ol. Label your structures **J**, **K** and **L**. Classify these alcohols as primary, secondary or tertiary.

[2]

(iii) Identify which alcohol reacts with alkaline aqueous iodine and write a balanced equation for the reaction, showing the structural formula of the products.

……[2]

[Total: 12]

Section B

Answer **two** questions from this section on separate writing paper.

5 **(a)** The melting points of four chlorides are given below.

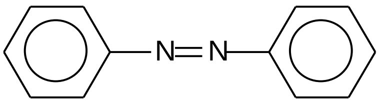
compound	*formula*	*m.p.* / °C
sodium chloride	NaC*l*	801
aluminium chloride	A*l*C*l*$_3$	178
carbon tetrachloride	CC*l*$_4$	–23
silicon tetrachloride	SiC*l*$_4$	–70

(i) Briefly relate these melting points to the structure of, and bonding in, each of these chlorides. [2]

(ii) Describe the reaction, if any, of each of these four chlorides with water, stating the approximate pH of any solution formed, and writing a balanced equation for any reaction that takes place. Offer an explanation for any differences that occur in their reactivities. [6]

(b) Scientists in Germany have developed a liquid crystal elastomers (LCE)–based adhesive that uses UV light to switch and control its level of stickiness within seconds.

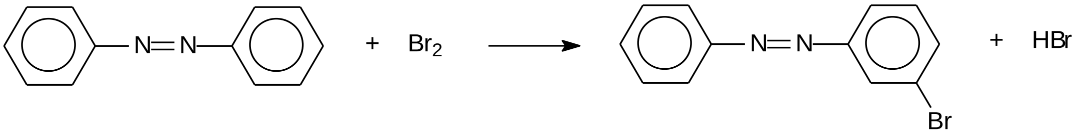
To control adhesion, the team used azobenzene, $C_{12}H_{10}N_2$ in the LCE as the light responsive molecule, which isomerises quickly from one state to another and changes size under UV light. This effect flexes the material enough to cause the microstructures to peel away from a surface and unstick, akin to how a gecko loses adhesion by moving its feet. When the light is removed, the material quickly recovers to its flat, sticky state.



azobenzene

(i) Outline the principles of Valence Shell Electron Pair Repulsion (VSEPR) theory and use it to suggest the bond angle around the nitrogen atom. [3]

(ii) Azobenzene can react with bromine under certain conditions as shown in the equation below.



Name the type of reaction and state the conditions necessary for the reaction to occur. [2]

(iii) Suggest the type of attraction that exists between the microstructures and the surface during adhesion. [1]

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

Compound **W** contains a primary amine functional group and has a molecular formula of $C_4H_7NO_3$. **W** gives an orange precipitate when treated with 2,4–dinitrophenylhydrazine but it has no reaction with Tollens' reagent. **W** gives a yellow precipitate when warmed with alkaline aqueous iodine.

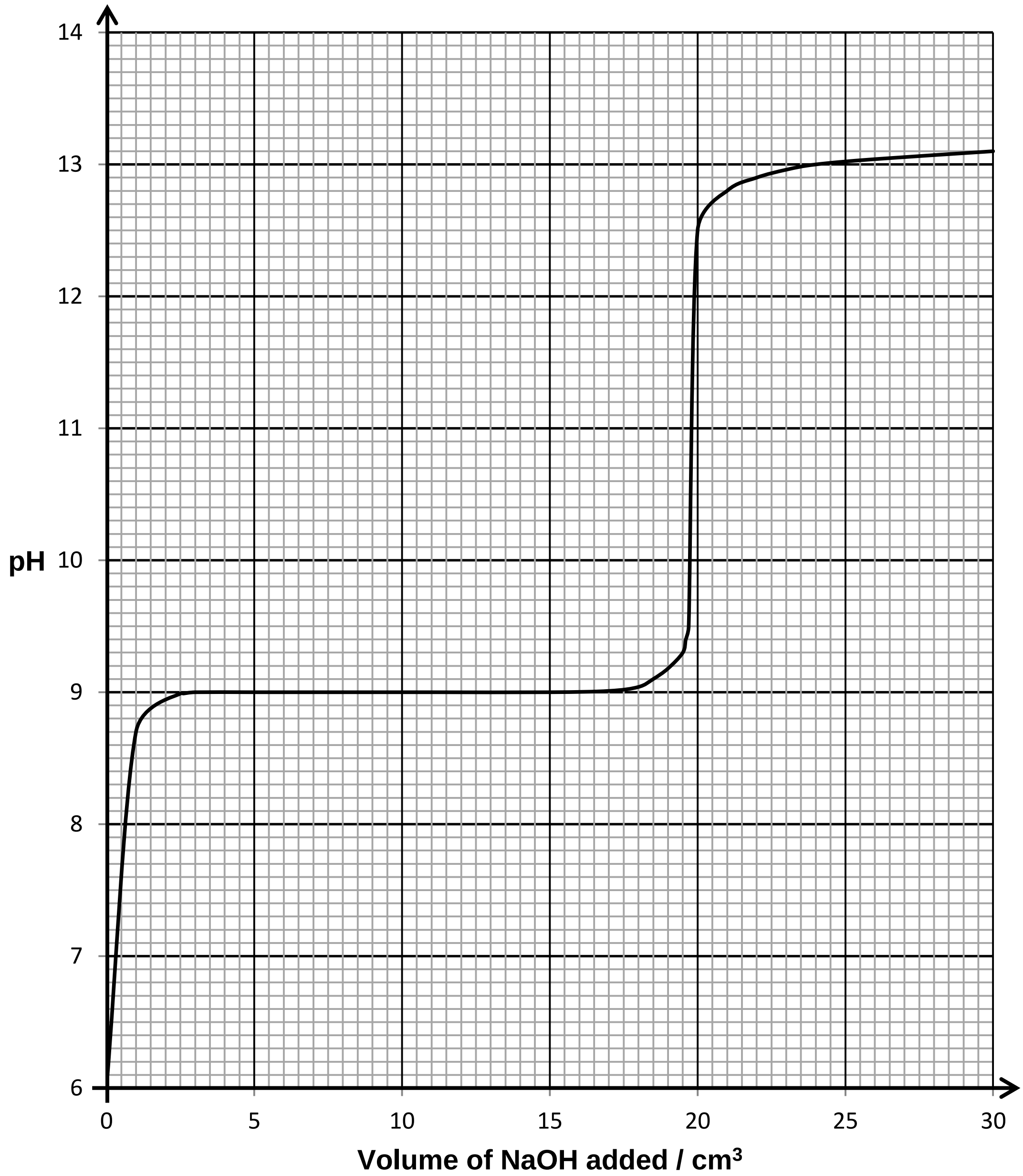
W has a proton chemical shift value (δ) of 13.0 ppm.

When **W** is heated with excess CH_3Cl, it gives an organic compound $C_7H_{14}NO_3Cl$, as the major product.

Suggest the structure for **W** and show how you deduced the structure, write equations for all of the reactions described above and suggest the types of reactions that are occurring. [6]

[Total: 20]

6 **(a)** In an experiment, 50.0 cm^3 of aqueous magnesium chloride were titrated with 1.00 mol dm^{-3} sodium hydroxide. The pH of the solution changed as in the diagram.



In this experiment, the hydrated magnesium ion, $Mg(H_2O)_6^{2+}$, acts as a weak acid.

(i) Write equation(s) to account for the initial pH of aqueous magnesium chloride. [1]

(ii) Hence, write an expression for the acid dissociation constant, K_a of $Mg(H_2O)_6^{2+}$ ion. [1]

(iii) Use the graph to determine the concentration of hydrogen ions, in mol dm^{-3}, present initially in the sample of aqueous magnesium chloride. [1]

(iv) The following table lists the information about two indicators.

indicator	colour in acid	colour in alkali	pH range over which the colour change occurs
alizarin yellow	yellow	orange	10.1 – 13.0
phenolphthalein	colourless	pink	8.2 – 10.0

Both indicators are added to aqueous magnesium chloride before the start of the titration.

State the colour of the solution at the following points of the titration.

(I) Before NaOH(aq) has been added.

(II) After 10 cm^3 of NaOH(aq) has been added.

(III) After 20 cm^3 of NaOH(aq) has been added.

[1]

(b) When hydrogen is reacted with iodine, the equilibrium is established.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -9.6 \text{ kJ mol}^{-1}$$

The reaction below has an activation energy of +173.2 kJ mol^{-1}.

(i) Calculate the activation energy of the reverse reaction. [1]

(ii) Suggest the effect **each** of the following conditions has on the position of equilibrium and the rate of the reaction.

pressure 10 atm

temperature 2000 K

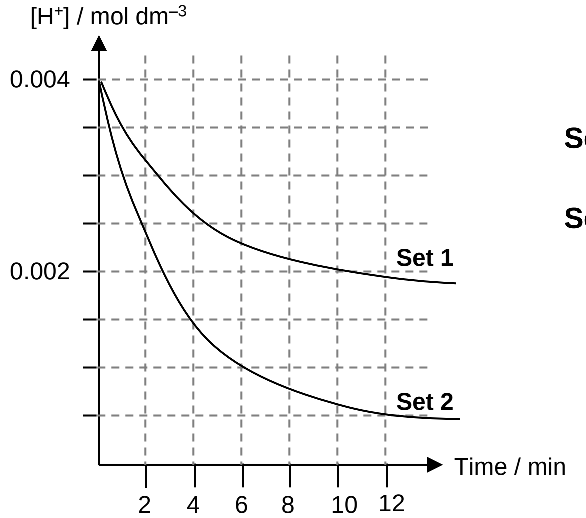
catalyst platinum

[6]

(c) The Harcourt and Esson reaction is that between hydrogen peroxide and acidified potassium iodide.

$$H_2O_2 + 2I^- + 2H^+ \longrightarrow 2H_2O + I_2$$

To determine the order of reaction of each reactant, two sets of reaction mixtures containing varying concentrations of I^- and H^+ were prepared. The concentration of hydrogen peroxide used for both experiments is 0.200 mol dm^{-3}. The results are as follows.



Set 1: $[I^-]$ = 0.175 mol dm^{-3}

Set 2: $[I^-]$ = 0.350 mol dm^{-3}

(i) Calculate the initial rate of reaction for **Set 1** and **2**. Show your working clearly. [1]

(ii) Use the information given above to determine the order of reaction with respect to I^- and H^+. Show your reasoning clearly. [2]

(iii) Using the information about **Set 1** and **2**, and your answers to **(c)(i)**, sketch a graph to show how the rate of reaction changes with concentration of iodine. Label your graph clearly. [2]

(iv) A student performed another experiment to determine the order of reaction with respect to H_2O_2, using the following concentrations.

	$[H_2O_2]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	initial rate / mol dm^{-3} min^{-1}
Set 3	0.3	0.10	0.004	

He made a random guess that the order of reaction with respect to hydrogen peroxide is two. Deduce an estimated value of the initial rate of reaction for **Set 3** if his guess is correct. [2]

(v) The actual order of reaction with respect to H_2O_2 is one.

The rate of the reaction was measured as 4.4×10^{-5} mol dm^{-3}s^{-1} when $[H_2O_2]$ = 0.002 mol dm^{-3}, $[H^+]$ = 0.2 mol dm^{-3} and $[I^-]$ = 0.2 mol dm^{-3}

Determine the rate constant for this reaction and state its units.

[2]

[Total: 20]

7 The oxygen family, also called the chalcogens, consists of the elements found in Group 16 of the Periodic Table and is considered among the main group elements. It consists of the elements oxygen, sulfur, selenium, tellurium and polonium.

(a) **(i)** State and explain the trend in the first ionisation energy of the Group 16 elements down the group. [2]

(ii) How would you expect the first ionisation energy of ${}_{34}Se$ to compare with that of ${}_{35}Br$? Give your reasoning. [2]

(b) **(i)** Describe the structure of a ${}^{128}Te$ atom, in terms of number and type of sub–atomic particles and give the electronic configuration for a tellurium(II) ion, Te^{2+}. [3]

(ii) State the formula of the oxide of tellurium in its highest oxidation state. [1]

(iii) State one physical property that you would expect this oxide of tellurium to possess. Explain, in terms of the structure and bonding present, why it possesses this property. [2]

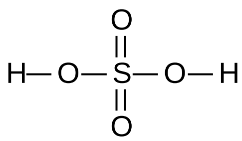
(iv) Write an equation to illustrate the behavior of this oxide of tellurium in water. [1]

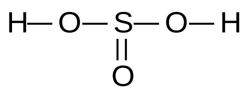
(c) When SO_3 is distilled into ICl_3 at 10 °C, a single ionic product is formed.

$$ICl_3 + SO_3 \longrightarrow (ICl_2^+)(SO_3Cl^-)$$

(i) Draw dot–and–cross diagrams to illustrate the bonding in **each** of the ions and predict their shapes. [4]

(ii) SO_3 dissolves in water to form sulfuric acid while the other oxide of sulfur, SO_2, gives H_2SO_3. The structures of the two acids are as shown below.





Explain why H_2SO_4 is a stronger acid than H_2SO_3. [2]

(d) $CH_3CH(OH)CH_2COCH_2CO_2H$ forms a cyclic 6–membered ring when heated with concentrated sulfuric acid.

(i) Suggest the role of concentrated sulfuric acid in this reaction. [1]

(ii) Write a balanced equation for the reaction and draw the organic compound formed. [2]

[Total: 20]

1 (a) (i) $2Fe^{3+}(aq) + Sn^{2+}(aq) \longrightarrow 2Fe^{2+}(aq) + Sn^{4+}(aq)$ [1]

ignore state symbols

(ii) [2]

titration number	1	2	3
initial burette reading / cm^3	0.00	19.95	2.10
final burette reading / cm^3	19.95	39.05	22.15
titre / cm^3	19.95	20.00	20.05

average volume of KI used $= \frac{1}{3}(19.95 + 20.00 + 20.05)$
$= \underline{20.00\ cm^3}$

$n(K_2Cr_2O_7)$ required $= \frac{20.00}{1000} \times 0.100$
$= \underline{0.00200\ mol}$

[1]: correctly determine the titre for run 2 and 3 and used all 3 titres to find the average titre (accept if students used any 2 titres which are within 0.05 cm^3)
[1]: $n(K_2Cr_2O_7)$

(iii) $6Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \longrightarrow 6Fe^{3+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$ [1]

ignore state symbols

(iv) $n(Fe^{2+})$ in 25.0 cm^3 of solution = 6 x 0.00200 [2]
= 0.0120 mol
$n(Fe^{2+})$ in 250 cm^3 of solution = 0.0120 x 10
= $\underline{0.120\ mol}$

mass of Fe present = 0.120 x 55.8
= 6.696 g

% by mass of iron in the sample of iron ore $= \frac{6.696}{11.05} \times 100\%$
$= \underline{60.6\ \%}$

[1]: $n(Fe^{2+})$ originally present in 250 cm^3 (scaling)
[1]: % by mass of iron in iron ore (ecf)

2 **(a)** **(i)** PSI of PM10 = $\frac{200-100}{350-150}(320-150)+100$ = $\underline{185}$ [2]

PSI of CO = $\frac{300-200}{34-17}(20-17)+200$ = $\underline{218}$

[1] each

(ii) overall PSI is the maximum value out of 185, 218, 112, 133 and 150. Hence overall PSI is 218. [1] ecf

(iii) I would advise the PE teacher to avoid strenuous physical exertion / conduct the lesson indoor (words to the effect based on valid reasoning). [1] ecf

(b) **(i)** $SO_2 + 2H_2O \longrightarrow SO_4^{2-} + 4H^+ + 2e^-$ (x 5) [1]

$2IO_3^- + 12H^+ + 10e^- \longrightarrow I_2 + 6H_2O$

overall: $\mathbf{5SO_2 + 4H_2O + 2IO_3^- \longrightarrow 5SO_4^{2-} + 8H^+ + I_2}$

(ii) $H^+ + OH^- \longrightarrow H_2O$ [2]

n(NaOH) reacted = 0.01 x 0.005
= 5 x 10^{-5} mol

n(H^+) reacted with NaOH = 5 x 10^{-5}

n(SO_2) in 1 m^3 sample of air = 5 x 10^{-5} x $\frac{5}{8}$
= $\underline{3.125 \times 10^{-5}\ \text{mol}}$

mass of SO_2 in 1 m^3 sample of air = 3.125 x 10^{-5} x 64.1
= 0.00200 g
= 2000 μg

concentration of SO_2 = $\underline{2000}$ μg m^{-3}

[1]: [SO_2] in mol m^{-3}
[1]: [SO_2] in μg m^{-3}

(c) **(i)** In 1 m^3, [1]

mass of air is 1 kg

mass of PM10 is $\frac{2\text{x}10^{-5}}{100}$ x 1 = 2 x 10^{-7} kg = 0.0002 g = 200 μg

Hence concentration of PM10 is $\underline{200}$ μg m^{-3}

(ii) Since concentration calculated in **(c)(i)** is more than 180, the sample of air has exceeded the limit. [1] ecf

The German city of Leipzig will be fined.

3 (a) (i) carboxylic acid **[1]**
aldehyde

[1] both correct

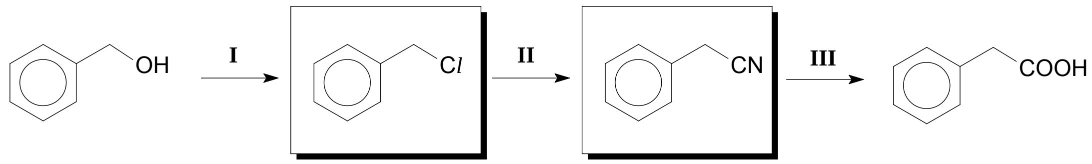
(ii) Add Tollens' reagent / 2,4–dinitrophenylhydrazine, warm (accept Fehling's) **[2]**

For aldehyde, a silver mirror (or grey ppt) is formed / orange ppt formed.
No ppt formed for carboxylic acid.

Add Na or Mg metal.
For aldehyde, no gas evolved.
For carboxylic acid, effervescence observed, gas gives a 'pop' sound with lighted splint.

[1]: reagent and condition
[1]: observation

(b) **[5]**



stage I: anhydrous PCl_5, room temp (accept $SOCl_2$, PCl_3 (w heat) or Br analogous, NaBr in concentrated H_2SO_4 (w heat))
stage II: ethanolic KCN, heat under reflux
stage III: dilute H_2SO_4, heat (accept dil. HCl)

[1] each intermediate
[1] each set of reagent and condition

(c) (i)

$$\mathbf{C_7H_6O_2 + \frac{15}{2}O_2 \longrightarrow 7CO_2 + 3H_2O}$$

(ii) **[3]**

$$\begin{array}{ccc} C_7H_6O(l) + C_7H_6O_3(s) + 15O_2(g) & \longrightarrow & 2C_7H_6O_2(s) + 15O_2(g) \\ \uparrow \Delta H_1^{\ominus} & & \downarrow \Delta H_3^{\ominus} \\ 14C(s) + 6H_2(g) + 17O_2(g) & \xrightarrow{\Delta H_2^{\ominus}} & 14CO_2(s) + 6H_2O(l) \end{array}$$

$\Delta H_1^{\ominus} = \Delta H_f^{\ominus}\ C_7H_6O(l) + \Delta H_f^{\ominus}\ C_7H_6O_3(s)$
$= (-87) + (-367)$
$= \underline{-454 \text{ kJ mol}^{-1}}$

$\Delta H_2^{\ominus} = 14\Delta H_c^{\ominus}$ carbon $+ 6\Delta H_c^{\ominus}$ hydrogen
$= 14\ (-393.5) + 6(-285.8)$
$= \underline{-7223.8 \text{ kJ mol}^{-1}}$

$\Delta H_3^{\ominus} = 2\Delta H_c^{\ominus}\ C_7H_6O_2(s)$
$= 2(-3228)$
$= \underline{-6456 \text{ kJ mol}^{-1}}$

[1] each unknown enthalpy change

(iii) By Hess' Law, [1]

$\Delta H_r^\ominus$ for reaction 1 $= -\Delta H_1^\ominus + \Delta H_2^\ominus - \Delta H_3^\ominus$

$= -(-454) + (-7223.8) - (-6456)$

$= \underline{-314 \text{ kJ mol}^{-1}}$

4 **(a)** **(i)** stage I: $K_2Cr_2O_7$, dilute H_2SO_4, warm with immediate distillation [2]

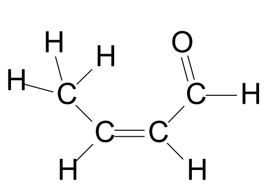
stage III: H_2, Pt / Pd, room temperature (accept Ni, with or w/o warm/heat)

[1] each

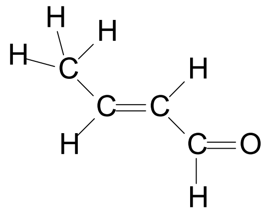
(ii) condensation [1]

$CH_3CHO + CH_3CHO \longrightarrow CH_3CH{=}CHCHO + H_2O$ (equation not required)

(iii) cis–trans isomerism [2]

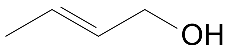


cis



trans

[1]: type of isomerism with correct label
[1]: displayed structure

(iv)  [2]

G is reduced to **H** (an alcohol) which reacts with sodium metal to give effervescence of H_2. **H** reacts with aqueous Br_2 because of the C=C bond present.

[1]: structure of **H**
[1]: explanation

(b) **(i)** compounds with the same molecular formula but different structural formula / structure [1]

(ii) [2]

$CH_3CH_2CH(OH)CH_3$	$CH_3CH(CH_3)CH_2OH$	$(CH_3)_3COH$
J	**K**	**L**
2^o	1^o	3^o

[1]: all 3 structural isomers correctly identified and labelled (in any order)
[1]: corresponding classification of 3 alcohols

(iii) **J** reacts with alkaline aqueous iodine [2]

$CH_3CH_2CH(OH)CH_3 + 4I_2 + 6OH^- \longrightarrow CH_3CH_2CO_2^- + CHI_3 + 5I^- + 5H_2O$

[1]: correctly identified the alcohol with positive reaction with I_2/OH^-
[1]: balanced equation

5 (a) (i) NaC*l* exists as a giant ionic lattice with strong electrostatic forces of attraction between Na^+ and Cl^- ions. A lot of energy is required to break these strong ionic bonds in order to melt NaC*l*. Hence, it has a very high melting point. [1]

$AlCl_3$, CCl_4 and $SiCl_4$ are simple molecular molecules with weak instantaneous dipole–induced dipole attraction between the molecules. Hence, they have low melting points. [1]

(ii) NaC*l* dissolves in water without further reaction to give a neutral solution (pH 7). Hydrolysis does not occur for Na^+ and Cl^-. [6] max

$NaCl(s) \longrightarrow Na^+(aq) + Cl^-(aq)$

$AlCl_3$ dissolves in water with some hydrolysis (due to the large polarising power of Al^{3+} ions) to give an acidic solution (pH 3)

$[Al(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H_3O^+(aq)$

CCl_4 will not undergo hydrolysis. (pH 7)
This is because CCl_4 has no vacant low–lying (energetically accessible) d–orbitals to accept the lone pair of electrons from the water molecules.
or
(steric hindrance) it is difficult for the water molecule to attack the carbon atoms due to the large chlorine atoms present.

$SiCl_4$ undergo complete hydrolysis in water to give a strongly acidic solution due to the presence of empty low–lying 3d orbitals to accommodate the lone pair of electrons from water molecules. (pH 1)

$SiCl_4 + 2H_2O \longrightarrow SiO_2 + 4HCl$
$SiCl_4 + 4H_2O \longrightarrow SiO_2.2H_2O + 4HCl$
$SiCl_4 + 4H_2O \longrightarrow Si(OH)_4 + 4HCl$

[1] each description with correct pH
[1] each balanced equation

(b) (i) Valence electron pairs (bond pairs and lone pairs) around an atom of a molecule arrange themselves as far apart as possible to minimise inter–electronic repulsion. [1]

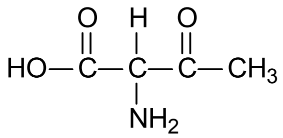
The strength of repulsion between electron pairs decreases in the order: lp–lp > lp–bp > bp–bp. [1]

Since there are 2 bond pairs and 1 lone pair around N atom, bond angle will be 117°. (accept 110° < angle < 120°) [1]

(ii) Type: substitution [1]
Conditions: Br_2, $AlBr_3$ or $FeBr_3$ catalyst [1]

(iii) instantaneous dipole–induced dipole / permanent dipole–permanent dipole / van der Waals [1]

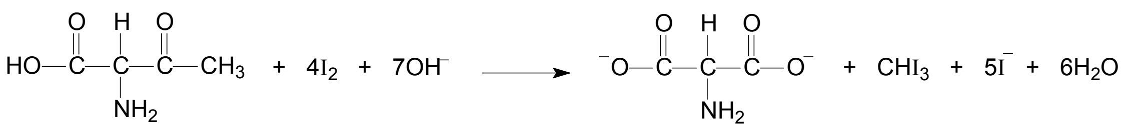
(c) [6]



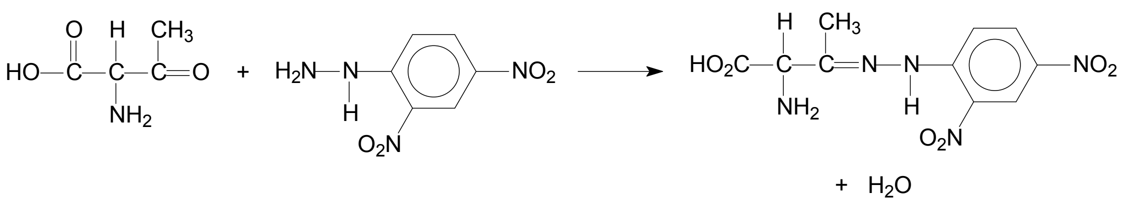
W

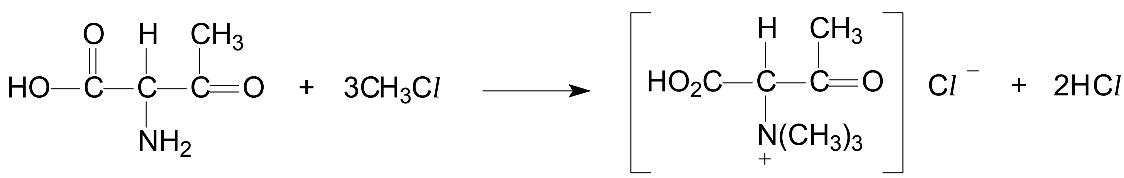
Observations	Type of reaction	Deduction
Compound **W** contains a primary amine functional group.		**W** contains R–NH_2.
W gives an orange precipitate when treated with 2,4–DNPH but it has no reaction with Tollens' reagent.	condensation	**W** is a ketone not an aldehyde.
W gives a yellow precipitate when warmed with alkaline aqueous iodine.	(mild) oxidation	**W** contains the structure $RCOCH_3$ or $RCH(OH)CH_3$.
W has a proton chemical shift (δ) of 13.0 ppm.		from page 34 of the *Data Booklet*, **W** contains –COOH.
W is heated with excess CH_3Cl, it gives $C_7H_{14}NO_3Cl$, as the major product.	substitution	further / multi–substitution occurs / product is a substituted amine

[2]: 5–8 points
[1]: 2–4 points



(accept if –CO_2H is not neutralised, i.e. $6OH^-/5H_2O$)





[1]: structure of **W**
[2]: deductions and types of reactions
[1] each balanced equation

6 **(a)** **(i)** $MgCl_2(s) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq)$ [1]

$Mg(H_2O)_6^{2+}(aq) + H_2O(l) \rightleftharpoons Mg(H_2O)_5(OH)^+(aq) + H_3O^+(aq)$

(ignore state symbol and if 1st equation is not given)

(ii) [1]

$$K_a = \frac{[Mg(H_2O)_5(OH)^+][H_3O^+]}{[Mg(H_2O)_6^{2+}]}$$

(iii) from the graph, pH = 6 [1]

$[H^+] = 10^{-6}$

$= \underline{1 \times 10^{-6} \text{ mol dm}^{-3}}$

(iv) [1]

(I) yellow

(II) yellowish pink / pinkish yellow

(III) orange pink

(b) **(i)** Activation energy of reverse reaction = 9.6 + 173.2 [1]

$= \underline{182.8 \text{ kJ mol}^{-1}}$

(ii) High pressure [6]

Position of equilibrium (P.O.E.) remains unchanged since there are equal number of moles of gaseous reactants and products particles.

Rate will increase since there are more gaseous particles per unit volume thus increases the frequency of effective collisions.

High temperature

P.O.E. shifts left, since backward endothermic reaction is favoured to remove the excess heat.

Rate will increase as the average kinetic energy of particles is increased, leading to greater frequency of effective collisions.

Presence of catalyst

P.O.E. remains unchanged, as the rate of the forward and reverse reaction increase by the same extent.

Rate of reaction will increase since the presence of catalyst provides an alternative pathway of lowered activation energy. More reactant molecules will possess energy greater than or equal to the activation energy, leading to greater frequency of effective collisions.

[1] each effect on P.O.E.

[1] each effect on rate of reaction

(d) **(i)** Taking gradient at t = 0, [1]

$$\text{set 1} = \frac{0.004}{8}$$

$= \underline{5 \times 10^{-4} \text{ mol dm}^{-3} \text{ min}^{-1}}$

$$\text{set 2} = \frac{0.004}{4}$$

$= \underline{1 \times 10^{-3} \text{ mol dm}^{-3} \text{ min}^{-1}}$

[1] both correct (accept 6–8 min for set 1, 3–4min for set 2)

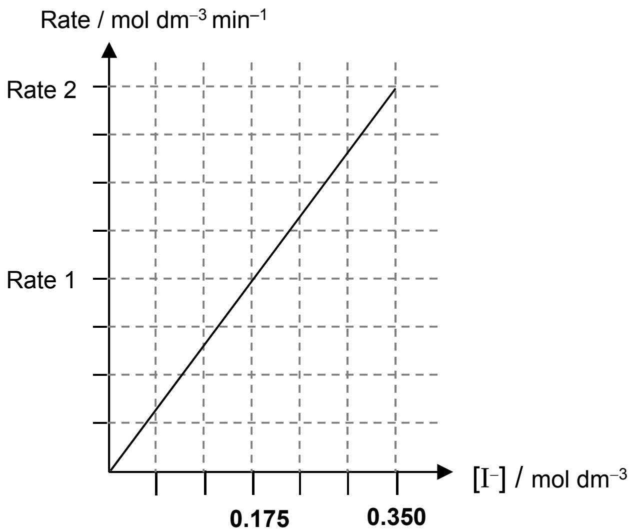
(ii) When $[H^+]$ decreases from 0.004 mol dm^{-3} to 0.002 mol dm^{-3}, time taken is 3 min [2]
When $[H^+]$ decreases from 0.002 mol dm^{-3} to 0.001 mol dm^{-3}, time taken is 3 min
Since $t_{½}$ is constant at 3 min, order of reaction wrt H^+ is <u>1</u>.

	$[H_2O_2]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	initial rate / mol dm^{-3} min^{-1}
Set 1	0.200	0.175	0.004	0.0005
Set 2	0.200	0.350	0.004	0.001

Comparing **Set 1** and **Set 2**, when concentration of $[I^-]$ is doubled, the rate is also <u>doubled</u>. Since rate is directly proportional to $[I^-]$, order of reaction wrt $[I^-]$ is <u>1</u>.

[1] each order of reaction

(iii) [2]



[1]: straight line passing thru the origin
[1]: labels using both sets of data

(iv) Based on student's guess, rate = $k\,[H_2O_2]^2\,[H^+]\,[I^-]$ [2]

$$\frac{\text{rate}_3}{\text{rate}_1} = \frac{(0.3)^2(0.004)(0.10)}{(0.2)^2(0.004)(0.175)}$$

rate_3 = 1.28 x 0.0005
= <u>6.43 x 10^{-4} mol dm^{-3} min^{-1}</u>

<u>Alternative</u>

	$[H_2O_2]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	initial rate / mol dm^{-3} min^{-1}
Set 1	0.2	0.175	0.004	0.0005
Set 1a	*0.2*	*0.10*	*0.004*	*0.000286*
Set 3	0.3	0.10	0.004	0.000644

When $[I^-]$ is decreased from 0.175 to 0.10 mol dm^{-3},

rate = 0.0005 x $\left(\frac{0.10}{0.175}\right)$ = 0.000286 mol dm^{-3}.

When [H_2O_2] is increased from 0.2 to 0.3 mol dm^{-3},

rate = 0.000286 x $\left(\frac{0.30}{0.20}\right)^2$ = $\underline{0.000644 \text{ mol dm}^{-3}}$

[1]: proportional decrease in rate when [I^-] decreases by 1.75.
[1]: rate increases by $(1.5)^2$ when [H_2O_2] increases by 1.5.

(v) Rate = k [H_2O_2] [I^-] [H^+] [2]
$4.4 \times 10^{-5} = k(0.002)(0.2)(0.2)$
$k = \underline{0.550 \text{ mol}^{-2} \text{ dm}^6 \text{ s}^{-1}}$

[1]: value of k
[1]: units

7 **(a)** **(i)** I.E. decreases down the group [2]
Nuclear charge increases, the number of electron shells also increases and valence electrons are further away from the nucleus.
nuclear charge attraction experienced by the valence electron decreases.

[1]: trend
[1]: explanation in terms of weaker attraction due to valence electron being further from nucleus / at a higher energy level

(ii) I.E. of Se is lower [2]
Se has one proton less (smaller nuclear charge) but relatively constant shielding effect and effective nuclear charge is smaller in Se
nuclear charge attraction experienced by the valence electron is weaker.

[1]: I.E. of Se is lower
[1]: explanation in terms of ENC

(b) **(i)** no. of protons = 52 [3]
= no. of electrons
no. of neutrons = 128 – 52
= 76

electronic configuration of Te: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^4$
electronic configuration of Te: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^2$
(accept abbreviated electronic configuration: [Kr] $4d^{10}$ $5s^2$ $5p^2$)

[1]: no. of protons and electrons
[1]: no. of neutrons
[1]: electronic configuration

(ii) TeO_3 [1]

(iii) TeO_3 has a simple molecular structure with weak intermolecular forces (id–id / vdW) [2]

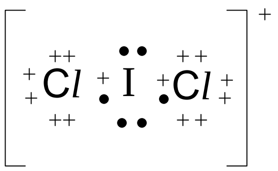
hence likely to be a volatile liquid or solid with low bp / m.p. that does not conduct electricity in all states

[1]: either physical property
[1]: structure and bonding

(iv) Hydrolysis [1]
$$\mathbf{TeO_3 + H_2O \longrightarrow H_2TeO_4}$$

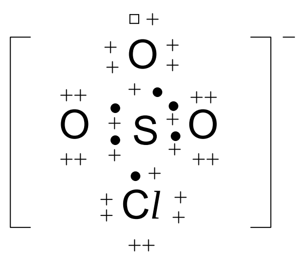
(c) **(i)** [4]

ICl_2^+



shape: bent

SO_3Cl^-



shape: tetrahedral

[1] each dot-and-cross
[1] each shape

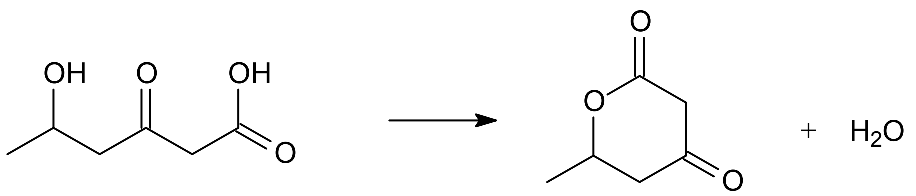
(ii) $H_2SO_4 + H_2O \rightleftharpoons HSO_4^- + H_3O^+$ [2]
$H_2SO_3 + H_2O \rightleftharpoons HSO_3^- + H_3O^+$

The HSO_4^- conjugate base has an additional electronegative O atom. This results in a greater electron–withdrawing effect which allows the negative charge on the anion is to be dispersed to a larger extent, stabilizing the anion.
The dissociation of H_2SO_4 is more favoured, POE will be shifted more to the right.

[1]: identify presence of an additional O atom in HSO_4^-
[1]: greater dispersal of charge

(d) **(i)** catalyst / dehydrating agent (do not accept drying agent) [1]

(ii) [2]



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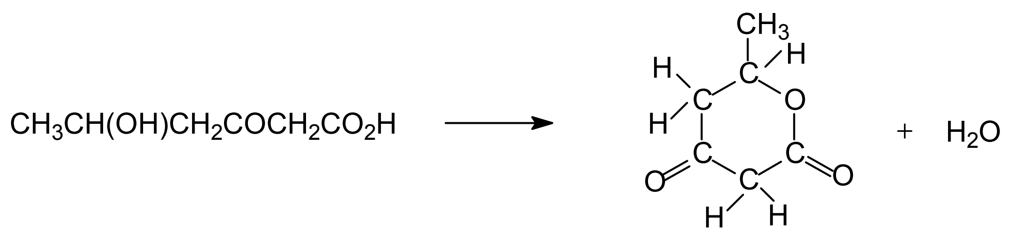

[1]: structural formula of organic product
[1]: balanced equation

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ANGLO-CHINESE JUNIOR COLLEGE
DEPARTMENT OF CHEMISTRY
Preliminary Examination

CHEMISTRY **8872/01**
Higher 1

Paper 1 Multiple Choice

24 August 2017

50 minutes

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 fluids.
Write your name, index number and tutorial class 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.

Section A

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

1 Ether has the formula, CH_3OCH_3.

In a sample of ether, 8.7 % contains the ^{18}O isotope, with the rest contains the ^{16}O isotope.

What is the relative molecular mass of ether in this sample?

A 46.2

B 46.8

C 47.2

D 47.8

2 Copper reacts with dilute nitric acid to produce nitrogen dioxide gas. The balanced ionic equation is given.

$$Cu + 2H^+ + 2HNO_3 \rightarrow Cu^{2+} + 2NO_2 + 2H_2O$$

Which of the following is correct?

	Oxidation state of N in		Role of copper
	HNO_3	NO_2	
A	+5	-3	Reducing agent
B	+5	+4	Reducing agent
C	-5	-3	Oxidising agent
D	-5	+4	Oxidising agent

3 10 cm^3 of propane was completely burnt in $\boldsymbol{x}$ cm^3 of excess oxygen. After cooling to room temperature, the volume of the residual gas was 60 cm^3. The residual gas was passed through aqueous sodium hydroxide was passed through and the volume reduced to $\boldsymbol{y}$ cm^3.

Which of the following is correct?

	x	y
A	50	30
B	60	20
C	70	20
D	80	30

4 An organic compound with the formula $C_xH_yO_2$ has undergone incomplete combustion, producing carbon dioxide and carbon monoxide in the ratio of 99 : 1.

The equation may be represented as follows:

$$C_xH_yO_2 + \underline{\;\boldsymbol{a}\;}\,O_2 \rightarrow \underline{\;\boldsymbol{b}\;}\,CO + \underline{\;\boldsymbol{c}\;}\,CO_2 + 0.5\boldsymbol{y}\;H_2O$$

$\boldsymbol{a}$, $\boldsymbol{b}$ and $\boldsymbol{c}$ can be expressed in terms of $\boldsymbol{x}$ and $\boldsymbol{y}$.

Which of the following is correct?

	a	b	c
A	99x + 0.5x + 0.25y - 1	x	99x
B	99x + 0.5x + 0.25y	x	99x
C	0.99x + 0.005x + 0.25y- 1	0.01x	0.99x
D	0.99x + 0.005x + 0.25y	0.01x	0.99x

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

The components of a 100 g sample of fertilizer is as shown in the table below:

Element	**Mass / g**
N	15
P	30
K	15
Other Elements	40

The recommended usage of fertilizer is 14 g of fertilizer per 5 dm^3 of water.

What is the concentration of nitrogen atoms in this recommended solution?

A 0.03 mol dm^{-3}

B 0.15 mol dm^{-3}

C 0.42 mol dm^{-3}

D 0.75 mol dm^{-3}

6 The elements **X** and **Y** are in Group 16 and 17 respectively in the same period.

Which of the following statements regarding **X** and **Y** is most likely to be true?

A **Y** has more unpaired electrons than **X**.

B **Y** atom is bigger than **X** atom.

C **X** is more electronegative than **Y**.

D The first ionisation energy of **X** will likely be less endothermic than that of **Y**.

7 The table gives the successive ionisation energies for an element *X*.

	1st	2nd	3rd	4th	5th	6th
Ionisation energy/ $kJ\ mol^{-1}$	950	1800	2700	4800	6000	12300

What could be the formula of the fluoride of *X*?

A XF

B XF_2

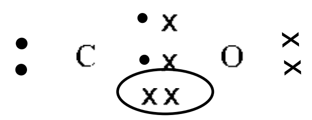
C XF_3

D XF_4

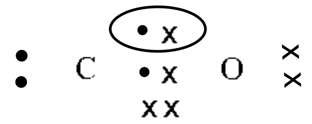
8 'Dot-and-cross' diagrams for CO are shown below.

Which circle pair of electrons represent a co-ordinate bond?

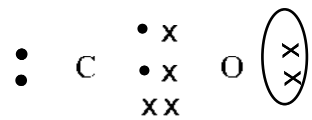
A



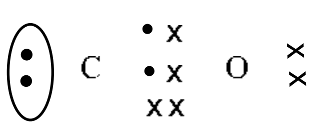
B



C



D



9 Which of the following molecules is linear and non-polar?

A CS_2

B SCN

C SO_2

D SiO_2

10 Consider the following four compounds.

1 $CH_3CH_2CH_2F$

2 $CH_3CH_2CH_2OH$

3 $CH_3CH_2CH_2CH_3$

4 $(CH_3)_3CH$

What is the order of increasing boiling points of the compounds (from lowest to highest)?

A $2 \rightarrow 1 \rightarrow 3 \rightarrow 4$

B $4 \rightarrow 3 \rightarrow 2 \rightarrow 1$

C $3 \rightarrow 1 \rightarrow 2 \rightarrow 4$

D $4 \rightarrow 3 \rightarrow 1 \rightarrow 2$

11 The enthalpy changes for two reactions are given by the equations:

$$2Cr(s) + \frac{3}{2}O_2(g) \rightarrow Cr_2O_3(s) \qquad \Delta H = -1130\ kJ\ mol^{-1}$$

$$C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g) \qquad \Delta H = -110\ kJ\ mol^{-1}$$

What is the enthalpy change, in kJ mol^{-1}, for the following reaction?

$$3C(s) + Cr_2O_3(s) \rightarrow 2Cr(s) + 3CO(g)$$

A -800

B +800

C -1460

D +1460

12 Hydrogencarbonate may react with acid according to the equation below.

$$HCO_3^-(aq) + H^+(aq) \longrightarrow H_2O(l) + CO_2(g) \qquad \Delta H^\theta = +12.7 \text{ kJ mol}^{-1}$$

Using the following enthalpy changes of formation provided, what is the standard enthalpy change of formation of $H^+(aq)$?

species	ΔH_f^θ / kJ mol^{-1}
$H_2O(l)$	–285.8
$CO_2(g)$	–393.5
$HCO_3^-(aq)$	–692.0

A –25.4 kJ mol^{-1}

B 0.0 kJ mol^{-1}

C +25.4 kJ mol^{-1}

D +1384 kJ mol^{-1}

13 In an experiment, 70 cm^3 of water at 25 °C was brought to boil by burning butane in excess oxygen. Calculate the volume of butane required if this process is only 85 % efficient.

[ΔH_c (butane) = –2877 kJ mol^{-1}; c = 4.2 J g^{-1} K^{-1}; Molar volume of gas under the given conditions = 24 dm^3]

A 0.0721 dm^3 **B** 0.156 dm^3 **C** 0.184 dm^3 **D** 0.216 dm^3

14 Which statement concerning the equilibrium reaction given below is correct?

$$\underset{\text{yellow}}{2CrO_4^{2-}(aq)} + 2H^+(aq) \rightleftharpoons \underset{\text{orange}}{Cr_2O_7^{2-}(aq)} + H_2O(l)$$

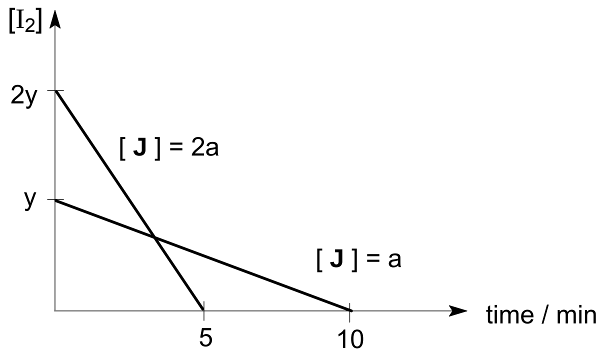
A It is a redox reaction.

B The equilibrium constant, K_c, has the units of mol^{-2} dm^6.

C The colour of the solution change from orange to yellow when pH increases.

D The addition of a catalyst will result in an increase in the concentration of $Cr_2O_7^{2-}(aq)$.

15 The kinetics of the reaction between iodine and compound **J** is investigated.



What conclusions can be drawn from the graphs?

A The reaction is second order with respect to compound **J** because rate of reaction increases by four times when its concentration is increased by two times.

B Both iodine and compound **J** react in equal mole ratio.

C The reaction is first order with respect to iodine because half-life is constant.

D The overall order of the reaction is 1.

16 **X**, **Y** and **Z** are elements in Period 3 of the Periodic Table.

A mixture containing the oxides of **X**, **Y** and **Z** was dissolved in excess dilute sulfuric acid and filtered. The oxide of **Z** was collected as a residue. When excess dilute sodium hydroxide was added to the filtrate, only a white precipitate of the hydroxide of **Y** was formed.

What are the possible identities of **X**, **Y** and **Z**?

	X	**Y**	**Z**
A	Mg	A*l*	P
B	A*l*	Mg	P
C	Mg	A*l*	Si
D	A*l*	Mg	Si

17 The oxide and chloride of an element **X** are separately mixed with water. The two resulting solutions have the same effect on litmus solution.

What is element **X**?

A Sodium

B Magnesium

C Aluminum

D Phosphorus

18 Which property of benzene is reflected as a consequence of the delocalised electrons present in its molecule?

A Benzene is cyclic.

B Benzene is a planar molecule.

C Benzene is a good conductor of electricity.

D Substitution on benzene takes place more easily than addition reactions.

19 2-methylpropylamine, $(CH_3)_2CHCH_2NH_2$ can be produced by the following reaction scheme starting with compound **B**.

$$\mathbf{B} \xrightarrow[\text{ethanol}]{\text{KCN in}} \mathbf{C} \xrightarrow{\text{reduction}} \text{2-methylpropylamine}$$

Which one of the following compounds is **B** likely to be?

A $CH_3CH_2CH_2Br$

B $CH_3CHBrCH_3$

C CH_3CH_2CHO

D CH_3COCH_3

20 Which of the following isomers of $C_5H_{11}Br$ gives the greatest number of different alkenes on treatment with hot ethanolic sodium hydroxide?

A $CH_3CH_2CH(CH_3)CH_2Br$

B $CH_3CH_2CH_2CHBrCH_3$

C $CH_3CH_2CHBrCH_2CH_3$

D $CH_3CH_2CH_2CH_2CH_2Br$

21 Four drops of 1-chorobutane, 1-bromobutane and 1-iodobutane were separately added to three test-tubes containing 1.0 cm^3 of aqueous silver nitrate at 60 °C. The following reaction occurred.

$$H_2O(l) + R{-}X(l) + Ag^+(aq) \rightarrow R{-}OH(aq) + AgX(s) + H^+(aq)$$

[R: C_4H_9–; X: halogen]

Which of the following best explains why the rate of formation of cloudiness (precipitate) in the tubes was in the order RC*l* < RBr < RI?

A The R–X bond polarity decreases from RC*l* to RI.

B The bond energy of R–X decreases from RC*l* to RI.

C The solubility of AgX(s) decreases from AgC*l* to AgI.

D The ionisation energy of the halogen decreases from C*l* to I.

22 Which one of the following compounds:

(i) is unaffected by hot alkaline potassium manganate(VII);

(ii) produces 0.5 mol of hydrogen when 1 mol of compound is treated with excess sodium?

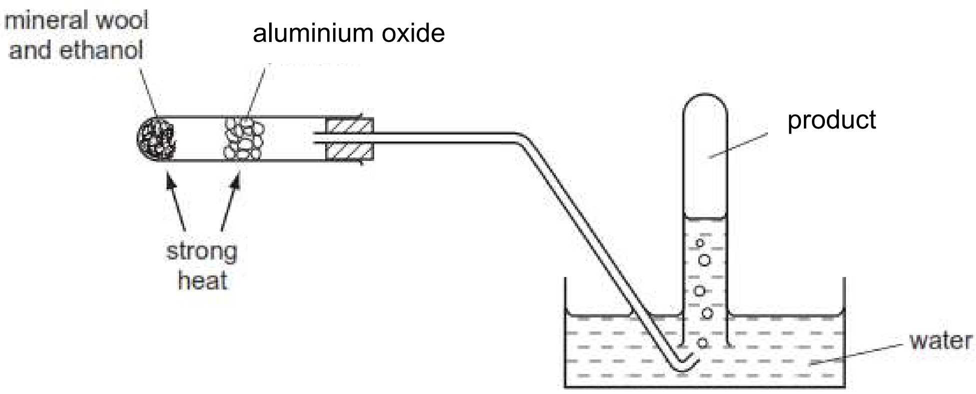
A $(CH_3)_2C(OH)C(OH)(CH_3)CH_2CH_3$

B $(CH_3)_2CHCH_2OH$

C $(CH_3)_3COH$

D $CH_3CH(OH)CH(OH)CH_3$

23 The diagram shows an experimental set-up.



Which compound can be produced by using the above apparatus?

A Oxygen

B Hydrogen

C Ethene

D Ethane

24 An alcohol of molecular formula $C_4H_{10}O_2$ contains two -OH groups and has an unbranched carbon chain.

On reaction with an excess of acidified potassium manganate(VII), this alcohol is converted into a compound of molecular formula $C_4H_6O_4$.

To which two carbons in the chain of the alcohol are the two -OH groups attached?

A 1st and 2nd

B 1st and 3rd

C 1st and 4th

D 2nd and 3rd

25 Which of the following reagents and conditions can distinguish between ethyl methanoate and ethyl ethanoate?

A Heat with NaOH(aq)

B Heat with H_2SO_4(aq)

C Heat with NaOH(aq) followed by Na_2CO_3(aq)

D Heat with acidified $KMnO_4$(aq)

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 The pH range and colour changes for two indicators are given below.

Indicator	**pH range**
X	violet 3.0 – 5.0 red
Y	yellow 5.6 – 7.6 blue

Which of the following solutions will give a red solution when indicator **X** is used and a yellow solution when indicator **Y** is used?

1 0.1 mol dm^{-3} HX (K_a = 2.5 x 10^{-10} mol dm^{-3})

2 0.1 mol dm^{-3} CH_3COOH (K_a = 1.8 x 10^{-5} mol dm^{-3})

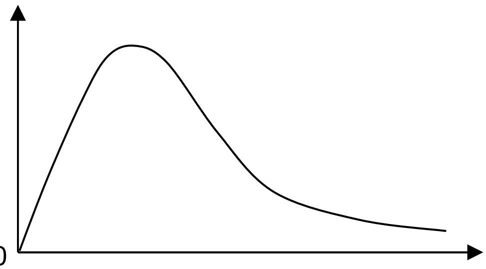
3 0.1 mol dm^{-3} HC*l*

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

27 The graph below shows the Boltzmann distribution of molecular energies at a given temperature.



As temperature increases, which statements are correct?

1 The proportion of molecules with any given energy increases.

2 The maximum of the curve is displaced to the right.

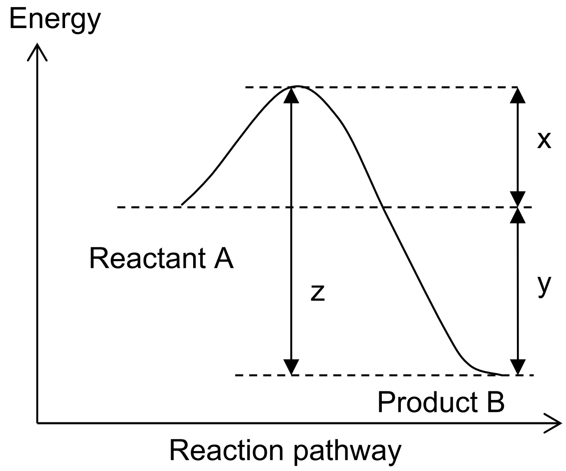
3 The proportion of molecules with energies above any given value increases.

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

28 The energy profile for a reversible reaction is shown below.



Which of the following statement is/are **correct**?

1 The reaction from **B** to **A** is endothermic.

2 The activation energy of the reaction **A** to **B** is *x*.

3 The activation energy of the reaction **B** to **A** is *z* - *y*.

29 Which of the following show an increase in radius?

1 Al < Mg < Na

2 Cl^{-} < S^{2-} < P^{3-}

3 Na^{+} < Ca^{2+} < K^{+}

The responses **A** to **D** should be selected on the basis of

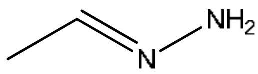
A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

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

Carbonyl compounds react with hydrazine, N_2H_4, in the same manner as 2,4-dintrophenylhydrazine.

Which of the following are correct?

1 The product is  when ethanal reacts with hydrazine.

2 The enthalpy change of the reaction is negative.

3 It is a condensation reaction.

END OF PAPER

Section A

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

1 Ether has the formula, CH_3OCH_3.

In a sample of ether, 8.7 % contains the ^{18}O isotope, with the rest contains the ^{16}O isotope.

What is the relative molecular mass of ether in this sample?

A 46.2

B 46.8

C 47.2

D 47.8

Ar of O = 8.7 x 18 + 91.3 x 16 /100 = 16.174
Relative Molecular Mass = 16.174 + 12 + 3+ 12 + 3 = 46.174 = 46.2

2 Copper reacts with dilute nitric acid to produce nitrogen dioxide gas. The balanced ionic equation is given.

$$Cu + 2H^+ + 2HNO_3 \rightarrow Cu^{2+} + 2NO_2 + 2H_2O$$

Which of the following is correct?

	Oxidation state of N in		Role of copper
	HNO_3	NO_2	
A	+5	-3	Reducing agent
B	+5	+4	Reducing agent
C	-5	-3	Oxidising agent
D	-5	+4	Oxidising agent

Cu is being oxidised. It is a reducing agent.
HNO_3 = (+1)+ ? + 3(-2) =0
? = +5

NO_2 = ？ + 2（-2）= 0
？ = +4

3 10 cm^3 of propane was completely burnt in x cm^3 of excess oxygen. After cooling to room temperature, the volume of the residual gas was 60 cm^3. The residual gas was passed through aqueous sodium hydroxide was passed through and the volume reduced to y cm^3.

Which of the following is correct?

	x	y
A	50	30
B	60	20
C	70	20
D	80	30

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

10cm^3 requires 50cm^3 of oxygen for complete combustion and 30cm^3 of CO_2 will be produced. Hence x = 50 + (60-30) = 80 cm^3. y = volume of excess oxygen = 60-30 cm^3

4 An organic compound with the formula $C_xH_yO_2$ has undergone incomplete combustion, producing carbon dioxide and carbon monoxide in the ratio of 99 : 1.

The equation may be represented as follows:

$$C_xH_yO_2 + \underline{\ a\ }O_2 \rightarrow \underline{\ b\ }CO + \underline{\ c\ }CO_2 + 0.5y\ H_2O$$

a, b and c can be expressed in terms of x and y.

Which of the following is correct?

	a	b	c
A	99x + 0.5x + 0.25y - 1	x	99x
B	99x + 0.5x + 0.25y	x	99x
C	0.99x + 0.005x + 0.25y- 1	0.01x	0.99x
D	0.99x + 0.005x + 0.25y	0.01x	0.99x

C = 0.01x + 0.99x = x
Check by balancing O atoms on both sides,
2 + 2(0.99x + 0.005x + 0.25y- 1) = 0.01x + 0.99x(2) + 0.5y
1.98x+ 0.01x+0.50y = 1.99x + 0.5y

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

The components of a 100 g sample of fertilizer is as shown in the table below:

Element	**Mass / g**
N	15
P	30
K	15
Other Elements	40

The recommended usage of fertilizer is 14 g of fertilizer per 5 dm^3 of water.

What is the concentration of nitrogen atoms in this recommended solution?

A 0.03 mol dm^{-3}

B 0.15 mol dm^{-3}

C 0.42 mol dm^{-3}

D 0.75 mol dm^{-3}

15/100 x 14grams = 2.1 grams
No of moles of N = 2.1/14 = 0.15mol
Concentration = 0.15/5 = 0.03 mol dm^{-3}

6 The elements **X** and **Y** are in Group 16 and 17 respectively in the same period.

Which of the following statements regarding **X** and **Y** is most likely to be true?

A **Y** has more unpaired electrons than **X**.

B **Y** atom is bigger than **X** atom.

C **X** is more electronegative than **Y**.

D The first ionisation energy of **X** will likely be less endothermic than that of **Y**.

X: ns^2np^4
Y: ns^2np^5 => less unpaired electrons than X

Y has more protons than X. Thus Y would be smaller than X. The electrons are more strongly attracted to the nucleus in Y than X. Thus Y would be more electronegative than X. More energy is needed to remove 1^{st} electron from its nucleus.

7 The table gives the successive ionisation energies for an element *X*.

	1st	2nd	3^{rd}	4th	5th	6th
ionisation energy/ $kJ\ mol^{-1}$	950	1800	2700	4800	6000	12300

What could be the formula of the fluoride of *X*?

A *X*F

B XF_2

C XF_3

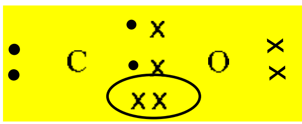
D XF_4

The greatest jump in energy is between 3^{rd} and 4^{th} IE. Thus 3 valence electrons are in X which means that the highest oxidation number of X is +3.

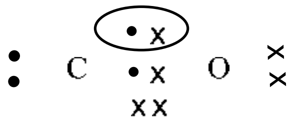
8 'Dot-and-cross' diagrams for carbon monoxide are shown below.

Which circle pair of electrons represent a co-ordinate bond?

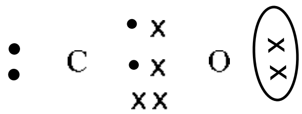
A



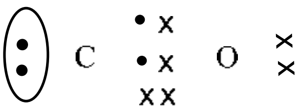
B



C



D



Coordinate bond is a covalent bond in which both electrons come from the same atom.

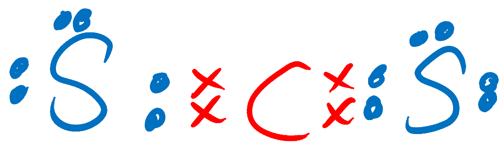
9 Which of the following molecules is linear and non-polar?

A CS_2

B SCN

C SO_2

D SiO_2



10 Consider the following four compounds.

1 $CH_3CH_2CH_2F$

2 $CH_3CH_2CH_2OH$

3 $CH_3CH_2CH_2CH_3$

4 $(CH_3)_3CH$

What is the order of increasing boiling points of the compounds (from lowest to highest)?

A 2 ⟶ 1 ⟶ 3 ⟶ 4

B 4 ⟶ 3 ⟶ 2 ⟶ 1

C 3 ⟶ 1 ⟶ 2 ⟶ 4

D 4 ⟶ 3 ⟶ 1 ⟶ 2

Compound 2 has hydrogen bonds between its molecules. Compound 1 is polar and has pd-pd interactions between its molecules.

Compound 3 and 4 are both structural isomers. Compound 3 is linear whereas compound 4 is branched. Thus compound 3 has more id-id interactions due to bigger surface area than compound 4.

11 The enthalpy changes for two reactions are given by the equations:

$2Cr(s) + \frac{3}{2}O_2(g) \rightarrow Cr_2O_3(s)$ $\Delta H = -1130 \text{ kJ mol}^{-1}$

$C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$ $\Delta H = -110 \text{ kJ mol}^{-1}$

What is the enthalpy change, in kJ mol^{-1}, for the following reaction?

$$3C(s) + Cr_2O_3(s) \rightarrow 2Cr(s) + 3CO(g)$$

A -800

B +800

C -1460

D +1460

$Cr_2O_3(s) \rightarrow 2Cr(s) + \cancel{\frac{3}{2}O_2(g)}$

$3C(s) + \cancel{3/2\ O_2(g)} \rightarrow 3CO(g)$

$3C(s) + Cr_2O_3(s) \rightarrow 2Cr(s) + 3CO(g)$

Enthalpy change of reaction = -110(3) + 1130 = + 800 kJ mol^{-1}

12 Hydrogencarbonate may react with acid according to the equation below.

$HCO_3^-(aq) + H^+(aq) \longrightarrow H_2O(l) + CO_2(g)$ $\Delta H^{\ominus} = +12.7 \text{ kJ mol}^{-1}$

Using the following enthalpy changes of formation provided, what is the standard enthalpy change of formation of $H^+(aq)$?

species	ΔH_f^{θ} / kJ mol^{-1}
$H_2O(l)$	–285.8
$CO_2(g)$	–393.5
$HCO_3^-(aq)$	–692.0

A –25.4 kJ mol^{-1}

B 0.0 kJ mol^{-1}

C +25.4 kJ mol^{-1}

D +1384 kJ mol^{-1}

$\Delta H = \Delta H_f(\text{products}) - \Delta H_f(\text{reactants})$
$+12.7 = -285.8 - 393.5 - (-692.0 + \Delta H_{H^+})$
$\Delta H_{H^+} = 0$

13 In an experiment, 70 cm^3 of water at 25 °C was brought to boil by burning butane in excess oxygen. Calculate the volume of butane required if this process is only 85 % efficient.

[ΔH_c (butane) = –2877 kJ mol^{-1}; c = 4.2 J g^{-1} K^{-1}; Molar volume of gas under the given conditions = 24 dm^3]

A 0.0721 dm^3 **B** 0.156 dm^3 **C** 0.184 dm^3 **D** 0.216 dm^3

Heat absorbed = Q = mcΔT = 70 x 4.18 x 75 = 21 945 J

Heat released = 100/85 x 21 945 = 25 817 J
No of moles of butane = 25 817x10^{-3} / 2877 = 0.008973 mol
Volume = 0.008973 x 24 = 0.216 dm^3

14 Which statement concerning the equilibrium reaction given below is correct?

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

yellow orange

A It is a redox reaction.

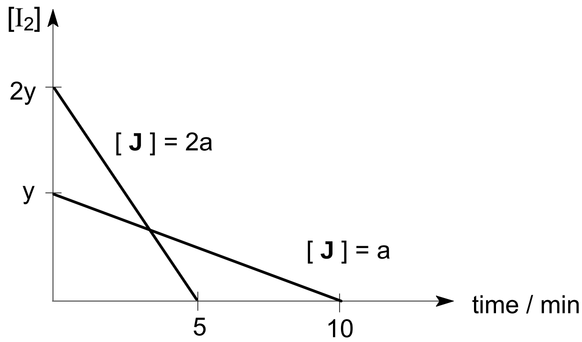
B The equilibrium constant, K_c, has the units of mol^{-2} dm^6.

C The colour of the solution change from orange to yellow when pH increases.

D The addition of a catalyst will result in an increase in the concentration of $Cr_2O_7^{2-}$(aq).

There is no change in oxidation state of Cr (+6 in both species).
K_c = $[Cr_2O_7^{2-}]/[CrO_4^{2-}]^2[H^+]^2$ hence, units is $mol^{-3}dm^9$
pH increases implies that there is a decrease in H+. By LCP, system shifts to the left as more H+ ions are produced.

15 The kinetics of the reaction between iodine and compound **J** is investigated.



What conclusions can be drawn from the graphs?

A The reaction is second order with respect to compound **J** because rate of reaction increases by four times when its concentration is increased by two times.

B Both iodine and compound **J** react in equal mole ratio.

C The reaction is first order with respect to iodine because half-life is constant.

D The overall order of the reaction is 1.

Gradient represents the rate of reaction. As [J] doubles, gradient of the graph quadruples. This implies that it is a 2nd order reaction.

16 **X**, **Y** and **Z** are elements in Period 3 of the Periodic Table.

A mixture containing the oxides of **X**, **Y** and **Z** was dissolved in excess dilute sulfuric acid and filtered. The oxide of **Z** was collected as a residue. When excess dilute sodium hydroxide was added to the filtrate, only a white precipitate of the hydroxide of **Y** was formed.

What are the possible identities of **X**, **Y** and **Z**?

	X	**Y**	**Z**
A	Mg	A*l*	P
B	A*l*	Mg	P
C	Mg	A*l*	Si
D	A*l*	Mg	Si

Z has to be an insoluble oxide which is silicon oxide. X oxide is soluble in acid and base. This X oxide is aluminium oxide which is amphoteric in nature.

17 The oxide and chloride of an element **X** are separately mixed with water. The two resulting solutions have the same effect on litmus solution.

What is element **X**?

A Sodium

B Magnesium

C Aluminum

D Phosphorus

Phosphorus oxide dissolves in water to give rise to acidic solution of phosphoric acid. Phosphorus chlorides also give rise to hydrochloric acid and phosphoric acid when it is hydrolysed in water.

18 Which property of benzene is reflected as a consequence of the delocalised electrons present in its molecule?

A Benzene is cyclic.

B Benzene is a planar molecule.

C Benzene is a good conductor of electricity.

D Substitution on benzene takes place more easily than addition reactions.

Substitution would be easier as compared to addition as resonance structure of benzene would keep the stable system intact.

19 2-methylpropylamine, $(CH_3)_2CHCH_2NH_2$ can be produced by the following reaction scheme starting with compound **B**.

$$\textbf{B} \xrightarrow[\text{ethanol}]{\text{KCN in}} \textbf{C} \xrightarrow{\text{reduction}} \text{2-methylpropylamine}$$

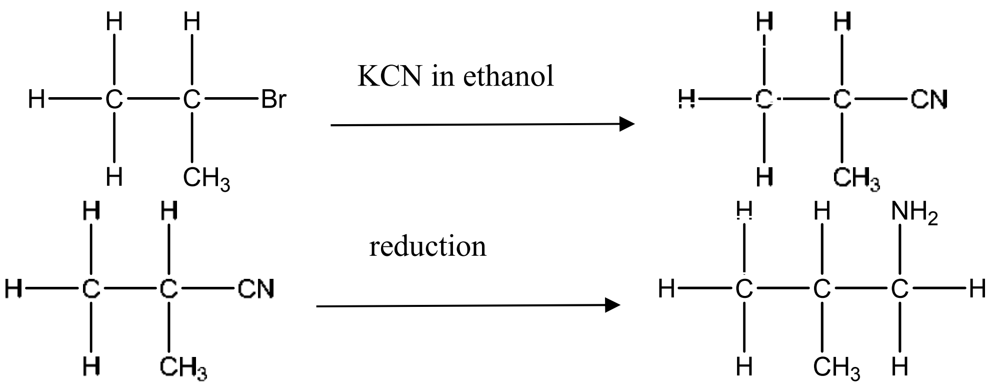
Which one of the following compounds is **B** likely to be?

A $CH_3CH_2CH_2Br$

B $CH_3CHBrCH_3$

C CH_3CH_2CHO

D CH_3COCH_3



2-methylpropylamine

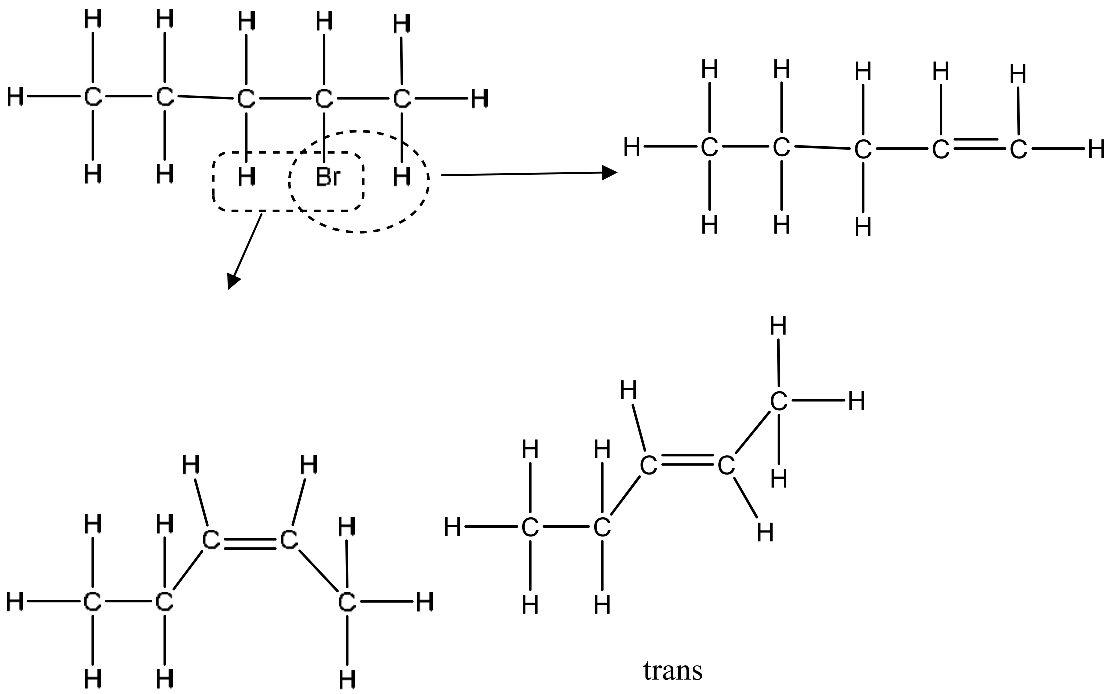
20 Which of the following isomers of $C_5H_{11}Br$ gives the greatest number of different alkenes on treatment with hot ethanolic sodium hydroxide?

A $CH_3CH_2CH(CH_3)CH_2Br$

B $CH_3CH_2CH_2CHBrCH_3$

C $CH_3CH_2CHBrCH_2CH_3$

D $CH_3CH_2CH_2CH_2CH_2Br$



cis

trans

21 Four drops of 1-chorobutane, 1-bromobutane and 1-iodobutane were separately added to three test-tubes containing 1.0 cm^3 of aqueous silver nitrate at 60 °C. The following reaction occurred.

$$H_2O(l) + R\text{–}X(l) + Ag^+(aq) \rightarrow R\text{–}OH(aq) + AgX(s) + H^+(aq)$$

[R: C_4H_9–; X: halogen]

Which of the following best explains why the rate of formation of cloudiness (precipitate) in the tubes was in the order RC*l* < RBr < RI?

A The R–X bond polarity decreases from RC*l* to RI.

B The bond energy of R–X decreases from RC*l* to RI.

C The solubility of AgX(s) decreases from AgC*l* to AgI.

D The ionisation energy of the halogen decreases from C*l* to I.

I is bigger than Cl. Thus the overlapping of orbitals between C-I is less effective as compared C-Cl and the bond strength is weaker.

22 Which one of the following compounds:

(i) is unaffected by hot alkaline potassium manganate(VII);

(ii) produces 0.5 mol of hydrogen when 1 mol of compound is treated with excess sodium?

A $(CH_3)_2C(OH)C(OH)(CH_3)CH_2CH_3$

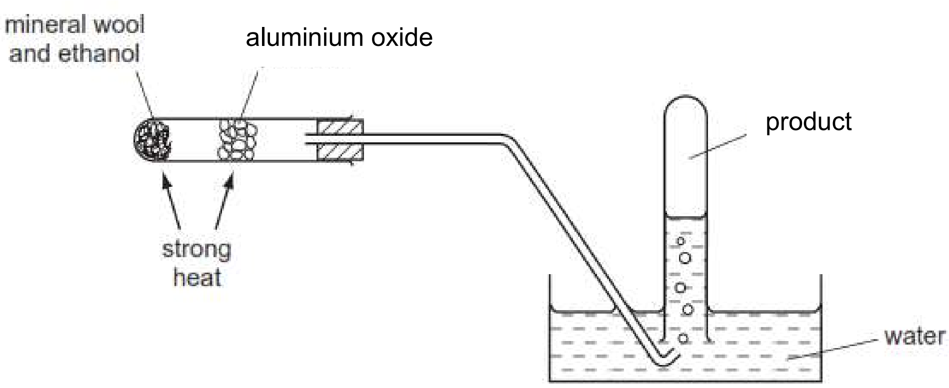
B $(CH_3)_2CHCH_2OH$

C $(CH_3)_3COH$

D $CH_3CH(OH)CH(OH)CH_3$

A and C are unaffected by oxidation due to tertiary alcohols. C can produce 0.5 mol of hydrogen gas as 1 mol of H^+ is given out from 1 mol of compound.

23 The diagram shows an experimental set-up.



Which compound can be produced by using the above apparatus?

A Oxygen

B Hydrogen

C Ethene

D Ethane

Ethene gas and water are produced as the ethanol is dehydrated.

24 An alcohol of molecular formula $C_4H_{10}O_2$ contains two -OH groups and has an unbranched carbon chain.

On reaction with an excess of acidified potassium manganate(VII), this alcohol is converted into a compound of molecular formula $C_4H_6O_4$.

To which two carbons in the chain of the alcohol are the two -OH groups attached?

A 1st and 2nd

B 1st and 3rd

C 1st and 4th

D 2nd and 3rd

$C_4H_{10}O_2 \rightarrow C_4H_6O_4$.
An Increase by 2 O atoms implies that two primary alcohol functional groups have been converted to 2 carboxylic acid functional groups with 4 oxygen atoms. The two primary alcohol functional groups must be situated at the 1^{st} and 4^{th} carbons.

25 Which of the following reagents and conditions can distinguish between ethyl methanoate and ethyl ethanoate?

A Heat with NaOH(aq)

B Heat with H_2SO_4(aq)

C Heat with NaOH(aq) followed by Na_2CO_3(aq)

D Heat with H_2SO_4(aq) followed by $KMnO_4$(aq)

Hydrolysis occurs. Both esters give ethanol, but 1 compound gives ethanoic acid and the other gives methanoic acid which will in turn be oxidised to carbon dioxide and water. Both will decolourise $KMnO_4$ but only ethyl methanoate will give carbon dioxide which will turn limewater chalky.

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 The pH range and colour changes for two indicators are given below.

Indicator	pH range
X	violet 3.0 – 5.0 red
Y	yellow 5.6 – 7.6 blue

Which of the following solutions will give a red solution when indicator **X** is used and a yellow solution when indicator **Y** is used?

1 0.1 mol dm^{-3} HX (K_a = 2.5 x 10^{-10} mol dm^{-3})

2 0.1 mol dm^{-3} CH_3COOH (K_a = 1.8 x 10^{-5} mol dm^{-3})

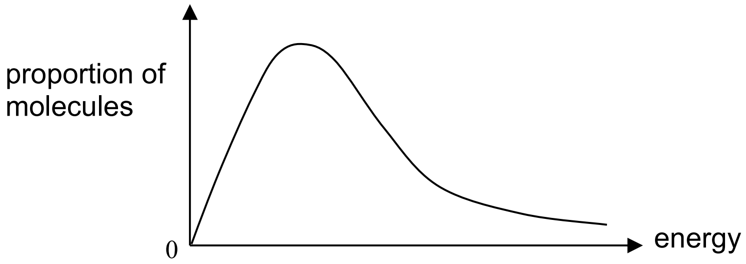
3 0.1 mol dm^{-3} HC*l*

Option 1: pH = 5.3
indicator X colour would be red and indicator Y colour would be yellow

Option 2: pH= 2.87
indicator X colour would be violet and indicator Y colour would be yellow

Option 3: pH = 1
indicator X colour would be violet and indicator Y colour would be yellow

27 The graph below shows the Boltzmann distribution of molecular energies at a given temperature.



As temperature increases, which statements are correct?

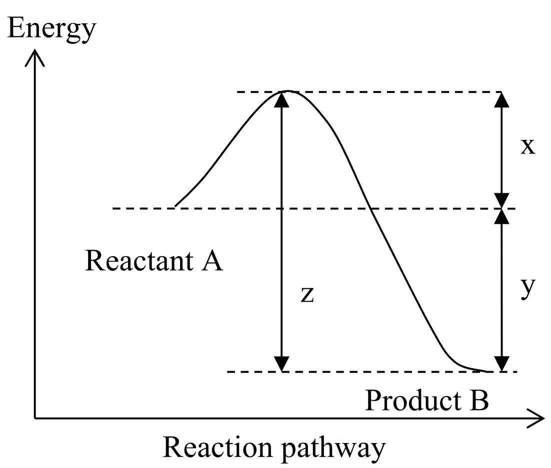
1 The proportion of molecules with any given energy increases.

2 The maximum of the curve is displaced to the right.

3 The proportion of molecules with energies above any given value increases.

It is not true that the proportion of molecules with lower energy would increase.
Maximum of curve displaces to the right as more particles gained higher in energy.
The proportion of molecules with higher kinetic energy increases as T increases and hence would have energies greater than in their original state.

28 The energy profile for a reversible reaction is shown below.

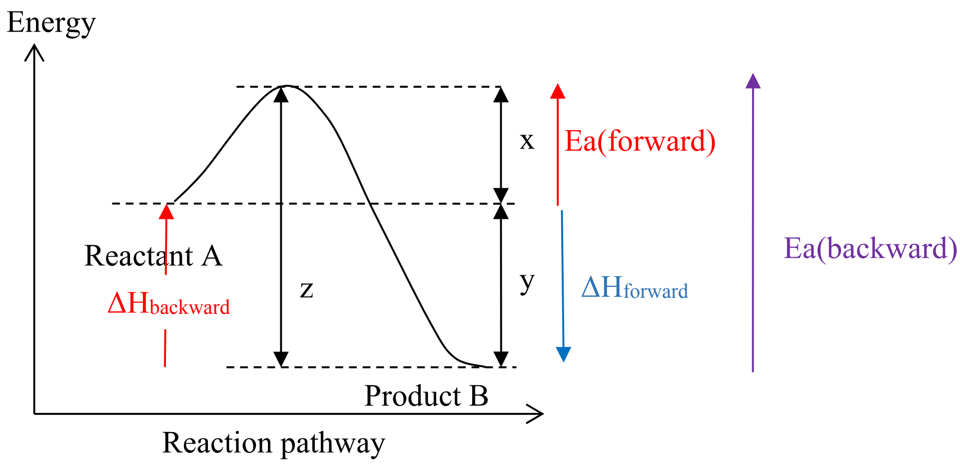


Which of the following statement is/are **correct**?

1 The reaction from **B** to **A** is endothermic.

2 The activation energy of the reaction **A** to **B** is *x*.

3 The activation energy of the reaction **B** to **A** is *z* - *y*.



29 Which of the following show an increase in radius?

1 $Al < Mg < Na$

2 $Cl^{-} < S^{2-} < P^{3-}$

3 $Na^{+} < Ca^{2+} < K^{+}$

Option 1: As proton number decreases, the electrostatic forces of attraction between nucleus and electrons decreases. Hence the atomic radius increases.

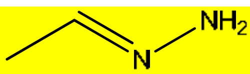
Option 2: As proton number decreases, the electrostatic forces of attraction between nucleus and electrons decreases. Thus the ionic radius increases.

Option 3: Sodium ion has one less principal quantum shell than Ca ion and K ion. Thus it would be smaller than the other 2 elements. Ca ion has smaller ionic radius than K ion as it has one more proton than K ion.

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

Carbonyl compounds react with hydrazine, N_2H_4, in the same manner as 2,4-dintrophenylhydrazine.

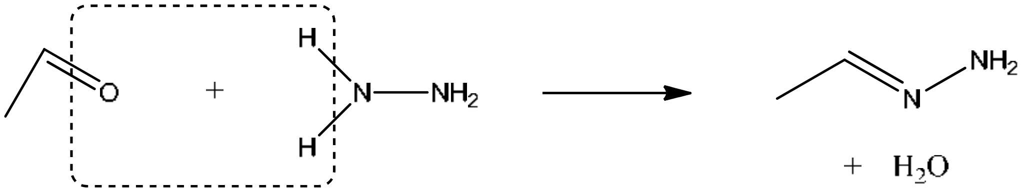
Which of the following are correct?

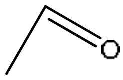
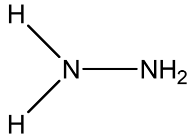
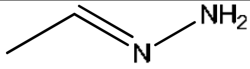
1 The product is 

when ethanal reacts with hydrazine.

2 The enthalpy change of the reaction is negative.

3 It is a condensation reaction.



ethanal	hydrazine	Product
		 + H_2O

Bonds Broken	Bonds formed
C=O(740)	C=N(610)
2N-H (390X2)	2H-O(2X460)

Bonds Broken – Bonds Formed = 1520 – 1530 = -10 kJ mol^{-1}
Carbonyl compounds undergo condensation(elimination-addition) with hydrazine.

END OF PAPER

Name and Form Class	Index Number	Subject Tutor

ANGLO-CHINESE JUNIOR COLLEGE
DEPARTMENT OF CHEMISTRY
Preliminary Examination

CHEMISTRY **8872/02**
Higher 1

Paper 2 15 August 2017

2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Writing Paper
Data Booklet
Graph Paper

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 a pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** the questions.

Section B
Answer **two** questions on separate answer paper.

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	
Section A	
B5	
B6	
B7	
Total	

Section A

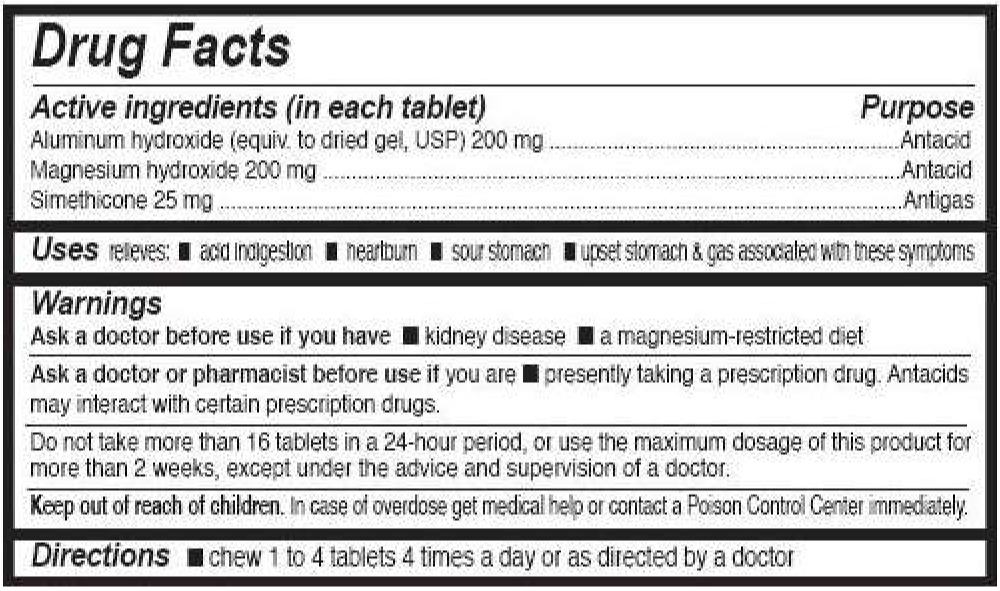
Answer **all** questions in this section in the spaces provided.

1 Aluminium is the most abundant Group 13 element and constitutes about 8 % of the Earth's crust. The extraction of aluminium is done by processing aluminium ore, bauxite to produce aluminium oxide also known as alumina.

A variety of aluminium compounds, for example aluminium chloride and aluminium hydroxide, are used for different purposes such as food additives, colouring and pharmaceuticals.

Aluminium hydroxide and magnesium hydroxide are antacids. They are used to treat symptoms of increased stomach acid, such as heartburn, upset stomach, sour stomach, or acid indigestion. Once ingested, they react with the hydrochloric acid in the stomach.

One label of a commercial product, Mintox™ is shown below.



Drug Facts

Active ingredients (in each tablet)	*Purpose*
Aluminum hydroxide (equiv. to dried gel, USP) 200 mg	Antacid
Magnesium hydroxide 200 mg	Antacid
Simethicone 25 mg	Antigas

Uses relieves: ■ acid indigestion ■ heartburn ■ sour stomach ■ upset stomach & gas associated with these symptoms

Warnings

Ask a doctor before use if you have ■ kidney disease ■ a magnesium-restricted diet

Ask a doctor or pharmacist before use if you are ■ presently taking a prescription drug. Antacids may interact with certain prescription drugs.

Do not take more than 16 tablets in a 24-hour period, or use the maximum dosage of this product for more than 2 weeks, except under the advice and supervision of a doctor.

Keep out of reach of children. In case of overdose get medical help or contact a Poison Control Center immediately.

Directions ■ chew 1 to 4 tablets 4 times a day or as directed by a doctor

(a) **(i)** Write down the electronic configuration of A*l*.

…………………………………………………………………………………[1]

(ii) Why is the ionic radius of aluminium far smaller than its atomic radius?

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………[1]

1 **(a)** **(iii)** Explain why aluminium forms compounds with an oxidation state of +3 but not sodium.

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………[1]

(b) **(i)** Which antacid in the tablet is more effective in reacting with the hydrochloric acid in the stomach? Support your answer with relevant working.

[2]

(ii) Calculate the maximum number of chewable tablets that a person can take in a week.

[1]

(iii) Assuming that a typical adult has a body mass of 70 kg, determine the maximum weekly intake of aluminium hydroxide in grams per kg of body mass.

[2]

1 **(c)** **(i)** Aluminium chloride is an active ingredient used in skin medication to control excessive sweating.

Aluminium chloride is often describe as *electron deficient*. Explain what is meant by *electron deficient*.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………[1]

(ii) In the vapour phase, aluminium chloride forms a gaseous product with a molar mass of 267 g mol^{-1}. With the aid of a clearly labelled diagram, explain how this product is formed from aluminium chloride.

[2]

[Total: 11]

2 In a university laboratory, the percentage purity of a sample of complex iron salt, $K_3Fe(C_2O_4)_3.3H_2O$ can be determined by analyzing the $C_2O_4^{2-}$ content through titrating with acidified $KMnO_4$.

1.20 g of impure $K_3Fe(C_2O_4)_3.3H_2O$ sample was dissolved and made up to 100 cm^3. 10.0 cm^3 of this solution was pipetted into a conical flask and 10.0 cm^3 of 1 mol dm^{-3} sulfuric acid was added. The mixture was heated and titrated with 0.0200 mol dm^{-3} $KMnO_4$. CO_2 is produced during the reaction.

It was determined that 12.30 cm^3 of $KMnO_4$ was required to reach the end-point.

(a) **(i)** Suggest why hydrochloric acid is not used to acidify the mixture.

…………………………………………………………………………………………

…………………………………………………………………………………………[2]

(ii) In the acidic medium, $C_2O_4^{2-}$ ions exist as $H_2C_2O_4$.
Write a half equation to show the conversion of $H_2C_2O_4$ to CO_2.

…………………………………………………………………………………………[1]

(b) **(i)** Calculate the amount of $KMnO_4$ used to react with 10.0 cm^3 of the iron complex salt solution.

[1]

(ii) Using the half-equation below and your answer in **(a)(ii)**, calculate the amount of $C_2O_4^{2-}$ present in 10.0 cm^3 of the iron complex salt solution.

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

[1]

(iii) Hence, determine the mass of $K_3Fe(C_2O_4)_3.3H_2O$ in 100 cm^3 of iron complex salt solution.
(molar mass of $K_3Fe(C_2O_4)_3.3H_2O$ = 491.1 g mol^{-1})

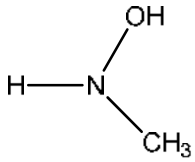
[2]

(iv) Calculate the percentage purity of the iron complex salt.

[1]

[Total: 8]

3 The emergence of multidrug-resistant bacteria has encouraged vigorous efforts to develop antibacterial agents. N-methylhydroxylamine has been found to show vast potential as an antibacterial agent.



N-methylhydroxylamine (pK_b = 8.04)

N-methylhydroxylamine has properties similar to ammonia and it dissolves in water as shown below:

$$CH_3NHOH(aq) + H_2O(l) \rightleftharpoons CH_3NH_2OH^+(aq) + OH^-(aq)$$

(a) Write the expression for the base dissociation constant of N-methylhydroxylamine in water.

[1]

(b) Calculate the base dissociation constant of the N-methylhydroxylamine solution.

[1]

An aqueous solution of 0.05 mol dm^{-3} hydrochloric acid was gradually added to 50.0 cm^3 of 0.02 mol dm^{-3} aqueous N-methylhydroxylamine.

(c) Determine the initial pH of N-methylhydroxylamine solution.

[2]

3 **(d)** Calculate the volume of hydrochloric acid needed at the equivalence point.

[1]

(e) State the volume of hydrochloric acid required to be added to another identical solution of N-methylhydroxylamine to obtain a solution which best resists pH change.

………………………………………………………………………………………[1]

(f) Calculate the pH of that solution.

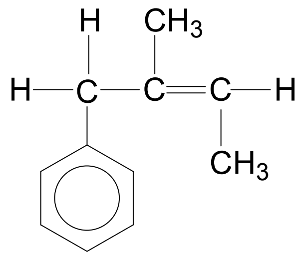
[1]

(g) Write **two** equations to show how the solution in **(e)** resists change in pH when small amounts of acid and alkali are added separately.

[2]

[Total: 9]

4 (a) Draw the structures of the organic product(s) formed when compound **A** below reacts with each of the following reagents.



compound **A**

Reagents and Conditions	Organic Product(s) formed
(i) HBr(g)	
(ii) $KMnO_4$; dilute H_2SO_4; heat under reflux	
(iii) Cl_2(g); $AlCl_3$; dark	

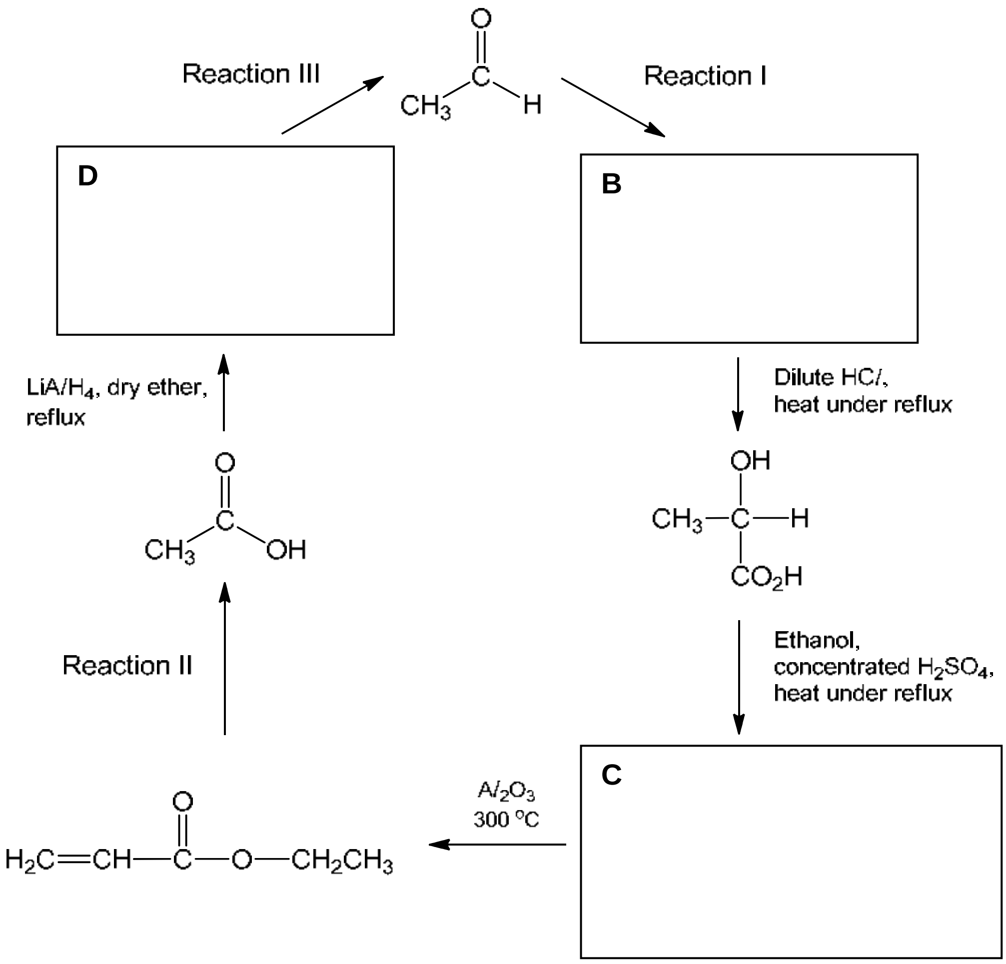
[4]

4 (b) State the type of isomerism exhibited by compound **A**, and hence draw the structures of the two isomers formed.

[2]

(c) Ethanal is a flammable liquid with a fruity smell. It occurs naturally in ripe fruit, coffee and fresh bread. A synthetic route involving ethanal is shown below.

(i) Draw the structural formulae of compounds **B**, **C** and **D** in the boxes below.



[3]

4 (c) (ii) Suggest reagents and conditions for

Reaction I, ...

Reaction II, ...

Reaction III, ...

[3]

[Total: 12]

Section B

Answer **two** questions from this section on the separate answer papers.

5 (a) In an experiment, the effect of reactant concentration on the rate of reaction between hydrogen peroxide and potassium iodide at 298K was investigated.

The rate of formation of iodine in the reaction:

$$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + I_2(aq)$$

is given by:

$$\text{rate} = k[H_2O_2]^a[I^-]^b[H^+]^c$$

whereby a, b and c are the orders of reaction.

The iodine liberated in the above reaction was reacted with a fixed amount of sodium thiosulfate until no more sodium thiosulfate was left. The excess iodine caused the solution to become coloured. By adding a few drops of starch, the iodine showed up more clearly as it formed a blue-black complex.

The time taken for the formation of the blue-black complex was measured. The reciprocal of this time ($\frac{1}{t}$) is used as a measure of the initial rate of reaction.

Concentration of KI/ mol dm^{-3}	Time/ s
0.10	5.5
0.075	7.4
0.050	11.3
0.025	22.7

(i) Plot a graph of initial rate against concentration of iodide ions. [3]

(ii) Hence, use your graph to determine the order of reaction with respect to iodide ions. [1]

(iii) In theory, the orders of reaction with respect to hydrogen peroxide and acid are one and zero respectively. [2]

Using your answer in **(a)(ii)** and given that $[H_2O_2]$ = 0.01 mol dm^{-3}, $[I^-]$ = 0.02 mol dm^{-3}, $[H^+]$ = 0.0005 mol dm^{-3} and rate = 2.30 x 10^{-6} mol dm^{-3} s^{-1}, determine the rate constant for this reaction and state its units.

(iv) Suggest what would happen to the initial rate of reaction if the temperature is changed to 308K. [1]

(b) (i) Describe the reactions, if any when separate samples of sodium and phosphorus are added to water containing universal indicator. [2]

(ii) Explain the acid-base character of oxides of sodium and phosphorus in water. Suggest the pH of any aqueous solution formed. [2]

5 **(c)** When heated with chlorine under suitable conditions, hydrocarbon **X,** C_6H_{14} forms a total of only 3 mono-chlorinated products.

(i) Draw the three possible chlorinated products of **X**. [3]

(ii) The following table provides the rate of abstraction of a hydrogen on a primary, secondary and tertiary carbon. [2]

Type of C	$-CH_3$	$-CH_2R$	$-CHR_2$
Relative rate	1	4	6

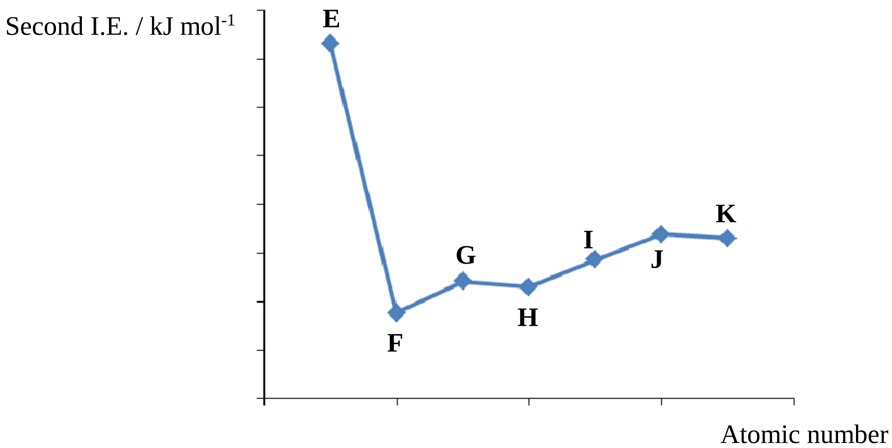
What is the expected ratio of the mono-chlorinated products of **X** formed?

(iii) State one environmental effect of chlorinated products of **X**. [1]

(iv) Describe a simple chemical test to distinguish the chlorinated products of **X** from hydrocarbon **X**. [3]

[Total: 20]

6 **(a)** Carbon forms the backbone of organic compounds and is in Period 2 of the Periodic Table. The second ionisation energy of some consecutive elements in Period 2 are plotted.



(i) Write an equation to represent second ionisation energy of carbon. [1]

(ii) By considering electronic configurations, explain why the second ionisation energy of carbon is lower than that of boron. [2]

(iii) Which letter represents carbon in the plot? Explain your answer. [2]

(b) Ethanoic acid and ethanol react together in the presence of concentrated sulfuric acid as the catalyst. The following equilibrium is established, in which the ester, ethyl ethanoate, is formed.

$$CH_3COOH(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$$

(i) State Le Chatelier's Principle. [1]

(ii) Use Le Chatelier's Principle to predict and explain how the position of equilibrium of this reaction would be affected when sodium hydroxide is added. [2]

(iii) Equimolar amounts of ethanoic acid and ethanol were mixed and at equilibrium, 1.00 mole of ethyl ethanoate is present. The total volume of the reaction mixture is 0.5 dm^3. [3]

Given that the value of K_c for the reaction between ethanoic acid and ethanol is 4.0, determine the initial concentration of ethanoic acid.

(c) Other than ethanoic acid, there are other compounds that have the same molecular formula, $C_2H_4O_2$. [3]

Give the skeletal formulae of **three** other possible isomers, with different functional groups from each other, which have this molecular formula.

6 **(d)** In the laboratory, there are three bottles of chemicals which are unlabelled. The three bottles contain one of the following, but not in the order given. [6]

Ethanoic acid

Propanone

Propanal

Suggest two simple chemical tests that will allow you to distinguish between the three unlabelled bottles. State clearly the observations and write equations for the reactions that occur.

[Total:20]

7 Diethylene glycol (DEG), with the formula $(HOCH_2CH_2)_2O$, is used in a wide range of industrial products. It is poisonous and has been involved in a number of prominent mass poisonings spanning back to 1937.

(a) Following its ingestion, DEG is rapidly absorbed and distributed within the human body which is made up of up to 60% water.

State and draw the type of bonding between DEG and water. [3]

(b) DEG is produced by the hydrolysis of the cyclic ethylene oxide, $(CH_2)_2O$.

$$2\ (CH_2)_2O + H_2O \rightarrow HO–CH_2CH_2–O–CH_2CH_2–OH$$

(i) The oxygen atom is bridging the two carbon atoms in the cyclic ethylene oxide. Draw the 'dot-and-cross' diagram of ethylene oxide with all bonding electrons and non-bonding electrons shown clearly. [1]

(ii) State a value for the bond angle around the oxygen atom in ethylene oxide molecule. [1]

(iii) Predict and explain whether ethylene oxide would be more soluble in propanone or hexane. [2]

(iv) Use the *Data Booklet* to calculate the enthalpy change when ethylene oxide is hydrolysed and show clearly which bonds are broken and formed in the above equation. [3]

(c) An organic compound **P**, $C_{10}H_{11}O_2Br$, does not react with aqueous sodium carbonate. However, it reacts slowly on heating in aqueous sodium hydroxide to form a water-soluble compound **Q**, $C_3H_5O_3Na$ and an insoluble oil **R**, C_7H_8O. [10]

The acidification of compound **Q** gives compound **S** which reacts with 2 moles of phosphorous pentachloride to give copious fumes. **R** gives benzoic acid upon oxidation.

Deduce the structures of compounds **P**, **Q**, **R** and **S**. Explain the chemistry of the reactions described and write equations where appropriate.

[Total:20]

End of Paper

Section A

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

1 Aluminium is the most abundant Group 13 element and constitutes about 8% of the Earth's crust. The extraction of aluminium is done by processing aluminium ore, bauxite to produce aluminium oxide also known as alumina.

A variety of aluminium compounds, for example aluminium chloride and aluminium hydroxide, are used for different purposes such as food additives, colouring and pharmaceuticals.

Aluminium hydroxide and magnesium hydroxide are antacids. They are used to treat symptoms of increased stomach acid, such as heartburn, upset stomach, sour stomach, or acid indigestion. Once ingested, they react with the hydrochloric acid in the stomach.

One label of a commercial product, Mintox™ is shown below.

Drug Facts

Active ingredients (in each tablet)	*Purpose*
Aluminum hydroxide (equiv. to dried gel, USP) 200 mg	Antacid
Magnesium hydroxide 200 mg	Antacid
Simethicone 25 mg	Antigas

Uses relieves: ■ acid indigestion ■ heartburn ■ sour stomach ■ upset stomach & gas associated with these symptoms

Warnings

Ask a doctor before use if you have ■ kidney disease ■ a magnesium-restricted diet

Ask a doctor or pharmacist before use if you are ■ presently taking a prescription drug. Antacids may interact with certain prescription drugs.

Do not take more than 16 tablets in a 24-hour period, or use the maximum dosage of this product for more than 2 weeks, except under the advice and supervision of a doctor.

Keep out of reach of children. In case of overdose get medical help or contact a Poison Control Center immediately.

Directions ■ chew 1 to 4 tablets 4 times a day or as directed by a doctor

(a) **(i)** Write down the electronic configuration of A*l*. [1]

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

(ii) Why is the ionic radius of aluminium far smaller than its atomic radius?

Al^{3+} ion has a higher proton to electron ratio, hence the remaining electrons experience stronger electrostatic forces of attraction to the nucleus.

In addition, Al^{3+} ion has <u>one less principal quantum shell</u> as compared to the neutral atom, hence the ionic radius is smaller than its atomic radius.

(iii) Explain why aluminium forms compounds with an oxidation state of +3 but not sodium. [1]

As compared to sodium, aluminium would require smaller amount of energy to remove the (2nd and 3rd) electrons which are from the outermost principle quantum shell.

(b) **(i)** Which antacid in the tablet is more effective in reacting with the hydrochloric acid in the stomach? Show relevant working to support your answer. [2]

Relevant working based on masses in the tablet

No of moles of $Mg(OH)_2$ = 200 x 10^{-3} / 58.3 = 3.43 x 10^{-3} mol
No of moles of $Al(OH)_3$ = 200 x 10^{-3} / 78 = 2.56 x 10^{-3} mol
$Al(OH)_3$ will produces more number of moles of hydroxide ions (7.68 x10^{-3}) than $Mg(OH)_2$(6.86 x10^{-3}) .

Thus aluminium hydroxide is more effective.

(ii) Calculate the maximum number of chewable tablets that a person can take in a week. [1]

4x 4 x 7 = 112

(iii) Assuming that a typical adult has a body mass of 70 kg, determine the maximum weekly intake of aluminium hydroxide in grams per kg of body mass. [2]

Maximum intake of aluminium hydroxide is 200 mg x 112

Maximum intake per body mass = 0.320 g per kg

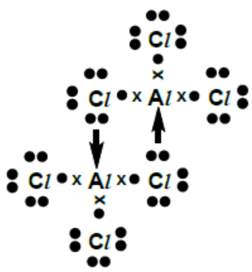
(c) **(i)** Aluminium chloride is an active ingredient used in skin medication to control excessive sweating.

Aluminium chloride is often describe as *electron deficient*. Explain what is meant by *electron deficient*. [1]

Electron deficient implies that the central atom, Al has <u>empty orbital</u> in $AlCl_3$

(ii) In the vapour phase, aluminium chloride forms a gaseous product with a molar mass of 267 g mol^{-1}. With an aid of a clearly labelled diagram, explain how this product is formed from aluminium chloride. [2]

Dative Bond



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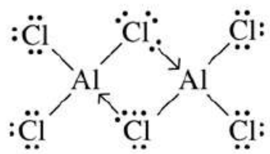


[Total: 11]

2 In a university laboratory, the percentage purity of a sample of complex iron salt, $K_3Fe(C_2O_4)_3.3H_2O$ can be determined by analyzing the $C_2O_4^{2-}$ content through titrating with acidified $KMnO_4$.

1.20 g of impure $K_3Fe(C_2O_4)_3.3H_2O$ sample was dissolved and made up to 100cm^3. 10.0 cm^3 of this solution was pipetted into a conical flask and 10.0cm^3 of 1 mol dm^{-3} sulfuric acid was added. The mixture was heated and titrated with 0.0200 mol dm^{-3} $KMnO_4$. CO_2 is produced during the reaction.

It was determined that 12.30 cm^3 of $KMnO_4$ was required to reach the end-point.

(a) **(i)** Suggest why hydrochloric acid is not used to acidify the mixture. [2]

Cl^- ions can possibly be oxidized to Cl_2 and hence will cause an increase in the titration readings.

(ii) In the acidic medium, $C_2O_4^{2-}$ ions exist as $H_2C_2O_4$.

Write a half equation to show the conversion of $H_2C_2O_4$ to CO_2. [1]

$H_2C_2O_4 \rightarrow CO_2 + 2H^+ + 2e$

(b) **(i)** Calculate the amount of $KMnO_4$ used to react with 10.0cm^3 of the iron complex salt solution. [1]

Amt of MnO_4^- = 12.3/1000 x 0.02 = 2.46 x 10^{-4} mol

(ii) Using the half-equation below and that in **(b)(ii)**, calculate the amount of $C_2O_4^{2-}$ present in 10.0 cm^3 of the iron complex salt solution.

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

[1]

Amount of e involved = 5 x 2.46 x 10^{-4}= 1.23 x 10^{-3}
Amount of $H_2C_2O_4$ = amount of $C_2O_4^{2-}$ = 5/2 x 2.46 x 10^{-4} = 6.15 x 10^{-4}

(iii) Hence, determine the mass of $K_3Fe(C_2O_4)_3.3H_2O$ in 100 cm^3 of iron complex salt solution.
(molar mass of $K_3Fe(C_2O_4)_3.3H_2O$ = 491.1 g mol^{-1}) [2]

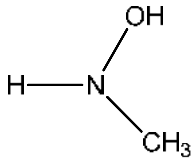
$K_3Fe(C_2O_4)_3.3H_2O \equiv 3C_2O_4^{2-}$
amount of $K_3Fe(C_2O_4)_3.3H_2O$ in 100cm^3 = 5/2/3 x 2.46 x 10^{-4} x 10
Mass of $K_3Fe(C_2O_4)_3.3H_2O$
= 5/2/3 x 2.46 x 10^{-4} x 10 x 491.1 = 1.01g

(iv) Calculate the percentage purity of the iron complex salt. [1]

1.01/1.20 x 100% = 84.2%

[Total: 8]

3 The emergence of multidrug-resistant bacteria has encouraged vigorous efforts to develop antibacterial agents. N-methylhydroxylamine has been found to show vast potential as an antibacterial agent.



N-methylhydroxylamine (pK_b = 8.04)

N-methylhydroxylamine has properties similar to ammonia and it dissolves in water as shown below:

$$CH_3NHOH(aq) + H_2O(l) \rightleftharpoons CH_3NH_2OH^+(aq) + OH^-(aq)$$

(a) Write the expression for the base dissociation constant of N-methylhydroxylamine in water. [1]

$$K_b = \frac{[CH_3NH_2OH^+][OH^-]}{[CH_3NHOH]}$$

(b) Calculate the base dissociation constant of the N-methylhydroxylamine solution. [1]

$K_b = 10^{-8.04} = 9.12 \times 10^{-9}$ mol dm^{-3}

An aqueous solution of 0.05 mol dm^{-3} hydrochloric acid was gradually added to 50.0 cm^3 of 0.02 mol dm^{-3} aqueous N-methylhydroxylamine.

(c) Determine the initial pH of N-methylhydroxylamine solution. [2]

$$CH_3NHOH(aq) + H_2O(l) \rightleftharpoons CH_3NH_2OH^+(aq) + OH^-(aq)$$

$$K_b = \frac{[CH_3NH_2OH^+][OH^-]}{[CH_3NHOH]}$$

Since $[OH^-] = [CH_3NH_2OH^+]$,

$$K_b = \frac{[OH^-]^2}{[CH_3NHOH]}$$

$$9.12 \times 10^{-9} = \frac{[OH^-]^2}{0.02}$$

$[OH^-]$ = $\underline{1.35 \times 10^{-5}}$ mol dm^{-3}

pH = 14 – [-log (1.48 × 10^{-5})]
= $\underline{9.13}$

(d) Calculate the volume of hydrochloric acid needed at the equivalence point. [1]

$$CH_3NHOH + HCl \longrightarrow CH_3NH_2OH^+Cl^-$$

Volume of HC*l* needed = (50.0 × 0.02) ÷ 0.05
= 20.0 cm^3

(e) State the volume of hydrochloric acid required to be added to another identical solution of N-methylhydroxylamine to obtain a solution which best resists pH change. [1]
$10.0\ cm^3$

(f) Calculate the pH of that solution. [1]
$pOH = pK_b = 8.04$
$pH = 14-8.04 = 5.96$

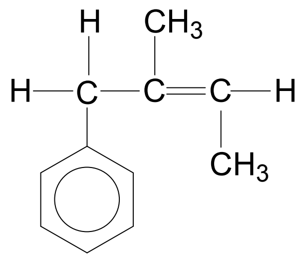
(g) Write **two** equations to show how the solution in **(e)** resists change in pH when small amounts of acid and alkali are added. [2]

$CH_3NHOH + H^+ \longrightarrow CH_3NH_2OH^+$

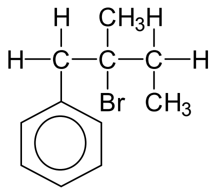
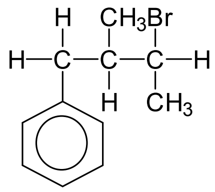
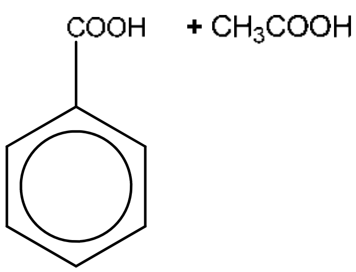
$CH_3NH_2OH^+ + OH^- \longrightarrow CH_3NHOH + H_2O$

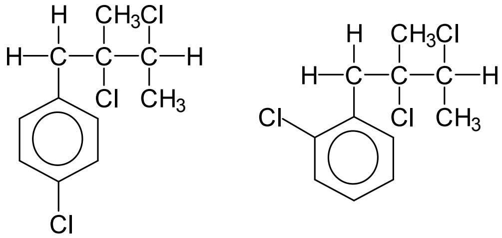
[Total: 9]

4 **(a)** Draw the structures of the organic product(s) formed when compound **A** below reacts with each of the following reagents.



compound **A**

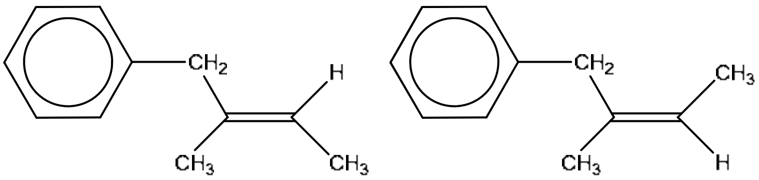
Reagents and Conditions	Organic Product(s) formed
(i) HBr(g)	Students to give either one of the correct structures  
(ii) $KMnO_4$; dilute H_2SO_4; heat under reflux	

(iii) Cl_2(g); $AlCl_3$; dark	Students to give either one of the correct structures 

[5]

(b) State the type of isomerism exhibited by compound **A**, and hence draw the structures of the two isomers formed. **[2]**

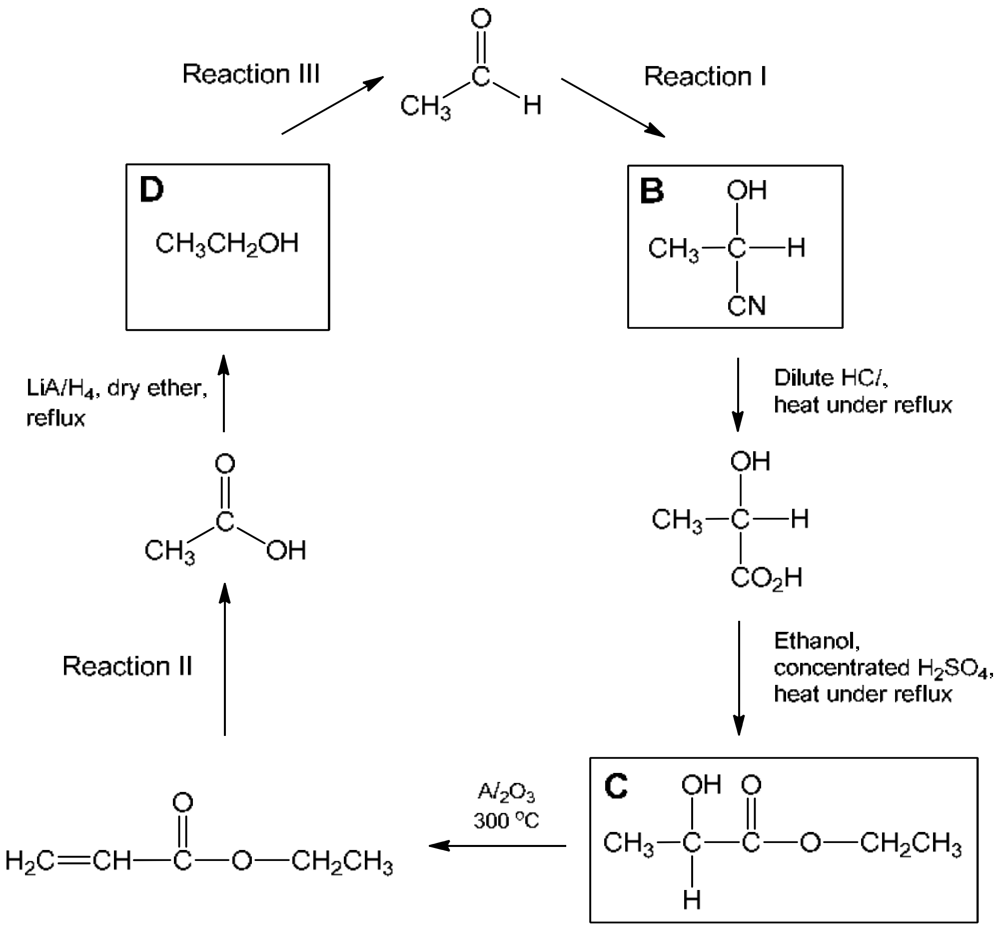
Cis-trans isomerism



cis trans

(c) Ethanal is a flammable liquid with a fruity smell. It occurs naturally in ripe fruit, coffee and fresh bread. A synthetic route involving ethanal is shown below.

(i) Draw the structural formulae of compounds **B**, **C** and **D** in the boxes below. **[3]**



(ii) Suggest reagents and conditions for

Reaction I, ...

Reaction II, ...

Reaction III, ... **[3]**

[Total: 14]

- reaction I, HCN, trace amount of NaOH(aq), 10 to 20°C
  or HCN, trace amount of KCN, 10 to 20°C
- reaction II, $KMnO_4$, H_2SO_4(aq), heat under reflux
- reaction III, $K_2Cr_2O_7$, H_2SO_4(aq), heat and distill

Section B (40 marks)

Answer **two** questions from this section on the separate answer papers.

1 **(a)** In an experiment, the effect of reactant concentration on the rate of reaction between hydrogen peroxide and potassium iodide at 298K was investigated.

The rate of formation of iodine in the reaction:

$$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + I_2(aq)$$

is given by:

$$\text{rate} = k[H_2O_2]^a[I^-]^b[H^+]^c$$

whereby a, b and c are the orders of reaction

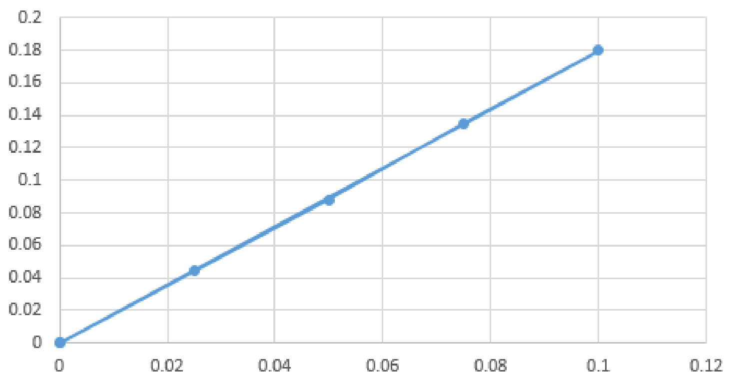
The iodine liberated in the above reaction reacts with a fixed amount of sodium thiosulfate until no more sodium thiosulfate is left. The excess iodine causes the solution becomes coloured. By adding a few drops of starch, the iodine is shown up more clearly as it forms a blue-black complex.

The time taken for the formation of blue-black complex is measured. The reciprocal of this time ($\frac{1}{t}$) is used as a measure of the initial rate of reaction.

Concentration of KI/ mol dm^{-3}	Time/ s
0.10	5.5
0.075	7.4
0.050	11.3
0.025	22.7

(i) Plot a graph of initial rate against concentration of iodide ions. [3]

Initial Rate / s^{-1}



Concentration of iodide ions/ mol dm^{-3}

(ii) Hence use your graph to determine the order of reaction with respect to iodide ions. [1]

Clearly initial rate is directly proportional to the concentration. Thus it is first order.

(iii) In theory, the orders of reaction with respect to hydrogen peroxide and acid are one and zero respectively. [2]

Using your answer in **a(ii)** and given that $[H_2O_2]$ = 0.01 mol dm^{-3}, $[I^-]$ = 0.02 mol dm^{-3}, $[H^+]$ = 0.0005 mol dm^{-3} and rate = 2.30 x 10^{-6} mol dm^{-3} s^{-1}, determine the rate constant for this reaction and state its units.

$$\text{rate} = k[H_2O_2][I^-]$$
$$2.30 \times 10^{-6} = k(0.01)(0.02)$$
$$k = 0.0115 \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$$

(iv) Suggest what would happen to the initial rate of reaction if the temperature is changed to 308K. [1]

The rate would be doubled.

(b) **(i)** Describe the reactions, if any when separate samples of sodium and phosphorus are added to water containing universal indicator. [2]

Sodium dissolves in water to form an alkaline blue/violet solution and effervescence is seen.

Phosphorus does not react with water. Hence it forms a green solution in presence of universal indicator.

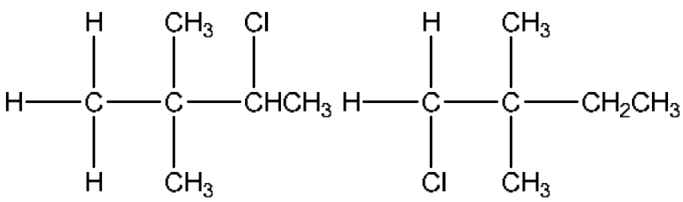
(ii) Explain the acid-base character of oxides of sodium and phosphorus in water. Suggest the pH of any aqueous solution formed. [2]

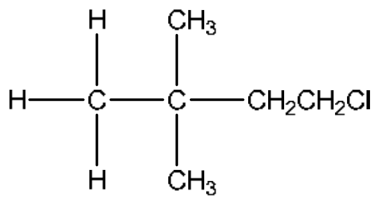
Sodium oxide is soluble in water to form an alkaline solution of aq NaOH.
$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$ pH =13

Phosphorus oxide is soluble in water to form an acidic solution of phosphoric acid.
$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$ pH =2

(c) When heated with chlorine under suitable conditions, hydrocarbon **X**, C_6H_{14} forms a total of only 3 mono-chlorinated products.

(i) Draw the three possible chlorinated products of **X**. [3]





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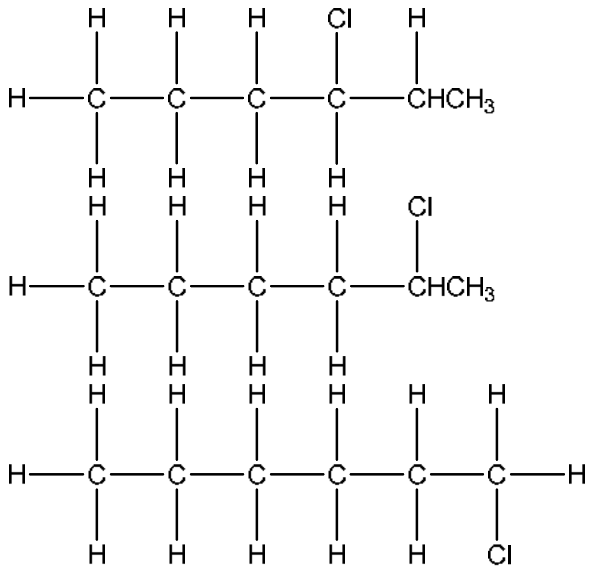
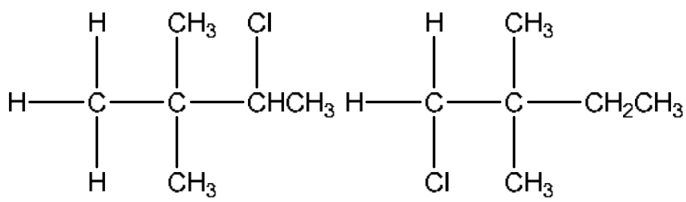
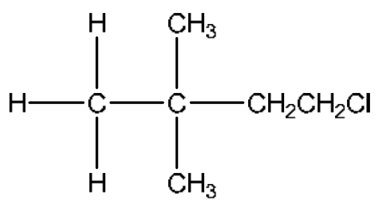


(ii) The following table provides the rate of abstraction of a hydrogen on a primary, secondary and tertiary carbon. [1]

Type of C	$-CH_3$	$-CH_2R$	$-CHR_2$
Relative rate	1	4	6

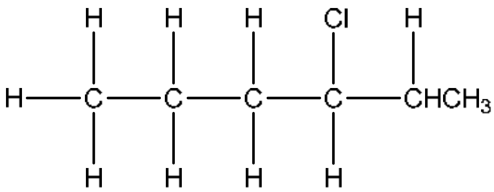
What is the expected ratio of the mono-chlorinated products of **X** formed?[2]



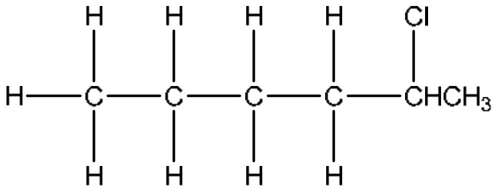


2X4 : 1x 9 : 3x1
8: 9: 3

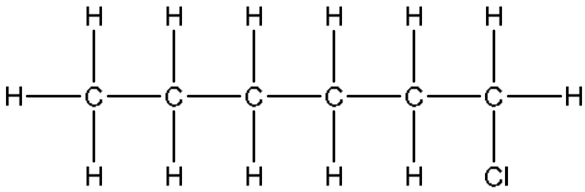
OR



4x 4 = 16



4x 4=16



6x 1=6
8: 8: 3

(iii) State one environmental effect of chlorinated products of **X**. [1]

Depletion of ozone layer

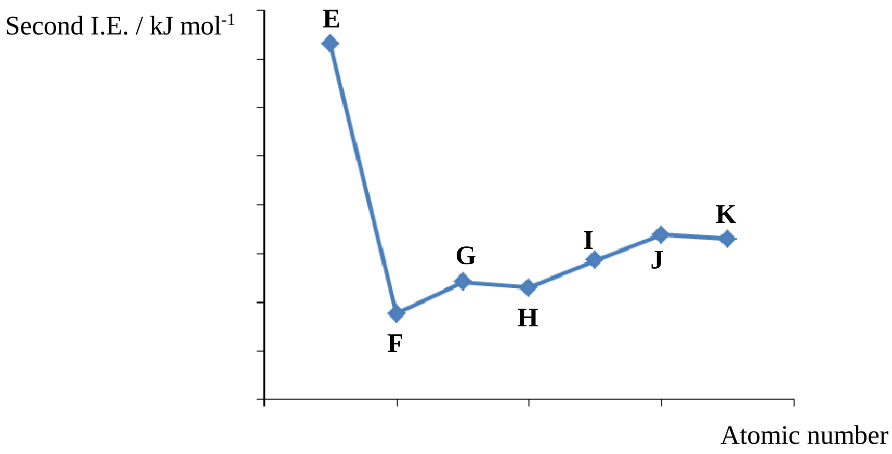
(iv) Describe a simple chemical test to distinguish the chlorinated products of **X** from hydrocarbon **X**. [3]

Aq NaOH, heat
Cool and add excess nitric acid
Lastly add silver nitrate solution

X: no white ppt
Chlorinated products: white ppt

[Total: 20 marks]

2 **(a)** Carbon forms the backbone of organic compounds and is in the Period 2 of the Periodic Table. The second ionisation energy of some consecutive elements in Period 2 are plotted.



(i) Write an equation to represent second ionisation energy of carbon. [1]

$C^+(g) \rightarrow C^{2+}(g) + e$

(ii) Considering electronic configurations, explain why the second ionisation energy of carbon is lower than that of boron. [2]

C^+ : $1s^2\ 2s^2\ 2p^1$

B^+ : $1s^2\ 2s^2$

The second IE of carbon involves removing an electron from the 2p subshell, which is further away from the nucleus. Hence, less energy is required.

(iii) Which letter represents carbon in the plot? Explain your answer. [2]

H. There is a large difference between the second IE of E and F. This suggests that E is Li as the electron is removed from the inner principal quantum shell.

(b) Ethanoic acid and ethanol react together in the presence of concentrated sulfuric acid as the catalyst. The following equilibrium is established, in which the ester, ethyl ethanoate, is formed.

$$CH_3COOH\ (l) + CH_3CH_2OH\ (l) \rightleftharpoons CH_3COOCH_2CH_3\ (l) + H_2O\ (l)$$

(i) State Le Chatelier's Principle. [1]

Le Chatelier's Principle states that when a change is introduced into the system, the system will respond in such a way to counteract the change.

(ii) Use Le Chatelier's Principle to predict and explain how adding sodium hydroxide to the system will affect the position of equilibrium of this reaction. [2]

When sodium hydroxide is added, the concentration of ethanoic acid decreases. Hence, POE will shift to the left to counter this change.

(iii) Equimolar amounts of ethanoic acid and ethanol were mixed and at equilibrium, 1.00 mole of ethyl ethanoate is present. The total volume of the reaction mixture is 0.5 dm^3.

Given that the value of K_c for the reaction between ethanoic acid and ethanol is 4.0, determine the initial concentration of ethanoic acid. [3]

	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

$K_c = 1 / (x-1)(x-1) = 4$

$(x-1)(x-1) = ¼$

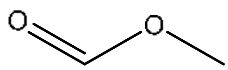
$x - 1 = ½$

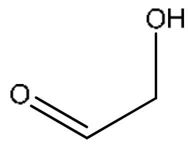
$x = 1.5$ mol

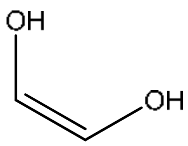
[ethanoic acid] = 1.5/0.5 = 3.00 mol dm^{-3}

(c) Other than ethanoic acid, there are other compounds that have the same molecular formula, $C_2H_4O_2$.

Give the skeletal formulae of **three** other possible isomers, with different functional groups from each other, which have this molecular formula. [3]







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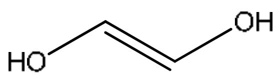

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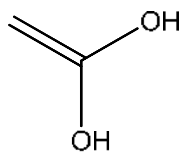


(d) In the laboratory, there are three bottles of chemicals which are unlabelled. The three bottles contain one of the following, but not in the order given.

Ethanoic acid

Propanone

Propanal

Suggest two simple chemical tests that will allow you to distinguish between the three unlabelled bottles. State clearly the observations and write equations for any reaction that occur. [6]

R & C: Na_2CO_3 (aq)

Observations: effervescence for ethanoic acid, no effervescence for propanone and propanal

Eqn: 2 CH_3COOH + Na_2CO_3 → 2 $CH_3COO^-Na^+$ + CO_2 + H_2O

R & C : $KMnO_4$ (aq), H_2SO_4 (aq), heat

Observations: purple $KMnO_4$ decolourised for propanal, purple $KMnO_4$ remains for propanone.

Eqn: CH_3CH_2CHO + [O] → CH_3CH_2COOH

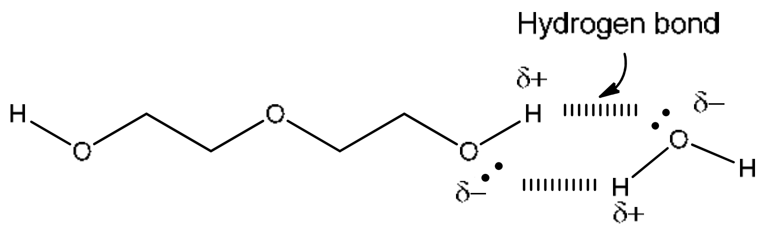
Accept any logical tests.

[Total:20]

3 Diethylene glycol (DEG), with the formula $(HOCH_2CH_2)_2O$, is used in a wide range of industrial products. It is poisonous and has been involved in a number of prominent mass poisonings spanning back to 1937.

(a) Following its ingestion, DEG is rapidly absorbed and distributed within the human body which is made up of up to 60% water.

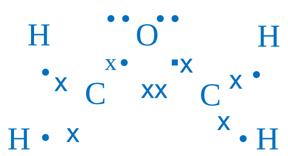
State and draw the type of bonding between DEG and water. [3]



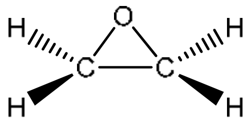
(b) DEG is produced by the hydrolysis of the cyclic ethylene oxide, $(CH_2)_2O$.

2 $(CH_2)_2O$ + H_2O → HO–CH_2CH_2–O–CH_2CH_2–OH

(i) The oxygen atom is bridging the two carbon atoms in the cyclic ethylene oxide. Draw the 'dot-and-cross' diagram of ethylene oxide showing all bonding electrons and non-bonding electrons clearly. [1]



(ii) Give a value for the bond angle around the oxygen atom in ethylene oxide molecule. [1]



60 °

(iii) Predict and explain whether ethylene oxide would be more soluble in propanone or hexane. [2]

Propanone

Ethylene oxide is polar and dissolves well in polar solvent such as propanone through permanent dipole-permanent dipole interaction

(iv) Use the *Data Booklet* to calculate the enthalpy change when ethylene oxide is hydrolysed showing clearly which bonds are broken and formed in the above equation. [3]

Bonds broken = 2 (O-H) +2(C-O)
Bonds formed = 2 (O-H) +2(C-O)

$\Delta H = 0 \text{ kJ mol}^{-1}$

(c) An organic compound **P**, $C_{10}H_{11}O_2Br$, does not react with aqueous sodium carbonate. However, it reacts slowly on heating in aqueous sodium hydroxide to form a water-soluble compound **Q**, $C_3H_5O_3Na$ and an insoluble oil **R**, C_7H_8O.

The acidification of compound **Q** gives compound **S** which reacts with 2 moles of phosphorous pentachloride to give copious fumes. **R** gives benzoic acid on oxidation.

Deduce the structures of compounds **P**, **Q**, **R** and **S**. Explain the chemistry of the reactions described, writing equations where appropriate. [10]

Compound **P** does not react with Na_2CO_3(aq). Hence, compound **P** is not a carboxylic acid.

Compound **P** undergoes alkaline hydrolysis when heated with NaOH(aq). **P** has alkyl halide functional group. The Br atom in compound **P** is substituted by –OH.

Compound **Q**, $C_3H_5O_3Na$, and compound **R**, C_7H_8O, were produced upon alkaline hydrolysis. Ester linkage present in compound **P**.

Q has an alcohol functional group. The acidification of compound **Q** gives compound **S** which reacts with 2 moles of phosphorous pentachloride to give copious fumes. Compound **S** is an alcohol and carboxylic acid.

Compound **R** gives benzoic acid on oxidation. Compound **R** contains a benzene ring with a side chain, (oxidation of side-chain) **R** has an alcohol group.

$C_6H_5CH_2OCOCH(Br)CH_3 + 2NaOH \longrightarrow CH_3CH(OH)COONa + C_6H_5CH_2OH + NaBr$

$C_6H_5CH_2OH + 2[O] \longrightarrow C_6H_5COOH + H_2O$

$CH_3CH(OH)COONa + H^+ \longrightarrow CH_3CH(OH)COOH + Na^+$

$CH_3CH(OH)COOH + 2PCl_5 \longrightarrow CH_3CH(Cl)COCl + 2HCl + 2POCl_3$

P is $C_6H_5CH_2OCOCH(Br)CH_3$ or $C_6H_5CH_2OCOCH_2CH_2Br$
Q is $CH_3CH(OH)COONa$ or $CH_2(OH)CH_2COONa$
R is $C_6H_5CH_2OH$
S is $CH_3CH(OH)COOH$ or $CH_2(OH)CH_2COOH$

[Total: 20]

End of Paper

Catholic Junior College
JC 2 Preliminary Examinations
Higher 1

CHEMISTRY

8872/01

Paper 1 Multiple Choice

Tuesday 29 August 2017
50 minutes

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 **10** printed pages

Section A

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 12.2.
What is the ratio of ^{12}C to ^{13}C?

A 4:1 **B** 3:1 **C** 3:4 **D** 1:4

2 10 cm^3 of a pure hydrocarbon **X** was completely burnt in 80 cm^3 of excess oxygen to give carbon dioxide gas and water vapour. After cooling to room temperature, the volume of gaseous mixture decreased from 105 cm^3 to 55 cm^3. A further reduction of 40 cm^3 was observed when the residual gas was passed through aqueous sodium hydroxide.
All gas volumes were measured at the same temperature and pressure.
What is the formula of **X**?

A C_2H_6 **B** C_3H_8 **C** C_4H_{10} **D** C_5H_{12}

3 A plasma is a gaseous mixture in which atoms have been completely stripped of their electrons, leaving bare nuclei. When passed through an electric field, the ^{1}H nucleus is deflected at an angle of +4°. What will be the angle of deflection for the ^{3}H nucleus in the same plasma?

A +0.75° **B** +1.3° **C** +4° **D** +12°

4 *Use of the Data Booklet is relevant to this question.*
What do the ions $^{23}Na^{+}$ and $^{24}Mg^{2+}$ have in common?

A Both ions have more electrons than neutrons.
B Both ions have 12 neutrons in their nuclei.
C Both ions contain the same number of nucleons in their nuclei.
D Both ions have an outer electronic configuration of $3s^2\,3p^6$.

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

Which of the following particles would, on losing an electron, have a half-filled set of p orbitals?

A C^- **B** N **C** N^- **D** O^+

6 The first seven successive ionisation energies (in kJ mol^{-1}) of an element **J** are given below:

1020 1950 2730 4580 6020 12300 15400

Which of the following statements about **J** is correct?

A It has a valence shell electronic configuration of $ns^2\ np^4$

B Its atomic radius is larger than its ionic radius.

C It has a lower second ionisation energy than that of its preceding element.

D It can form a chloride that has a trigonal pyramidal shape.

7 In which of the following pairs of compounds is the bond angle in particle **I** greater than that in particle **II**?

	I	**II**
A	PH_3	BH_3
B	NO_3^-	ClO_2^-
C	SF_6	I_3^-
D	ClF_3	$BeCl_2$

8 Which one of the following statements about aluminium chloride is correct?

A $AlCl_3$ is pyramidal.

B $AlCl_3$ has a higher melting point than Al_2O_3.

C The Al_2Cl_6 dimer contains hydrogen bonding.

D The $AlCl_3$ is known as a halogen carrier in the chlorination of benzene.

9 Which of the following processes is endothermic?

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

B $SO_2(g) + \frac{1}{2}O_2(g) \rightarrow SO_3(g)$

C $2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

D $Li^+(g) + Cl^-(g) \rightarrow LiCl(s)$

10 Iron can be obtained by the reduction of its oxide by carbon monoxide:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g) \qquad \Delta H = –27 \text{ kJ mol}^{–1}$$

By using the data (enthalpy change of formation) given in the table, find the enthalpy change of formation of Fe_2O_3(s).

	ΔH_f / kJ mol$^{–1}$
CO(g)	–111
CO_2(g)	–394

A –310 kJ mol^{-1}

B –411 kJ mol^{-1}

C –822 kJ mol^{-1}

D –849 kJ mol^{-1}

11 Which of the following options is correct for the following equilibrium?

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = −950 \text{ kJ mol}^{–1}$$

	Condition	**Position of equilibrium**	$\boldsymbol{K_c}$
A	Increase in temperature	Right	Increase
B	Addition of catalyst	Right	No change
C	Addition of HC*l*(g)	No change	No change
D	Decrease in pressure	Right	No change

12 The Haber process is the industrial manufacture of ammonia. The following equilibrium exists at the expected conditions needed for the Haber process:

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

Which of the following changes would increase both the proportion of ammonia present at equilibrium and the value of equilibrium constant, K_c?

A adding more finely divided iron

B changing the temperature to 100 ^oC.

C changing the temperature to 600 ^oC.

D setting the total pressure to 400 atm

13 0.100 moles of HC*l* was mixed with 0.300 moles of NaOH and the total volume was 2 dm^3. What is the pH of the resulting solution?

A 13.3 **B** 13.0 **C** 1.0 **D** 0.7

14 For the reaction **L**(aq) + **2M**(aq) → **N**(aq), the rate equation is

$$\text{Rate} = k\,[H^+][\mathbf{M}]^2$$

Which of the following is **false**?

A H^+ is a catalyst in the reaction.

B When the concentration of **L** is halved, the rate remains unchanged.

C The unit for the rate constant is mol^{-2} dm^6 s^{-1}.

D If the concentration of **M** is doubled, the rate of the experiment increases by two times.

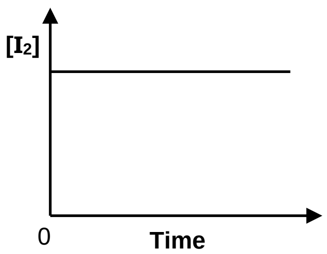
15 Iodine reacts with propanone according to the following equation.

$$I_2 + CH_3COCH_3 \rightarrow CH_3COCH_2I + HI$$

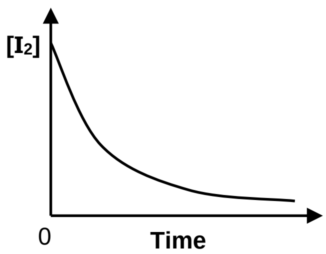
The reaction of iodine with propanone is found to be zero order with respect to iodine.

Which graph correctly shows how the $[I_2]$ changes with time?

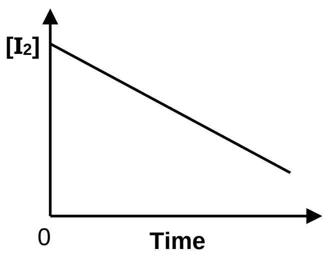
A



C



B



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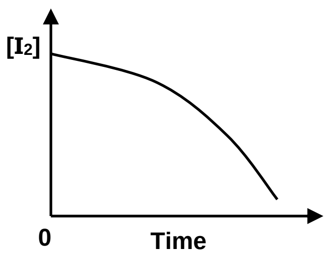


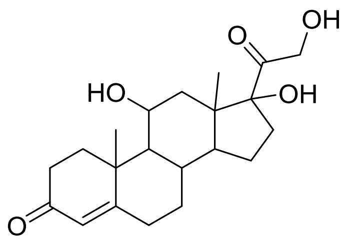
16 An unknown element **X** undergoes radioactive decay to form element **Y**. The radioactive decay is a first-order reaction with a half-life of 47.0 minutes.
How long will it take for the molar proportion of **X** to **Y** to be 1:7?

A 23.5 min **B** 47.0 min **C** 94.0 min **D** 141.0 min

17 The proton number of the element **E** is less than 20.
When the chloride of **E** is dissolved in water, a slightly acidic solution is obtained.
When the oxide of **E** is dissolved in water, an alkaline solution is obtained.
In which Group of the Periodic Table is **E** likely to be found?

A 1 **B** 2 **C** 13 **D** 14

18 Cortisol is a hormone that can increase blood sugar and aids in the metabolism of fat, protein, and carbohydrates.



cortisol

Which of the following will not react with cortisol?

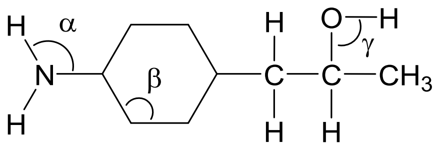
A solid sodium carbonate

B red phosphorus and excess Br_2

C cold, alkaline potassium managate(VII)

D 2,4-dinitrophenylhydrazine

19 What are the angles α, β and γ in the following molecule?



	α	β	γ
A	120	120	90
B	109	109	107
C	107	120	105
D	107	109	105

20 A catalytic converter is part of the exhaust system of many modern cars. Which one of the following reactions occurs in the catalytic converter?

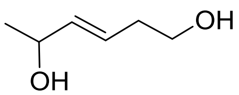
A $2C_xH_y + (4x + y)NO \rightarrow 2xCO_2 + yH_2O + (2x + \frac{y}{2})N_2$

B $2SO_2 + 2NO \rightarrow 2SO_3 + N_2$

C $CO_2 + NO \rightarrow CO + NO_2$

D $2C + O_2 \rightarrow 2CO$

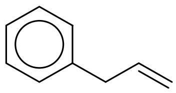
21 Hex-3-en-1,5-diol has the following structure.



How many moles of PCl_5 will react with the products formed from heating 1 mole of hex-3-en-1,5-diol in the presence of acidified potassium manganate(VII)?

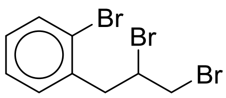
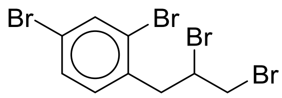
A 1 **B** 2 **C** 3 **D** 4

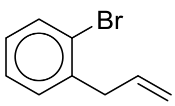
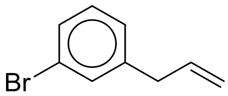
22 Bromine, along with iron(III) bromide, is dissolved in compound **P** and left to stand in the dark.

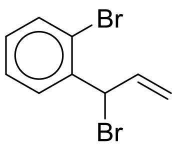
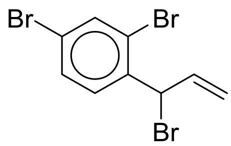


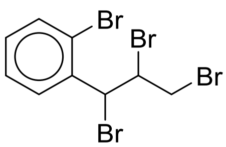
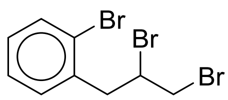
compound **P**

Which of the following pairs is likely to be the major products formed?

A  and 

B  and 

C  and 

D  and 

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23 Chlorofluorocarbons (CFCs) have been widely used in aerosol sprays, refrigerators and in making foamed plastics, but are now known to destroy ozone in the upper atmosphere. Which of the following will not destroy ozone, and therefore can be used as a replacement for CFCs?

A $CHBr_2CH_2CH_2CCl_3$

B $CH_3CHFCH_2CH_2F$

C $CH_2ClCH_2CHFCH_3$

D $CHF_2CH_2CH_2CHBr_2$

24 A glass of wine was exposed to air for a period of time. This causes the wine to have a sour taste. A student proposed that a portion of ethanol present in the wine has been oxidised, thus giving rise to the sour taste.

Which of the following reagents can be used to confirm the above hypothesis?

A Na **B** NaOH **C** K_2CO_3 **D** $KMnO_4$

25 Butanoic acid was heated under reflux with a mixture of ethanol and propanol in the presence of concentrated sulfuric acid. Which of the following is a possible product of this reaction?

A ethyl propanoate

B propyl butanoate

C butyl butanoate

D propyl ethanoate

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 Chlorine gas reacts with sodium hydroxide according to the following equation.

$$3Cl_2 + 6OH^- \rightarrow 5Cl^- + ClO_3^- + 3H_2O$$

Which of the following statements is true for this reaction?

1 C*l* is oxidised.

2 C*l* is reduced.

3 Oxidation state of O does not change.

27 Which of the following shows a correct example of a conjugate acid / base pair?

1 CH_3CO_2H, $CH_3CO_2^-Na^+$

2 CH_3NH_2, $CH_3NH_3^+Cl$

3 H_2O, OH^-

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

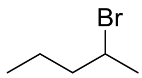
Based on its position in the Periodic Table, which properties will element **X** (atomic number 14) have?

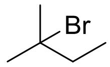
1 Its oxide has a simple molecular structure.

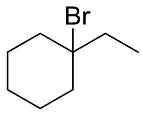
2 Its chloride hydrolyses in water to give an acidic solution.

3 Element **X** has high melting and boiling point.

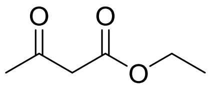
29 An unknown halogen derivative, **Q**, was heated with alcoholic potassium hydroxide. A product that exhibits geometric isomerism is obtained. Which of the following is a possible identity of compound **Q**?

1 

2 

3 

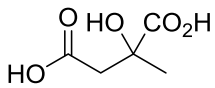
30 Compound **Y** is reacted with aqueous hydrogen cyanide in alkaline condition at 20 °C to produce compound **Z**. Compound **Z** is then heated under reflux with dilute sulfuic acid and the products isolated.

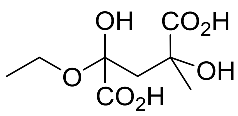


Compound **Y**

Which of the following are the possible products from the above reaction?

1 CH_3CH_2OH

2 

3 

Catholic Junior College
JC 2 Preliminary Examinations
Higher 1

CHEMISTRY

8872/01

Paper 1 Multiple Choice

Tuesday 29 August 2017
50 minutes

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

Section A

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 12.2.
What is the ratio of ^{12}C to ^{13}C?

A 4:1 **B** 3:1 **C** 3:4 **D** 1:4

Answer: A

Let the percentage of ^{12}C be x.

Hence, the percentage of ^{13}C is $(100 - x)$

$$\left(\frac{x}{100} \times 12\right) + \left(\frac{100-x}{100} \times 13\right) = 12.2$$

x = 80%

Hence, ^{12}C to ^{13}C is 80:20 which is 4:1

2 10 cm^3 of a pure hydrocarbon **X** was completely burnt in 80 cm^3 of excess oxygen to give carbon dioxide gas and water vapour. After cooling to room temperature, the volume of gaseous mixture decreased from 105 cm^3 to 55 cm^3. A further reduction of 40 cm^3 was observed when the residual gas was passed through aqueous sodium hydroxide.
All gas volumes were measured at the same temperature and pressure.
What is the formula of **X**?

A C_2H_6 **B** C_3H_8 **C** C_4H_{10} **D** C_5H_{12}

Answer: C

	C_xH_y(g) +	$(x + \frac{y}{4})O_2$ (g) →	xCO_2(g) +	$\frac{y}{2}H_2O(l)$
Initial (cm^3)	10	80	0	0
Final (cm^3)	0	55-40 = 15	40	105-55 = 50 cm^3 after cooling
Vol used (cm^3)	10	80-15=65	40	50
Ratio	1	6.5	4	5

By inspection, x = 4.

$\therefore \frac{y}{2} = 5 \quad \therefore y = 10$

∴ molecular formula of the hydrocarbon is C_4H_{10}.

3 A plasma is a gaseous mixture in which atoms have been completely stripped of their electrons, leaving bare nuclei. When passed through an electric field, the ^{1}H nucleus is deflected at an angle of $+4^{o}$. What will be the angle of deflection for the ^{3}H nucleus in the same plasma?

A $+0.75^{o}$ **B** $+1.3^{o}$ **C** $+4^{o}$ **D** $+12^{o}$

Answer: B

angle of deflection = $k\left(\dfrac{\text{charge}}{\text{mass}}\right)$

For the ^{1}H nucleus, $4 = k\left(\dfrac{+1}{1}\right)$. Hence k is 4.

For the ^{3}H nucleus, angle = $4\left(\dfrac{+1}{3}\right) = 1.3^{o}$.

4 *Use of the Data Booklet is relevant to this question.*
What do the ions $^{23}Na^{+}$ and $^{24}Mg^{2+}$ have in common?

A Both ions have more electrons than neutrons.

B Both ions have 12 neutrons in their nuclei.

C Both ions contain the same number of nucleons in their nuclei.

D Both ions have an outer electronic configuration of $3s^2\,3p^6$.

Answer: B

	$^{23}Na^{+}$	$^{24}Mg^{2+}$
No. of protons	11	12
No. of electrons	11 – 1 = 10	12 – 2 = 10
No. of neutrons	23 – 11 = 12	24 – 12 = 12
No. of nucleons (protons + neutrons)	23	24
Electronic Configuration	$1s^2\,2s^22p^6$	$1s^2\,2s^22p^6$

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

Which of the following particles would, on losing an electron, have a half-filled set of p orbitals?

A C^- **B** N **C** N^- **D** O^+

Answer: C

	Full electronic configuration of species	Full electronic configuration after losing an electron
C^-	$1s^2\ 2s^2 2p_x^1 2p_y^1 2p_z^1$ (already has half filled set of p orbitals)	$1s^2\ 2s^2 2p_x^1 2p_y^1 2p_z^0$
N	$1s^2\ 2s^2 2p_x^1 2p_y^1 2p_z^1$ (already has half filled set of p orbitals)	$1s^2\ 2s^2 2p_x^1 2p_y^1 2p_z^0$
N^-	$1s^2\ 2s^2 2p_x^2 2p_y^1 2p_z^1$	$1s^2\ 2s^2$ $\mathbf{2p_x^1 2p_y^1 2p_z^1}$ (has half filled set of p orbitals)
O^+	$1s^2\ 2s^2 2p_x^1 2p_y^1 2p_z^1$ (already has half filled set of p orbitals)	$1s^2\ 2s^2 2p_x^1 2p_y^1 2p_z^0$

6 The first seven successive ionisation energies (in kJ mol^{-1}) of an element **J** are given below:

1020 1950 2730 4580 6020 12300 15400

Which of the following statements about **J** is correct?

A It has a valence shell electronic configuration of $ns^2\ np^4$

B Its atomic radius is larger than its ionic radius.

C It has a lower second ionisation energy than that of its preceding element.

D It can form a chloride that has a trigonal pyramidal shape.

Answer: D

Most significant increase in IE is between 6020 and 12300 (5^{th} and 6^{th} IE). Hence element **J** is from Group 15 with 5 valence electrons.

A Incorrect. The valence shell configuration is <u>**ns^2np^3.**</u> (5 valence electrons)

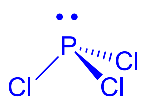
B Incorrect. It is likely to gain 3 electrons to form **J**$^{3-}$ anion and hence the atomic radius is expected to be smaller than the anionic radius.

C Electronic configuration of **J**$^+$(g): <u>**ns^2np^2**</u>

Electronic configuration of the singly charged preceding element: <u>**ns^2np^1**</u>

Element **J** is NOT expected to have a lower second ionisation energy than that of its preceding element.

D Correct. With 5 valence electrons, **J** is likely to form a chloride with 3 bond pairs and 1 lone pair (for central atom **J** to achieve octet). Hence **J** can form a chloride that has as trigonal pyramidal shape. Eg: phosphorus is a group 15 element:



7 In which of the following pairs of compounds is the bond angle in particle **I** greater than that in particle **II**?

	I	**II**
A	PH_3	BH_3
B	NO_3^-	ClO_2^-
C	SF_6	I_3^-
D	ClF_3	$BeCl_2$

Answer: B

This qns can be done by counting the number of bond pairs and lone pair of electrons.

	I	**Bp and lp**	**Shape and angle**	**II**	**Bp and lp**	**Shape and angle**
A	PH_3	3 bp 1 lp	Trigonal pyramidal < 109°	BH_3	3 bp 0 lp	Trigonal planar 120°
B	NO_3^-	3 bp 0 lp	Trigonal planar 120°	ClO_2^-	2 bp 2 lp	Bent < 109°
C	SF_6	6 bp 0 lp	Octahedral 90°	I_3^-	2 bp 3 lp	Linear 180°
D	ClF_3	3 bp 2 lp	T shaped < 90°	$BeCl_2$	2 bp 0 lp	Linear 180°

8 Which one of the following statements about aluminium chloride is correct?

A $AlCl_3$ is pyramidal.

B $AlCl_3$ has a higher melting point than Al_2O_3.

C The Al_2Cl_6 dimer contains hydrogen bonding.

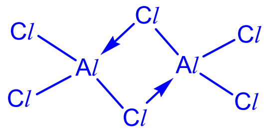
D The $AlCl_3$ is known as a halogen carrier in the chlorination of benzene.

Answer: D

A $AlCl_3$ has 3 bond pairs and no lone pairs. It is trigonal planar in shape.

B $AlCl_3$ is simple molecular and hence will have a lower melting point than Al_2O_3 which is giant ionic.

C The Al_2Cl_6 dimer **contains** two co-ordinate bonds, not hydrogen bonds.



D The $AlCl_3$ catalyst is also known as a halogen carrier in the chlorination of benzene.

9 Which of the following processes is endothermic?

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

B $SO_2(g) + \frac{1}{2}O_2(g) \rightarrow SO_3(g)$

C $2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

D $Li^+(g) + Cl^-(g) \rightarrow LiCl(s)$

Answer: A

A This shows bond breaking / dissociation which is endothermic.

B SO_2 undergoes combustion and combustion reactions are exothermic.

C Neutralisation reaction is exothermic as the ionic eqution is $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$. Bond formation (to form the molecule from the ions) is exothermic.

D Electrostatic forces of attraction between oppositely charged ions result in the formation of ionic bonds. Bond formation is exothermic. Also, the equation represent lattice energy of Li*Cl* where 1 mol of ionic solid Li*Cl* is formed from its separate gaseous ions.

10 Iron can be obtained by the reduction of its oxide by carbon monoxide:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g) \qquad \Delta H = -27 \text{ kJ mol}^{-1}$$

By using the data (enthalpy change of formation) given in the table, find the enthalpy change of formation of $Fe_2O_3(s)$.

	ΔH_f / kJ mol^{-1}
CO(g)	–111
CO_2(g)	–394

A –310 kJ mol^{-1}

B –411 kJ mol^{-1}

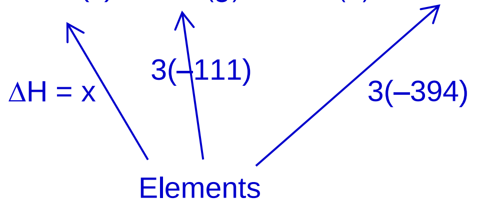
C –822 kJ mol^{-1}

D –849 kJ mol^{-1}

Answer: C

$\Delta H = -27$ kJ mol^{-1}

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$



Using Hess' Law,

x + 3(–111) + (–27) = 3(–394)
x = –822 kJ mol^{-1}

11 Which of the following options is correct for the following equilibrium?

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -950\ kJ\ mol^{-1}$$

	Condition	Position of equilibrium	K_c
A	Increase in temperature	Right	Increase
B	Addition of catalyst	Right	No change
C	Addition of HC*l*(g)	No change	No change
D	Decrease in pressure	Right	No change

Answer: D

	Condition	Position of equilibrium	K_c
A	Increase in temperature	Right (False) Position of eqm will shift to favour the endothermic side which is the left hand side.	Increase (False) K_c should decrease.
B	Addition of catalyst	Right (False) No change in position of equilibrium	No change (True) K_c is independent of catalyst.
C	Addition of HCl (g)	Right (False) Basic NH_3 gas reacts with HCl gas to form a white solid of NH_4Cl. Hence, some $NH_3(g)$ is removed from the equilibrium mixture and the position of equilibrium shifts left.	No change (True)
D	Decrease in pressure	Right (True) Position of eqm will shift to favour the side with greater no. of moles of gaseous molecules which is the right hand side.	No change (True)

12 The Haber process is the industrial manufacture of ammonia. The following equilibrium exists at the expected conditions needed for the Haber process:

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

Which of the following changes would increase both the proportion of ammonia present at equilibrium and the value of equilibrium constant, K_c?

A adding more finely divided iron

B changing the temperature to 100 °C.

C changing the temperature to 600 °C.

D setting the total pressure to 400 atm

Answer: B

As this reaction is in the syllabus, students are expected to know that the reaction is exothermic.

Typical conditions used in the Haber process are

- a pressure of 200-300 atm.
- a moderate temperature of *about* 450 - 500 °C.
- Iron *catalyst* (finely-divided)

	Change	Proportion of ammonia present	K_c
A	adding more finely divided iron	Not affected	Not affected
B	changing the temperature to 100 °C	The drop in temperature would favour the forward exothermic reaction and hence increase the proportion of ammonia	Increases
C	changing the temperature to 600 °C.	The increase in temperature would favour the backward endothermic reaction and hence decrease the proportion of ammonia	Decreases
D	setting the total pressure to 400 atm	The increase in pressure would favour the formation of newer number of moles of gas (forward reaction) and hence increase the proportion of ammonia.	Not affected

13 0.100 moles of HC*l* was mixed with 0.300 moles of NaOH and the total volume was 2 dm^3. What is the pH of the resulting solution?

A 13.3 **B** 13.0 **C** 1.0 **D** 0.7

Answer: B

HC*l* + NaOH → NaC*l* + H2O

Since HC*l* ≡ NaOH, NaOH is present in excess by 0.300 – 0.100 = 0.200 moles.

NaOH → Na^+ + OH^-

$[OH^-] = \frac{0.200}{2} = 0.100$ mol dm^{-3}

pOH = -lg(0.100) = 1.0

pH = 14 – pOH (at 25 °C) = 13.0

14 For the reaction **L**(aq) + **2M**(aq) → **N**(aq), the rate equation is

$$\text{Rate} = k\,[H^+][\mathbf{M}]^2$$

Which of the following is **false**?

A H^+ is a catalyst in the reaction.

B When the concentration of **L** is halved, the rate remains unchanged.

C The unit for the rate constant is $mol^{-2}\ dm^6\ s^{-1}$.

D If the concentration of **M** is doubled, the rate of the experiment increases by two times.

Answer: D

A True. It is not a reagent as seen in the overall reaction, but it affects the rate.

B True. Reaction is zero order wrt [**L**] as [**L**] is not involved in the rate equation. Hence, any change in [**L**] will not affect the rate.

C True.

$$\text{Rate} = k\,[H^+][\mathbf{M}]^2$$

mol dm^{-3} s^{-1} **mol dm^{-3}** **(mol dm^{-3})^2**

Hence units of k has to be mol^{-2} dm^6 s^{-1} in order for the units on the left and the right of the equal sign to be the same.

D False. Reaction is second order wrt [**M**]. So when [**M**] is doubled, the rate of the reaction should increase by 4 times.

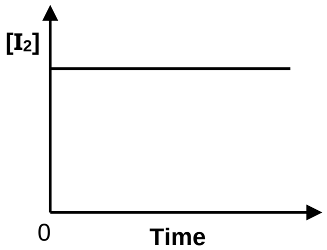
15 Iodine reacts with propanone according to the following equation.

$$I_2 + CH_3COCH_3 \rightarrow CH_3COCH_2I + HI$$

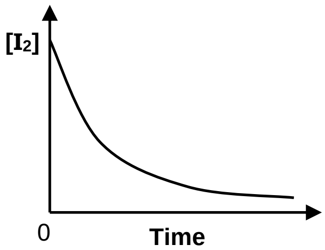
The reaction of iodine with propanone is found to be zero order with respect to iodine.

Which graph correctly shows how the $[I_2]$ changes with time?

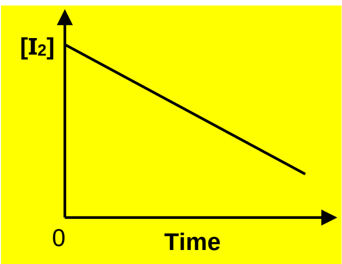
A



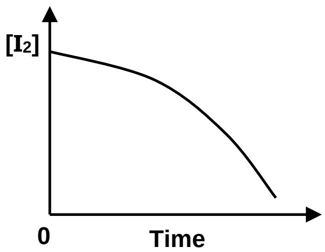
C



B



D



Answer: B

Zero order with respect to iodine means that the rate of the reaction (gradient in the $[I_2]$ – time graph) is constant.

Incorrect answers:

A Gradient is zero. It means that rate of reaction is zero.

C Gradient (rate) is decreasing as $[I_2]$ decreases.

D Gradient (rate) is increasing as $[I_2]$ decreases.

16 An unknown element **X** undergoes radioactive decay to form element **Y**. The radioactive decay is a first-order reaction with a half-life of 47.0 minutes.
How long will it take for the molar proportion of **X** to **Y** to be 1:7?

A 23.5 min **B** 47.0 min **C** 94.0 min **D** 141.0 min

Answer: D

Let a be the initial amt of X

X: $a \longrightarrow \frac{1}{2}a \longrightarrow \frac{1}{4}a \longrightarrow \frac{1}{8}a$

Y: $0 \longrightarrow \frac{1}{2}a \longrightarrow \frac{3}{4}a \longrightarrow \frac{7}{8}a$

Thus, 3 half-lives have passed. Time taken = 47 × 3 = 141 min

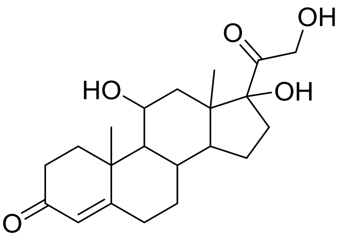
17 The proton number of the element **E** is less than 20.
When the chloride of **E** is dissolved in water, a slightly acidic solution is obtained.
When the oxide of **E** is dissolved in water, an alkaline solution is obtained.
In which Group of the Periodic Table is **E** likely to be found?

A 1 **B** 2 **C** 13 **D** 14

Answer: B

Chlorides that dissolve to give acidic solution → $MgCl_2$, $AlCl_3$, $SiCl_4$, PCl_5
Oxides that dissolves to give alkaline solution → Na_2O, MgO
Thus the element E is most likely Mg, a Group 2 element.

18 Cortisol is a hormone that can increase blood sugar and aids in the metabolism of fat, protein, and carbohydrates.



cortisol

Which of the following will not react with cortisol?

A solid sodium carbonate

B red phosphorus and excess Br_2

C cold, alkaline potassium managate(VII)

D 2,4-dinitrophenylhydrazine

Answer: A

Cortisol contains alcoholic –OH groups, ketone functional groups and an alkene functional group. It does not have a carboxylic acid functional group. Thus,

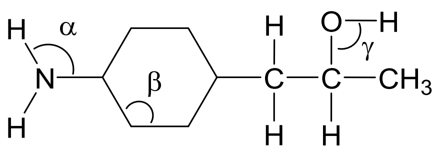
A no reaction

B PBr_3 formed will react with –OH groups

C mild oxidation of alkene functional group to form diol

D condensation reaction with ketone to form orange crystals

19 What are the angles α, β and γ in the following molecule?



	α	β	γ
A	120	120	90
B	109	109	107
C	107	120	105
D	107	109	105

Answer: D

α: There are 3 bond pairs, 1 lone pair around N central atom $\rightarrow$ 107°
β: There are 4 bond pairs, no lone pair around C central atom $\rightarrow$ 109°
γ: There are 2 bond pairs, 2 lone pair around O central atom $\rightarrow$ 105°

20 A catalytic converter is part of the exhaust system of many modern cars. Which one of the following reactions occurs in the catalytic converter?

A $2C_xH_y + (4x + y)NO \rightarrow 2xCO_2 + yH_2O + (2x + \frac{y}{2})N_2$

B $2SO_2 + 2NO \rightarrow 2SO_3 + N_2$

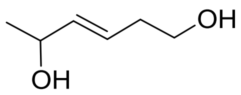
C $CO_2 + NO \rightarrow CO + NO_2$

D $2C + O_2 \rightarrow 2CO$

Answer: A

Catalytic converters convert harmful exhaust gases into inert ones, such as carbon dioxide and water vapor. Thus options **B – C** are incorrect as harmful gases such as SO_3, NO_2 and CO are formed.

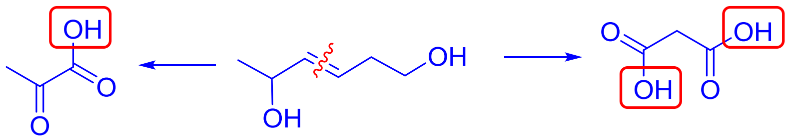
21 Hex-3-en-1,5-diol has the following structure.



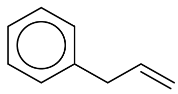
How many moles of PCl_5 will react with the products formed from heating 1 mole of hex-3-en-1,5-diol in the presence of acidified potassium manganate(VII)?

A 1 **B** 2 **C** 3 **D** 4

Answer: C

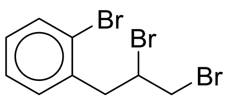
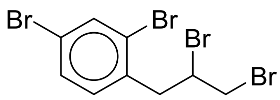


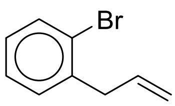
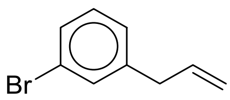
22 Bromine, along with iron(III) bromide, is dissolved in compound **P** and left to stand in the dark.

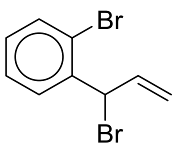
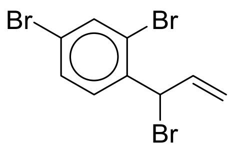


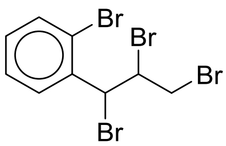
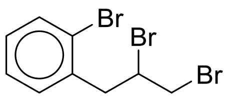
compound **P**

Which of the following pairs is likely to be the major products formed?

A  and 

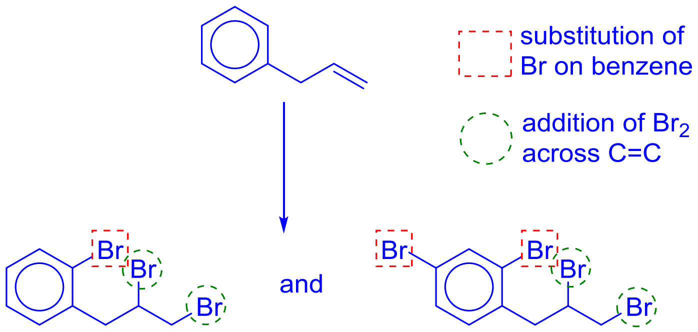
B  and 

C  and 

D  and 

Answer: A

When **P** is reacted with bromine in the dark, addition across the C=C occurrs. In the presence of $FeBr_3$ catalyst, substitution of the benzene will occur too. To form the major product from the substitution of Br on the benzene, Br has to be at position 2 and/or 4 with respect to the alkyl sidechain. Substitution of the alkyl group will not occur due to the absence of UV light.



23 Chlorofluorocarbons (CFCs) have been widely used in aerosol sprays, refrigerators and in making foamed plastics, but are now known to destroy ozone in the upper atmosphere. Which of the following will not destroy ozone, and therefore can be used as a replacement for CFCs?

A $CHBr_2CH_2CH_2CCl_3$

B $CH_3CHFCH_2CH_2F$

C $CH_2ClCH_2CHFCH_3$

D $CHF_2CH_2CH_2CHBr_2$

Answer: B

CFCs will release C*l* or Br radicals when exposed to UV light in the upper atmosphere (stratosphere) as the C-C*l* bonds and C-Br bonds will break (homolytically). These radicals are responsible for the breaking down of the ozone layer. Only C-F bonds are not broken when exposed to UV light in the stratosphere. Thus, a suitable CFC replacement would be option B where there is no C*l* or Br in the molecule.

24 A glass of wine was exposed to air for a period of time. This causes the wine to have a sour taste. A student proposed that a portion of ethanol present in the wine has been oxidised, thus giving rise to the sour taste.

Which of the following reagents can be used to confirm the above hypothesis?

A Na **B** NaOH **C** K_2CO_3 **D** $KMnO_4$

Answer: C

To prove the hypothesis correct, the student has to test for the presence of carboxylic acid (ethanol is oxidised to ethanoic acid, giving rise to the sour taste).

A Na : both ethanol and ethanoic acid will result in effervescence of H_2(g)

B NaOH : only ethanoic acid will react, however, there is no observable change and thus cannot be used as a distinguishing test

C K_2CO_3 : ethanoic acid reacts and the effervescence released (CO_2) produce white ppt when passed through $Ca(OH)_2$ solution.

D $KMnO_4$: only ethanol will decolourise purple $KMnO_4$

25 Butanoic acid was heated under reflux with a mixture of ethanol and propanol in the presence of concentrated sulfuric acid. Which of the following is a possible product of this reaction?

A ethyl propanoate

B propyl butanoate

C butyl butanoate

D propyl ethanoate

Answer: B

The only two possible products are $\underbrace{\textbf{ethyl}}_{\text{alcohol}}$ $\underbrace{\textbf{butanoate}}_{\text{carboxylic acid}}$ **and** $\overbrace{\textbf{propyl}}^{\text{alcohol}}$ $\overbrace{\textbf{butanoate}}^{\text{carboxylic acid}}$**.**

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 Chlorine gas reacts with sodium hydroxide according to the following equation.

$$3Cl_2 + 6OH^- \rightarrow 5Cl^- + ClO_3^- + 3H_2O$$

Which of the following statements is true for this reaction?

1 C*l* is oxidised.

2 C*l* is reduced.

3 Oxidation state of O does not change.

Answer: A

Statement 1 is true. C*l* is oxidised from 0 in Cl_2 to +5 in ClO_3^-.

Statement 2 is true. C*l* is reduced from 0 in Cl_2 to –1 in Cl^-.

Statement 3 is true. Oxidation state of O is is –2 in OH^-, H_2O and ClO_3^-.

27 Which of the following shows a correct example of a conjugate acid / base pair?

1 CH_3CO_2H, $CH_3CO_2^-Na^+$

2 CH_3NH_2, $CH_3NH_3^+Cl$

3 H_2O, OH^-

Answer: A (1, 2 and 3)

1 CH_3CO_2H (acid), $CH_3CO_2^-Na^+$ (conjugate base)

2 CH_3NH_2 (base), $CH_3NH_3^+Cl$ (conjugate acid)

3 H_2O (acid), OH^- (conjugate base)

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

Based on its position in the Periodic Table, which properties will element **X** (atomic number 14) have?

1 Its oxide has a simple molecular structure.

2 Its chloride hydrolyses in water to give an acidic solution.

3 Element **X** has high melting and boiling point.

Answer: C (2 and 3 only)

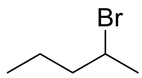
Element X is silicon.

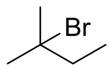
Statement 1: False. SiO_2 is a giant covalent compound.

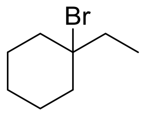
Statement 2: True. $SiCl_4$ hydrolyses complete in water to give a pH 2 solution.

Statement 3: True. Si has a giant covalent structure, thus have high m.p. and b.p.

29 An unknown halogen derivative, **Q**, was heated with alcoholic potassium hydroxide. A product that exhibits geometric isomerism is obtained. Which of the following is a possible identity of compound **Q**?

1 

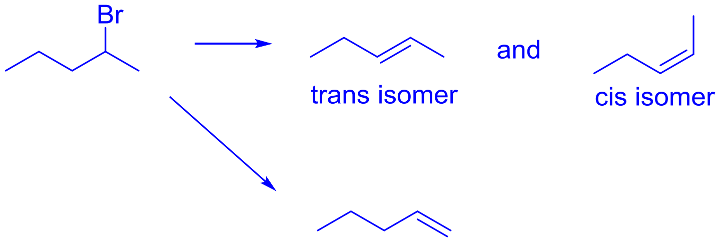
2 

3 

Answer: D (1 only)

Compound Q undergoes elimination to form alkene.

Option 1: 2 different alkenes are produced. One of the alkenes exhibits geometric isomerism.



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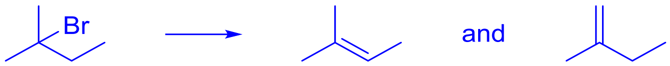
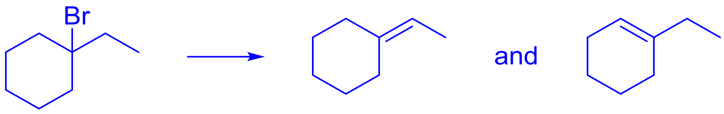
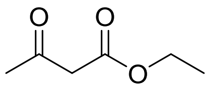
Option 2: Both alkenes formed do not exhibit geometric isomerism.



Option 3: Both alkenes formed do not exhibit geometric isomerism.



30 Compound **Y** is reacted with aqueous hydrogen cyanide in alkaline condition at 20 °C to produce compound **Z**. Compound **Z** is then heated under reflux with dilute sulfuric acid and the products isolated.

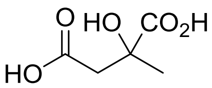


Compound **Y**

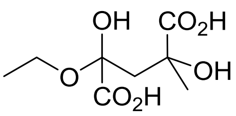
Which of the following are the possible products from the above reaction?

1 CH_3CH_2OH

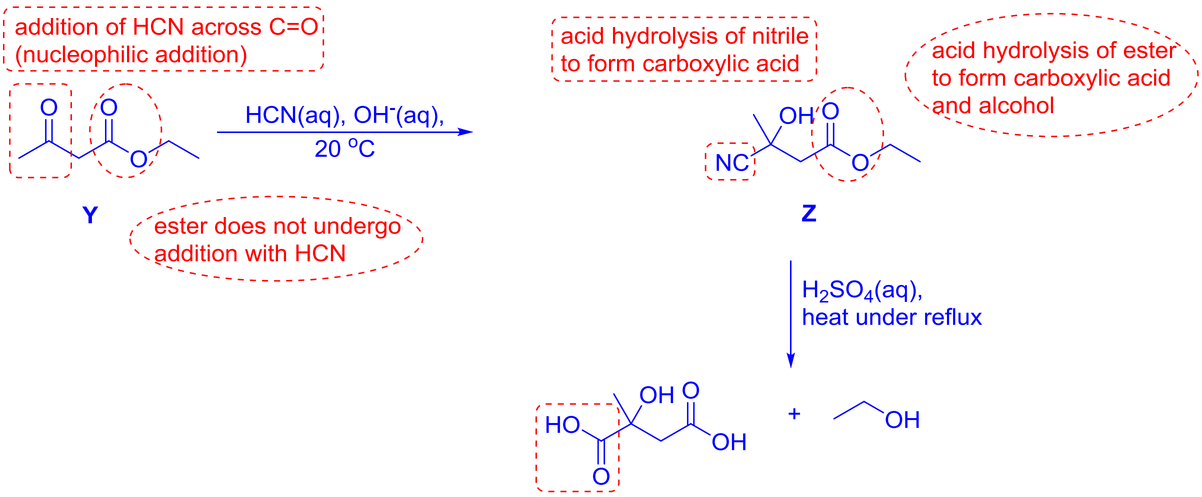
2



3



Answer: B



Catholic Junior College

JC2 Preliminary Examinations

Higher 1

CANDIDATE NAME

CLASS 2T

CHEMISTRY

Paper 2

8872/02
Friday 18 August 2017
2 hours

Candidates answer Section A on the Question Paper.
Additional Materials: Data Booklet
Answer paper

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 **two** questions on separate answer paper.

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.

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

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

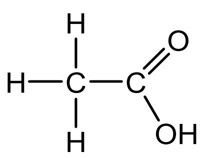
	For Examiner's Use		
Section A	Q1	9	
	Q2	12	
	Q3	7	
	Q4	6	
	Q5	6	40
Section B	Q6	20	
	Q7	20	
	Q8	20	40
Total			80

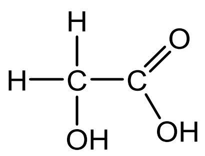
This document consists of **14** printed pages

Section A

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

1 Ethanoic acid and 2-hydroxyethanoic acid are weak acids containing two carbons each.


ethanoic acid


2-hydroxyethanoic acid

Ethanoic acid is a component in antiseptic that can be used to treat skin infections, whereas 2-hydroxyethanoic acid is commonly used in skincare products.

(a) Ethanoic acid dissociates according to the following equation:

$$CH_3CO_2H \rightleftharpoons CH_3CO_2^- + H^+$$

Write an expression for the acid dissociation constant, K_a, of ethanoic acid.

[1]

(b) The K_a of ethanoic acid is 1.74 x 10^{-5} mol dm^{-3}.
Given that the $[H^+]$ = [conjugate base], calculate the $[H^+]$ and hence the pH of 0.100 mol dm^{-3} of ethanoic acid.

[2]

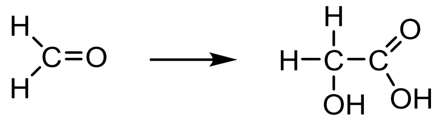
(c) The K_a of 2-hydroxyethanoic acid is 1.48 x 10^{-4} mol dm^{-3}.
Explain why 2-hydroxyethanoic acid has a higher K_a value than ethanoic acid.

....

....

.... [2]

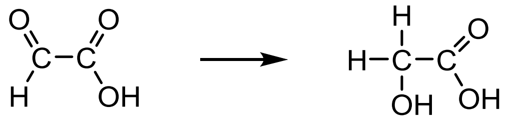
(d) Propose a simple reaction scheme to obtain 2-hydroxyethanoic acid from methanal.



methanal 2-hydroxyethanoic acid

[3]

(e) 2-hydroxyethanoic acid can also be obtained from oxoethanoic acid in a one-step reaction. State the reagents and conditions for this conversion.



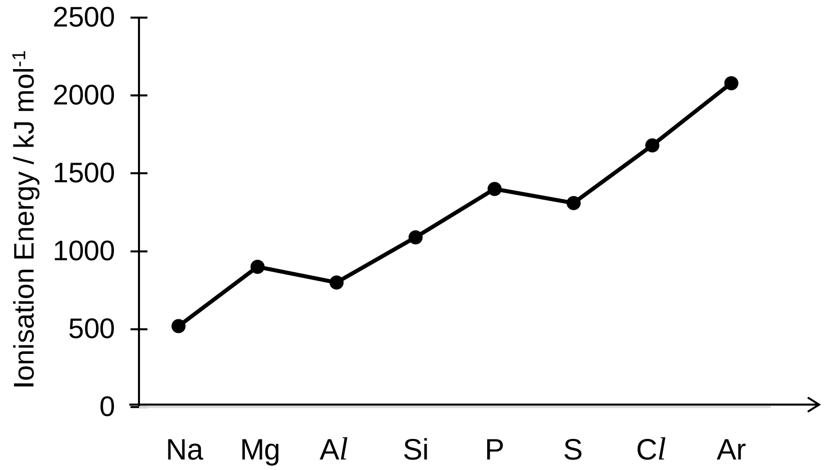
oxoethanoic acid 2-hydroxyethanoic acid

Reagents and conditions:

.... [1]

[Total: 9]

2 **(a)** The diagram below shows the first ionisation energies of the Period 3 elements from Na to Ar.



(i) Write an equation to represent the *first ionisation energy* of S.

....[1]

(ii) Explain why the first ionisation energy generally increases across Period 3.

....

....

....

....

....

....[2]

(iii) With the aid of electronic configurations, predict whether the **second** ionisation energy of Si will be higher or lower than the second ionisation of A*l*. Give your reasoning.

....

....

....

....

....[2]

(b) Sodium and magnesium are elements from Period 3 of the Periodic Table.

(i) State and explain two reasons why the melting point of magnesium is higher than that of sodium.

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……………………………………………………………………………………..........[2]

Magnesium can react with oxygen gas to form magnesium oxide, MgO, which is often used as a refractory material in the lining of furnaces.

(ii) Draw a dot-and-cross diagram to show the bonding in MgO.

[1]

(iii) Explain why the lattice energy of MgO is less exothermic than that of Mg_3N_2.

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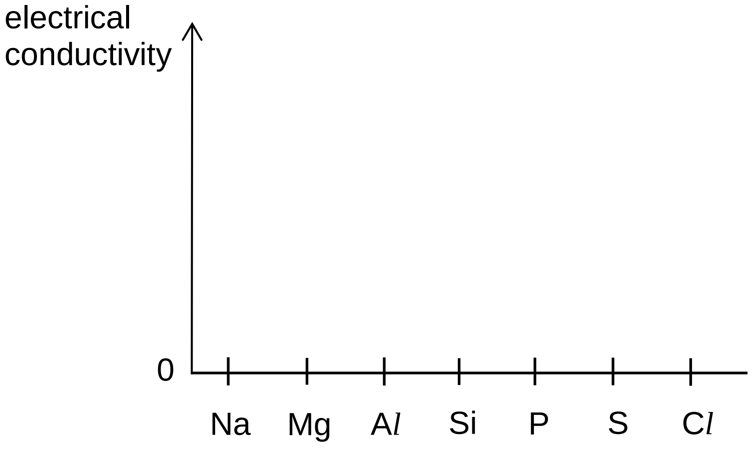
……………………………………………………………………………………..........[3]

(c) Using the axes below, sketch the graph to show the electrical conductivity of the Period 3 elements from Na to C*l*.



[1]

[Total: 12]

3 An aromatic ester with the molecular formula $C_8H_8O_2$ was synthesised in the laboratory using suitable reactants and heated under reflux with concentrated sulfuric acid catalyst for about 6 hours.
The enthalpy change for this esterification reaction can be regarded as 0 kJ mol^{-1}.

(a) Draw a Boltzmann distribution curve for the reactants at this temperature and use it to explain why the reaction is significantly slower when the catalyst is removed.

....

....

....

....

....

.... [3]

(b) The esterification reaction is reversible and hence has an equilibrium constant, K_c. Explain briefly how the equilibrium position and K_c are expected to change when the temperature is increased.

……………………………………………………………………………………….........

.... [2]

(c) When the aromatic ester is hydrolysed with H_2SO_4(aq), methanoic acid, HCO_2H, is not among the products.
Suggest two possible structural formulae for the ester.

[2]
[Total: 7]

4 **(a)** Hexa-1,4-diene, $CH_2CHCH_2CHCHCH_3$, has geometrical isomers.

(i) Draw the structural formula of each of the isomers so as to identify this isomerism and label each structure. [2]

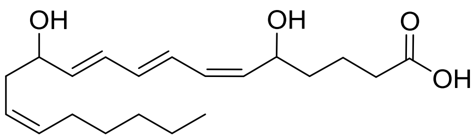
(ii) Explain how this isomerism arises.

……………………………………………………………………………………….........

……………………………………………………………………………………….........

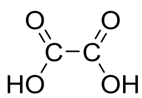
……………………………………………………………………………………….......[1]

(b) Leukotriene B4 is a biomolecule in the human body.



Leukotriene B4

Draw **all possible organic products** formed when leukotriene B4 is subjected to heating under reflux in the presence of acidified $KMnO_4$(aq). Note that any ethanodioic acid formed is further oxidised according to the following equation.



$$+ \ [O] \longrightarrow 2CO_2 + H_2O$$

[3]

[Total: 6]

5 In March 2017, residents in a small town in Alberta, Canada, received a shock when pink coloured water flowed from their taps. The colour was due to potassium manganate(VII), $KMnO_4$, used in the early stages of water treatment to remove pathogens and metal ions such as iron and manganese ions. $KMnO_4$ should have been removed before the treated water reached the homes of the consumers, but a water treatment valve malfunctioned which caused the incident to happen.

$KMnO_4$ has a relative formula mass of 158 and it exists as black crystals at room condition. When dissolved in water, small quantities of the solid are sufficient to give very intense shades of pink and purple solutions.

(a) Define the term *relative formula mass*.

....

.... [1]

$KMnO_4$ is used to remove Mn^{2+} present in water. $KMnO_4$ will oxidise Mn^{2+} to MnO_2 precipitate which can easily be filtered from the water.

The half equation that shows the reduction of MnO_4^- under the treatment conditions is:

$$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$$

(b) With reference to the *Data Booklet*, write down the oxidation half equation.

.... [1]

(c) Hence, give the overall equation that shows the removal of Mn^{2+} during the treatment of water.

.... [1]

(d) During treatment, the concentration of $KMnO_4$ used is 1 mg dm^{-3}. Convert this concentration value into mol dm^{-3} and hence calculate the maximum mass of MnO_2 that can be precipitated per cubic metre of water.
(1 g = 1000 mg; 1 cubic metre = 1000 dm^3)

[3]

[Total: 6]

Section B

Answer **two** questions from this section on separate answer paper.

6 Hydrogen peroxide and acidified potassium iodide can react according to the equation below.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow 2H_2O + I_2$$

The rate of reaction can be followed by measuring the amount of iodine produced after various times, from which the concentration of H_2O_2 remaining can be calculated.

In one such study, the following reaction mixture was prepared.

initial $[H^+]$ = 0.200 mol dm^{-3}
initial $[I^-]$ = 0.200 mol dm^{-3}
initial $[H_2O_2]$ = 0.0200 mol dm^{-3}

The table below shows $[H_2O_2]$ at various times.

time / s	**$[H_2O_2] \times 10^{-3}$ / mol dm^{-3}**
0	20.0
80	16.7
183	13.5
315	10.3
490	7.10
760	3.90

(a) **(i)** Explain the term *rate of reaction*. [1]

(ii) Explain why the initial concentration of H_2O_2 used is much lower than the concentrations of H^+ and I^- used. [1]

(iii) Plot a graph of the above results. [2]

(iv) Use your graph to determine:

I the order of reaction with respect to $[H_2O_2]$,

II the initial rate, in mol dm^{-3} s^{-1}.

Show all working and construction lines clearly on your graph. [4]

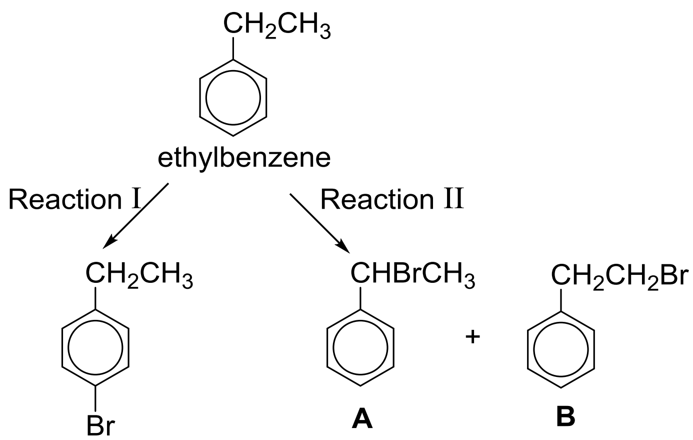
(v) Further experiments were carried out by changing [H^+] and [I^-], but keeping the initial [H_2O_2] constant. The following results were obtained.

Experiment	initial [H^+] / mol dm^{-3}	initial [I^-] / mol dm^{-3}	initial rate/ mol dm^{-3} s^{-1}
1	0.400	0.200	1.0×10^{-4}
2	0.200	0.100	2.5×10^{-5}
3	0.100	0.200	2.5×10^{-5}

Determine the orders with respect to [H^+] and [I^-]. Explain your reasoning. [2]

(b) Describe the reactions, if any, of the oxides P_4O_{10} and SiO_2 with water. State the approximate pH values of the resulting solutions and explain your answer with the aid of relevant equations for any reactions that occur. [3]

(c) Ethylbenzene can undergo substitution reactions to give three different products as shown in the scheme below.



(i) Explain why ethylbenzene does not undergo addition reactions readily. [1]

(ii) State the reagents and conditions for reactions **I** and **II**. [2]

(iii) Suggest the ratio in which **A** and **B** might be formed, assuming that the ease of substitution of H is the same for the formation of both compounds. [1]

(d) An alkaline solution of Cu^{2+}(aq) is used in organic chemistry to test for a particular functional group.

(i) Describe the appearance of a positive result of this test. [1]

(ii) Compounds **X** and **Y** both have the molecular formula $C_5H_{10}O$ and give an orange precipitate with 2,4-dinitrophenylhydrazine. However, compound **X** shows a positive result in the test in **(d)(i)** while compound **Y** does not. Suggest a possible structure for compound **X** and for compound **Y**, showing the skeletal formula in your answers. [2]

[Total: 20]

7 **(a)** Ethanol, CH_3CH_2OH, is manufactured in the industry by reacting ethene with steam in the presence of a catalyst. The reaction is reversible and the equation is as follows:

$$CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \qquad \Delta H = -45\ \text{kJ mol}^{-1}$$

(i) Draw a labelled reaction pathway diagram for this reaction. [2]

For every 1.0 mol dm^{-3} of ethene and 0.6 mol dm^{-3} of steam reacted and allowed to reach equilibrium, only 5% of the ethene is converted into ethanol at each pass through the reactor. To increase the overall yield of ethanol, ethanol is regularly removed from the equilibrium mixture as it is formed, and more ethene is added into the reaction mixture.

(ii) Using the information given above, calculate K_c (including units) at this temperature. [2]

(iii) Calculate the amount, in moles, of ethene (in every dm^3) that must be added to increase the equilibrium concentration of ethanol to 0.20 mol dm^{-3}. [2]

(iv) State the catalyst used for the reaction. [1]

(v) Apart from the methods mentioned above, suggest one other method which will result in an increase in the conversion of ethene into ethanol without changing the temperature and without adding more steam. Explain your answer briefly. [2]

(b) Ethanol is one of several compounds used as an 'anti-knock' agent that is added to unleaded petrol to prevent damage to car engines. Prior to the use of ethanol as an anti-knocl

To prevent accumulation of lead deposits in the engines, a small quantity of 1,2-dichloroethane was added to the gasoline to form $PbCl_2$ that can be flushed from the engine and into the air, but the compound quickly solidifies at atmospheric temperature. The accumulation of toxic lead compounds in the environment quickly resulted in a worldwide ban of leaded petrol.

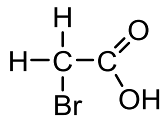
(i) Catalytic converters were fitted in cars to minimise the emissions of undesirable exhaust gases emitted such as carbon monoxide, oxides of nitrogen and unburnt hydrocarbons. State the environmental damage of one of the gases listed. [1]

(ii) The oxidation state of Pb in $PbCl_2$ is +2. What is the maximum oxidation state Pb is able to obtain and explain why this is so. [1]

(iii) Write an equation to show how the chloride of lead (where lead is at its maximum oxidation state) reacts with water. [1]

(iv) Explain why the reaction stated in **(b)(iii)** proceeds with greater ease than a similar reaction involving the chloride of silicon. [1]

(c) Ethene can be used as a starting material to synthesise 2-bromoethanoic acid.



2-bromoethanoic acid

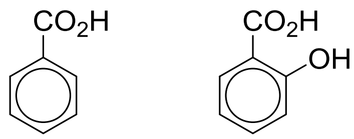
(i) Propose a reaction scheme that will convert ethene to 2-bromoethanoic acid, bearing in mind that each step should result in a fairly good yield of products. [3]

(ii) State the functional groups present in 2-bromoethanoic acid. [2]

(iii) Describe a simple chemical test to show the presence of bromine in 2-bromoethanoic acid. [2]

[Total: 20]

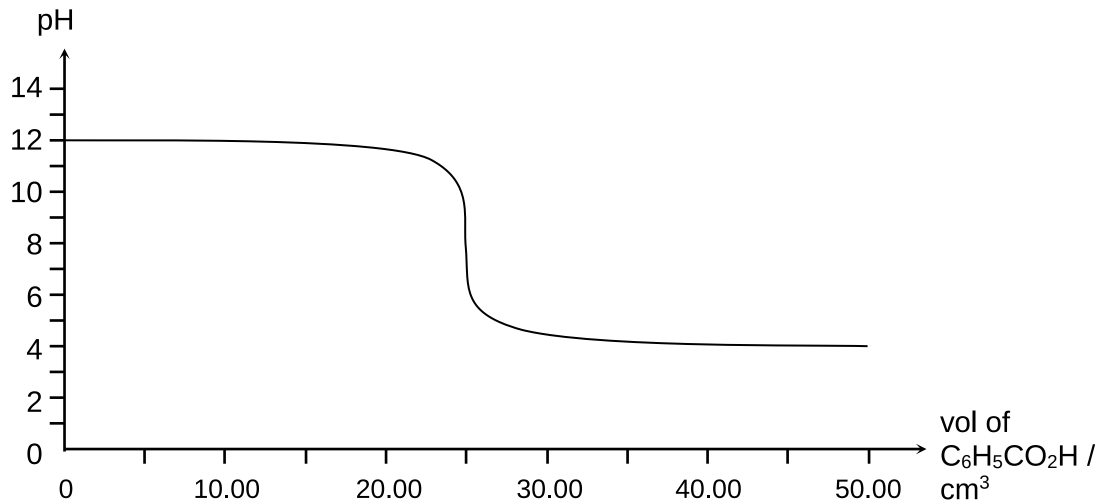
8 **(a)** Benzoic acid and salicylic acid are both important precursors for the industrial synthesis of many other organic substances.



benzoic acid salicylic acid

It was observed that salicylic acid has a lower solubility in water compared to benzoic acid in water. This is due to salicylic acid forming less extensive hydrogen bonding with water molecules. With the aid of a labelled diagram, suggest a reason for this observation. [2]

(b) In a titration carried out under standard conditions, a solution of benzoic acid is added to 20.00 cm^3 of aqueous sodium hydroxide. The change in pH was measured and the following titration curve was obtained.



(i) Using the titration curve, calculate the concentration of OH^- at the beginning of the reaction. [1]

(ii) Suggest a suitable indicator for the above reaction, stating the expected colour change. [2]

(iii) Explain your choice of indicator. [1]

(iv) Using the answer in **(b)(i)**, calculate the concentration of the solution of benzoic acid. [2]

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

In another experiment, 60.00 cm^3 of 0.600 mol dm^{-3} benzoic acid is added to 40.00 cm^3 of 0.800 mol dm^{-3} aqueous sodium hydroxide and the increase in temperature is measured.

Given that the enthalpy change of this reaction is –56.9 kJ mol^{-1}, calculate the increase in temperature. [3]

(d) In the 1940s, it was difficult to oxidise methylbenzene to benzoic acid using the oxygen present in air. Many methods resulted in incomplete oxidation or produced low yields of benzoic acid. It was later discovered that aluminium oxide is able to support controlled oxidation of methylbenzene to benzoic acid in the presence of air.

Aluminium oxide is amphoteric. Write balanced equations to illustrate this fact. [2]

(e) Compound **X** is a four carbon organic molecule. Upon addition of aqueous silver nitrate, a yellow precipitate was observed almost immediately. The yellow precipitate was then filtered off and the solution was left to stand. After a period of time, white precipitate was observed in the filtrate.

In a separate experiment, compound **X** was heated under reflux with aqueous sodium hydroxide to give compound **Y**. When compound **Y** was reacted with phosphorus(V) chloride, steamy fumes were observed. When one mole of compound **Y** was reacted with alkaline aqueous iodine, only one mole of yellow precipitate **Z** was produced.

Using the information given, deduce the structures of **X**, **Y** and **Z**. In your answer, state clearly the types of reactions that occurred. [7]

[Total: 20]

Catholic Junior College

JC2 Preliminary Examinations
Higher 1

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

Paper 2

8872/02
Friday 18 August 2017
2 hours

Candidates answer Section A on the Question Paper.
Additional Materials: Data Booklet
Answer paper

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 **two** questions on separate answer paper.

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.

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

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

Answer Scheme

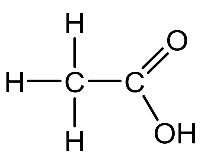
	For Examiner's Use		
Section A	Q1	/ 9	
	Q2	/ 12	
	Q3	/ 7	
	Q4	/ 6	
	Q5	/ 6	/ 40
Section B	Q6	/ 20	
	Q7	/ 20	
	Q8	/ 20	/ 40
Total			/ 80

This document consists of **19** printed pages and 1 blank page

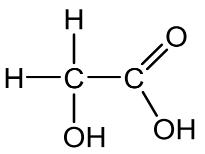
Section A

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

1 Ethanoic acid and 2-hydroxyethanoic acid are weak acids containing two carbons each.



ethanoic acid



2-hydroxyethanoic acid

Ethanoic acid is a component in antiseptic that can be used to treat skin infections, whereas 2-hydroxyethanoic acid is commonly used in skincare products.

(a) Ethanoic acid dissociates according to the following equation:

$$CH_3CO_2H \rightleftharpoons CH_3CO_2^- + H^+$$

Write an expression for the acid dissociation constant, K_a, of ethanoic acid.

$$K_a = \frac{[CH_3CO_2^-][H^+]}{[CH_3CO_2H]}$$

[1]

(b) The K_a of ethanoic acid is 1.74×10^{-5} mol dm^{-3}.
Given that the [H$^+$] = [conjugate base], calculate the [H$^+$] and hence the pH of 0.100 mol dm^{-3} of ethanoic acid.

$$K_a = \frac{[CH_3CO_2^-][H^+]}{[CH_3CO_2H]}$$

$$1.74 \times 10^{-5} = \frac{[H^+]^2}{(0.100)}$$

$$[H^+] = 1.32 \times 10^{-3} \text{ mol dm}^{-3}$$

$$pH = -\lg (1.32 \times 10^{-3}) = 2.88$$

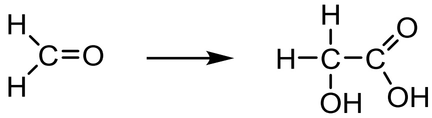
[2]

(c) The K_a of 2-hydroxyethanoic acid is 1.48×10^{-4} mol dm^{-3}.
Explain why 2-hydroxyethanoic acid has a higher K_a value than ethanoic acid.

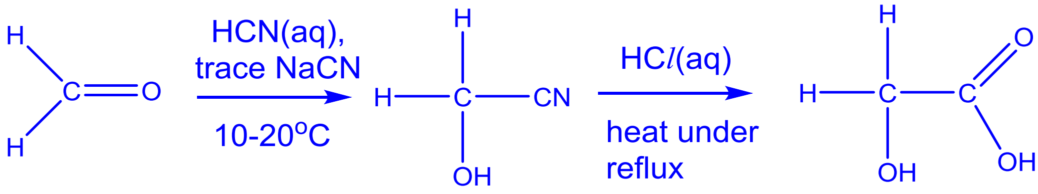
The –OH group (on the α-carbon) is electron withdrawing. This stabilises the conjugate base by dispersing the negative charge on O, decreasing the tendency to recombine with H$^+$ OR weakens the O-H bond of the –CO$_2$H group allowing for greater ease of dissociation of H$^+$. Hence, 2-hydroxyethanoic acid is a stronger acid, resulting is a higher K_a value.

[2]

(d) Propose a simple reaction scheme to obtain 2-hydroxyethanoic acid from methanal.



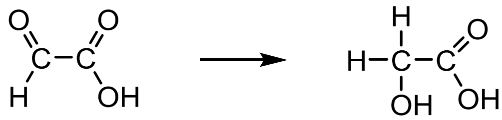
methanal 2-hydroxyethanoic acid



methanal 2-hydroxyethanoic acid

[3]

(e) 2-hydroxyethanoic acid can also be obtained from oxoethanoic acid in a one-step reaction. State the reagents and conditions for this conversion.



oxoethanoic acid 2-hydroxyethanoic acid

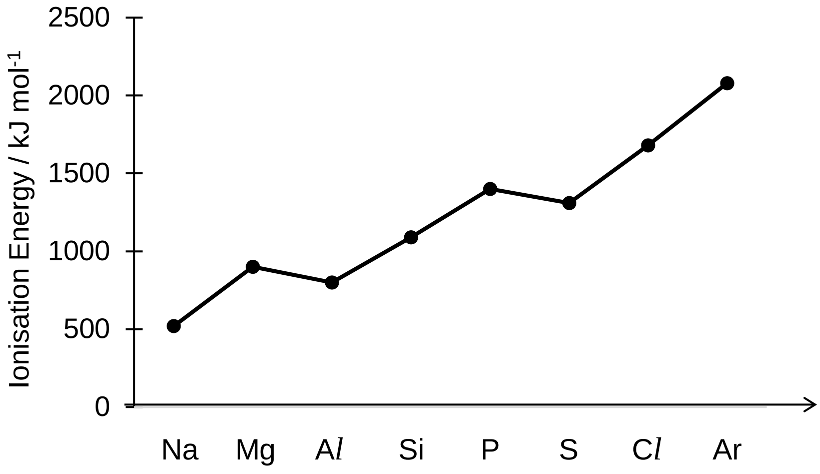
Reagents and conditions:

$NaBH_4$ in methanol .... [1]

Note: $LiAlH_4$ in dry ether cannot be used as this will reduce the carboxylic acid group as well.

[Total: 9]

2 **(a)** The diagram below shows the first ionisation energies of the Period 3 elements from Na to Ar.



(i) Write an equation to represent the *first ionisation energy* of S.

$S(g) \rightarrow S^+(g) + e^-$ ....[1]

(ii) Explain why the first ionisation energy generally increases across Period 3.

The nuclear charge increases (due to the increase in number of protons).
The atomic radius decreases (thus the outermost electron is nearer to the nucleus).
The screening/shielding effect remains almost the same (as the electron is "added" to the same outermost electron shell).

Therefore, the outermost electron becomes more strongly attracted by the positive nucleus and thus, more energy is required to remove the electron.
..................[2]

(iii) With the aid of electronic configurations, predict whether the **second** ionisation energy of Si will be higher or lower than the second ionisation of A*l*. Give your reasoning.

Al^+: $1s^2 2s^2 2p^6 3s^2$; Si^+: $1s^2 2s^2 2p^6 3s^2 3p^1$

The second I.E. of Si will be lower than the second I.E. of A*l*.

Less energy is required to remove a 3p electron in Si^+ than a 3s electron in Al^+ since the 3p subshell has a higher energy than the 3s subshell.

..................[2]

(b) Sodium and magnesium are elements from Period 3 of the Periodic Table.

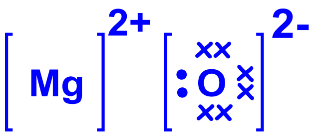
(i) State and explain two reasons why the melting point of magnesium is higher than that of sodium.

Mg has stronger metallic bond strength compared to Na as Mg has a greater number of valence electrons contributed to the 'sea' of delocalised electrons, than Na. As more energy is required to overcome the stronger metallic bonds in Mg, Mg has a higher melting point. Mg^{2+} has a larger ionic charge and smaller cationic size than Na. This results in higher charge density of Mg^{2+} and stronger metallic bond strength.

.......[2]

Magnesium can react with oxygen gas to form magnesium oxide, MgO, which is often used as a refractory material in the lining of furnaces.

(ii) Draw a dot-and-cross diagram to show the bonding in MgO.



[1]

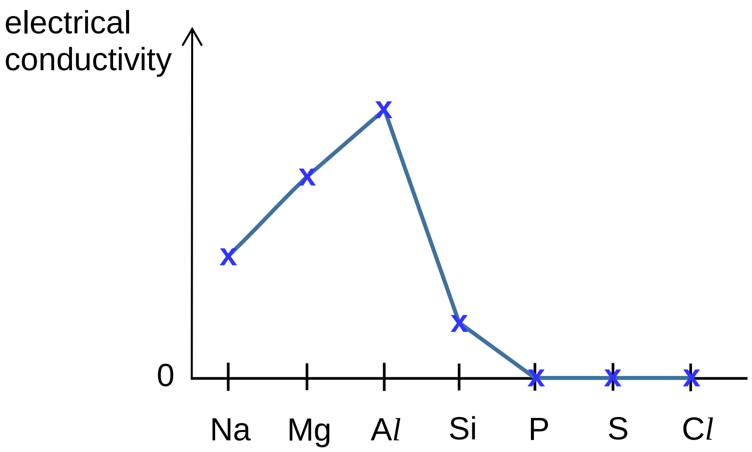
(iii) Explain why the lattice energy of MgO is less exothermic than that of Mg_3N_2.

Both MgO and Mg_3N_2 contain the same cation, Mg^{2+}. Although O^{2-} has a smaller ionic radius than N^{3-}, O^{2-} has a smaller ionic charge than N^{3-}.

$\Delta H_{latt} \propto \frac{q_+ q_-}{r_+ + r_-}$ **; as charge is more dominant than radius in affecting lattice energy, lattice energy of MgO is less exothermic than Mg_3N_2.**

.......[3]

(c) Using the axes below, sketch the graph to show the electrical conductivity of the Period 3 elements from Na to C*l*.

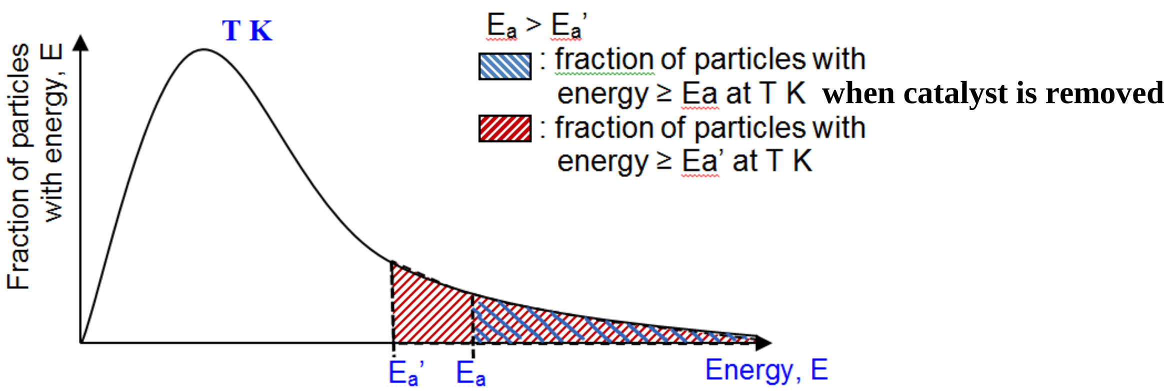


[1]

[Total: 12]

3 An aromatic ester with the molecular formula $C_8H_8O_2$ was synthesised in the laboratory using suitable reactants and heated under reflux with concentrated sulfuric acid catalyst for about 6 hours.
The enthalpy change for this esterification reaction can be regarded as 0 kJ mol^{-1}.

(a) Draw a Boltzmann distribution curve for the reactants at this temperature and use it to explain why the reaction is significantly slower when the catalyst is removed.



The catalyst speeds up the rate of reaction **by lowering the activation energy** of the reaction by providing an **alternative reaction pathway** with lower activation energy.

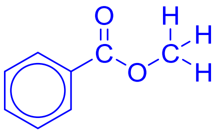
When a catalyst is removed, as shown by the Boltzmann distribution, **there is a lower fraction of molecules with energy ≥ activation energy**, this also reduces the frequency of **effective** collisions between molecules, and the rate of reaction falls.

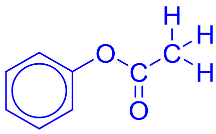
[3]

(b) The esterification reaction is reversible and hence has an equilibrium constant, K_c. Explain briefly how the equilibrium position and K_c are expected to change when the temperature is increased.

As the enthalpy change is 0 kJ mol^{-1}, a temperature increase will not have any effect on the equilibrium position and the K_c will not change. [2]

(c) When the aromatic ester is hydrolysed with H_2SO_4(aq), methanoic acid, HCO_2H, is not among the products.
Suggest two possible structural formulae for the ester.

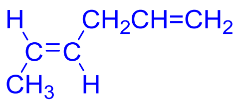




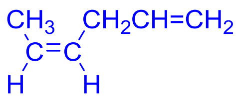
[2]
[Total: 7]

4 **(a)** Hexa-1,4-diene, $CH_2CHCH_2CHCHCH_3$, has geometrical isomers.

(i) Draw the structural formula of each of the isomers so as to identify this isomerism and label each structure. [2]



trans isomer



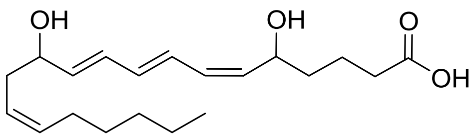
cis isomer

(ii) Explain how this isomerism arises.

Geometric isomerism arises in alkenes due to the **restricted rotation about π bond in the C=C** and **each carbon in the C=C have 2 different groups attached to it.**

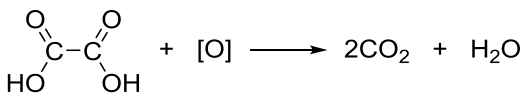
....[1]

(b) Leukotriene B4 is a biomolecule in the human body.

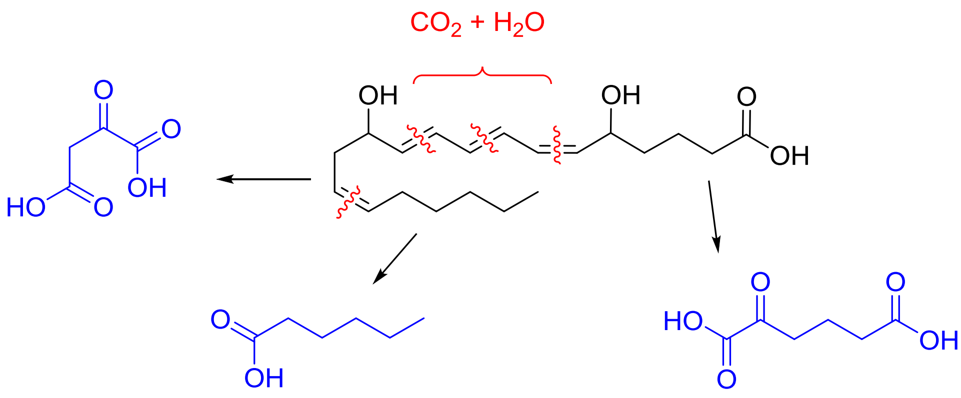


Leukotriene B4

Draw **all possible organic products** formed when leukotriene B4 is subjected to heating under reflux in the presence of acidified $KMnO_4$(aq). Note that any ethanodioic acid formed is further oxidised according to the following equation.



[3]



[Total: 6]

5 In March 2017, residents in a small town in Alberta, Canada, received a shock when pink coloured water flowed from their taps. The colour was due to potassium manganate(VII), $KMnO_4$, used in the early stages of water treatment to remove pathogens and metal ions such as iron and manganese ions. $KMnO_4$ should have been removed before the treated water reached the homes of the consumers, but a water treatment valve malfunctioned which caused the incident to happen.

$KMnO_4$ has a relative formula mass of 158 and it exists as black crystals at room condition. When dissolved in water, small quantities of the solid are sufficient to give very intense shades of pink and purple solutions.

(a) Define the term *relative formula mass*.

It is the ratio of the average mass of one formula unit of the compound to $\frac{1}{12}$ the mass of an atom of ^{12}C isotope, expressed on the ^{12}C scale. [1]

$KMnO_4$ is used to remove Mn^{2+} present in water. $KMnO_4$ will oxidise Mn^{2+} to MnO_2 precipitate which can easily be filtered from the water.

The half equation that shows the reduction of MnO_4^- under the treatment conditions is:

$$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$$

(b) With reference to the *Data Booklet*, write down the oxidation half equation.

$Mn^{2+} + 2H_2O \rightarrow MnO_2 + 4H^+ + 2e^-$ [1]

(c) Hence, give the overall equation that shows the removal of Mn^{2+} during the treatment of water.

$3Mn^{2+} + 2H_2O + 2MnO_4^- \rightarrow 5MnO_2 + 4H^+$ [1]

(d) During treatment, the concentration of $KMnO_4$ used is 1 mg dm^{-3}. Convert this concentration value into mol dm^{-3} and hence calculate the maximum mass of MnO_2 that can be precipitated per cubic metre of water.
(1 g = 1000 mg; 1 cubic metre = 1000 dm^3)

Concentration of $KMnO_4$ in mol dm^{-3} = $\frac{1\times10^{-3}}{158} = 6.329\times10^{-6}$

Maximum amount of solid MnO_2 that forms in 1 dm^3 $= \frac{5}{2}\times(6.329\times10^{-6})$
$= 1.582 \times 10^{-5}$

Mass of MnO_2 formed in 1 dm^3 = $(1.582 \times 10^{-5})(54.9 + 2(16.0))$
$= 1.375 \times 10^{-3}$g

Mass of MnO_2 formed per cubic metre of water = $1.375 \times 10^{-3} \times 1000$
= 1.375g [3]

[Total: 6]

Section B

Answer **two** questions from this section on separate answer paper.

6 Hydrogen peroxide and acidified potassium iodide can react according to the equation below.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow 2H_2O + I_2$$

The rate of reaction can be followed by measuring the amount of iodine produced after various times, from which the concentration of H_2O_2 remaining can be calculated.

In one such study, the following reaction mixture was prepared.

initial $[H^+]$ = 0.200 mol dm^{-3}
initial $[I^-]$ = 0.200 mol dm^{-3}
initial $[H_2O_2]$ = 0.0200 mol dm^{-3}

The table below shows $[H_2O_2]$ at various times.

time / s	**$[H_2O_2] \times 10^{-3}$ / mol dm^{-3}**
0	20.0
80	16.7
183	13.5
315	10.3
490	7.10
760	3.90

(a) **(i)** Explain the term *rate of reaction*. [1]

The rate of reaction is defined as the <u>change in the concentration of reactants or products per unit time</u>.

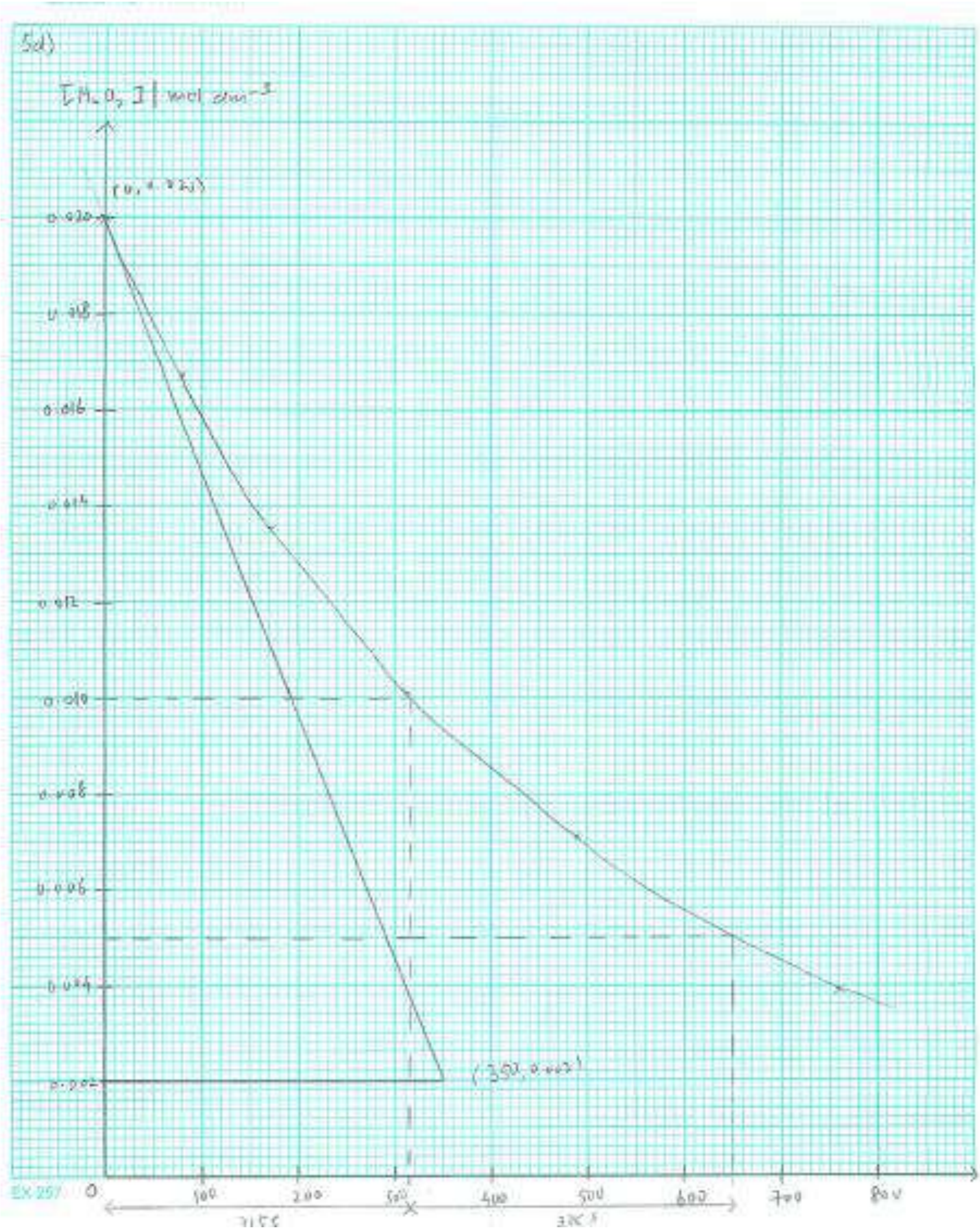
(ii) Explain why the initial concentration of H_2O_2 used is much lower than the concentrations of H^+ and I^- used. [1]

This is to ensure that concentrations of H^+ and I^- are <u>effectively constant</u> and <u>only the concentration of H_2O_2 varies with time</u>.

OR

This is to ensure that the order of reaction with respect to H^+ and I^- is <u>pseudo-zero order</u>.

(iii) Plot a graph of the above results. [2]



(iv) Use your graph to determine:

I the order of reaction with respect to [H_2O_2],

Using half-life,

1^{st} half-life = 315 s

2^{nd} half-life = 335 s

Since <u>both half-lives are fairly constant</u>, the order of reaction with respect to [H_2O_2] is 1.

II the initial rate, in mol dm^{-3} s^{-1}.

From the graph,

Initial rate = $\dfrac{0.02 - 0.002}{350}$ **= 5.14 x 10^{-5} mol dm^{-3} s^{-1}**

Show all working and construction lines clearly on your graph. [4]

(v) Further experiments were carried out by changing [H^+] and [I^-], but keeping the initial [H_2O_2] constant. The following results were obtained.

Experiment	initial [H^+] / mol dm^{-3}	initial [I^-] / mol dm^{-3}	initial rate/ mol dm^{-3} s^{-1}
1	0.400	0.200	1.0 x 10^{-4}
2	0.200	0.100	2.5 x 10^{-5}
3	0.100	0.200	2.5 x 10^{-5}

Determine the orders with respect to [H^+] and [I^-]. Explain your reasoning. [2]

By inspection,using experiments 1 and 3, when [I^-] is constant at 0.200 mol dm^{-3}, and [H^+] is decreased by 4 times, the reaction rate also decreased by 4 times. Therefore, the order of reaction with respect to [H^+] is 1.

Using experiments 1 and 2, when [I^-] is halved and [H^+] is also halved, the reaction rate decreased by 4 times. Since the order with respect to [H^+] is 1, by inspection, the order of reaction with respect to [I^-] is 1.

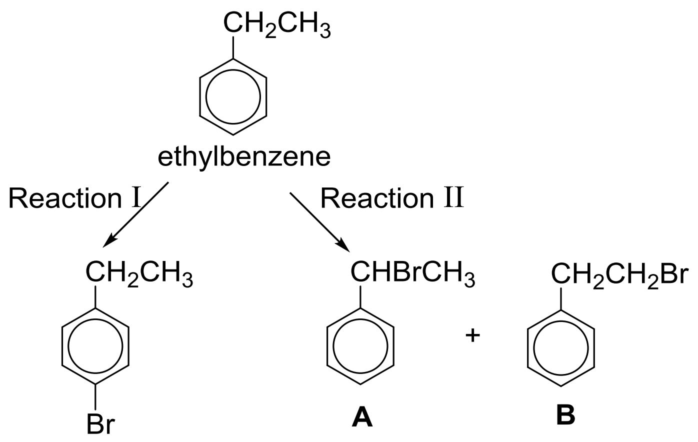
(b) Describe the reactions, if any, of the oxides P_4O_{10} and SiO_2 with water. State the approximate pH values of the resulting solutions and explain your answer with the aid of relevant equations for any reactions that occur. [3]

$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$

P_4O_{10} completely hydrolyses in water to give a strongly acidic solution of pH = 2

SiO_2 does not dissolve in water due to strong covalent bonds between atoms, thus the solution remains at pH = 7

(c) Ethylbenzene can undergo substitution reactions to give three different products as shown in the scheme below.



(i) Explain why ethylbenzene does not undergo addition reactions readily. [1]

Ethylbenzene does not undergo addition reactions readily but undergoes substitution reactions so as <u>to retain the stable ring structure</u>.

(ii) State the reagents and conditions for reactions **I** and **II**. [2]

Reaction I: Br_2, <u>anhydrous</u> $FeBr_3$ catalyst or Br_2, Fe catalyst

Reaction II: <u>limited</u> Br_2, *uv* light

(iii) Suggest the ratio in which **A** and **B** might be formed, assuming that the ease of substitution of H is the same for the formation of both compounds. [1]

A : B = 2 : 3

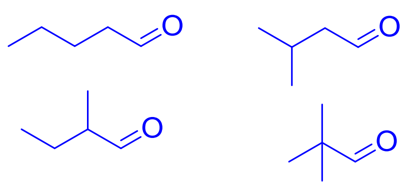
(d) An alkaline solution of Cu^{2+}(aq) is used in organic chemistry to test for a particular functional group.

(i) Describe the appearance of a positive result of this test. [1]

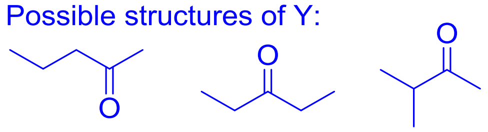
Red precipitate of Cu_2O seen

(ii) Compounds **X** and **Y** both have the molecular formula $C_5H_{10}O$ and give an orange precipitate with 2,4-dinitrophenylhydrazine. However, compound **X** shows a positive result in the test in **(d)(i)** while compound **Y** does not. Suggest a possible structure for compound **X** and for compound **Y**, showing the skeletal formula in your answers. [2]

Possible structures of X:



Possible structures of Y:

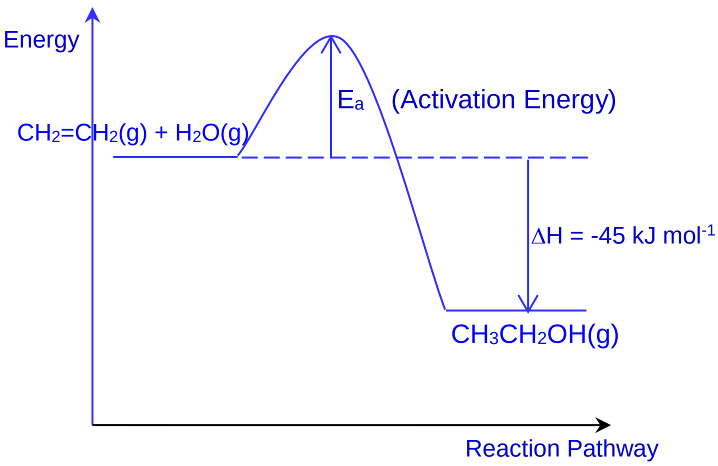


[Total: 20]

7 (a) Ethanol, CH_3CH_2OH, is manufactured in the industry by reacting ethene with steam in the presence of a catalyst. The reaction is reversible and the equation is as follows:

$$CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \qquad \Delta H = -45 \text{ kJ mol}^{-1}$$

(i) Draw a labelled reaction pathway diagram for this reaction. [2]



For every 1.0 mol dm^{-3} of ethene and 0.6 mol dm^{-3} of steam reacted and allowed to reach equilibrium, only 5% of the ethene is converted into ethanol at each pass through the reactor. To increase the overall yield of ethanol, ethanol is regularly removed from the equilibrium mixture as it is formed, and more ethene is added into the reaction mixture.

(ii) Using the information given above, calculate K_c (including units) at this temperature. [2]

	$CH_2{=}CH_2(g)$ +	$H_2O(g)$ $\rightleftharpoons$	$CH_3CH_2OH(g)$
Initial / mol dm^{-3}	1.0	0.6	0.0
Change / mol dm^{-3}	-0.05	-0.05	+0.05
Eqm / mol dm^{-3}	0.95	0.55	0.05

$K_c = \frac{[CH_3CH_2OH]}{[CH_2{=}CH_2][H_2O]} = \frac{0.05}{0.95 \times 0.55} = 0.0957 \text{ mol}^{-1} \text{ dm}^3$

(iii) Calculate the amount, in moles, of ethene (in every dm^3) that must be added to increase the equilibrium concentration of ethanol to 0.20 mol dm^{-3}. [2]

Let the amount of ethene to be added be x.

	$CH_2{=}CH_2(g)$ +	$H_2O(g)$ $\rightleftharpoons$	$CH_3CH_2OH(g)$
Initial / mol dm^{-3}	1.0 + x	0.6	0.0
Change / mol dm^{-3}	-0.20	-0.20	+0.20
Eqm / mol dm^{-3}	0.8 + x	0.40	0.20

$K_c = \frac{0.20}{(0.80+x)\times 0.40} = 0.0957$; x = 4.42 moles

(iv) State the catalyst used for the reaction. [1]

Concentrated H_3PO_4

(v) Apart from the methods mentioned above, suggest one other method which will result in an increase in the conversion of ethene into ethanol without changing the temperature and without adding more steam. Explain your answer briefly. [2]

Increasing the pressure will shift equilibrium to favour the production of **fewer number of moles of gas molecules**. Hence the equilibrium shifts forward and more ethanol is produced.

(b) Ethanol is one of several compounds used as an 'anti-knock' agent that is added to unleaded petrol to prevent damage to car engines. Prior to the use of ethanol as an anti-knocking agent, a compound called tetraethyl lead was used.

To prevent accumulation of lead deposits in the engines, a small quantity of 1,2-dichloroethane was added to the gasoline to form $PbCl_2$ that can be flushed from the engine and into the air, but the compound quickly solidifies at atmospheric temperature. The accumulation of toxic lead compounds in the environment quickly resulted in a worldwide ban of leaded petrol.

(i) Catalytic converters were fitted in cars to minimise the emissions of undesirable exhaust gases emitted such as carbon monoxide, oxides of nitrogen and unburnt hydrocarbons. State the environmental damage of one of the gases listed. [1]

Carbon monoxide: toxic gas that binds to human haemoglobin to inhibit the transport of oxygen

Oxides of nitrogen: Contributes to acid rain

Unburnt hydrocarbons: cause the environmental damage of photochemical smog.

(ii) The oxidation state of Pb in $PbCl_2$ is +2. What is the maximum oxidation state Pb is able to obtain and explain why this is so. [1]

+4. This corresponds to the maximum number of valence electrons Pb has / used for bonding.

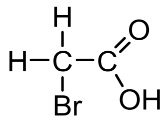
(iii) Write an equation to show how the chloride of lead (where lead is at its maximum oxidation state) reacts with water. [1]

$PbCl_4 + 2H_2O \rightarrow PbO_2 + 4HCl$

(iv) Explain why the reaction stated in **(b)(iii)** proceeds with greater ease than a similar reaction involving the chloride of silicon. [1]

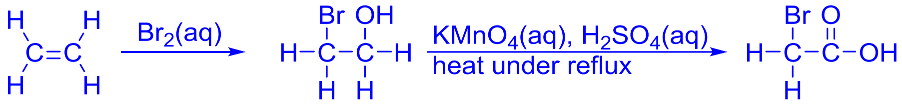
Pb is a larger atom than Si hence the Pb-C*l* covalent bond is longer and weaker than the Si-C*l* bond.

(c) Ethene can be used as a starting material to synthesise 2-bromoethanoic acid.



2-bromoethanoic acid

(i) Propose a reaction scheme that will convert ethene to 2-bromoethanoic acid, bearing in mind that each step should result in a fairly good yield of products. [3]



(ii) State the functional groups present in 2-bromoethanoic acid. [2]

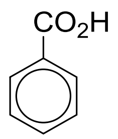
Primary bromoalkane and carboxylic acid

(iii) Describe a simple chemical test to show the presence of bromine in 2-bromoethanoic acid. [2]

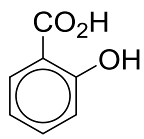
To a sample of 2-bromoethanoic acid, add aqueous NaOH and heat.
Allow to cool and add dilute nitric acid, followed by aqueous $AgNO_3$.
Cream ppt of AgBr formed confirms the presence of bromine.

[Total: 20]

8 **(a)** Benzoic acid and salicylic acid are both important precursors for the industrial synthesis of many other organic substances.



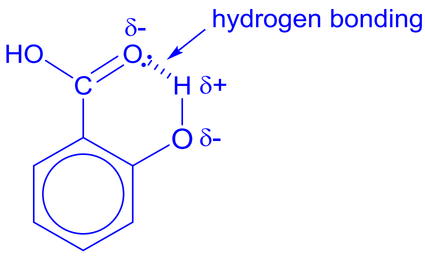
benzoic acid



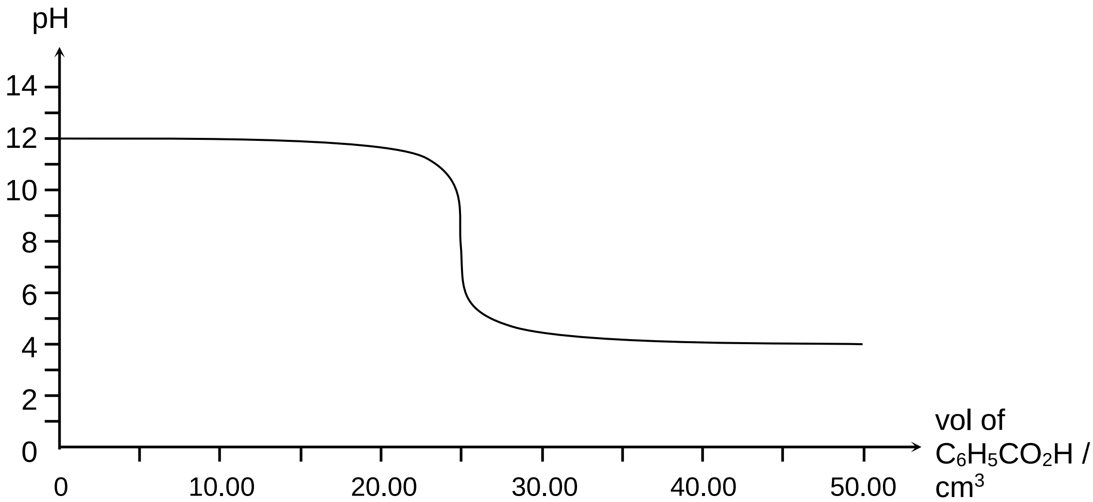
salicylic acid

It was observed that salicylic acid has a lower solubility in water compared to benzoic acid in water. This is due to salicylic acid forming less extensive hydrogen bonding with water molecules. With the aid of a labelled diagram, suggest a reason for this observation. [2]

Salicylic acid forms <u>intramolecular hydrogen bonding</u>, reducing the extensiveness of intermolecular hydrogen bonding. Thus, salicylic acid is less soluble in water than benzoic acid.



(b) In a titration carried out under standard conditions, a solution of benzoic acid is added to 20.00 cm^3 of aqueous sodium hydroxide. The change in pH was measured and the following titration curve was obtained.



(i) Using the titration curve, calculate the concentration of OH^- at the beginning of the reaction. [1]

Since pH = 12, pOH = 14 – 2 = 2

$[OH^-] = 10^{-2} = 0.0100$ mol dm^{-3}

(ii) Suggest a suitable indicator for the above reaction, stating the expected colour change. [2]

Phenolphthalein, pink to colourless

(iii) Explain your choice of indicator. [1]

The pH range for colour change that lies within the pH range of rapid change of the titration.

(iv) Using the answer in **(b)(i)**, calculate the concentration of the solution of benzoic acid. [2]

Amt of NaOH used = $0.01 \times \frac{20.00}{1000}$ = 0.000200 mol

Thus amt of benzoic acid reacted = 0.000200 mol

[benzoic acid] = $\frac{0.002}{25}$ × 1000 = 0.00800 mol dm^{-3}

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

In another experiment, 60.00 cm^3 of 0.600 mol dm^{-3} benzoic acid is added to 40.00 cm^3 of 0.800 mol dm^{-3} aqueous sodium hydroxide and the increase in temperature is measured.

Given that the enthalpy change of this reaction is –56.9 kJ mol^{-1}, calculate the increase in temperature. [3]

Amt of NaOH used = 0.8 × $\frac{40.00}{1000}$ = 0.0320 mol

Amt of benzoic acid used = 0.6 × $\frac{60.00}{1000}$ = 0.0360 mol

Thus amt of water produced = 0.0320 mol

Thus heat released = 56.9 × 1000 × 0.0320 = 1821 J (4.s.f.)

Thus increase in T = $\frac{1821}{100 \times 4.18}$ = 4.36 K

(d) In the 1940s, it was difficult to oxidise methylbenzene to benzoic acid using the oxygen present in air. Many methods resulted in incomplete oxidation or produced low yields of benzoic acid. It was later discovered that aluminium oxide is able to support controlled oxidation of methylbenzene to benzoic acid in the presence of air.

Aluminium oxide is amphoteric. Write balanced equations to illustrate this fact. [2]

$Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$

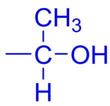
$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2[Al(OH)_4]^-$

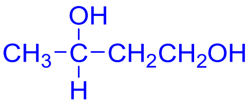
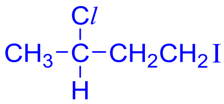
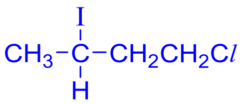
(e) Compound **X** is a four carbon organic molecule. Upon addition of aqueous silver nitrate, a yellow precipitate was observed almost immediately. The yellow precipitate was then filtered off and the solution was left to stand. After a period of time, white precipitate was observed in the filtrate.

In a separate experiment, compound **X** was heated under reflux with aqueous sodium hydroxide to give compound **Y**. When compound **Y** was reacted with phosphorus(V) chloride, steamy fumes were observed. When one mole of compound **Y** was reacted with alkaline aqueous iodine, only one mole of yellow precipitate **Z** was produced.

Using the information given, deduce the structures of **X**, **Y** and **Z**. In your answer, state clearly the types of reactions that occurred. [7]

Clues / observations	Type of reaction	Deduction
X, a four carbon organic	Substitution /	Since **X** has only 4 C and two

molecule, was reacted with $AgNO_3$(aq) and yellow precipitate was observed almost immediately. After a period of time, white precipitate was observed	hydrolysis	different silver halides are precipitated, **X** contains an **<u>iodobutane</u>**. **X** also contains a **<u>chlorobutane</u>**
X is heated under reflux with aqueous sodium hydroxide to give compound **Y**	(nucleophilic) substitution	**Y** has two **<u>–OH groups</u>** / **Y** is a **<u>diol</u>**
Y is reacted with PCl_5, steamy fumes are observed	(nucleophilic) substitution	
1 mole of **Y** is reacted with alkaline I_2(aq) to give 1 mole of yellow precipitate **Z**	Triiodomethane test or mild oxidation	**Z is <u>CHI_3</u>.** Thus **Y** has **<u>1</u>**  **<u>group.</u>**

Thus **Y** is  and **X** is  or 

[Total: 20]

Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination 2017
Year 6

H1 CHEMISTRY 8872/01

Paper 1 Multiple Choice

25 September 2017
50 minutes

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”.

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

Which of these samples of gas contains twice the number of atoms as 4 g of helium gas, He?

A 22 g of carbon dioxide, CO_2

B 8 g of methane, CH_4

C 4 g of hydrogen, H_2

D 12 g of steam, H_2O

2 Bones contain a complex mixture of calcium salts, protein and other material.

When a sample of 50.0 g bone is strongly heated in air, the only residue formed is calcium oxide and its mass is determined to be 14.0 g.

What is the percentage by mass of calcium in the bone?

A 10%

B 14%

C 20%

D 23%

3 Ethanedioate ions, $C_2O_4^{2-}$, are oxidised by acidified aqueous potassium manganate (VII) to give carbon dioxide. What volume of 0.020 mol dm^{-3} potassium manganate (VII) is required to completely oxidise 2.0×10^{-3} mol of the salt $NaHC_2O_4.H_2C_2O_4$?

The half equation for MnO_4^- is given below:

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

A 20 cm^3 **B** 40 cm^3

C 80 cm^3 **D** 100 cm^3

4 Which of the following corresponds to the electronic configuration of 3 electrons of highest energy for a Group 13 element at its ground state?

A $3s^23p^3$ **B** $1s^12s^12p^1$

C $4s^24p^1$ **D** $3s^13p^2$

5 The hydrogen molecule contains a covalent bond.

What holds the atoms together in this covalent molecule?

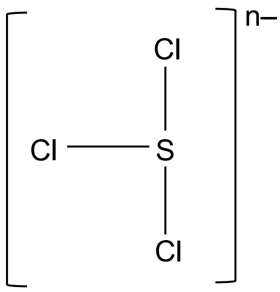
A The electrostatic attraction between the electrons in the bond pair and the two nuclei.

B The electrostatic attraction between the electron of one hydrogen atom and the nucleus of the other hydrogen atom.

C The electrostatic attraction between the atoms in the molecule.

D The energy released in the formation of the covalent bond.

6 SCl_3^{n-} has a T–shaped structure as shown below.



What is the value of n?

A	0	**B**	1
C	2	**D**	4

7 When 5 mol of nitrogen gas and 9 mol of hydrogen gas were put into a 2 dm^3 container and heated, the equilibrium mixture contained 2 mol of ammonia gas.

The equilibrium is represented by the following equation.

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

What is the numerical value of the equilibrium constant, K_c, at the temperature of the experiment?

A $\dfrac{1}{2(3^3)}$ **B** $\dfrac{2^2}{1(3^3)}$ **C** $\dfrac{2^2}{4(6^3)}$ **D** $\dfrac{2^2}{3(2\times3)^3}$

8 Which statement can be deduced from the following information?

$$2CO\,(g) + O_2(g) \rightleftharpoons 2CO_2(g) \qquad \Delta H = -566\ \text{kJ mol}^{-1}$$

A Increasing the pressure at constant temperature increases the value of the equilibrium constant.

B Decreasing the volume of the container containing the reaction mixture at constant temperature decreases the amount of CO and O_2 at equilibrium.

C Increasing the temperature decreases the rate of the forward reaction.

D Adding a catalyst increases the yield and rate of production of CO_2.

9 The value of the ionic product of water, K_w, varies with temperature as shown.

Temperature / °C	K_w / mol^2 dm^{-6}
25	1.0×10^{-14}
62	1.0×10^{-13}

Which statement is true?

A The ionic dissociation of water is exothermic.

B The pH of water is higher at 62°C than 25°C.

C Water is acidic at 62°C.

D $[OH^-] = 3.16 \times 10^{-7}$ mol dm^{-3} at 62°C.

10 A 2.0 cm^3 solution of a strong acid has pH 1. What additional volume of water is needed to increase the pH of the solution to pH 3?

A 98 cm^3
B 100 cm^3
C 198 cm^3
D 200 cm^3

11 Using bond energy values from the *Data Booklet*, what is the enthalpy change of formation of N_2H_4 (g)?

A –250 kJ mol^{-1}

B –146 kJ mol^{-1}

C +146 kJ mol^{-1}

D +250 kJ mol^{-1}

12 250 cm^3 of 0.50 mol dm^{-3} KOH(aq) at 29.0 °C was mixed in a polystyrene cup, with an equal volume of 0.50 mol dm^{-3} H_2SO_4(aq) at the same initial temperature. The final temperature was 32.4 °C.

What is the enthalpy change of neutralisation of the reaction?

Given heat capacity of the mixture and polystyrene cup = 1.7 kJ K^{-1}

A – 3760 kJ mol^{-1}

B – 57.1 kJ mol^{-1}

C – 46.2 kJ mol^{-1}

D – 28.6 kJ mol^{-1}

13 Which compound has the most exothermic lattice energy?

A Magnesium chloride

B Sodium bromide

C Aluminium fluoride

D Lead (II) iodide

14 Which statement **does not** explain why addition of a catalyst leads to a significant increase in the rate of a reaction?

A The average kinetic energy of the molecules is slightly greater in the presence of a catalyst.

B The activation energy of the forward and backward reaction is lowered when a catalyst is added.

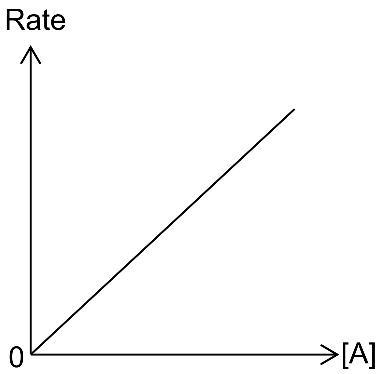
C The frequency of effective collisions between molecules with kinetic energy greater than the activation energy is greater with the presence of a catalyst.

D The number of reactant molecules with at least activation energy increases.

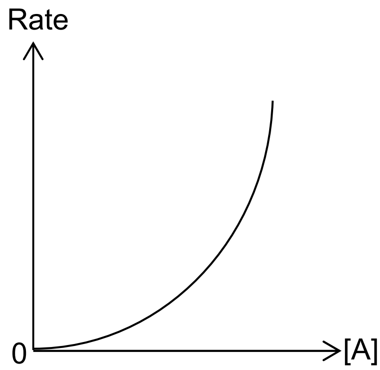
15 Consider the hypothetical reaction: $2A \rightarrow B + C$.

Given that the rate constant, k, of the reaction is 0.188 mol dm^{-3} s^{-1}, which of the following graphs correctly reflects the reaction kinetics of the reaction?

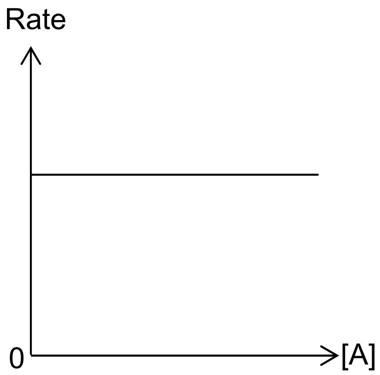
A



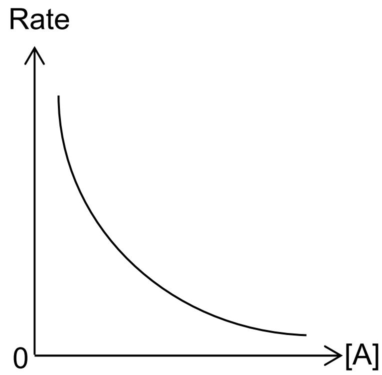
B



C



D



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16 Elements can form chlorides by reacting them with Cl_2. The chlorides formed by elements **R** and **S** can conduct electricity in the molten state.

Which are the possible identities of **R** and **S**?

A magnesium, phosphorus

B sodium, aluminium

C silicon, phosphorus

D magnesium, sodium

17 Which compound can undergo a substitution reaction to form 2–chloropropane?

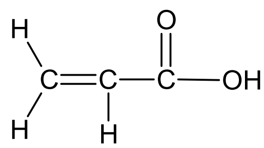
A $CH_3CH(OH)CH_3$

B $CH_3CH{=}CH_2$

C CH_3CH_2CHO

D $CH_3CH(NH_2)CH_3$

18 Acrylic acid is co–polymerised with other monomers to make sticky coatings.



acrylic acid

What are the numbers of σ and π bonds present in one molecule of acrylic acid?

	σ	π
A	7	1
B	8	1
C	7	2
D	8	2

19 How many different products, including stereoisomers, are formed when $CH_3C(CH_3)_2CH(OH)CH_2CH_3$ is treated with hot concentrated sulfuric acid?

A 0 **B** 1 **C** 2 **D** 3

20 Which statement **best** explains why iodoalkanes are the most reactive halogenoalkane?

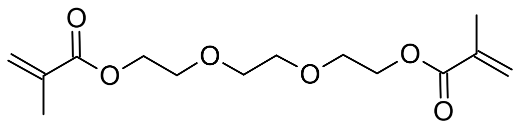
A Iodine has the most number of electrons.

B Iodine is the least electronegative halogen.

C The C–I bond is the longest.

D The iodide ion is the most stable halide.

21 The following compound is used to make light–cured dental fillings.



How many hydrogen atoms are present in one of these molecules?

A 20 **B** 22 **C** 24 **D** 26

22 Which pure compound would give only one positive test result with the following reagents?

- alkaline aqueous iodine
- phosphorous pentachloride
- 2,4–dinitrophenylhydrazine

A butanal

B butanone

C butan–2–ol

D ethanol

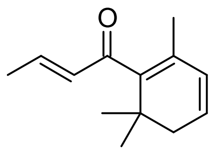
23 The diagram shows a reaction pathway.

$$\text{1–bromobutane} \xrightarrow{\text{step 1}} \text{intermediate} \xrightarrow{\text{step 2}} \text{propanoic acid}$$

Which reagents are suitable for steps 1 and 2?

	reagent for step 1	reagent for step 2
A	HCN, trace NaOH	dilute H_2SO_4
B	alcoholic KCN	dilute H_2SO_4
C	aqueous NaOH	$KMnO_4$
D	alcoholic NaOH	$KMnO_4$

24 Beta–damascenone is a major contributor to the aroma of roses.



beta–damascenone

Which statement is true of this compound?

A All the C–C–C bond angles are 120°.

B It forms hydrogen bonds with water.

C It undergoes substitution with aqueous bromine.

D It reduces alkaline Cu^{2+} to Cu_2O.

25 An organic compound on complete combustion produces equal volumes of carbon dioxide and water vapour.

What is a possible identity of the compound?

A CH_4

B CH_3OH

C $CH_3CH_2CH_3$

D CH_3COCH_3

Section B

For each question, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements which you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 The successive ionisation energies, in kJ mol^{-1}, of an elements **X** and **Y** are given below.

X	580	1820	2740	11600	14840	18380	23320
Y	940	2050	2970	4140	6590	7880	14900

Which of the following statements are true about element **X** and **Y**?

1 The first ionisation energy of **X** is lower than that of the element preceding it in the Periodic Table.

2 **X** and **Y** forms a compound with the formula $\mathbf{X_2Y_3}$.

3 When oxides of **X** and **Y** are added separately to water containing Universal Indicator solution, the solution turns blue and red respectively.

27 Which of the following statements describe a phenomenon which can be explained by hydrogen bonding?

1 2–nitrobenzoic acid is more volatile than 4–nitrobenzoic acid.

2 Ice has a lower density than water at 0°C.

3 The boiling point of alcohol increases with increasing relative molecular mass.

28 Element **X** is one of the elements in the third period of the Periodic Table. The oxide of **X** has a giant ionic structure while the chloride of **X** has a simple molecular structure.

Which statements are **correct**?

1 The oxide of **X** has a higher melting point than that of magnesium oxide.

2 The oxide of **X** reacts with excess aqueous potassium hydroxide to form a colourless complex ion.

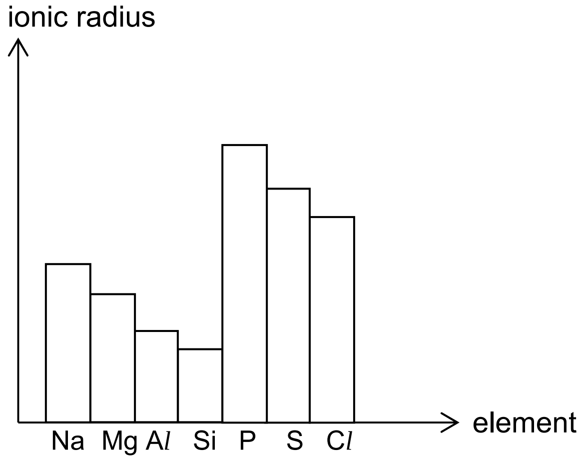
3 The third ionisation energy of **X** is lower than the second ionisation energy of sodium.

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

29 The graph below shows the ionic radii of seven elements found in Period 3.



Which statements correctly explain the trend shown in the graph?

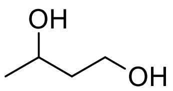
1 The ionic radius decreases from P^{3-} ion to Cl^{-} ion due to increasing nuclear charge.

2 The ionic radius decreases from Na^{+} ion to Si^{4+} ion due to decreasing shielding effect by inner shell electrons.

3 The ionic radius of P^{3-} ion is greater than that of Si^{4+} ion due to less attraction between electrons.

30 Which compounds will form CH_3COCH_2COOH upon treatment with hot alkaline $KMnO_4$, followed by acidification?

1



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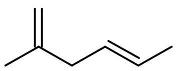
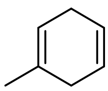


3



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2017 DHS YEAR 6 H2 CHEMISTRY (8872) PRELIMINARY EXAMINATION
Paper 1 MCQ – Answers

1	2	3	4	5	6	7	8	9	10
D	**C**	**C**	**C**	**A**	**B**	**A**	**B**	**D**	**C**

11	12	13	14	15	16	17	18	19	20
C	**C**	**C**	**A**	**C**	**D**	**A**	**D**	**C**	**C**

21	22	23	24	25	26	27	28	29	30
B	**A**	**D**	**B**	**D**	**B**	**B**	**C**	**D**	**A**

Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examinations 2017
Year 6

H1 CHEMISTRY — 8872/02

Paper 2 Section A (Structured) — **11 September 2017**

Paper 2 Section B (Free Response) — **2 hours**

Additional Materials: Data Booklet
Writing Paper
Cover Sheet

INSTRUCTIONS TO CANDIDATES

1 Answer **ALL** questions in both sections.

2 Write your **name**, **index number** and **class** on this cover page.

Section A

3 Write your answers in the spaces provided on this question paper.

Section B

4 Write your **name**, **index number** and **class** on the Cover Sheet provided.

5 Write your answers on the separate writing papers provided.

6 Start each question on a fresh sheet of paper.

7 At the end of the examination:

- Fasten all your work securely together with the Cover Sheet on top.

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

You are advised to show all workings in calculations.

You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use	
Question No.	**Section A Marks**
1	**13**
2	**14**
3	**13**
Total	**40**

Section A

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

1 (a) Vanadium is a metal with four possible stable oxidation states in aqueous solutions.

Vanadium–containing species	Oxidation state of vanadium	Colour of aqueous solution containing species
VO_2^+	+5	Yellow
VO^{2+}	+4	Blue
V^{3+}	+3	Green
V^{2+}	+2	Violet

A solution of VO_2^+ can be easily reduced by metals like zinc and tin. Depending on the reducing strength of the metal, VO_2^+ would be reduced to different products.

A 250 cm^3 solution containing 0.60 mol dm^{-3} $VO_2^+(aq)$ was reduced to $V^{2+}(aq)$ by an excess amount of zinc. After filtration to remove the excess zinc, 25.0 cm^3 of the filtrate containing $V^{2+}(aq)$ was pipetted into the conical flask and titrated against 1.0 mol dm^{-3} nitric acid, which acted as an oxidising agent, until there was no further change in the colour of the solution.

The half–equation for the reduction of nitric acid is

$$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$$

The titre values were as recorded.

Final burette reading / cm^3	11.00	21.05	31.45
Initial burette reading / cm^3	0.00	11.00	21.50
Volume of HNO_3 / cm^3	11.00	10.05	9.95

(i) By using appropriate titre values, calculate the average titre value for the titration.

[1]

(ii) Determine the reacting mole ratio of V^{2+} and NO_3^-.

[2]

(iii) Hence, determine the oxidation state of vanadium after titration and the colour of the vanadium–containing solution, using the table in **(a)**.

[2]

(iv) Using your answer in **(iii)**, construct a balanced equation for the reaction between V^{2+}(aq) and nitric acid.

[1]

(b) Describe the bonding in the element vanadium. Draw a diagram to illustrate your answer.

....

....

.... [2]

(c) **(i)** Write the full electronic configuration of vanadium in VO^{2+}.

.... [1]

(ii) Draw labelled diagrams of two p orbitals from different quantum shells of the element vanadium, illustrating their shapes and sizes.

[1]

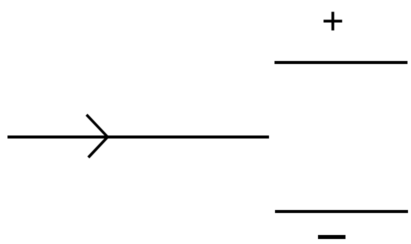
(iii) Beams consisting of the particles, $^{16}O^{2-}$ and $^{51}V^{2+}$, are subjected to an electric field. The angle of deflection of the particles is proportional to their charge/mass ratio.

Given that the angle of deflection of $^{51}V^{2+}$ in the electric field is +5°, suggest the angle of deflection of $^{16}O^{2-}$ in the electric field.

....

[1]

(iv) Using your answer in **(iii)**, sketch and label on the diagram below to show how beams of each of the two particles are affected by the electric field.

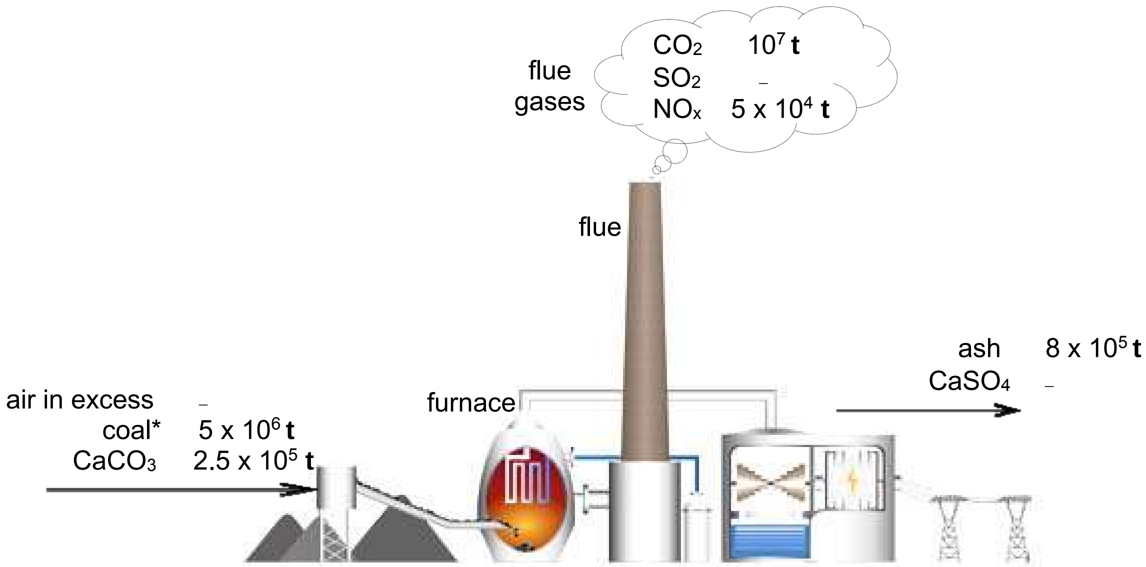


[2]
[Total: 13]

2 A coal–fired power station (which generates electricity) is fitted with a Flue Gas Desulfurisation (FGD) plant, which removes some of the sulfur dioxide from flue (waste) gases.

In the FGD plant, the flue gases are treated with powdered limestone, $CaCO_3$, where sulfur dioxide is absorbed and reacted to produce calcium sulfite, $CaSO_3$. This is oxidised by air to form solid calcium sulfate, $CaSO_4$.

The diagram below shows the amounts of substances used, and produced, by such a coal–fired power station with an FGD plant in **one** year.



Power station & FGD plant

**coal is chiefly hydrocarbons*

(a) **(i)** State the process that produces the energy in the power station.

.... [1]

(ii) Identify a gas, not listed in the diagram, which will be a chief component of the flue gas.

.... [1]

(iii) Explain why oxides of nitrogen (NO_x) are present in the flue gases.

....

.... [1]

(b) Write a balanced equation in each case to show how

- sulfur dioxide is removed from flue gases;

....

- calcium sulfate is formed.

....
[2]

(c) Using your answer in **(b)**, determine the maximum mass of sulfur dioxide which could be removed in the FGD plant.
[1**t** = 1 tonne = 1000 kg]

[1]

(d) Given that your answer in **(c)** was only 90% of the sulfur dioxide removed from the flue gases, calculate the mass of sulfur dioxide which is released into the atmosphere in **five** years by this power station when the same mass of coal is burnt each year.

[1]

(e) Another method for removing sulfur dioxide from the flue gases is to absorb it in a slurry of magnesium oxide, to produce magnesium sulfite, $MgSO_3$.

Explain why magnesium oxide can also be used to remove sulfur dioxide.

....

....
[1]

(f) Besides magnesium oxide, other metal oxides like sodium oxide and calcium oxide can also be used to remove sulfur dioxide.

The melting points of the three metal oxides are shown below.

oxides	m.p. / ^{o}C
MgO	2852
Na_2O	1132
CaO	2572

(i) Given that the ionic radius of O^{2-} is 0.140 nm and with reference to *Data Booklet*, calculate $|\frac{q_+q_-}{r_+ + r_-}|$ for the metal oxides and complete the table below. (œ represents the charge of ion and ß represents its ionic radius)

oxides	$\lvert\frac{q_+q_-}{r_+ + r_-}\rvert$
MgO	
Na_2O	8.5
CaO	

[1]

(ii) Using your answer in **(i)**, explain the melting points of these oxides.

[1]

(iii) For an ionic compound to dissolve in water, its ionic bonds have to be broken.

The pH of the resulting solutions when one mole of MgO and Na_2O are added to water separately are shown in the table below.

Predict and suggest an explanation for the pH value of CaO, with reference to your answer in **(i)**.

oxides	pH of resulting solution
MgO	9
Na_2O	13
CaO	

....

....

....

.... [2]

(g) Seawater is a natural reagent that can be used to absorb and remove SO_2. When SO_2 is absorbed in water, the following two equilibria reactions take place:

$$SO_2(g) + H_2O(l) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_4^{2-}(aq) + 2H^+(aq) \quad \text{— (1)}$$

$$\underset{\text{(from seawater)}}{HCO_3^-(aq)} + H^+(aq) \rightleftharpoons H_2O(l) + CO_2(g) \quad \text{— (2)}$$

Explain how the use of seawater would allow the removal of sulfur dioxide.

....

....

....

.... [2]

[Total: 14]

3 Sulfuric acid is a strong mineral acid which is an important chemical used in industry and in the school laboratory. It is manufactured industrially by the Contact process.

The key reaction involves the reaction between sulfur dioxide and oxygen.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H < 0$$

69.2 mol of sulfur dioxide is mixed with 34.6 mol of oxygen in a 2 dm^3 vessel and passed over several beds of loosely packed porous vanadium catalyst. The amount of sulfur trioxide at equilibrium is found to be 65.6 mol.

(a) **(i)** Calculate a value for the equilibrium constant, K_c, stating its units.

[2]

(ii) Use your value of K_c to calculate the $[O_2]$ necessary for 99% of the SO_2 to be converted to SO_3.

[2]

(iii) Explain qualitatively why the rate of achieving equilibrium increases in the presence of vanadium catalyst.

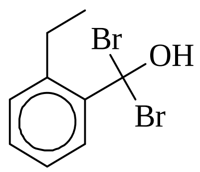
-- [2]

(iv) Sketch a graph to show how the rates of the forward and reverse reactions change from the time the two gases are mixed to the time the reaction reaches equilibrium. Label your lines clearly.

[1]

(b) Sulfuric acid is commonly used to acidify a solution of potassium manganate (VII).

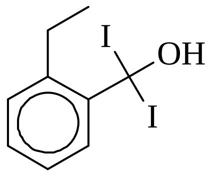
(i) Draw the structure of the organic product formed when compound **W** is heated with acidified potassium manganate (VII).



compound **W**

[1]

(ii) A derivative of compound **W** is shown below.



compound **X**

Describe a chemical test to distinguish samples containing compounds **W** and **X** and state what would be observed.

....

....

....

.... [2]

(iii) When compound **W** is treated with chlorine under two different conditions, isomeric monochlorides are formed.

Two isomers are formed via condition 1 and four isomers are formed via condition 2.

Draw the structures of one isomer formed via condition 1 and condition 2 respectively and state the reagents and conditions required for condition 1.

Isomer formed via Condition 1

Isomer formed via Condition 2

Condition 1

Reagent: ……………………………………………

Conditions: ………………………………………....

[3]
[Total: 13]

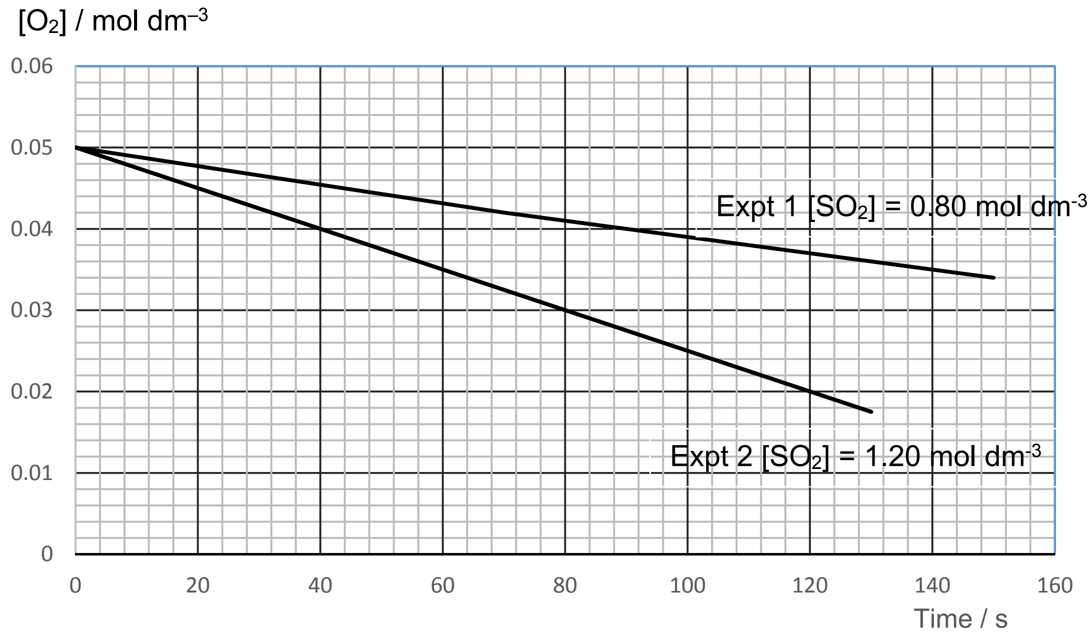
Section B

Answer **two** questions from this section on separate answer paper.

1 **(a)** The Contact Process is an industrial process for manufacturing sulfuric acid and occurs at 450 °C. The key stage in this process is the reaction between sulfur dioxide and oxygen.

$$2SO_2\,(g) + O_2(g) \rightarrow 2SO_3(g)$$

Two experiments were conducted at 450 °C to investigate the kinetics of this reaction. The graph below shows the results obtained when concentrations of sulfur dioxide were varied.



(i) Define the term *order of reaction.* [1]

(ii) Use the graph above to deduce the order of reaction with respect to both sulfur dioxide and oxygen. [3]

(iii) Using one of the graph above and your answer in **(ii)**, calculate the value of rate constant, stating its units. [2]

(iv) Using your answer in **(ii)**, sketch the graph of concentration of sulfur dioxide against time for this reaction, while keeping $[O_2]$ constant. Use construction lines to label the first and second half-lives in your sketch. [1]

(v) Sketch and label clearly, on the same axes as in **(iv)**, how the graph would look like if the experiment was conducted at 200 °C. [1]

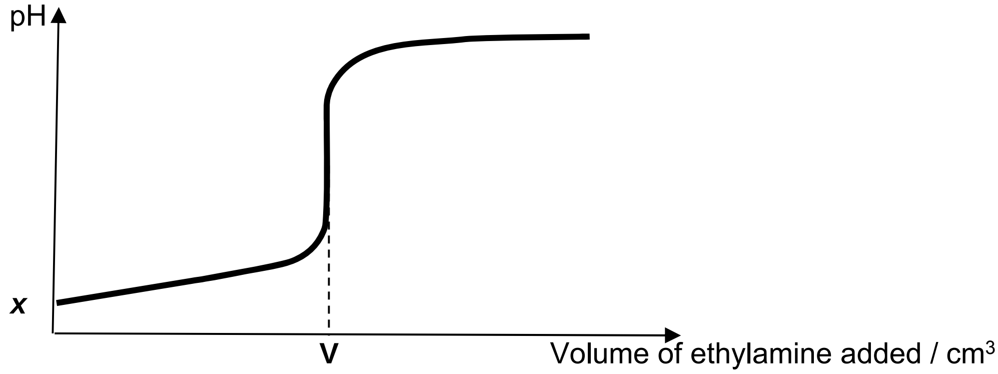
Ethylamine, $CH_3CH_2NH_2$, is a *weak base*.

$$CH_3CH_2NH_2 + H_2O \rightleftharpoons CH_3CH_2NH_3^+ + OH^-$$

(b) What is meant by the term *weak base*? [1]

(c) Write an expression for the base dissociation constant of ethylamine, K_b. [1]

(d) The graph below shows the pH changes during the titration of 10.0 cm^3 of 0.10 mol dm^{-3} sulfuric acid with 0.10 mol dm^{-3} ethylamine. During this titration, ethylamine is added gradually, from a burette, until a total volume of 30.00 cm^3 has been added to the acid.



(i) Calculate ***x***, the initial pH of sulfuric acid before titration.

[1]

(ii) What is the equivalence volume of ethylamine, **V**, for the neutralisation of 10.0 cm^3 of 0.10 mol dm^{-3} sulfuric acid?

[2]

(iii) An aqueous solution of ethylamine and its salt can act as a buffer. Copy the titration curve onto your answer script and label the buffer region.

[1]

(iv) Use the data in the following table to suggest a suitable indicator for the titration of sulfuric acid with ethylamine. Justify your answer.

State the colour change of your chosen indicator at the end–point of this titration.

indicator	colour in acid	colour in alkali	pH range over which the colour change occurs
Bromocresol green	yellow	blue	3.8 – 5.4
Cresol red	yellow	red	7.2 – 8.8
Alizarin yellow	yellow	orange	10.1 – 13.0

[2]

(e) Concentrated sulfuric acid is a common reagent used in many organic reactions. When concentrated sulfuric acid is added to 3–hydroxypentanoic acid, one possible product formed is **A**, with the molecular formula $C_5H_8O_2$. **A** turns blue litmus paper red. **A** also gives effervescence when heated with acidified potassium manganate (VI) and only one organic product, **B,** is formed.

Suggest the structural formula of **A** and **B.**

[2]

(f) How would you expect the acidity of 3–hydroxypentanoic acid to compare with that of pentanoic acid? Explain your answer.

[2]

[Total: 20]

2 Below shows part of an edited abstract from a scientific journal.

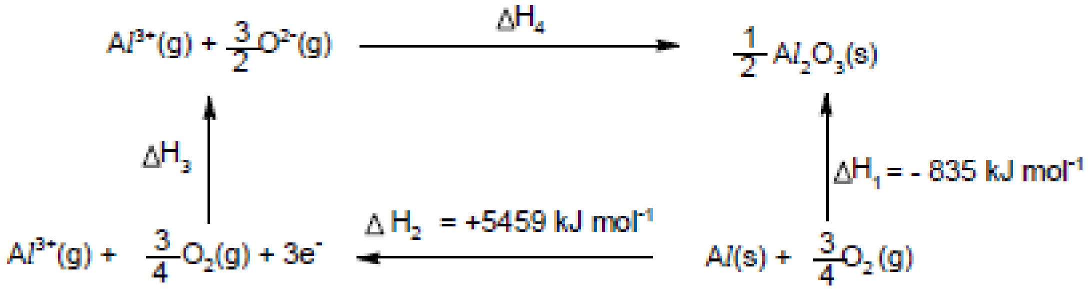
'Two aluminium compounds, $AlCl_3$ and Al_2O_3, were used to determine the effect of Al compounds on pH and bioavailability of Al in 2 acid soils. Al–tolerant (ET8) wheat seedlings were used as a testing plant to confirm bioavailability of Al^{3+} in soil solution. The results showed that the $AlCl_3$ compound increased the bioavailability of Al^{3+} in soil solutions and decreased bulk soil pH. However, Al_2O_3 did not change soil pH and the bioavailability of Al^{3+} in soil solution.'

Md. Toufiq IQBAL (2012), Effect of Al compounds on soil pH and bioavailability of Al in two acid soils, Turk J Agric, 720 – 728

(a) (i) Suggest why Al_2O_3 did not change the bioavailability of Al^{3+} in soil solution. [1]

(ii) Explain how does $AlCl_3$ decrease soil pH in solution? Giving a balanced equation to support your answer. [3]

(b) Consider the following energy cycle involving Al_2O_3.



(i) What enthalpy change does ΔH_1 represent? [1]

(ii) Explain what is meant by the term *enthalpy change of formation, ΔH_f, of $O^{2-}(g)$.*

Given that ΔH_f of $O^{2-}(g)$ is +950 kJ mol^{-1}, calculate ΔH_3. [2]

(iii) Hence, use the above cycle and Hess' Law to calculate ΔH_4, [1]

(iv) Construct a reaction pathway diagram for the reaction below, showing clearly the activation energy and the enthalpy change of the reaction.

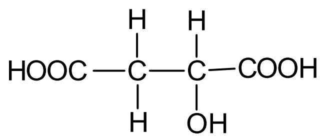
$$Al(s) + \frac{3}{4}O_2(g) \longrightarrow \frac{1}{2}Al_2O_3(s) \quad \Delta H_1 = -835 \text{ kJ mol}^{-1} \quad E_a = +126 \text{ kJ mol}^{-1}$$

[2]

(v) Calculate the activation energy of the reverse reaction. [1]

Most plant species tolerate the toxic effect of A*l* by forming stable complexes using an organic acid derivative, malate.

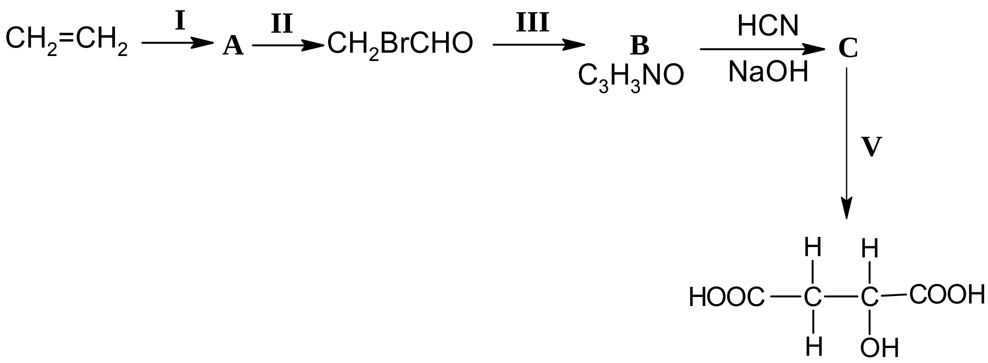
(c) Malate is formed when malic acid reacts with excess aqueous NaOH. Draw the displayed formula of malate.



Malic acid

[2]

(d) Malic acid can be formed from ethene. CH_2BrCHO is one of the intermediates as seen in the reaction scheme below.



(i) Suggest an identity for compound **A**, **B** and **C**.

[3]

(ii) Suggest reagents and conditions for reaction **I, II**, **III** and **V**.

[4]

[Total: 20]

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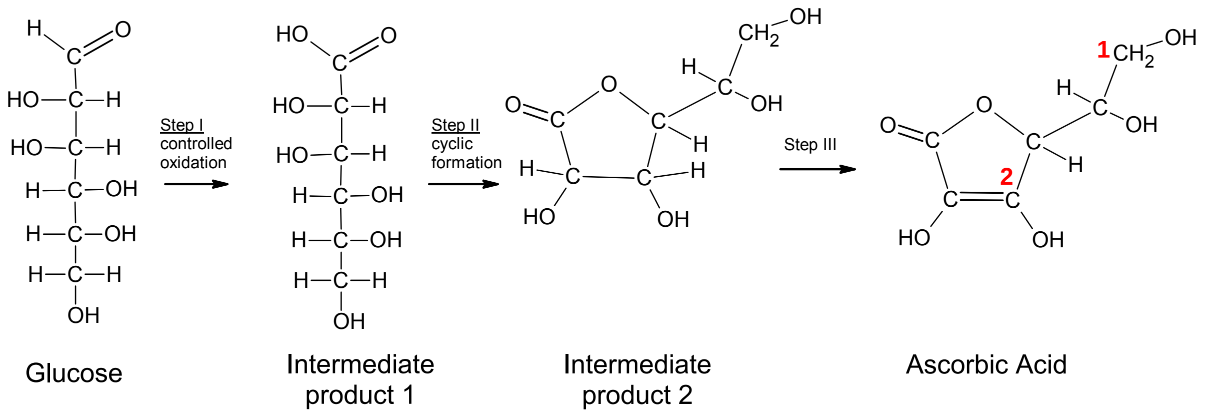
3 Ascorbic acid, better known as vitamin C, is a vitamin found in food and used as a dietary supplement. As a supplement, it is used to treat and prevent scurvy. It is known to be water soluble.

The building block for ascorbic acid is the glucose molecule. The proposed synthetic pathway is shown below.



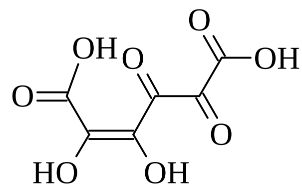
(a) **(i)** Name the functional groups present in intermediate product 2. [1]

(ii) State the type of reaction found in **step II** and hence, copy *intermediate product 1* and **circle** the functional group(s) that is/are involved in the reaction. [2]

(iii) With reference to structure and bonding, explain why ascorbic acid is soluble in water. [2]

(iv) Predict, with reason, the relative solubility of ascorbic acid and glucose. [1]

(v) The ascorbic acid molecule was heated with acidified potassium dichromate (VI) to form the compound shown below.



It was then reacted with hydrazine, $H_2N{=}NH_2$, which reacts in a similar way to 2,4–dinitrophenylhydrazine.

Draw the structural formula of the product formed upon reaction with hydrazine. [1]

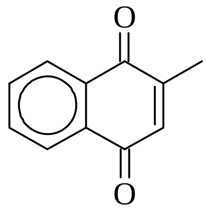
(vi) Write a balanced equation for the reaction between one mole of intermediate product 1 and excess PCl_5. [1]

(vii) For each of C_1 and C_2 of ascorbic acid, state

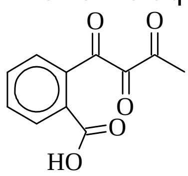
I type of hybridisation
II shape
III no. of σ and π bonds

[3]

(b) Vitamin C and K are both important nutrients with many health benefits. The structure of Vitamin K is shown below.



Vitamin K

Compound **A** ($C_{11}H_8O_2$) is a constitutional isomer of Vitamin K.
Compound **A** gives a yellow precipitate with alkaline aqueous iodine. When treated with hot acidified $KMnO_4$, the product  is formed. One mole of compound **A** also reacts with one mole of bromine in tetrachloromethane but does not react with Na.

Compound **B** is formed when HC*l*(g) is added to compound **A**. Compound **B** is heated with aqueous NaOH to give compound **C**. Compound **C** does not react with acidified $K_2Cr_2O_7$.

Suggest the structures for **A**-**C**, and explain the observations described above.

[9]

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Dunman High School
2017 Year 6 H1 Chemistry (8872) Preliminary Examination
Paper 2

Section A

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

1 **(a)** **(i)** Average titre value = (10.05 + 9.95) / 2
= 10.00 cm^3

(ii) Amount of nitric acid = (10.0/1000) / 1 = 0.01 mol
Since $VO_2^+ \equiv V^{2+}$,
Amount of V^{2+} in 25.0 cm^3 = 25/250 x 0.60 x 250/1000
= 0.015 mol
Mole ratio of V^{2+}: NO_3^- = 0.015 : 0.01
= 3 : 2

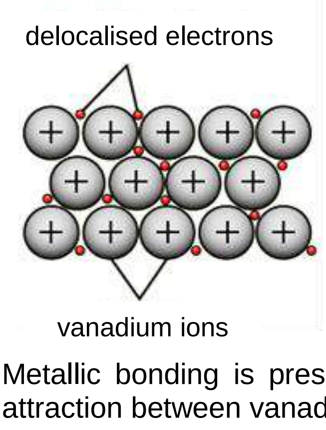
(iii) Let final oxidation state of vanadium be x.
$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$
$V^{2+} \rightarrow V^{x+} + (x - 2)e^-$
Since V^{2+}: NO_3^- = 3 : 2,
$6 = 3(x - 2)$
$x = +4$

Final oxidation product: VO^{2+}
Colour of solution: Blue

(iv) $NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$

$3V^{2+} + 2NO_3^- + 2H^+ \rightarrow 3VO^{2+} + 2NO + H_2O$

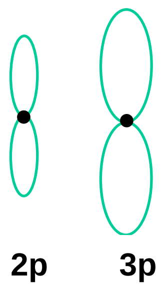
(b)



Metallic bonding is present in vanadium where there is electrostatic forces of attraction between vanadium ions and the delocalised sea of electrons.

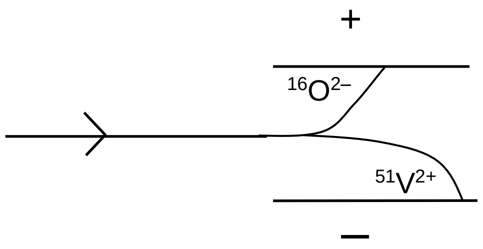
(c) **(i)** $1s^22s^22p^63s^23p^63d^1$

(ii)



(iii) –15.9°

(iv)



2 **(a)** (i) Combustion of coal.

(ii) $H_2O(g)$ or water vapour.

(iii) NO_x is likely formed from reaction of oxygen and nitrogen in the air at high temperatures during combustion of coal.

(b) $SO_2 + CaCO_3 \rightarrow CaSO_3 + CO_2$

$CaSO_3 + ½ O_2 \rightarrow CaSO_4$

(c) Mass of SO_2 that could be removed in FGD plant depends on mass of $CaCO_3$ used.

Moles of $CaCO_3$ used = $2.5 \times 10^5 \times 10^6/100.1 = 2.4975 \times 10^9$ mol
Maximum moles of SO_2 can be removed = Moles of $CaCO_3$ used

Maximum mass of SO_2 = $2.4975 \times 10^9 \times 64.1$
= 1.60×10^{11} g or 1.60×10^8 kg or 1.60×10^5 t

(d)

Mass of SO_2 in flue gases 5 year = $(1.6009 \times 10^{11}$ g $\times 0.10/0.90) \times 5$
= 8.89×10^{10} g or 8.89×10^7 kg or 8.89×10^4 t

(e) Magnesium oxide is basic and can undergo acid-base reaction with (acidic) sulfur dioxide.

(f) **(i)**

oxides	$\left|\frac{q_+q_-}{r_+ + r_-}\right|$
MgO	19.5
Na_2O	8.5
CaO	16.7

(ii) $\left|\frac{q_+q_-}{r_+ + r_-}\right|$: MgO > CaO > Na_2O

Magnitude of lattice energy (given by $\left|\frac{q_+q_-}{r_+ + r_-}\right|$) : MgO > CaO > Na_2O

Ionic bond strength of metal oxides: MgO > CaO > Na_2O

Amount of energy to overcome ionic bonds in oxide: MgO > CaO > Na_2O
$\therefore$ melting point: MgO > CaO > Na_2O

(iii)

oxides	pH of resulting solution
MgO	9
Na_2O	13
CaO	10 pH of MgO < pH < pH of Na_2O

CaO has a less exothermic/ lower magnitude of lattice energy than MgO. Thus, CaO should be more soluble than MgO and so giving a higher concentration of $OH^–$ ions when oxide is added to water. pH of the resulting solution of CaO is between that of Na_2O and MgO.

(g) When SO_2 is absorbed in the water, it will react with water and oxygen to from sulfate and H^+ ions. The presence of $HCO_3^–$ in the seawater will remove H^+ ions, causing a decrease in [H^+]. This will shift the position of equilibrium (1) to the right, removing SO_2.

OR

When SO_2 is absorbed in the water, it will react with water and oxygen to from sulfate and H^+ ions. The presence of $HCO_3^–$ in the seawater will remove H^+ ions as CO_2, which will escape into the atmosphere. This will shift the position of equilibrium (2) forward, which in turn shifts the position of equilibrium (1) to the right , removing SO_2.

3 (a) (i)

	$2SO_2(g)$ +	$O_2(g)$ $\rightleftharpoons$	$2SO_3(g)$
initial moles / mol	69.2	34.6	0
change in moles / mol	– 65.6	– 32.8	+ 65.6
moles at eqm / mol	3.6	1.8	65.6
conc at eqm / mol dm^{-3}	1.8	0.9	32.8

$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$

$= \frac{(32.8)^2}{(1.8)^2(0.9)}$

= 368.94

= 369 mol^{-1} dm^3

(ii)

For 99% SO_2 to be converted to SO_3, it means that 1% SO_2 remains.

$$\frac{[SO_3]}{[SO_2]} = \frac{99}{1}$$

Hence, K_c = 368.94 $= (\frac{99}{1})^2 \frac{1}{[O_2]}$

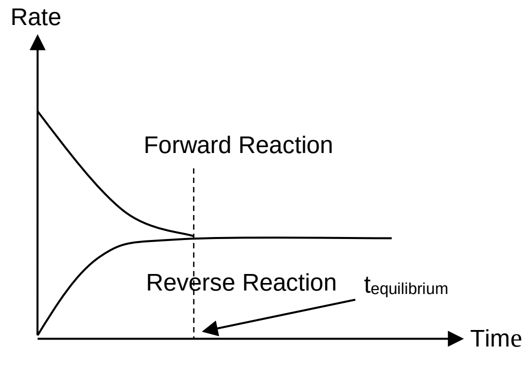
$[O_2]$ = 26.565

= 26.6 mol dm^{-3}

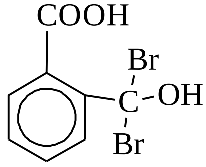
(iii) When a catalyst is present,

- number of reactant particles with at least the activation energy ($E_a'{}_{(cat)}$) increases
- number of effective collisions per unit time taking place in the reaction increases. Rate of reaction is proportional to the frequency of effective collisions.
  Hence, rate of reaction increases.

(iv)



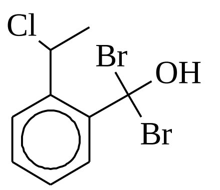
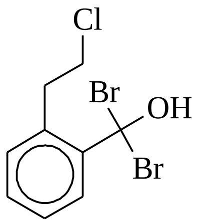
(b) (i)

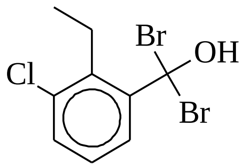
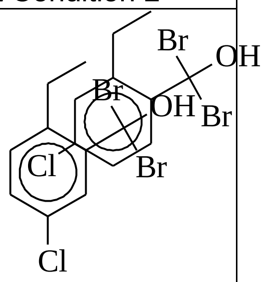
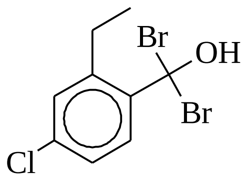
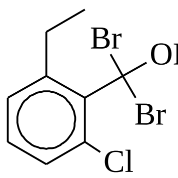


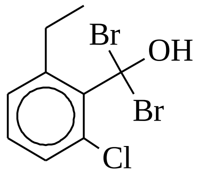
(ii) Add an equal volume of NaOH(aq) to RX and heat (in a water bath). Cool the mixture and add excess aqueous HNO_3. Finally, add aqueous $AgNO_3$.

For compound W: cream AgBr precipitate was obtained
For compound X: yellow AgI precipitate was obtained

(iii)

Isomer formed via Condition 1	
	

Isomer formed via Condition 2	
	
	



Condition 1
Reagent: limited Cl_2(g)
Conditions: uv light or high temperature

Section B

1 (a) (i) *Order of reaction* is the power to which the concentration of that reactant is raised in the rate equation.

(ii) Order w.r.t O_2 is zero as the graph of $[O_2]$ against time is a downward sloping straight line / the gradient of the line i.e. rate of reaction is constant with changing $[O_2]$.

When $[SO_2]$ = 0.80 mol dm^{-3},

r_1, rate of reaction = $\left|\frac{0.04-0.05}{88}\right|$ = 1.13 x 10^{-4}

When $[SO_2]$ = 1.20 mol dm^{-3},

r_2, rate of reaction = $\left|\frac{0.030-0.05}{80}\right|$ = 2.50 x 10^{-4}

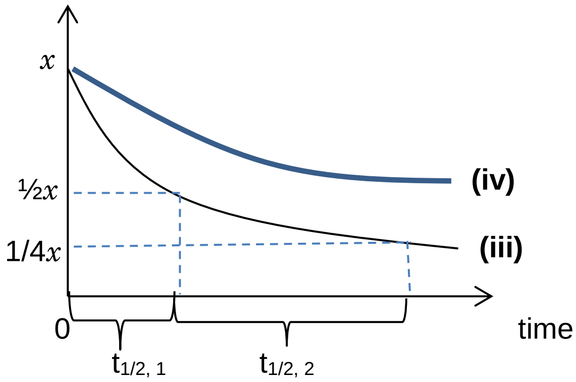
r_2/r_1 = 2.21 ≈ 2.25

When $[SO_2]$ x 1.5 times, rate of reaction x 2.25 times, reaction is second order w.r.t SO_2.

(iii) rate = $k[SO_2]^2$
When $[SO_2]$ = 0.8 mol dm^{-3},
k = 1.77 x 10^{-4} mol^{-1} dm^3 s^{-1}

(k = 1.74 x 10^{-4} if $[SO_2]$ = 1.2 mol dm^{-3})

(iii) $[SO_2]$ / mol dm^{-3}



(b) Weak base is one which **dissociates partially** in water to **give hydroxide ions**.

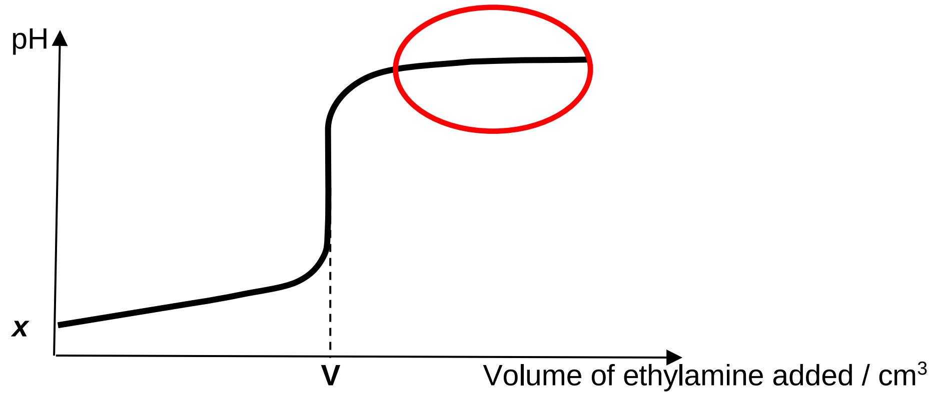
(c)

$$K_b = \frac{\left[CH_3CH_2NH_3^+\right]\left[OH^-\right]}{\left[CH_3CH_2NH_2\right]} \text{ mol dm}^{-3}$$

(d) (i) $[H^+]$ = 0.20 mol dm^{-3}
pH = –lg(0.20)
= 0.699

(ii) $2CH_3CH_2NH_2 + H_2SO_4 \rightarrow (CH_3CH_2NH_3^+)_2SO_4^{2-}$
amount of sulfuric acid = 10.0/1000 x 0.1
= 0.001 mol
amount of $CH_3CH_2NH_2$ = 0.002 mol
equivalence volume = 0.002 / 0.10
= 20.0 cm^3

(iii)



(iv) This is a strong acid–weak base titration and hence the salt is acidic.
Bromocresol green will be a suitable indicator as the pH transition range of the indicator lies within the rapid pH change over the equivalence point.
Colour change at the end-point will be yellow to green/blue.

(e) $CH_3CH_2CH{=}CHCOOH$
CH_3CH_2COOH

(f) 3–hydroxypentanoic acid is a stronger acid than pentanoic acid.
–OH, hydroxyl group is electron–withdrawing and hence disperse the negative charge of the conjugate base. This stabilises the conjugate base and makes 3–hydroxypentanoic acid a stronger acid.

2 (a) (i) Al_2O_3 is insoluble in water. Hence bioavailability of Al^{3+} is not increased in solution

(ii) $AlCl_3$ undergoes hydrolysis to give an acidic solution.

The high charge density of hydrated Al^{3+} ion enables it to attract electrons away from one of its surrounding water molecules, thereby polarising or weakening the O–H bond which results in the release of a proton.

$$[Al(H_2O)_6]^{3+} \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} + H^+$$

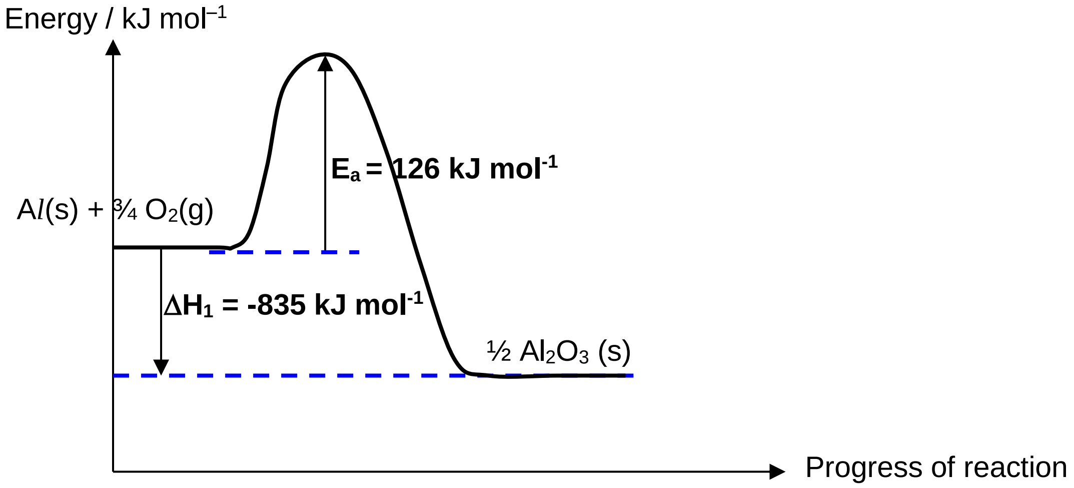
(b) (i) Enthalpy change of combustion of Al or ½ $\Delta H_f(Al_2O_3)$

(ii) Enthalpy change of formation is the energy change when 1 mol of $O^{2-}(g)$ is formed from O_2 (g) .

$$\Delta H_3 = 950 \times \frac{3}{2}$$
$$= +\,1.43 \times 10^3 \text{ kJ mol}^{-1}$$

(iii) $\Delta H_4 = -\Delta H_3 - \Delta H_2 + \Delta H_1$
$= -\,(1.43 \times 10^3) - (5459) - 835$
$= -\,7.72 \times 10^3 \text{ kJ mol}^{-1}$

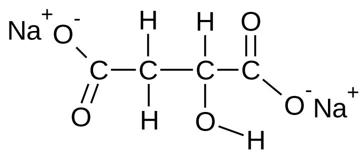
(iv)



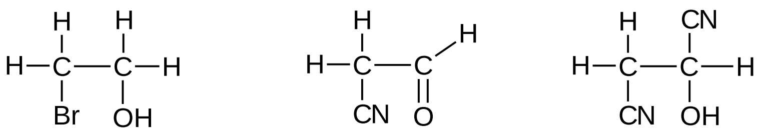
(v) Activation energy of the reverse reaction = 835 + 126

= 961 kJ mol^{-1}

(c)



(d) **(i)**



A **B** **C**

(ii) Reaction I – aqueous bromine

Reaction II – $K_2Cr_2O_7$ in dilute H_2SO_4, heat with immediate distillation

Reaction III – KCN in ethanol, heat under reflux

Reaction V – dilute H_2SO_4, heat under reflux

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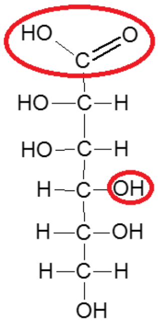
3 (a) (i) Alcohol and ester.

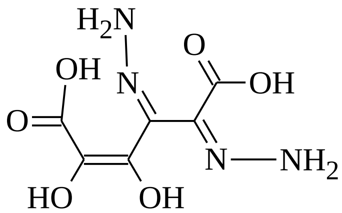
(ii) Condensation.



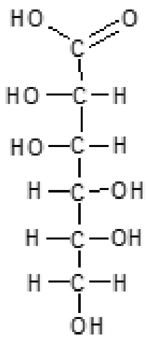
(iii) Ascorbic acid has a simple molecular structure. The hydrogen bonds formed between ascorbic acid and water molecules releases sufficient energy to overcome the intermolecular hydrogen bonding between ascorbic acid and also between water.

(iv) Glucose is more soluble in water than ascorbic acid as there are more alcohol groups available to form more extensive hydrogen bonds with water.

(v)



(vi)



$+ 6PCl_5 \rightarrow CH_2Cl(CHCl)_4COCl + 6HCl + 6POCl_3$

(vii)

Carbon atom	Type of hybridisation	Shape	No. of σ and π bonds
C_1	sp^3 hybridised	tetrahedral	4σ bonds
C_2	sp^2 hybridised	trigonal planar	3σ and 1π bonds

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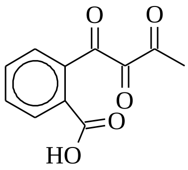
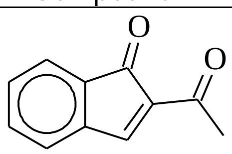
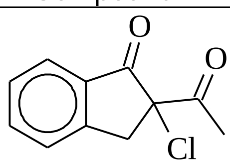
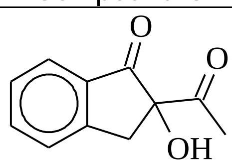
(b)

Observations	**Deductions**
Compound **A** gives a yellow precipitate with alkaline aqueous iodine.	• Compound **A** undergoes oxidation. ⇒ either $-COCH_3$ or $-CH(OH)CH_3$ present.
When treated with hot concentrated $KMnO_4$, the product  is formed.	• Compound **A** undergoes oxidation. ⇒ Alkene is present. ⇒ Secondary alcohol may be present.
One mole of Compound **A** also reacts with one mole of bromine in tetrachloromethane	• Compound **A** undergoes (electrophilic) addition. ⇒ One C=C bond is present.
but does not react with Na.	• Compound **A** does not undergo acid–metal displacement / redox with Na. ⇒ no alcohol, or carboxylic acid present.
Compound **B** is formed when HC*l*(g) is added to Compound **A**.	• Compound **A** undergoes (electrophilic) addition. ⇒ Alkene is present. ⇒ Compound B is a chloroalkane.
When Compound **B** is heated with aqueous NaOH, followed by aqueous $AgNO_3$, Compound **C** and a white precipitate is formed.	• Compound **B** undergoes (nucleophilic) substitution. ⇒ Alcohol present in Compound **C**.
Compound **C** does not react with acidified $K_2Cr_2O_7$.	• Compound **C** does not undergo oxidation. ⇒ Tertiary alcohol present in Compound **C**.

Compound **A**	Compound **B**	Compound **C**
		

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HWA CHONG INSTITUTION
Preliminary Examinations
Higher 1

NAME		**CT GROUP**	**16S**

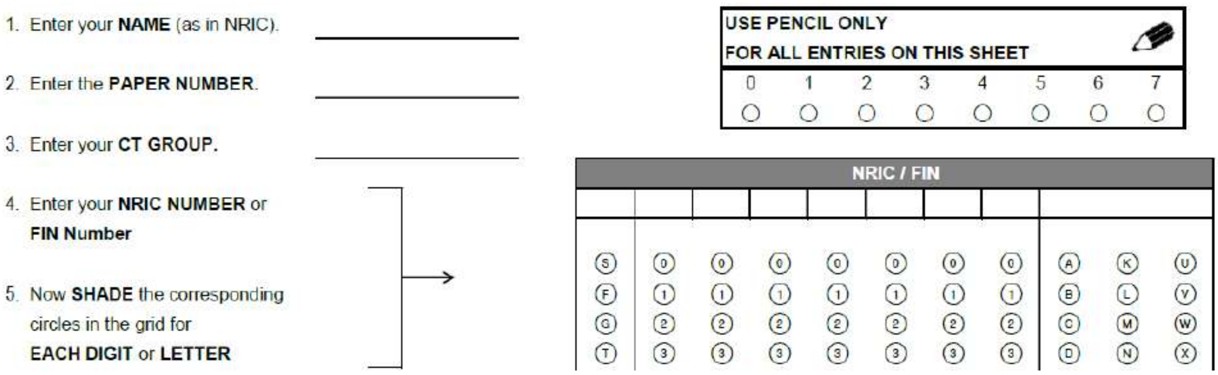
CHEMISTRY 8872/01

Paper 1 Multiple Choice **20 September 2017**

Additional Materials: Data Booklet
Optical Mark Sheet (OMS) **50 minutes**

INSTRUCTIONS TO CANDIDATES:

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, Centre number and index number on the Answer Sheet in the spaces provided.
Complete the information on the optical mark sheet (OMS) as shown below.



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 OMS.

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.

Section A

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.*

Which one of the following has the same number of particles as one mole of magnesium atoms?

A the number of ions in 2 dm^3 of 0.25 mol dm^{-3} of aqueous hydrochloric acid

B the number of delocalised electrons in one mol of copper metal

C the number of atoms in 71 g of chlorine gas

D the number of ions in 58.5 g of sodium chloride

2 What mass of carbon dioxide will be formed by the complete combustion of 4.00 g of butan-1-ol?

A 2.38 g **B** 3.03 g **C** 9.51 g **D** 12.1 g

3 The percentage by mass of water in a hydrated manganese(II) chloride salt is 36.4%.

What is the empirical formula of the hydrated salt?

A $MnCl_2.2H_2O$

B $MnCl_2.3H_2O$

C $MnCl_2.4H_2O$

D $MnCl_2.5H_2O$

4 Which of the following has the same electronic configuration as the chloride ion, Cl^-?

A Ca^{2+} **B** Na^+ **C** Ne **D** F^-

5 In which of the following reactions is the underlined element being reduced?

A $\underline{N}H_3 + HCl \rightarrow \underline{N}H_4Cl$

B $H_2\underline{O}_2 + 2I^- + 2H^+ \rightarrow 2H_2\underline{O} + I_2$

C $2\underline{V}^{3+} + H_2O_2 \rightarrow 2\underline{V}O^{2+} + 2H^+$

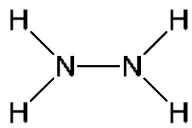
D $Ca\underline{C}O_3 \rightarrow CaO + \underline{C}O_2$

6 When heated, solid iodine forms iodine vapour.

What does this information suggest about the nature of the particles in these two physical states of iodine?

	solid	vapour
A	ionic	atomic
B	ionic	molecular
C	molecular	atomic
D	molecular	molecular

7 Hydrazine, N_2H_4, is useful as a rocket fuel. It has some properties that are similar to those of ammonia, NH_3.



hydrazine

Why are hydrazine molecules more soluble in water than ammonia molecules?

A There are more van der Waals' forces between hydrazine and water than between ammonia and water.

B There are more hydrogen bonds between hydrazine and water than between ammonia and water.

C There are stronger permanent dipole interactions between hydrazine and water than between ammonia and water.

D The covalent bonding in hydrazine is stronger than that in water.

8 Which of the equations correctly define the standard enthalpy change of formation of a compound?

A $2C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \longrightarrow C_2H_5OH(l)$

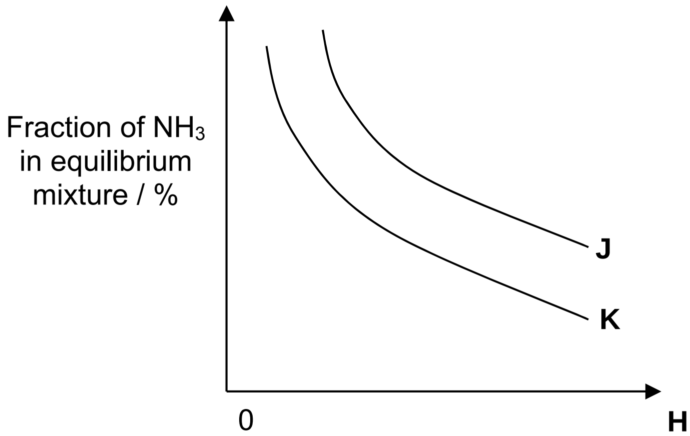
B $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$

C $Na(s) + Cl(g) \longrightarrow NaCl(s)$

D $C(g) + 2O(g) \longrightarrow CO_2(g)$

9 The graph below shows the fraction of ammonia in the equilibrium mixture obtainable if equilibrium was established under different temperature and pressure conditions during the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H < 0$$



What do **H**, **J** and **K** represent and what is the relative magnitude of **J** and **K**?

	H	**J** and **K**	relative magnitude
A	pressure	temperature	**J** > **K**
B	pressure	temperature	**K** > **J**
C	temperature	pressure	**J** > **K**
D	temperature	pressure	**K** > **J**

10 The table shows some data on two acid-base indicators.

indicator	approximate pH range of colour change	colour change	
		acid	alkali
thymolphthalein	9 – 10	colourless	blue
chlorophenol red	6 – 7	yellow	red

Which conclusion can be drawn about a solution in which thymolphthalein is colourless and chlorophenol red is red?

A It is weakly acidic.

B It is weakly alkaline.

C It is neutral.

D It is strongly alkaline.

11 10 cm^3 of 0.01 mol dm^{-3} solution of H_2SO_4 is diluted with 90 cm^3 of water.

What is the pH of the resulting solution?

A 1.7 **B** 2.0 **C** 2.7 **D** 3.0

12 An enzyme required in laboratory process operates at maximum efficiency when placed in an aqueous solution buffered at pH 5.6.

Which combination of substances when dissolved in water would give the appropriate buffer solution?

A 0.5 mol of HC*l* and 1 mol of CH_3COONa

B 0.5 mol of HC*l* and 1 mol of CH_3COOH

C 1 mol of CH_3COOH and 1 mol of NaOH

D 1 mol of CH_3COONH_4

13 Which statement about the order of reaction is correct?

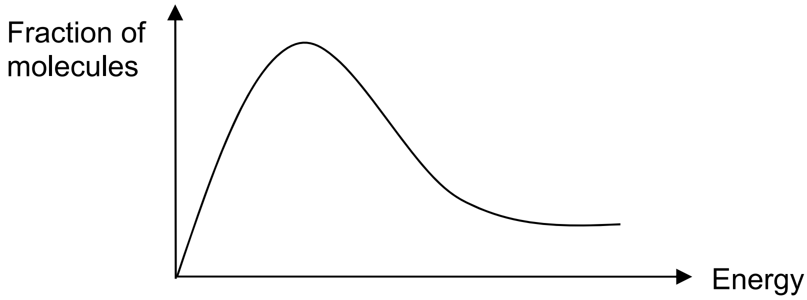
A It is the sum of the powers of the concentrations of the species included in the rate equation.

B It is the sum of the powers of the concentrations of the reactants and products.

C It is the sum of the number 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.

14 The diagram represents the Boltzmann distribution of molecular energies at a given temperature.



Which of the following statements is **incorrect**?

A The total number of molecules is constant at all temperatures.

B When temperature decreases, the maximum of the curve is displaced to the left.

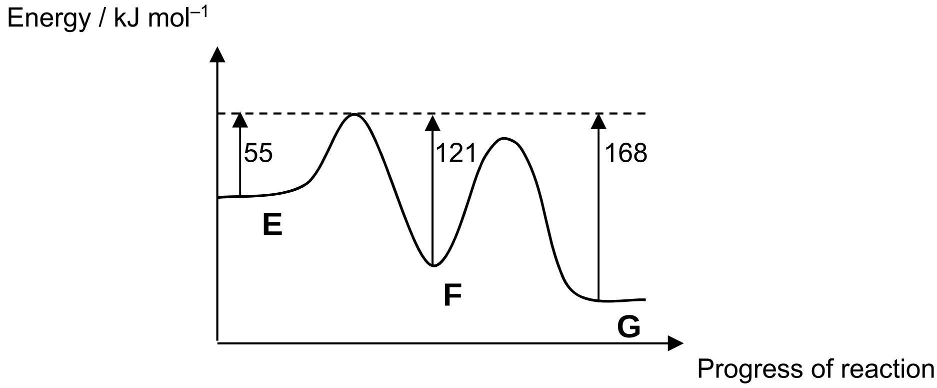
C When temperature increases, the fraction of molecules with any given energy also increases.

D When temperature increases, the fraction of molecules with energies greater than the activation energy increases.

15 The reaction pathway diagram for a two–step reaction is shown below.

Step 1: **E** $\rightleftharpoons$ **F**

Step 2: **F** $\longrightarrow$ **G**



Which statement about the reaction is correct?

A Step 2 is more exothermic than step 1.

B The enthalpy change of reaction for both the forward and backward reaction of step 1 is the same.

C The activation energy for the backward reaction of step 1 is 66 kJ mol^{-1}.

D The enthalpy change of reaction for the conversion of **E** to **G** is the sum of the enthalpy changes of step 1 and step 2.

16 The ions P^{3-}, S^{2-} and Cl^{-} have radii 0.212nm, 0.184nm and 0.181 nm respectively.

Which one of the following correctly explains the decrease in radius from P^{3-} to Cl^{-}?

A increase in both the total number of electrons and nuclear charge

B total number of electrons remaining constant with an increase in nuclear charge

C increase in the total number of electrons with nuclear charge remaining constant

D decrease in the total number of electrons with nuclear charge remaining constant

17 Which of the following statements about the electrical conductivity of elements across Period 3 is **incorrect**?

A Electrical conductivity increases from sodium to aluminium as the number of delocalised cations and electrons increases.

B Sodium, magnesium and aluminium are good electrical conductors as their metallic lattices contain delocalised electrons.

C Silicon is a semiconductor as the electrons within the covalent bonds are held tightly and are not easily delocalised.

D Phosphorous, sulfur, chlorine and argon are non–conductors as there are no mobile charge carriers in their simple molecular structures.

18 Phosphorus can form PCl_3 and PCl_5. However, nitrogen can only form NCl_3.

Which statement is a correct explanation of this?

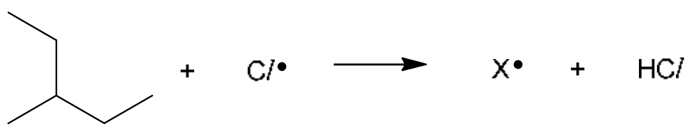
A Nitrogen can attain an oxidation state of +5.

B The N–C*l* bond is weaker than the P–C*l* bond.

C The valence orbitals of P are higher in energy than that of N.

D The n = 2 principal quantum shell can contain a maximum of 8 electrons.

19 When heated with chlorine, the following hydrocarbon undergoes free radical substitution. In the propagation step, the free radical X• is formed by the loss of one hydrogen atom.



How many different forms of X• are theoretically possible?

A 3 **B** 4 **C** 5 **D** 6

20 Dichlorodifluoromethane, CCl_2F_2, is widely used in aerosol propellants and as a refrigerant.

Which statement helps to explain why dichlorodifluoromethane is chemically inert?

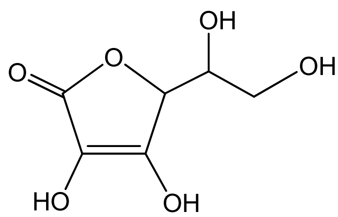
A The carbon–fluorine bond energy is large.

B Fluorine atoms have high electronegativity.

C The carbon–fluorine bond has a high polarity.

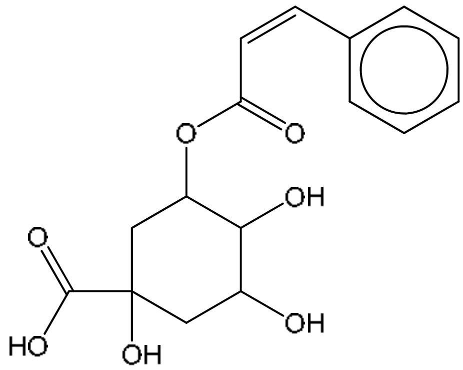
D Van der Waals' forces between CCl_2F_2 molecules are weak.

21 What is the total number of sigma bonds in a molecule of vitamin C as shown below?



A 12 **B** 14 **C** 16 **D** 20

22 Compound **Q** below is a derivative of chlorogenic acid which is found in coffee beans.



compound **Q**

Which of the following statements is correct?

A 1 mol of **Q** will react with 2 moles of NaOH(aq) on heating.

B 1 mol of **Q** will react with 4 moles of NaOH(aq) in the cold.

C When 1 mol of **Q** reacts with an excess of sodium carbonate, 1 mol of carbon dioxide gas and 1 mole of water will be formed.

D When 1 mol of **Q** reacts with an excess of sodium metal, 4 moles of hydrogen gas will be evolved.

23 Which of the following pairs of reagents can **both** be used separately to distinguish $CH_3COCH_2CH_3$ and $CH_3CH(OH)CH{=}CH_2$?

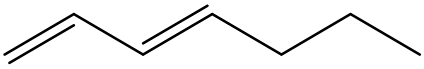
A alkaline aqueous iodine and sodium metal

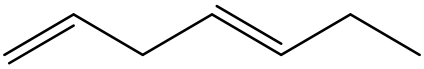
B 2,4-dinitrophenylhydrazine and hot acidified potassium manganate(VII)

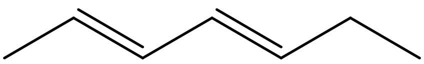
C Tollens' reagent and bromine in tetrachloromethane

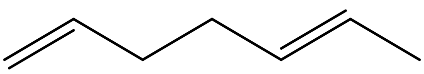
D H_2, nickel catalyst, heat and hot acidified potassium manganate(VII)

24 Which of the following will **not** be produced when 2,4–dibromoheptane reacts with hot ethanolic sodium hydroxide?

A 

B 

C 

D 

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25 A sample of ethanal is treated with HCN in the presence of a little KCN. The organic product is then heated under reflux with dilute sulfuric acid.

What will be the final organic product?

A CH_3COCO_2H

B $CH_3CH_2CONH_2$

C $CH_3CH(OH)CO_2H$

D $CH_3CH(OH)CH_2NH_2$

Section B

For **questions 26-30**, one or more of the numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct.

The responses **A** to **D** should be selected on the basis of:

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is to be used as a correct response.

26 Which pairs of compounds contain one that is giant ionic and one that is simple molecular?

1 NaF and BH_3

2 HCl and I_2

3 Al_2O_3 and SiO_2

27 Which particles have the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$?

1 $_{24}Cr$

2 $_{25}Mn^+$

3 $_{26}Fe^{2+}$

28 Which statements containing the third period elements (sodium to argon) and their compounds are correct?

1 Electronegativity increases across Period 3 elements.

2 Aluminium oxide is the only oxide which is amphoteric.

3 The maximum oxidation state is shown by silicon.

29 An organic compound has the formula $C_4H_6Cl_2$.

Which are correctly named isomers of this compound?

1 3,4-dichlorobut-3-ene

2 1,4-dichlorobut-2-ene

3 1,1-dichlorobut-1-ene

The responses **A** to **D** should be selected on the basis of:

A	**B**	**C**	**D**
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is to be used as a correct response.

30 Which alcohols can be formed by the reduction of a ketone?

1 2-methylbutan-2-ol

2 2-methylpentan-3-ol

3 hexan-2-ol

2017 H1 Chemistry Preliminary Examination Paper 1 Answer Key

Paper 1

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

HWA CHONG INSTITUTION
C2 Preliminary Examinations
Higher 1

CANDIDATE NAME		**CT GROUP**	16S
CENTRE NUMBER		**INDEX NUMBER**	

CHEMISTRY — 8872/02

Paper 2 — **11 September 2017**

Candidates answer Section A on the Question Paper. — **2 hours**

Additional Materials: Answer paper
Data Booklet
Graph paper (2 sheets)

READ THESE INSTRUCTIONS FIRST

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

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** the questions.

Section B
Answer **two** questions on separate answer paper.

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 EXAMINERS' USE ONLY

					TOTAL
Multiple Choice	**Section A (Structured)**		**Section B (Free Response)**		
	Q1	**/ 20**	**Q4**	**/ 20**	
	Q2	**/ 10**	**Q5**	**/ 20**	
	Q3	**/ 10**	**Q6**	**/ 20**	
/ 30	**Subtotal**	**/ 40**	**Subtotal**	**/ 40**	**110**

This document consists of **11** printed pages (including this cover page).

Section A

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

1 **(a)** Nitrogen and hydrogen react together to form ammonia in the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

Industrially, the following conditions are used for the Haber process.

pressure	250 atm
temperature	450 ˚C
catalyst	finely divided iron catalyst

(i) With the aid of Le Chatelier's Principle, explain why a moderate temperature of 450 °C is used for the Haber process.

....

....

....

....

.... [2]

(ii) Explain how iron catalyst can increase the rate of formation of ammonia.

....

.... [1]

(iii) State and explain the effect of using a pressure of 400 atm on the position of equilibrium and the equilibrium constant.

....

....

....

....

.... [2]

Given that 4 moles of N_2 and 8 moles of H_2 are allowed to reach dynamic equilibrium in a 2 dm^3 vessel. It is found that the total number of moles of gases present in the vessel at equilibrium is 8.

(iv) Write a K_c expression for the equilibrium in the formation of ammonia.

[1]

(v) Calculate the number of moles of each gas at equilibrium, showing your workings clearly.

number of moles of N_2: …………...mol; H_2: …………...mol

NH_3: …………...mol

[2]

(vi) Hence, calculate the equilibrium constant and state its units.

K_c = …………………… units = ……………………

[2]

(b) **(i)** Ammonia burns in oxygen to give nitrogen dioxide and steam. Write an equation, with state symbols, which represents the enthalpy change of combustion of ammonia.

………………………………………………………………………………………… [1]

(ii) Hence, use the following information to calculate a value for the enthalpy change of combustion of ammonia.

Enthalpy change of formation of nitrogen dioxide	- 34 kJ mol^{-1}
Enthalpy change of formation of steam	- 242 kJ mol^{-1}
Enthalpy change of formation of ammonia	- 46 kJ mol^{-1}

[2]

(iii) Using relevant information from the *Data Booklet* as well as your answer in **b(ii)**, calculate a value for the bond energy of the bond between the nitrogen atom and the oxygen atom in nitrogen dioxide, assuming that the bond energy of both bonds are the same.

bond energy: …………………….. kJ mol^{-1}
[2]

(iv) The combustion of 44 g of ammonia produces 89 g of nitrogen dioxide. Calculate the percentage efficiency of this reaction.

[2]

(c) Ammonia reacts with bromoethane.

Write an equation for the reaction that occurs and give the reagent and conditions necessary. State fully which class of organic compound the product belongs to.

Equation: …………………………………………………………………………………..

Reagents and conditions: ………………………………………………………..……………

Class of organic compound: ………………………………………………………………. [3]

[Total: 20]

2 This question is about Period 3 elements and their compounds.

(a) Period 3 elements react with oxygen to form oxides.

(i) Describe the reaction of aluminium oxide and phosphorus(V) oxide with hydrochloric acid and sodium hydroxide, if any.

....

.... [2]

(ii) Write equations for all reactions that occur in **(b)(i)**.

aluminium oxide: ....

....

phosphorus oxide: ....

....
[3]

(b) **(i)** In the vapour phase, an equilibrium is established between aluminium chloride and its dimer as follows:

$$2AlCl_3(g) \rightleftharpoons Al_2Cl_6(g)$$

With the aid of a diagram, explain how the dimer is formed.

....

....

....

.... [3]

(ii) At 180 °C, aluminium chloride, Al_2Cl_6, sublimes. Explain, based on its structure and bonding, why it sublimes at a relatively low temperature.

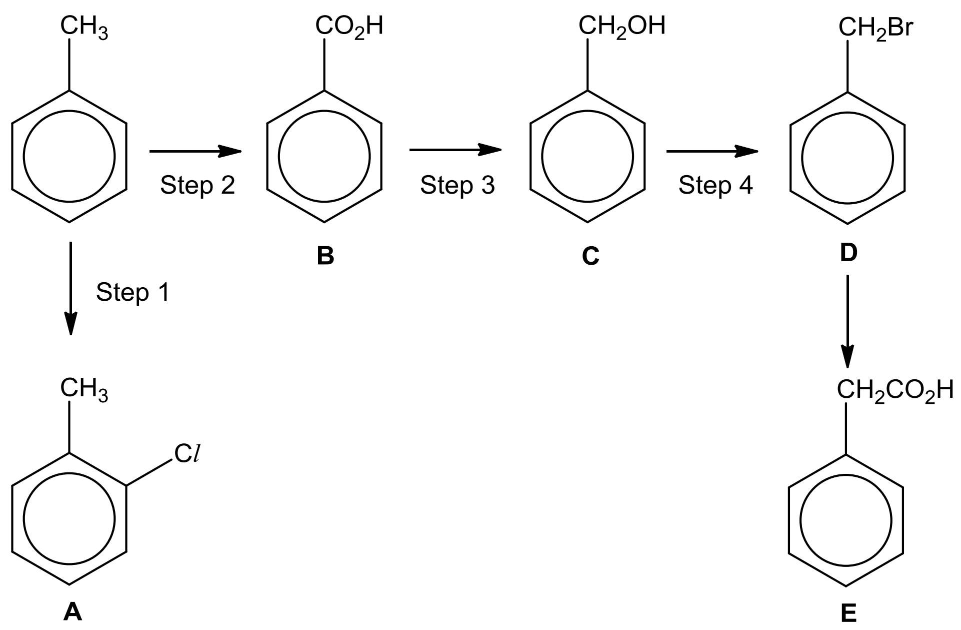
....

....

.... [2]

[Total: 10]

3 The following diagram shows some reactions of methylbenzene.



(a) State the reagents and conditions necessary for Step 1.

Reagents and conditions: ……………………………………………………………….[1]

(b) State the types of reaction for Steps 2 and 3.

Step 2: ……………………………………………………………………………………..

Step 3: ……………………………………………………………………………………...

[2]

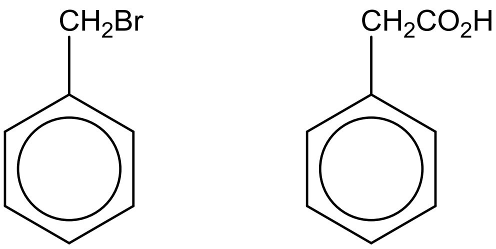
(c) Explain why **B** is acidic.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [2]

The structures of **D** and **E** are shown again below for parts **(d)** and **(e)**.



D **E**

(d) There is *another* method to obtain **D** from methylbenzene in *one* step. Give the reagents and conditions for this method and explain why this method is **not** preferred.

Reagents and conditions: ……………………………………………………………………..

……………………………………………………………………………………………………

……………………………………………………………………………………….…… [2]

(e) Propose a 2-step synthesis for the conversion of **D** to **E**. Give the reagents and conditions for all steps and the structure of any intermediate.

[3]

[Total: 10]

Section B

Answer **two** questions from this section on separate answer paper.

4 **(a)** In the production of instant noodles, a key step involves deep frying the noodles in cooking oil to remove all traces of moisture. By dehydrating the noodles in this manner, the shelf life of the product increases dramatically.

(i) Cooking oil is primarily made up of long hydrocarbon chains, and has an approximate boiling point of 300 °C, whereas water has a boiling point of 100 °C.

Explain why cooking oil has a higher boiling point by reference to the type of bonding involved. [3]

(ii) Predict and explain what you would observe when equal volumes of cooking oil and water is mixed. [2]

(iii) Using your answers from **(a)(i)** and **(a)(ii)**, explain how deep frying removes moisture from the noodles. [2]

(b) Na*Cl*, also known as table salt, is an important seasoning used in instant noodles.

(i) Draw a 'dot-and-cross' diagram that shows the bonding in sodium chloride. [1]

(ii) Describe the structure and bonding of sodium chloride, and explain why sodium chloride has a high melting point, and is brittle. [3]

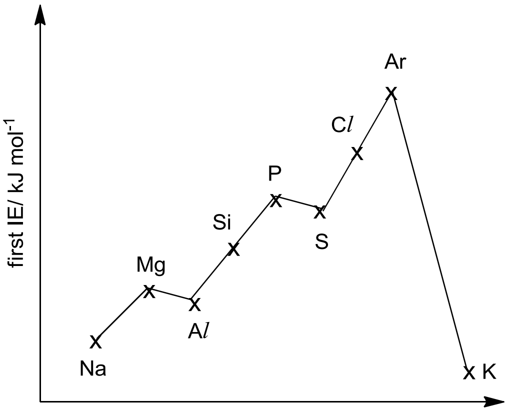
(iii) Define the term *lattice energy*. Explain how and why the lattice energies of sodium chloride, and sodium oxide, Na_2O, have different numerical values. [4]

(iv) Describe the reactions of sodium chloride, aluminium chloride, $AlCl_3$, and silicon chloride, $SiCl_4$, with excess water. Write equations where appropriate. [4]

(v) Suggest what influence the type of bonding present in these three chlorides in **(b)(iv)** has on their reaction with water. [1]

[Total: 20]

5 **(a)** The diagram below shows the first ionisation energies of the elements sodium to potassium.



(i) Define the term *first ionisation energy*. [1]

(ii) Several factors influence the values of the first ionisation energies shown above.

For each of the pairs of elements listed below, explain the difference between the values of their first ionisation energies. You should use a different explanation for each pair.

sodium and potassium
magnesium and aluminium
phosphorus and sulfur
chlorine and argon [5]

(iii) **X** and **Y** are elements from Period 3.

Based on the data below, suggest the identities of the following elements, **X** and **Y**, from their successive ionisation energies in kJ mol^{-1} and explain your reasoning.

	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}	7^{th}	8^{th}	9^{th}	10^{th}
X	737	1451	7733	10542	13630	18020	21711	25661	31653	35458
Y	1251	2298	3822	5159	6542	9362	11018	33604	38600	43961

[4]

(b) Compound **A** has the molecular formula $C_9H_{12}O$. When **A** is exposed *uv* light in the presence of chlorine gas, it forms 3 monosubstituted compounds.

When **A** is heated with acidified potassium dichromate(VI), $K_2Cr_2O_7$, it forms compound **B**, which gives an orange precipitate in the presence of 2,4-dinitrophenylhydrazine.

When **A** is heated with excess concentrated sulfuric acid, it forms compounds **C**, **D**, and **E**, which are isomers of each other. In addition, **C** and **D** are stereoisomers.

Identify and suggest structures for **A**, **B**, **C**, **D** and **E**. Show how you deduced these structures and suggest the types of reactions that are occurring. [10]

[Total: 20]

6 **(a)** **(i)** Draw a 'dot-and-cross' diagram that shows the bonding in H_2O_2. [1]

(ii) Use your diagram in **(a)(i)** to suggest and explain the shape of H_2O_2. [2]

(iii) Suggest a value for the bond angle in H_2O_2, giving reasons for your choice. [2]

(b) H_2O_2 can be oxidised or reduced, depending on the species it is mixed with.

A stock solution of H_2O_2 was diluted by adding 20.0 cm^3 of the stock solution into a standard flask which was filled with distilled water to make a 100 cm^3 standard solution. 25.0 cm^3 of the standard solution was titrated with 0.200 mol dm^{-3} $KMnO_4$. 21.80 cm^3 of $KMnO_4$ solution was required to reach the end point. The following reaction occurs.

$$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$$

(i) Explain whether H_2O_2 is acting as an oxidising agent or reducing agent in the titration. [1]

(ii) Determine the amount of H_2O_2, in moles, that reacted with $KMnO_4$. [2]

(iii) Hence, determine the concentration of H_2O_2 in the stock solution. [2]

(c) 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 of reaction was followed by measuring the concentration of the remaining iodide ions after fixed time intervals. An experiment was carried out, starting using 0.05 mol dm^{-3} hydrogen peroxide. The following results were obtained.

Time/s	**Experiment 1** $[H_2O_2]$ = 0.0500 mol dm^{-3}
	$[I^-]$/ mol dm^{-3}
0	10.00×10^{-4}
25	7.45×10^{-4}
50	5.60×10^{-4}
75	4.25×10^{-4}
100	3.15×10^{-4}

(i) Plot a graph of $[I^-]$ against time. [3]

(ii) Use your graph to find the order of reaction with respect to I^-. [2]

(iii) **Experiment 2** was carried out using 0.100 mol^{-3} H_2O_2 instead, and it was found that the initial rate of reaction doubled. State and explain the order of reaction with respect to H_2O_2. [1]

(iv) The order of reaction with respect to H^+ is zero. Hence, write the rate equation for the reaction. [1]

(v) Determine the initial rate of reaction. Hence, calculate the rate constant, giving its units. [3]

[Total: 20]

2017 H1 Chemistry Preliminary Examination Paper 2 Answers

Section A

1 **(a)** **(i)** Since the forward reaction is exothermic, a low temperature will cause the position of equilibrium to shift to the right to produce more heat and thus producing more NH_3. However, the rate of reaction will be slow at low temperature, therefore, to increase the rate of reaction, a moderate temperature of 450°C is used.

(ii) Iron catalyst provides an alternative reaction pathway with a lower activation energy.

(iii) At a higher pressure, position of equilibrium shifts to the right so as to decrease the pressure by favouring the production of fewer number of moles of gases. The equilibrium is not affected as it is only affected by temperature.

(iv)

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

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

Let the number of moles of N_2 reacted be x

	N_2	$3H_2$	$2NH_3$
Initial no. of moles / mol	4	8	0
Change in no. of moles / mol	- x	- 3x	+ 2x
Equilibrium no. of moles / mol	4 - x	8 - 3x	2x

Given that the total number of moles of gases at equilibrium is 8,

4 - x + 8 – 3x + 2x = 8

Solving for x, x = 2

At equilibrium, there is 2 mol of N_2, 2 mol of H_2 and 4 mol of NH_3.

(vi)

$$K_c = \frac{\left(\frac{4}{2}\right)^2}{\left(\frac{2}{2}\right)\left(\frac{2}{2}\right)^3} = 1.00\ \text{mol}^{-2}\,\text{dm}^6$$

(b) **(i)** $NH_3(g) + \frac{7}{4}O_2(g) \rightarrow NO_2(g) + \frac{3}{2}H_2O(g)$

(ii) $\Delta H = \Delta H_f(NO_2) + \frac{3}{2}\Delta H_f(H_2O) - \Delta H_f(NH_3) - \frac{7}{4}\Delta H_f(O_2)$

$\Delta H = (-34) + (\frac{3}{2} \times -242) – (-46) – 0 = -351 \text{ kJ mol}^{-1}$

(iii) $\Delta H = \Sigma BE(\text{bonds broken}) - \Sigma BE(\text{bonds formed})$

Bonds broken = $3BE(N\text{-}H) + \frac{7}{4}BE(O\text{=}O)$

$= 3 \times 390 + \frac{7}{4} \times 496 = 2038 \text{ kJ mol}^{-1}$

Bonds formed = $3BE(O\text{-}H) + 2BE(N\text{-}O) = 3 \times 460 + 2BE(N\text{-}O)$
$= 1380 + 2BE(N\text{-}O)$

$-351 = 2038 – 1380 – 2BE(N\text{-}O)$
$BE(N\text{-}O) = +504 \text{ kJ mol}^{-1}$

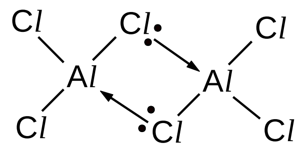
(iv) n(ammonia) = $\frac{44}{17} = 2.59$ mol = n(NO_2)
Theoretical mass of $NO_2 = 2.59 \times 46 = 119.14$ g
Percentage efficiency = $\frac{89}{119.14} \times 100 = 74.7\%$

(c) $NH_3 + CH_3CH_2Br \rightarrow CH_3CH_2NH_2 + HBr$
Ethanolic concentrated NH_3, heat in a sealed tube
The organic products belongs to the primary amine functional group.

[Total: 20]

2 **(a)** **(i)** Al_2O_3 dissolves in both HCl and excess NaOH. P_4O_{10} dissolves in NaOH.

(ii) $Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$
$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2Na[Al(OH)_4](aq)$
$P_4O_{10}(s) + 12NaOH(aq) \rightarrow 4Na_3PO_4(aq) + 6H_2O(l)$

(b) **(i)** 

The aluminium atom in $AlCl_3$ has only 6 electrons surrounding it hence it is electron-deficient. The lone pair of electrons from a chlorine atom in a neighbouring molecule would be donated via a dative bond, resulting in a dimer.

(ii) Al_2Cl_6 has simple molecular structure. The dispersion forces between the Al_2Cl_6 molecules are weak and hence, only a small amount of energy is needed to overcome the weak interactions.

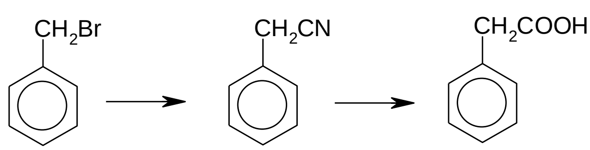
[Total: 10]

3 **(a)** Cl_2(g), $AlCl_3$, (rt)

(b) Step 2: oxidation
Step 3: reduction

(c) **B** dissociates to give H^+ and the conjugate base, $C_6H_5CO_2^-$ (benzoate). The negative charge on the benzoate ion is delocalised equally over two highly electronegative oxygen atoms. The negative charge is dispersed and the carboxylate anion is greatly stabilised.

(d) Reagents and conditions: Br_2(*l*), UV light
The substitution is uncontrollable and multi-substituted products may be obtained.

(e) 

Step 1: Ethanolic KCN, heat
Step 2: Dilute H_2SO_4, heat

[Total: 10]

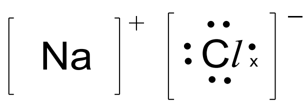
Section B

4 **(a)** **(i)** Cooking oil is primarily made up of long hydrocarbon chains, and experiences dispersion forces between molecules, whereas water experiences hydrogen bonding between water molecules. Because of the long hydrocarbon chains, the dispersion forces experienced by these molecules is extensive and stronger than the hydrogen bonding experienced by water molecules. Thus, more energy is required to overcome the dispersion forces in cooking oil compared to water, and the boiling point of cooking oil is thus higher.

(ii) The cooking oil and water is immiscible (no need to comment on relative density). This is because the molecules in cooking oil are largely non-polar, and do not form favourable interactions with the polar water molecules.

(iii) When the noodles undergoes deep frying, the high temperature of the heated oil causes the water in the noodles to vaporize. As water molecules do not form favourable interactions with the cooking oil, the water molecules escape as steam, thus drying out the noodles.

(b) **(i)**



(ii) Sodium chloride has a giant ionic lattice structure, and experiences strong electrostatic forces of attraction between oppositely charged cations and anions.

The attraction between oppositely charged ions is very strong and requires a lot of energy to overcome. Thus, a high temperature must be achieved to provide enough energy for melting to occur.

In the giant ionic lattice, the cations and anions are arranged in an alternating fashion. When a force is applied, the lattice structure is disrupted, causing similarly charged ions to be aligned with one another. The resulting repulsion between like charges causes the lattice to shatter, thus accounting for sodium chloride's brittle nature.

(iii) Lattice energy is the heat evolved when one mole of pure ionic solid is formed from its constituent gaseous ions.

$$LE \propto \frac{q^+q^-}{r^+ + r^-}$$

The chloride anion has a smaller charge (–1) compared to the oxide anion (–2). The chloride anion has a larger ionic radii compared to the oxide anion (period 3 vs period 2). Since lattice energy is directly proportional to charge and inversely proportional to ionic radii, the magnitude of the lattice energy of sodium chloride is smaller than that of sodium oxide.

(iv) Sodium chloride dissolves in water to form a colourless solution of neutral pH.
$NaCl_{(s)} + aq \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$

In an excess of water, $AlCl_3$ dissolves to form a colourless solution of acidic pH. Al^{3+} forms a complex ion with 6 water molecules, as shown below.
$AlCl_{3(s)} + 6\ H_2O_{(l)} \rightarrow [Al(H_2O)_6]^{3+}_{(aq)} + 3\ Cl^{-}_{(aq)}$
$[Al(H_2O)_6]^{3+}_{(aq)} + H_2O_{(l)} \rightleftharpoons [Al(H_2O)_5OH]^{2+}_{(aq)} + H_3O^{+}_{(aq)}$

A violent reaction with water producing fumes of HC*l* gas. Complete hydrolysis occurs in this case.
$SiCl_{4(l)} + 4\ H_2O_{(l)} \rightarrow SiO_2.2H_2O_{(s)} + 4\ HCl_{(aq)}$

(v) Sodium chloride is an ionic compound while silicon chloride is a covalent compound. Therefore, as the degree of covalency increases across the period, so does the extent of hydrolysis with water.

5 (a) (i) First ionisation energy is the energy required to form 1 mol of unipositively charged cations from 1 mol of gaseous atoms.

(ii) Potassium has one more quantum shell than sodium, thus the outermost electron is further away from the nucleus in potassium compared to sodium. Therefore, the attraction between the outermost electron and the nucleus of potassium is weaker, and requires less energy to remove compared to that of sodium.

The 3*p* subshell of aluminium is further away from the nucleus than the 3*s* subshell. There is weaker attraction between the nucleus and the outermost electron. Hence less energy is required to remove the 3*p* electron from aluminium, resulting in a lower ionisation energy for aluminium.

Sulfur has a set of paired electrons in the p subshell, whereas the p orbitals in phosphorus are singly filled. The inter-electronic repulsion between the paired electrons causes the outermost electron of sulfur to be easier to remove, thus less energy is required to ionise sulfur.

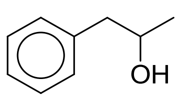
Argon has more protons than chlorine, thus the nuclear charge of argon is higher. As electrons are added to the same quantum shell, shielding effect is relatively constant for chlorine and argon. Thus the effective nuclear charge increases from chlorine to argon, implying that the attraction between the nucleus and the outermost electron has increased. Thus, more energy is required to remove the electron.

(iii) X is magnesium
After the 2nd ionisation energy, there is a large increase in the 3rd IE, which suggests that the 3rd electron is from an inner quantum shell. Thus X is a Group 2 element.

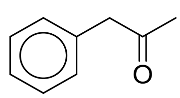
Y is chlorine
After the 7th ionisation energy, there is a large increase in the 8th IE, which suggests that the 8th electron is from an inner quantum shell. Thus X is a Group 17 element.

(b)

Observations	**Deductions**
Molecular formula of $C_9H_{12}O$	• High C:H ratio, benzene ring may be present. • One oxygen atom present suggests an alcohol or a ketone may be present.
exposed *uv* light in the presence of chlorine gas	• Substitution reaction
3 monosubstituted compounds	• Molecule is highly symmetrical / only 3 possible positions where substitution can occur
heated with acidified $K_2Cr_2O_7$	• Oxidation has occurred, **A** must be an alcohol
B gives an orange precipitate with 2,4-DNPH	• Carbonyl compound present
heated with excess concentrated sulfuric acid	• Dehydration
C and **D** are stereoisomers	• C=C bond present, **C** and **D** are geometic isomers.



A



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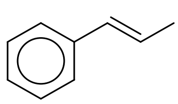
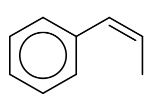


C



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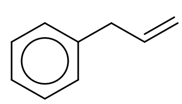
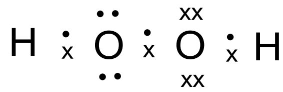


E

6 **(a)** **(i)**



(ii) Around each oxygen atom, there are 2 bond pairs and 2 lone pairs of electrons. Thus, it is bent around each oxygen atom.

(iii) The bond angle is 104.5°. As the lone pair-lone pair repulsion is greater than the bond pair-bond pair repulsion, the bond pairs will be pushed closer together thus bond angle smaller than 109.5°.

(b) **(i)** H_2O_2 is reducing agent. The oxidation state of Mn is reduced from +7 to +2.

(ii) $n(MnO_4^-) = (21.80 \div 1000) \times 0.200 = 4.36 \times 10^{-3}$ mol
$n(H_2O_2) = 4.36 \times 10^{-3} \times 5/2 = 0.0109$ mol

(iii) $n(H_2O_2)$ in 100 cm^3 standard solution = $0.0109 \times 4 = 0.0436$ mol
$[H_2O_2]$ in stock solution = $0.0436 \div 20/1000 = 2.18$ mol dm^{-3}

(c) **(i)** correct axis, labels, units
suitable scale
shape of graph

(ii) construction lines to show at least 2 constant half-life, $t_{1/2} \approx 60$ s
conclude that reaction is 1st order with respect to I^-

(iii) When the $[H_2O_2]$ is doubled, the initial rate doubles. Thus rate is directly proportional to $[H_2O_2]$, thus the order with respect to H_2O_2 is 1.

(iv) Rate = $k\,[H_2O_2][I^-]$

(v) Determine initial rate by drawing tangent at t = 0 s
Initial rate = $-[(3.00 - 4.00 \times 10^{-4}) \div (63 - 0)] = 1.11 \times 10^{-5}$ mol dm^{-3} s^{-1}

Using the rate equation,
$1.11 \times 10^{-5} = k(0.05)(10.00 \times 10^{-4})$
$k = 0.222$ mol^{-1} dm^3 s^{-1}

OR

$t_{1/2} = \ln 2 / k[H_2O_2]$
$60 = \ln 2 / k(0.05)$
$k = 0.231$ mol^{-1} dm^3 s^{-1}

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JC2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME			
CLASS		INDEX NUMBER	

CHEMISTRY

8872/01

Paper 1 Multiple Choice Questions

15 September 2017

50 minutes

Additional Materials: *Data Booklet*
Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your 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 **11** 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 How many neutrons are present in 0.13 g of ^{13}C?
[L = the Avogadro constant]

A 0.06L **C** 0.13L

B 0.07L **D** 0.91L

2 Which factor helps to explain why the first ionisation energies of the Group 1 elements decrease from lithium to rubidium?

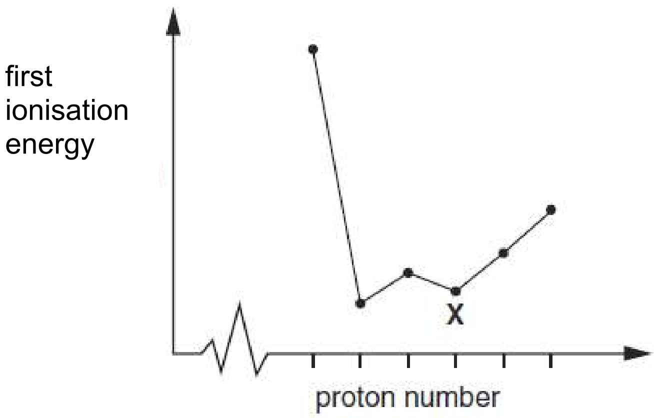
A The nuclear charge of the elements increases.

B The outer electron is in an ‘s’ subshell.

C The repulsion between spin-paired electrons increases.

D The distance between the nucleus and the valence electron increases.

3 The sketch below shows the variation of first ionisation energy with proton number for six elements of consecutive proton numbers between 1 and 18 (H to Ar).



What is the identity of the element **X**?

A Mg **C** Si

B A*l* **D** P

4 Which orbital must an electron with the principal quantum n = 2 occupy?

A a spherically-shaped orbital

B either an s or p orbital

C the orbital closest to the nucleus

D a dumb-bell shaped orbital

5 Which of the following statements describes a phenomenon which **cannot** be explained by hydrogen bonding?

A Ice floats on water.

B The boiling point of carboxylic acids increase with increasing relative molecular mass.

C 2-nitrophenol is more volatile than 4-nitrophenol.

D Ethanoic acid molecules forms dimers when dissolved in benzene.

6 Ammonia, NH_3 reacts with boron trifluoride, BF_3 to give an addition product. Which of the following statements about the addition product is **not** true?

A The boron atom is electron deficient.

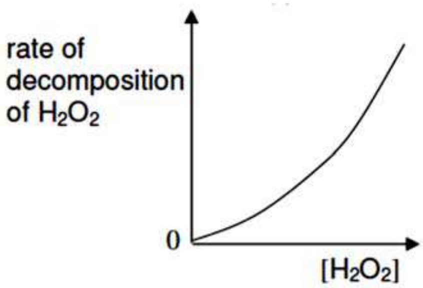
B It contains a dative covalent bond.

C It is polar.

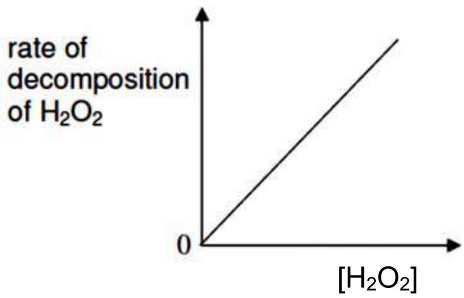
D There are seven sigma bonds.

7 Which graph would confirm that the rate of decomposition of hydrogen peroxide is first order with respect to the concentration of hydrogen peroxide?

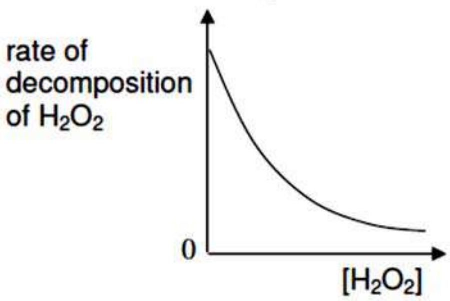
A



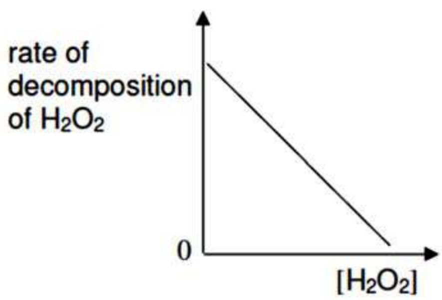
B



C



D



8 The reaction of a compound **RS** is shown below.

$$\mathbf{RS}(g) \longrightarrow \mathbf{R}(g) + \mathbf{S}(g)$$

The rate equation for the reaction is rate = k[**RS**] and the rate constant is found to be 3.6×10^{-3} s^{-1}. If the initial concentration of **RS** is 2.0×10^{-2} mol dm^{-3}, what will be the concentration of **RS** after 385 seconds?

A 1.0×10^{-2} mol dm^{-3}

B 5.0×10^{-3} mol dm^{-3}

C 2.5×10^{-3} mol dm^{-3}

D 2.0×10^{-3} mol dm^{-3}

9 Which one of the following is a correct statement about the effect of a catalyst on a reaction at equilibrium?

A It provides an alternative route with a lower E_a for the reaction to take place.

B It increases the equilibrium constant for the forward reaction.

C It increases the yield of product in equilibrium.

D It increases the rate of the forward reaction only.

10 Which of the following statements does **not** describe a reaction at equilibrium?

A Forward and backward reactions occur at equal rate.

B The reaction takes place in a closed system.

C K_c increases as the reaction progresses.

D Concentrations of reactants and products are constant.

11 Which of the following enthalpy changes is positive?

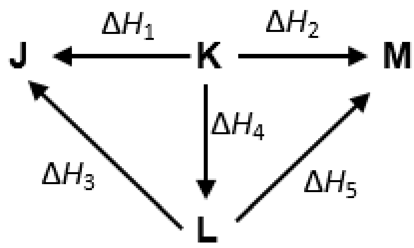
A $H_2O(l) \longrightarrow H_2O(s)$

B $2C_2H_6(g) + 7O_2(g) \longrightarrow 4CO_2(g) + 6H_2O(l)$

C $2Br(g) \longrightarrow Br_2(g)$

D $Na(g) \longrightarrow Na^+(g) + e^-$

12 The energy cycle below shows the reaction pathways between Compounds **J** – **M**.



What is the enthalpy change for the following reaction?

Compound **J** $\longrightarrow$ Compound **M**

A $\Delta H_1 + \Delta H_2$

B $\Delta H_2 - \Delta H_3 + \Delta H_4$

C $-\Delta H_3 - \Delta H_5$

D $\Delta H_4 + \Delta H_5 - \Delta H_1$

13 What is the enthalpy change for the following process equivalent to?

$$Al(g) \longrightarrow Al^{2+}(g) + 2e^-$$

A the second ionisation energy of aluminium

B the enthalpy change of vapourisation of aluminium

C the sum of the first ionisation energy and second ionisation energy of aluminium

D the sum of the enthalpy change of vaporisation, first ionisation energy and second ionisation energy of aluminium

14 A mixture was made by adding 20 cm^3 of a solution of pH 2.5 to 30 cm^3 of another solution of pH 4.5. What is the final pH of the mixture?

A 1.2

B 2.9

C 3.5

D 3.7

15 Which of the following pairs of solutions will produce an alkaline buffer solution upon mixing equal volumes of each solution?

A 1.50 mol dm^{-3} of HCl and 1.00 mol dm^{-3} of NaOH

B 1.00 mol dm^{-3} of NH_3 and 2.00 mol dm^{-3} of HCl

C 0.50 mol dm^{-3} of H_2SO_4 and 2.00 mol dm^{-3} of NH_3

D 1.00 mol dm^{-3} of $C_6H_5CO_2H$ and 0.50 mol dm^{-3} of KOH

16 A student isolated an organic compound with the molecular formula C_4H_8. How many possible isomers (including structural and geometrical isomers) can be deduced from the molecular formula?

A 3 **C** 5

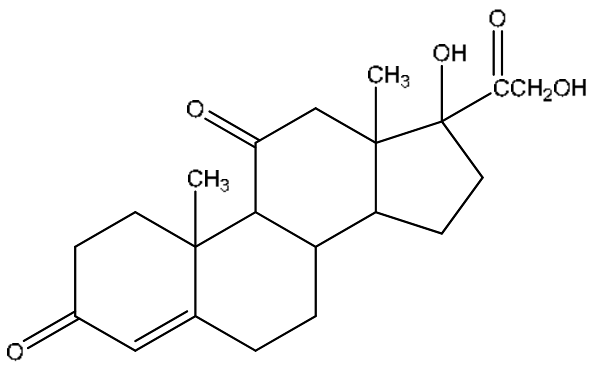
B 4 **D** 6

17 3-methylpentane was reacted with chlorine gas in the presence of ultraviolet light. What is the total number of possible structural isomers formed, assuming only mono-substitution took place?

A 4 **C** 6

B 5 **D** 14

18 Cortisone is an anti-inflammatory hormone.



cortisone

Cortisone is first reacted with hydrogen in the presence of a platinum catalyst, and the product is then oxidised by warming with acidified $KMnO_4$.

Given that no carbon-carbon σ bond is broken in this process, how many C=O double bonds will there be in the structure of the final product?

A 3 **C** 5

B 4 **D** 6

19 What will be the final product **Q** in this sequence of reactions?

$$H_2C{=}CHCH{=}O \xrightarrow[\text{then } H_2O]{NaBH_4 \text{ in } CH_3OH} \mathbf{P} \xrightarrow[\text{heat}]{K_2Cr_2O_7/\ H^+} \mathbf{Q}$$

A $CH_2CHCOOH$

B CH_3CH_2COOH

C $HOCH_2CH(OH)CH_2OH$

D HO_2CCOCO_2H

20 The table shows the results of simple chemical tests on a compound **U**.

Reagents	**Observations**
2,4-dinitrophenylhydrazine	Orange ppt
Fehling's reagent	Brick red ppt
Alkaline aqueous iodine	Yellow ppt

What could compound **U** be?

A CH_3CHO **C** $CH_3CH(OH)CH_3$

B CH_3CH_2CHO **D** CH_3COCH_3

21 Which of the following options shows the correct reagents and conditions for step 1 and 2?

$$CH_2(Cl)CH{=}CH_2 \xrightarrow{\textbf{step 1}} \textbf{E} \xrightarrow{\textbf{step 2}} CH_2(CH_2NH_2)CH{=}CH_2$$

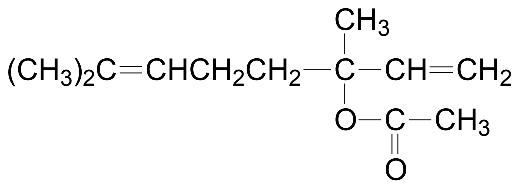
	Step 1	**Step 2**
A	KCN in ethanol, heat	H_2, Pt
B	KCN in ethanol, heat	$LiAlH_4$
C	HCN, trace NaOH(aq), cold	$LiAlH_4$
D	NH_3 in ethanol, heat	H_2, Pt

22 Which alcohol is used to manufacture the ester, $CH_3CH_2CH(OH)CO_2CH(CH_3)_2$?

A CH_3CO_2H **C** $CH_3CH_2CH_2OH$

B $CH_3CH(OH)CH_3$ **D** CH_3OH

23 Linalyl acetate is a naturally-occurring compound and it is a principal component of the essential oils of lavender.



Linalyl acetate

Which of the following statements about linalyl acetate is not true?

A It exhibits cis-trans isomerism.

B It does not react with 2,4-dinitrophenylhydrazine.

C It decolourises bromine water.

D It reacts with hot acidified potassium dichromate(VI) to give CH_3COOH as one of the products.

24 Which of the following forms an oxide that is soluble in both water and aqueous sodium hydroxide?

A magnesium

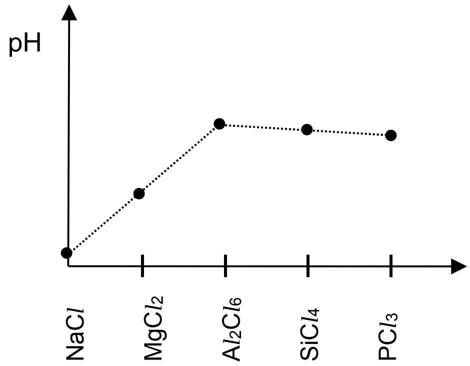
B silicon

C aluminium

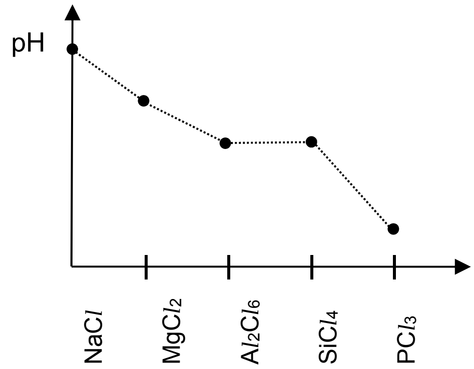
D phosphorus

25 The chlorides of the elements sodium to phosphorus are separately added to water. Which of the following diagrams best represents the pH of the solutions produced?

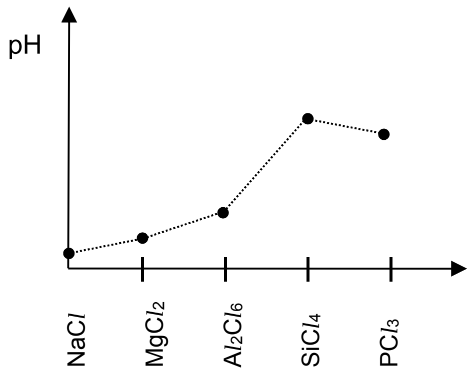
A



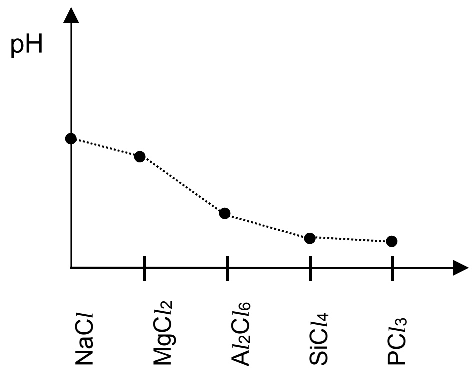
B



C



D



Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, 2 and **3** are correct	**1** and **2** are correct	**2** and **3** are correct	**1** only is correct

26 In flooded soils, like those used for rice cultivation, the oxygen content is low. In such soils, anaerobic bacteria cause the loss of nitrogen from the soil as shown in the following sequence.

$$NO_3^-(aq) \xrightarrow{\textbf{W}} NO_2^-(aq) \xrightarrow{\textbf{X}} NO(g) \xrightarrow{\textbf{Y}} N_2O(g) \xrightarrow{\textbf{Z}} N_2(g)$$

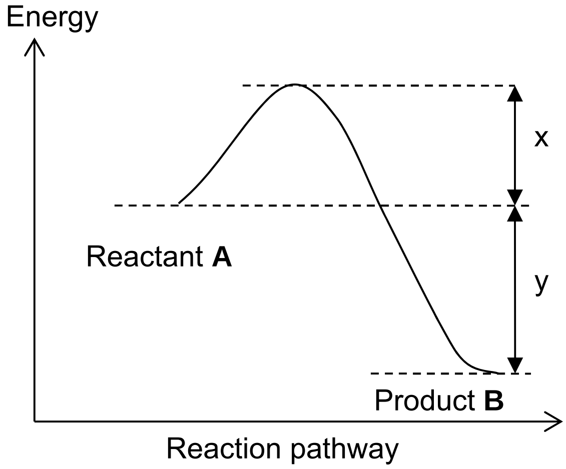
Which of the following steps involve a reduction in the oxidation number of nitrogen by 1?

1 **X**, **Y** and **Z**

2 **W** and **Y**

3 **W** and **X**

27 The energy profile for a reversible reaction is shown below.



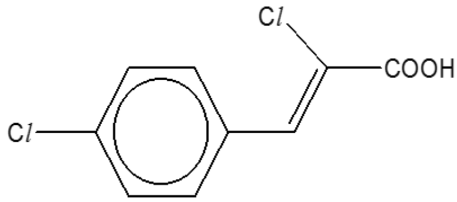
Which of the following statements are correct?

1 The reaction from **B** to **A** is endothermic.

2 The activation energy of the reaction **A** to **B** is *x*.

3 The activation energy of the reaction **B** to **A** is *x* + *y*.

28 Compound **A** is used as a starting material for a class of anti-bacterial drugs known as quinolones. Which of the following statements about compound **A** are correct?



compound **A**

1 1 mole of **A** reacts with CH_3OH to give 1 mole of H_2O.

2 1 mole of **A** reacts with Na metal to give 0.5 mole of H_2.

3 1 mole of **A** reacts with $CaCO_3$ to give 1 mole of CO_2.

29 For which types of compound are **all** of the following statements correct?

- They are unreactive towards mild oxidising agents.
- They form esters.
- They react with sodium.

1 aldehydes

2 carboxylic acids

3 tertiary alcohols

30 Which of the following trends concerning Period 3 elements from Na to C*l* are true?

1 There is a change from metallic behaviour to non-metallic behaviour.

2 Their compounds show an increase in the maximum oxidation number across the period.

3 The melting points of the elements decrease across the period.

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INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME: **WORKED SOLUTIONS**

CLASS

INDEX NUMBER

CHEMISTRY **8872/01**

Paper 1 Multiple Choice **15 Sep 2017**

50 minutes

Additional Materials: Data Booklet
Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

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Answers

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

This document consists of **18** printed pages.

Section A

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

1 How many neutrons are present in 0.13g of ^{13}C?
[L = the Avogadro constant]

A 0.06L
B 0.07L
C 0.13L
D 0.91L

Answer is **B**

No. of mol of ^{13}C = 0.13/13 = 0.01
No. of atoms of ^{13}C = 0.01 L
No. of neutrons per ^{13}C atom = 7
No. of neutrons in 0.01L of ^{13}C = 0.07L

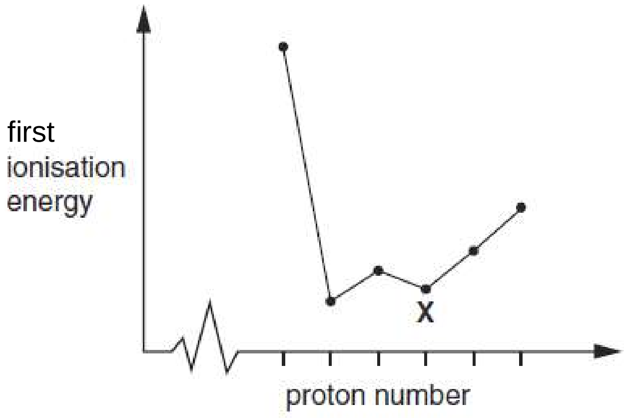
2 Which factor helps to explain why the first ionisation energies of the Group I elements decrease from lithium to rubidium?

A The nuclear charge of the elements increases.
B The outer electron is in an 's' subshell.
C The repulsion between spin-paired electrons increases.
D The distance between the nucleus and the valence electron increases.

Answer is **D**

The valence electron is further away from the nucleus as you go down the group due to an increase in the number of principal quantum shells.

3 The sketch below shows the variation of first ionisation energy with proton number for six elements of consecutive proton numbers between 1 and 18 (H to Ar).



What is the identity of the element **X**?

A Mg

B A*l*

C Si

D P

Answer is **B**

The lowest first IE represent group **1** element, as when going across the period the increase in nuclear charge outweighs the negligible increase in shielding effect (due to ineffective shielding of electrons added to the same outermost shell).

Hence X is A*l*. Moreover, A*l* first IE is lower than Mg as its electron is removed from 3p orbital which is further away from nucleus as compare to 3s orbital.

4 Which orbital must an electron with the principal quantum n = 2 occupy?

A a spherically-shaped orbital

B either an s or p orbital

C the orbital closest to the nucleus

D a dumb-bell shaped orbital

Answer is **B**

Orbitals available at principal quantum n = 2 are 2s (spherically-shaped) and 2p (dumb-bell-shaped) orbital

5 Which of the following statements describes a phenomenon which **cannot** be explained by hydrogen bonding?

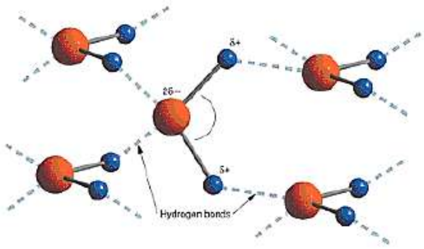
A Ice floats on water.

B The boiling point of carboxylic acids increase with increasing relative molecular mass.

C 2-nitrophenol is more volatile than 4-nitrophenol.

D Ethanoic acid molecules forms dimers when dissolved in benzene.

Answer is **B**



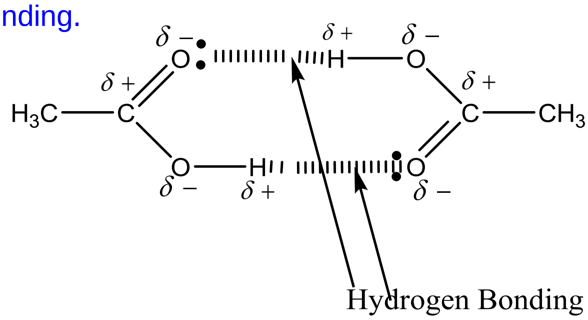
H-bonding in ice

Option **A** is incorrect as it is the hydrogen bonding between H_2O that caused the molecules to be more spaced out and less dense. Hence, ice float on water.

Option **B** is correct as carboxylic acid relative molecular mass increases when the carbon chain increases. However, this will result in the instantaneous dipole-induced dipole forces of attraction to increase which results in an increase in boiling point. The hydrogen bond does not affect the boiling point.

Option **C** is incorrect as 2-nitrophenol can form an intramolecular hydrogen bond due to the proximity of the OH and NO_2 groups so less intermolecular hydrogen bond occurs. Hence, 2-nitrophenol has a lower boiling point and is more volatile.

Option **D** is incorrect as ethanoic acid does form dimers in benzene via hydrogen bonding.



6 Ammonia, NH_3 reacts with boron trifluoride, BF_3 to give an addition product. Which of the following statements about the addition product is **not** true?

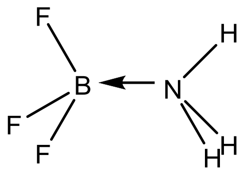
A The B atom is electron deficient.

B It contains a dative covalent bond.

C It is polar.

D There are seven sigma bonds.

Answer is **A**



Addition product

Option **A** is correct as with the dative bond formed from N to B in the product, B is no longer electron deficient.

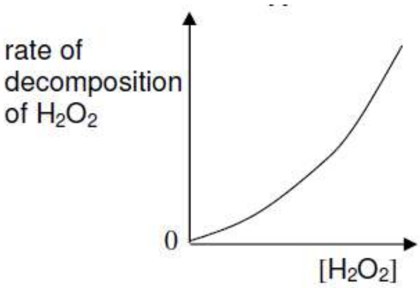
Option **B** is incorrect as the dative bond is between N and B.

Option **C** is incorrect as it is polar as the sum of all the dipole moments do not cancel out.

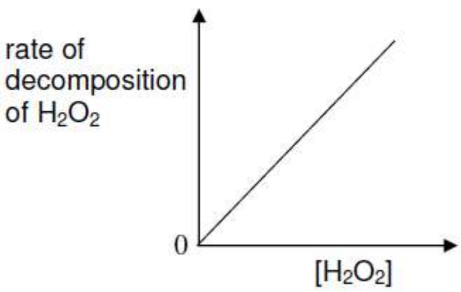
Option **D** is correct as there are 7 sigma bonds in the product after counting all the single bonds in the diagram above.

7 Which graph would confirm that the rate of decomposition of hydrogen peroxide is first order with respect to the concentration of hydrogen peroxide?

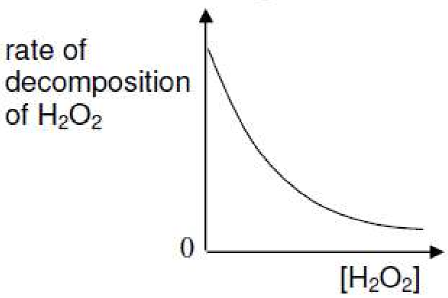
A



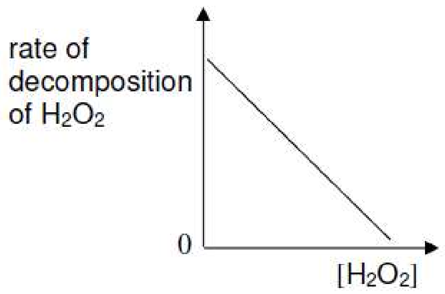
B



C



D



Answer is **B**.

Rate = k $[H_2O_2]$
$\quad\|\qquad\quad\|$
y-axis $\qquad$ x-axis

So it is a y=mx +c graph, a straight line that passes through the origin.

8 The reaction of a compound **RS** is shown below.

$$\mathbf{RS}(g) \longrightarrow \mathbf{R}(g) + \mathbf{S}(g)$$

The rate equation for the reaction is rate = k[**RS**] and the rate constant is found to be 3.6×10^{-3} s^{-1}. If the initial concentration of **RS** is 2.0×10^{-2} mol dm^{-3}, what will be the concentration of **RS** after 385 seconds?

A 1.0×10^{-2} mol dm^{-3}

B 5.0×10^{-3} mol dm^{-3}

C 2.5×10^{-3} mol dm^{-3}

D 2.0×10^{-3} mol dm^{-3}

Answer is **B**

Using $t_{1/2} = \ln 2/k$

$t_{1/2} = \ln 2 / (3.6 \times 10^{-3})$

$= 192.5$s

385 seconds = 2 half lives

$2.0 \times 10^{-2} \rightarrow 1.0 \times 10^{-2} \rightarrow 0.5 \times 10^{-2} (= 5.0 \times 10^{-3})$

9 Which one of the following is a correct statement about the effect of a catalyst on a reaction at equilibrium?

A It provides an alternative route for the reaction to take place.

B It increases the equilibrium constant for the forward reaction.

C It increases the yield of product in equilibrium.

D It increases the rate of the forward reaction only.

Answer is **A**

Option **A** is correct as a catalyst will lower the activation energy of a reaction by providing an **alternative pathway** for the reaction to occur.

Option **B** is wrong as the equilibrium constant is only affected by **temperature**.

Option **C** and **D** are wrong as a catalyst will only speed up **both forward and backward reaction** but It will **not** increase the yield of reaction.

10 Which of the following statements does **not** describe a reaction at equilibrium?

A Forward and backward reactions occur at equal rate.

B The reaction takes place in a closed system.

C K_c increases as the reaction progresses.

D Concentrations of reactants and products are constant.

Answer is **C**

Option **A** and **D** are wrong as based on the definition of dynamic equilibrium, a system at equilibrium is when the rate of forward reaction is the same as the backward reaction and the concentration of both reactants and products are constant.

Option **B** is wrong as an equilibrium system must take place in a closed system.

Option **C** is correct as if Kc is increasing, it means that either the reactants concentration is dropping or the product concentration is increasing. So equilibrium position is still shifting, hence the reaction has not reached equilibrium yet.

11 Which of the following enthalpy changes is positive?

A $H_2O(l) \longrightarrow H_2O(s)$

B $2C_2H_6(g) + 7O_2(g) \longrightarrow 4CO_2(g) + 6H_2O(l)$

C $2Br(g) \longrightarrow Br_2(g)$

D $Na(g) \longrightarrow Na^+(g) + e^-$

Answer is **D**

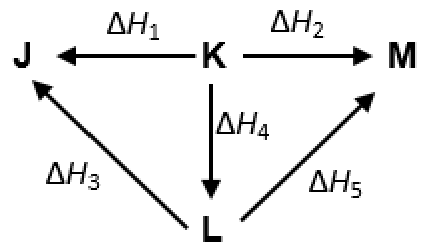
Option **A** is wrong as the equation represents the freezing of water and freezing is exothermic as more H-bonds are formed during freezing.

Option **B** is wrong as the equation represents the combustion of ethane. All combustion reactions are exothermic.

Option **C** is wrong as the equation represents the formation of the Br-Br bond. It is exothermic as bond formation is always exothermic.

Option **D** is correct as the equation represents the first ionisation energy of sodium. The first ionisation energy is always endothermic as energy is needed to remove the most loosely held electron.

12 The energy cycle below shows the reaction pathways between Compounds **J** – **M**.



What is the enthalpy change for the following reaction?

Compound **J** $\longrightarrow$ Compound **M**

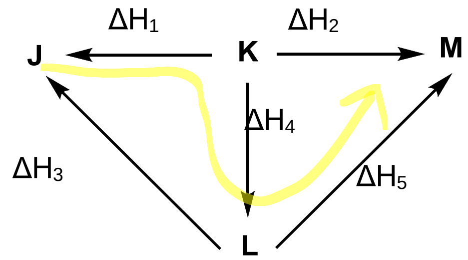
A $\Delta H_1 + \Delta H_2$

B $\Delta H_2 - \Delta H_3 + \Delta H_4$

C $-\Delta H_3 - \Delta H_5$

D $\Delta H_4 + \Delta H_5 - \Delta H_1$

Answer is **D**



By Hess's law, following the yellow arrow:

enthalpy change from **J** to **M** = $- \Delta H_1 + \Delta H_4 + \Delta H_5$

$= \Delta H_4 + \Delta H_5 - \Delta H_1$ (option **D**).

13 What is the enthalpy change for the following process equivalent to?

$$Al(g) \longrightarrow Al^{2+}(g) + 2e^-$$

A the second ionisation energy of aluminium

B the enthalpy change of vaporisation of aluminium

C the sum of the first ionisation energy and second ionisation energy of aluminium

D the sum of the enthalpy change of vaporisation, first ionisation energy and second ionisation energy of aluminium

Answer is **C**

Option **A** is wrong as the second ionisation energy of aluminium is

$$Al^{+}(g) \longrightarrow Al^{2+}(g) + e^{-}$$

Option **B** is wrong as the enthalpy change of vaporisation of aluminium is

$$Al(s) \longrightarrow Al(g)$$

Option **C** is correct as the equation is the sum of the first ionisation energy and second ionisation energy of aluminium

$$Al(g) \longrightarrow Al^{+}(g) + e^{-} \quad (1^{st}\ \text{I.E.})$$
$$Al^{+}(g) \longrightarrow Al^{2+}(g) + e^{-} \quad (2^{nd}\ \text{I.E.})$$

Option **D** is wrong as the equation shows $Al(g)$ forming $Al^{2+}(g)$ and not $Al(s)$ forming $Al^{2+}(g)$.

14 A mixture was made by adding 20 cm^3 of a solution of pH 2.5 to 30 cm^3 of another solution of pH 4.5. What is the final pH of the mixture?

A 1.2 **C** 3.5

B 2.9 **D** 3.7

Answer is **B**

$[H^+]$ in first solution = $10^{-2.5}$ mol dm^{-3}

$[H^+]$ in second solution = $10^{-4.5}$ mol dm^{-3}

$[H^+]$ in mixture = $\frac{0.020 \times 10^{-2.5} + 0.030 \times 10^{-4.5}}{0.050}$ = 1.284×10^{-3} mol dm^{-3}

pH of mixture = $-\log_{10}(1.284 \times 10^{-3})$ = 2.89 = 2.9 (1d.p.)

15 Which of the following pairs of solutions will produce an alkaline buffer solution upon mixing equal volumes of each solution?

A 1.50 mol dm^{-3} of HCl and 1.00 mol dm^{-3} of NaOH

B 1.00 mol dm^{-3} of NH_3 and 2.00 mol dm^{-3} of HCl

C 0.50 mol dm^{-3} of H_2SO_4 and 2.00 mol dm^{-3} of NH_3

D 1.00 mol dm^{-3} of $C_6H_5CO_2H$ and 0.50 mol dm^{-3} of KOH

Answer is **C**

Assume that the volumes of each solution is 1 dm^3

Option **A** contains 1.5 mol of HCl reacting with 1 mol of NaOH, the resulting solution will contain 0.5 mol of HCl.

Option **B** contains 1 mol of NH_3, a weak base, reacting with 2 mol of HCl, the resulting solution will contain 1 mol of HCl.

Option **C** contains 2 x 0.5 = 1 mol of H^+ from 0.5 mol of H_2SO_4 reacting with 2 mol of NH_3. The resulting solution will contain 1 mol of NH_3 and 1 mol of NH_4^+, an alkaline buffer.

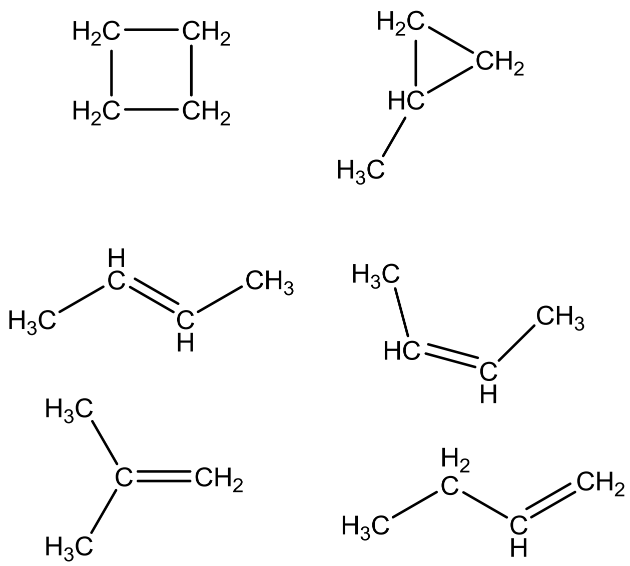
Option **D** contains 1 mol of $C_6H_5CO_2H$ reacting with 0.5 mol of KOH. The resulting solution will contain 0.5 mol of $C_6H_5CO_2H$ and 0.5 mol of $C_6H_5CO_2^-$, an acidic buffer.

16 A student isolated an organic compound with the molecular formula C_4H_8. How many possible isomers (including structural and geometrical isomers) can be deduced from the molecular formula?

A 3
B 4
C 5
D 6

Answer is **D**

There are 6 possible isomers that can be formed for C_4H_8

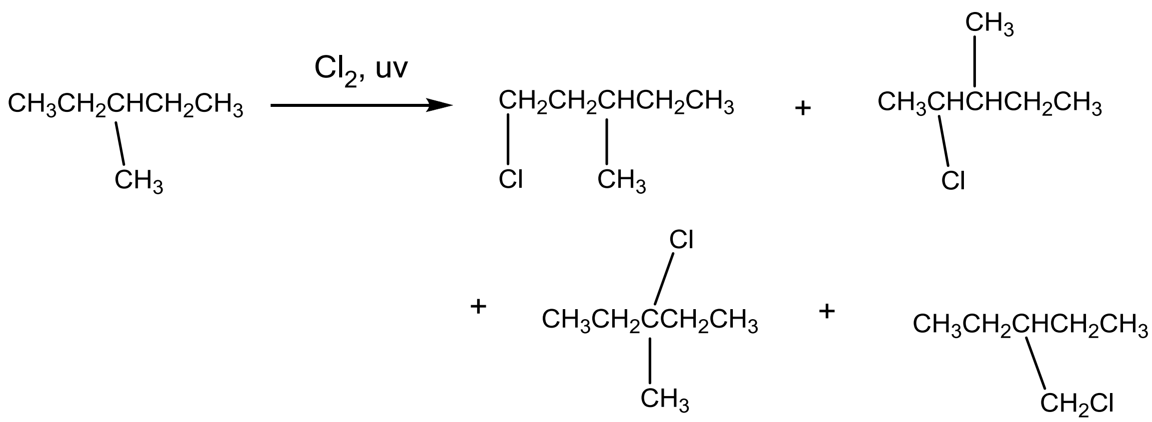


17 3-methylpentane was reacted with chlorine gas in the presence of ultraviolet light. What is the total number of possible structural isomers formed, assuming only mono-substitution took place?

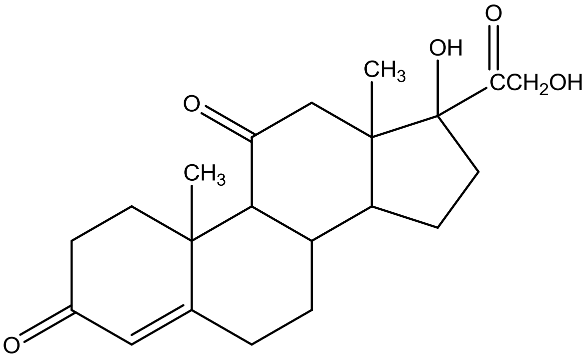
A 4
B 5
C 6
D 14

Answer is **A**

The four possible structural isomers formed are:



18 Cortisone is an anti-inflammatory hormone.



cortisone

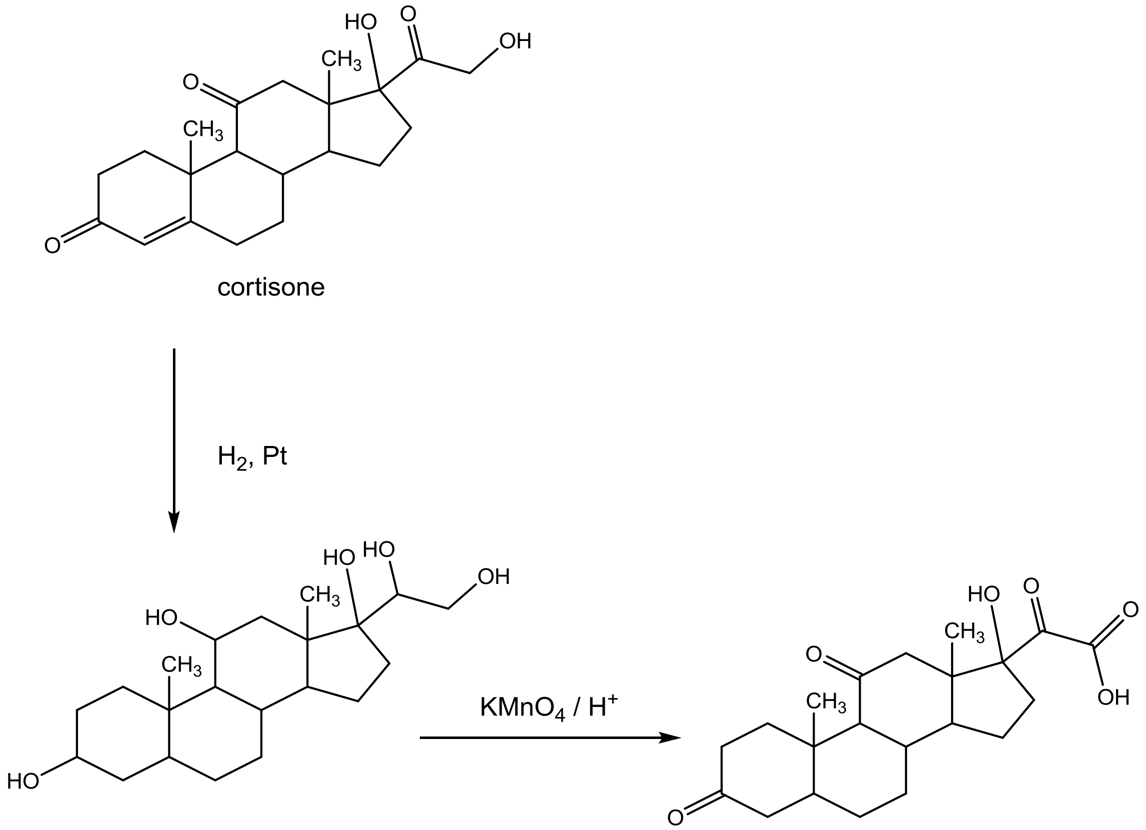
Cortisone is first reacted with hydrogen in the presence of a platinum catalyst, and the product is then oxidised by warming with acidified $KMnO_4$.

Given that no carbon-carbon σ bond is broken in this process, how many C=O double bonds will there be in the structure of the final product?

A 3 **C** 5

B 4 **D** 6

Answer is **B**



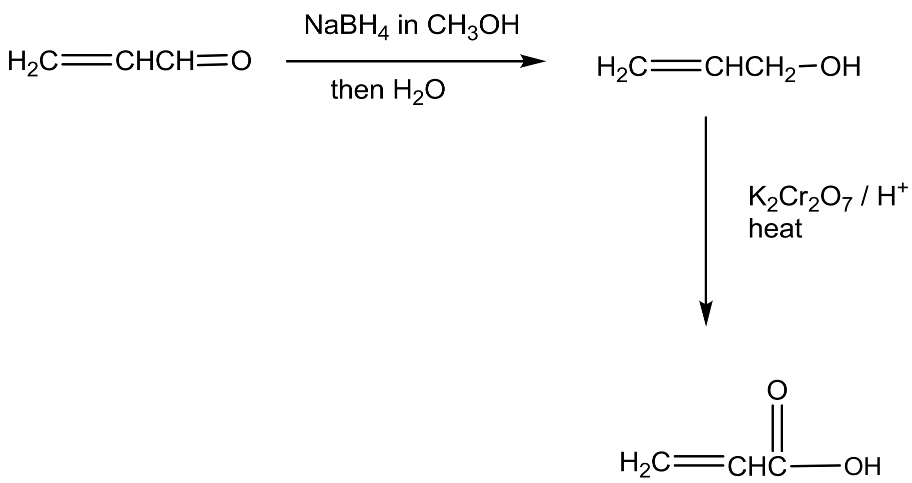
No. of double bonds = 4

19 What will be the final product **Q** in this sequence of reactions?

$$H_2C{=}CHCH{=}O \xrightarrow[\text{then } H_2O]{NaBH_4 \text{ in } CH_3OH} \mathbf{P} \xrightarrow[\text{heat}]{K_2Cr_2O_7/\,H^+} \mathbf{Q}$$

A $CH_2CHCOOH$
B CH_3CH_2COOH
C $HOCH_2CH(OH)CH_2OH$
D HO_2CCOCO_2H
Answer is **A**

$NaBH_4$ can also reduce carbonyl group but it cannot reduce alkene. $K_2Cr_2O_7$ will only oxidise alcohol in P but it cannot oxidise alkene.



20 The table shows the results of simple chemical tests on a compound **U**.

Reagents	Observations
2,4-dinitrophenylhydrazine	Orange ppt
Fehling's reagent	Brick red ppt
Alkaline aqueous iodine	Yellow ppt

What could compound **U** be?

A CH_3CHO
B CH_3CH_2CHO
C $CH_3CH(OH)CH_3$
D CH_3COCH_3

Answer is **A**

Based on the three tests, compound U should be a carbonyl compound as it gives an orange ppt. with 2,4-DNPH. It is also an aldehyde as it gives a brick red ppt. with Fehling's reagent and it has a CH_3CO group as it forms a yellow ppt. with alkaline aqueous iodine.

21 Which of the following options shows the correct reagents and conditions for step 1 and 2?

$$CH_2(Cl)CH{=}CH_2 \xrightarrow{\textbf{step 1}} \textbf{E} \xrightarrow{\textbf{step 2}} CH_2(CH_2NH_2)CH{=}CH_2$$

	Step 1	**Step 2**
A	KCN in ethanol, heat	H_2, Pt
B	KCN in ethanol, heat	$LiAlH_4$
C	HCN, trace NaOH(aq), cold	$LiAlH_4$
D	NH_3 in ethanol, heat	H_2, Pt

Answer is **B**

The reaction will proceed in this manner:

$$CH_2(Cl)CH{=}CH_2 \xrightarrow[\text{heat}]{\text{KCN in ethanol}} CH_2(CN)CH{=}CH_2 \xrightarrow{LiAlH_4} CH_2(CH_2NH_2)CH{=}CH_2$$

22 Which alcohol is used to manufacture the ester, $CH_3CH_2CH(OH)CO_2CH(CH_3)_2$?

A CH_3CO_2H

B $CH_3CH(OH)CH_3$

C $CH_3CH_2CH_2OH$

D CH_3OH

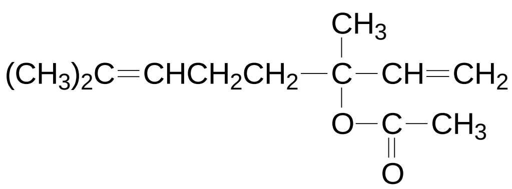
Answer is **B**

$CH_3CH_2CH(OH)CO_2CH(CH_3)_2$ is made from:

$CH_3CH_2CH(OH)COOH$ and $HOCH(CH_3)_2$

$HOCH(CH_3)_2$ can be rewritten as $CH_3CH(OH)CH_3$ (Option B).

23 Linalyl acetate is a naturally-occurring compound and it is a principal component of the essential oils of lavender.



Linalyl acetate

Which of the following statements about linalyl acetate is not true?

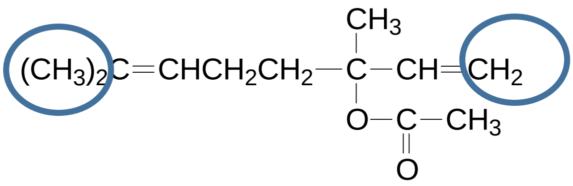
A It exhibits *cis-trans* isomerism.

B It does not react with 2,4-dinitrophenylhydrazine.

C It decolourises bromine water.

D It reacts with hot acidified potassium dichromate(VI) to give CH_3COOH as one of the products.

Answer is **A**



Answer **A** is correct as the groups attached to one side of each C=C bond are identical (circled in the diagram). So there are no cis-trans isomers.

24 Which of the following forms an oxide that is soluble in both water and aqueous sodium hydroxide?

A magnesium

B silicon

C aluminium

D phosphorus

Answer is **D**

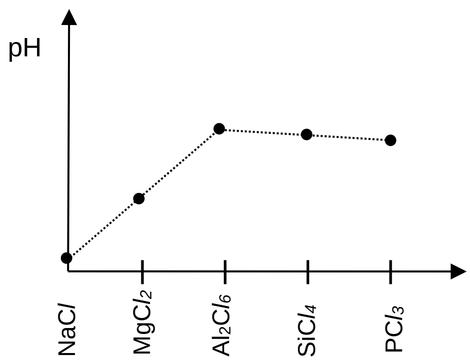
Phosphorus trioxide P_4O_6 is a non-metallic acidic oxide that reacts with water an aqueous sodium hydroxide in the following manner:

$P_4O_6(s) + 6H_2O(l) \longrightarrow 4H_3PO_3(aq)$

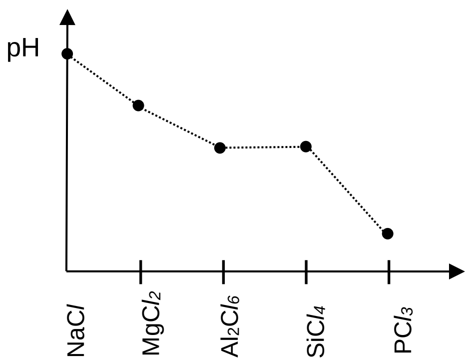
$P_4O_6(s) + 8NaOH(aq) \longrightarrow 4Na_2HPO_3(aq) + 2H_2O(l)$

25 The chlorides of the elements sodium to phosphorous are separately added to water. Which of the following diagrams best represents the pH of the solutions produced?

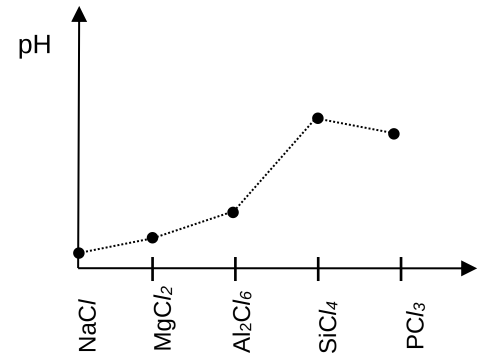
A



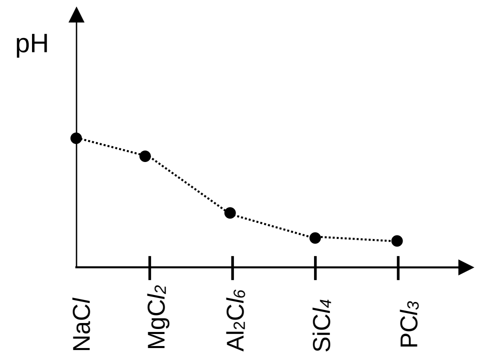
B



C



D



Answer is **D**

Across the Period 3, when the chlorides become more covalent, its tendency to undergo hydrolysis increases. Hence the pH of the resulting solution drops steadily across the period.

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, 2 and **3** are correct	**1** and **2** are correct	**2** and **3** are correct	**1** only is correct.

26 In flooded soils, like those used for rice cultivation, the oxygen content is low. In such soils, anaerobic bacteria cause the loss of nitrogen from the soil as shown in the following sequence.

$$NO_3^-(aq) \xrightarrow{\textbf{W}} NO_2^-(aq) \xrightarrow{\textbf{X}} NO(g) \xrightarrow{\textbf{Y}} N_2O(g) \xrightarrow{\textbf{Z}} N_2(g)$$

Which of the following steps involve a reduction in the oxidation number of nitrogen by 1?

1 **X**, **Y** and **Z**

2 **W** and **Y**

3 **W** and **X**

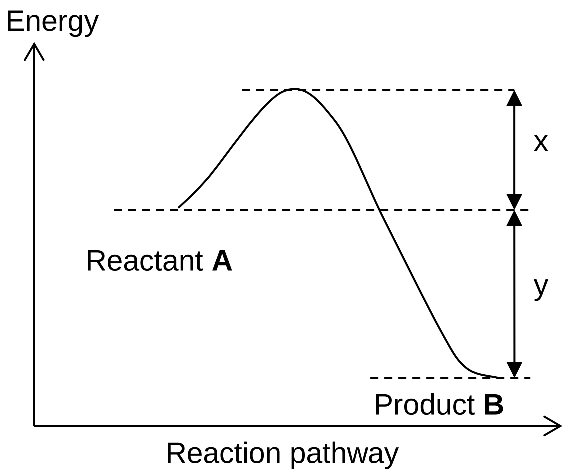
Answer is **D**

Oxidation number (oxidation state) of nitrogen:
+5 in NO_3^-
+3 in NO_2^-
+2 in NO
+1 in N_2O
 0 in N_2

In **W** change in oxidation number = +2
In **X** change in oxidation number = +1
In **Y** change in oxidation number = +1
In **Z** change in oxidation number = +1

So option **1** is the correct.

27 The energy profile for a reversible reaction is shown below.



Which of the following statements are correct?

1 The reaction from **B** to **A** is endothermic.

2 The activation energy of the reaction **A** to **B** is *x*.

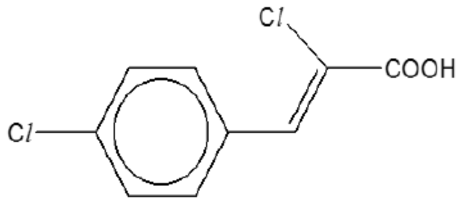
3 The activation energy of the reaction **B** to **A** is *x* + *y*.

Answer is **A**

Reactant **B** has lower energy than the product **A**, hence reaction is endothermic

Activation energy, E_a is the minimum amount of energy that molecular collisions must possess in order for a chemical reaction to occur. It is measured from the reactant to the transition state.

28 Compound **A** is used as a starting material for a class of anti-bacterial drugs known as quinolones. Which of the following statements about compound **A** are correct?



compound **A**

1 1 mole of **A** reacts with CH_3OH to give 1 mole of H_2O.

2 1 mole of **A** reacts with Na metal to give 0.5 mole of H_2.

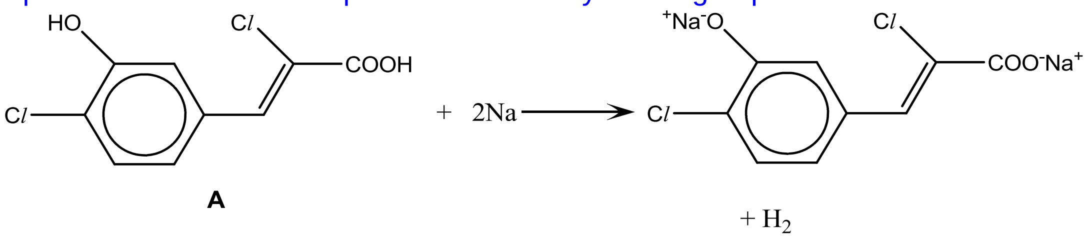
3 1 mole of **A** reacts with $CaCO_3$ to give 1 mole of CO_2.

Answer is **B**

Option **1** is correct as only carboxylic acid group in A reacts with PCl_5:

$$RCOOH + PCl_5 \longrightarrow RCOCl + POCl_3 + HCl$$

Option **2** is correct as both phenol and carboxylic acid group in A reacts with Na metal:



Option **3** is wrong as **2** moles of A reacts with $CaCO_3$ to form 1 mole of CO_2

$$\mathbf{2}ROOH + CaCO_3 \longrightarrow Ca(RCOO^-)_2 + CO_2 + H_2O$$

29 For which types of compound are **all** of the following statements correct?

- They are unreactive towards mild oxidising agents.
- They form esters.
- They react with sodium.

1 aldehydes

2 carboxylic acids

3 tertiary alcohols

Answer is **C**

Option **1** is wrong because aldehydes can be oxidised but it cannot react with sodium and cannot form esters.

Option **2** and **3** are correct as both carboxylic acid and tertiary alcohols cannot be oxidised, they both react with sodium and they both can form esters.

30 Which of the following trends concerning Period 3 elements from Na to C*l* are true?

1 There is a change from metallic behaviour to non-metallic behaviour.

2 Their compounds show an increase in the maximum oxidation number across the period.

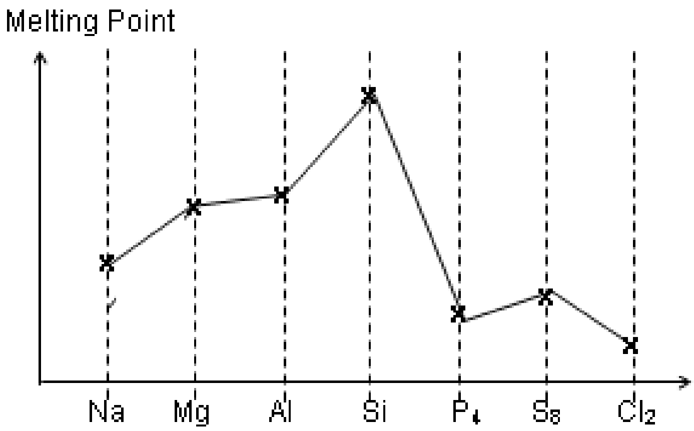
3 The melting points of the elements decrease across the period.

Answer is **B**

Option **1** is correct as the covalent character of the elements increase from Na to C*l*.

Option **2** is correct as the number of valence electrons increase Na to C*l* hence the maximum oxidation state of the element increases.

Option **3** is wrong as the melting point of the elements increase across the period and reaches a maximum at Si before decreasing across the period.



INNOVA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME

CLASS INDEX NUMBER

CHEMISTRY

8872/02

Paper 2 Structured Questions

24 Aug 2017

Candidates answer on the question paper.

2 hours

Additional Materials: *Data Booklet*
Writing paper

READ THESE INSTRUCTIONS FIRST

Write your index number, name and civics group on all the work you hand in.
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 **2 out of 3** questions on writing paper 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.

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

For Examiner's Use	
Section A	
1	**15**
2	**9**
3	**16**
Section B	
4	**20**
5	**20**
6	**20**
Significant Figures and Units	
Handwriting and Presentation	
Total	**80**

This document consists of **15** printed pages and **1** blank page.

For Examiner's Use

Answer ALL questions on the space provided.

1 **(a)** The element potassium can exist as a number of isotopic species.

Complete the table below for two isotopic species of potassium.

isotopic species	protons	neutrons	electrons	electronic configuration
$^{39}_{19}K$	19			$1s^2$ ……………………....
		21	18	$1s^2$ ……………………....

[4]

(b) The structure of an alkene can be determined by identifying the products formed when it undergoes a type of reaction that involves the breakage of the C=C double bond.

In **(i)** and **(ii)** use the products shown to determine the structure of the original alkene.

(i) products: CO_2 and $(CH_3)_2CO$

(ii) products: CH_3CO_2H and $CH_3CH_2CO_2H$

[2]

(c) State the reagent(s) and condition(s) required for the reactions in **(b)(i)** and **b(ii)**.

……………………………………………………………………………………………...

[1]

(d) State the type of reaction in **(b)(i)** and **b(ii)**.

……………………………………………………………………………………………...

[1]

For Examiner's Use

(e) Alkenes can be prepared in the laboratory by heating alcohols with excess concentrated sulfuric acid. The set up shown below can be used to prepare a sample of ethene.

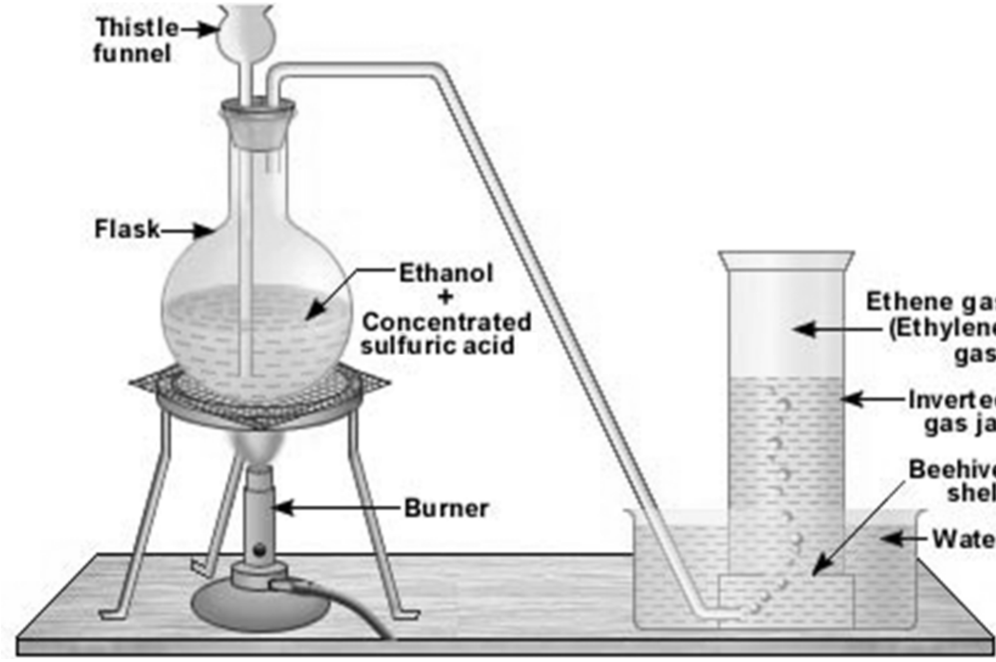


Figure 1.1

From the set up in **Figure 1.1**, the ethene gas collected in the inverted gas jar can be further purified by first bubbling it through another solution **A** and then passing it through a test tube containing anhydrous calcium chloride.

(i) Suggest an identity for solution **A** and explain its purpose.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

[2]

(ii) Suggest why anhydrous calcium chloride is required to obtain pure ethene.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

[1]

Ethane-1,2-diol, $CH_2(OH)CH_2(OH)$ may be formed instead of ethene if the water in **Figure 1.1** is replaced with reagent **B**.

(iii) Suggest an identity of reagent **B** and state the condition to be used.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

[1]

For Examiner's Use

(iv) What changes do you expect to observe to reagent **B**?

……………………………………………………………………………………………

……………………………………………………………………………………………
[1]

(v) Suggest one simple chemical test that could be used to distinguish between ethane-1,2-diol and ethanol, and state the observation expected for each compound.

……………………………………………………………………………………………

……………………………………………………………………………………………

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……………………………………………………………………………………………

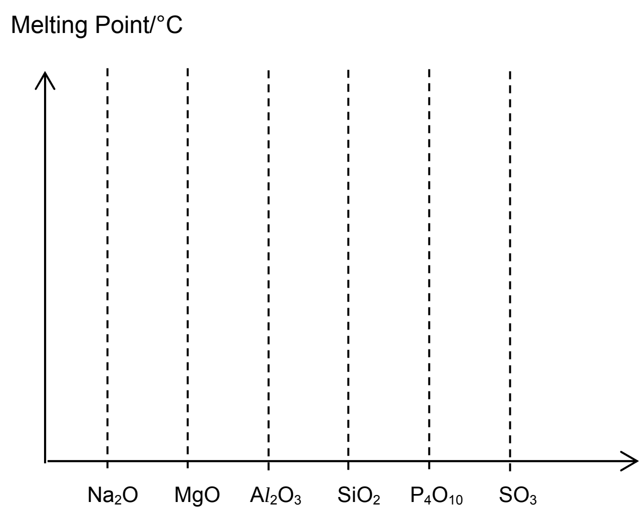
……………………………………………………………………………………………

……………………………………………………………………………………………
[2]

[Total: 15]

2 **(a)** **(i)** The oxides Na_2O, MgO, Al_2O_3, SiO_2, P_4O_{10} and SO_3 differ considerably in their physical properties.

In the space provided below, sketch a graph of the melting point of these oxides.



[2]

For Examiner's Use

(ii) Explain, as fully as you can, why the melting point varies across the oxides of Period 3 elements.

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………………………………………………………………………………………………… [4]

(b) Both aluminium and phosphorus can form chlorides.

PCl_5 hydrolyses in water to produce hydrochloric acid and phosphoric acid, H_3PO_4(aq).

$AlCl_3$ also hydrolyses in water to produce an acidic solution.

(i) Write a balanced equation to show the reaction between PCl_5 and water.

………………………………………………………………………………………………… [1]

(ii) Explain using equation(s) why $AlCl_3$ undergoes hydrolysis with water to produce an acidic solution.

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………………………………………………………………………………………………… [2]

[Total: 9]

For Examiner's Use

3 Carbonic acid-bicarbonate buffer is the most important buffer for maintaining acid-base balance in our blood. The equilibrium reactions involved are as follows.

$$H^+(aq) + HCO_3^-(aq) \overset{K_1}{\rightleftharpoons} H_2CO_3(aq)$$

$$H_2CO_3(aq) \overset{K_2}{\rightleftharpoons} H_2O(l) + CO_2(g)$$

(a) Carbonic acid-bicarbonate can act as a buffer because they are *conjugate acid-base pair*.

(i) Using H_2CO_3 as an example, what do you understand by the term *conjugate acid-base pair*.

....

....

....

.... [1]

(ii) Define the term *buffer*.

....

....

.... [1]

(iii) Explain how carbonic acid-bicarbonate acts as buffer using relevant equations.

....

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....

....

....

.... [3]

For Examiner's Use

(b) During exercise, our body expends the energy in glucose and produces large amounts of CO_2 and H^+. This causes the pH of our blood to drop and may lead to a medical condition known as acidosis. Increased breathing during exercise will help to reverse this drop in pH.

Describe how increased breathing alters the carbonic acid-bicarbonate buffer equilibrium leading to the removal H^+ from the blood.

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[3]

(c) With reference to the equilibrium below, answer the following questions.

$$H^+(aq) + HCO_3^-(aq) \overset{K_1}{\rightleftharpoons} H_2CO_3(aq)$$

(i) Write an expression for the equilibrium constant of this reaction, K_1, stating clearly its units.

[2]

(ii) In our kidney, HCO_3^- is removed from the body. Predict what will happen to the value of K_1.

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…………………………………………………………………………………………

…………………………………………………………………………………………

[1]

For Examiner's Use

(d) pH of blood is carefully maintained at 7.4 for our body to function optimally. pH of a carbonic acid-bicarbonate buffer solution can be calculated using modified Henderson-Hasselbalch equation.

$$pH = pK - \log_{10}\left(\frac{[HCO_3^-]}{[CO_2]}\right)$$

where pK is the negative logarithm of K (where $K = K_1.K_2$).

(i) Given the value of pK is 6.1, calculate the ratio of $[CO_2]$ and $[HCO_3^-]$ in our blood.

[1]

(ii) The desired concentration of HCO_3^- in the blood is 12 millimole per litre. Using your answer in **(d)(i)**, what is the corresponding concentration of CO_2 in mol dm^{-3}?

[1]

(iii) Calculate the mass of $NaHCO_3$ that needs to be dissolved in 1 dm^3 of water to obtain the desired concentration of HCO_3^- in a lab setting.

[1]

For Examiner's Use

(e) Besides exercise, alcohol beverage consumption can also lead to acidosis. This occurs when lactic acid, 2-hydroxypropanoic acid, is formed when ethanol is metabolised in the body.

The main component in alcohol beverages is ethanol.

(i) Ethanol can be converted to ethanoic acid. State the reagent(s) and condition(s) for this reaction in a lab setting.

Reagent(s) and condition(s)

....

.... [1]

(ii) Explain why lactic acid cannot be formed using its corresponding alcohol in the lab setting.

....

....

....

.... [1]

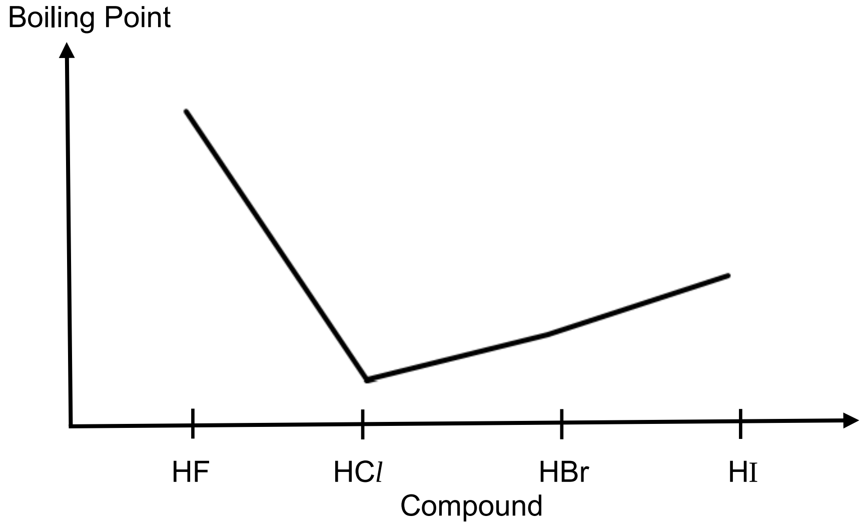
[Total:16]

SECTION B (Free Response Questions)

Answer **two** questions from this section on separate answer paper.

4 Hydrogen halides are diatomic inorganic compounds with the formula HX where X is one of the halogen atoms: fluorine, chlorine, bromine, iodine or astatine. They exist as gases that dissolve in water to give acids which are commonly known as hydrohalic acids.

The boiling points of hydrogen halides are shown in the graph below.



(a) **(i)** Explain why the boiling point of HF is the highest. [2]

(ii) Explain why the boiling points of hydrogen halides increase from HC*l* to HI. [2]

(b) With the aid of a diagram, draw the type of bonding present between HF molecules. [2]

(c) Explain if hydrohalic acids are able to conduct electricity when dissolved in water. [1]

At high temperature, hydrogen iodide partially dissociates into hydrogen and iodine according to the equation:

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g) \qquad \Delta H > 0$$

At 500K, the equilibrium constant, K_c, for the dissociation reaction is 6.25×10^{-3}. Some pure HI is placed into an evacuated glass tube and heated to 500K. In the equilibrium sample, the concentration of I_2 is 3.10×10^{-5} mol dm^{-3}.

(d) **(i)** Determine the concentrations of HI(g) in this equilibrium mixture at 500K. [1]

(ii) Hence, calculate the initial concentration of HI added originally. [1]

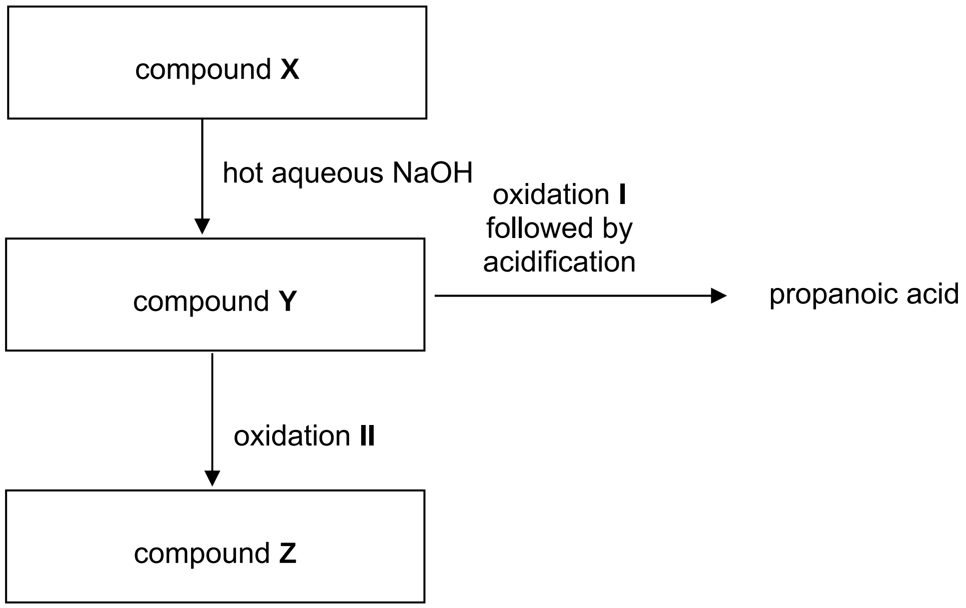
(iii) Suggest and explain how the value of K_c would change if the temperature of the glass tube was raised. [2]

(e) Compound **X** is a halogenoalkane with molecular formula C_4H_9Cl. When heated under reflux with aqueous NaOH, compound **Y** is formed.

Compound **Y** is able to undergo oxidation with two different sets of reagents and conditions. Using the first set of reagents and conditions, followed by acidification, propanoic acid is formed. However, when compound **Y** is oxidised using the second set of reagents and conditions, product **Z** is formed. Compound **Z** reacts with 2,4 -dinitrophenylhydrazine but not with Tollens' reagent.

(i) Using the information given above and the flow chart below, deduce and draw the structures of compounds **X**, **Y** and **Z** in your writing paper.

[3]



(ii) State the reagents and conditions for oxidation **I** and oxidation **II**.

[2]

(iii) Predict the shape and bond angle about $Cl – C – H$ in compound **X**, C_4H_9Cl.

[2]

(iv) State and explain whether compound **X**, C_4H_9Cl is polar or non-polar.

[2]

[Total: 20]

5 This question is about chlorine.

(a) Due to its toxic nature, chlorine was used as an offensive weapon in World War I in Flanders. It was first deployed in 1915 when the German army released the gas from hundreds of cylinders. The threat of causing many men dying in agony was eventually countered by issuing gas masks, termed the "hypo helmet", which was a hood that was dipped in aqueous sodium thiosulfate, $Na_2S_2O_3$.

(i) When chlorine gas was absorbed by sodium thiosulfate found in the "hypo helmet", chlorine was reduced to chloride while thiosulfate ions, $S_2O_3^{2-}$ was oxidised to sulfate ions, SO_4^{2-}.

Write a balanced equation for the reaction between chlorine and thiosulfate ions in an acidic medium.

[1]

(ii) Assuming that each treated "hypo helmet" effectively absorbed 500 cm^3 of chlorine gas during a battle at room temperature and pressure, and the production of each "hypo helmet" required 700 cm^3 of aqueous sodium thiosulfate, calculate the concentration in mol dm^{-3} of sodium thiosulfate required. [You may assume the mole ratio between Cl_2 and $S_2O_3^{2-}$ to be 2 : 3 if you are not able to write the equation between Cl_2 and $S_2O_3^{2-}$]

[3]

(b) Chlorine reacts with the Period 3 elements magnesium to phosphorus to form their chlorides. The melting point of these chlorides are given in the table below.

compound	magnesium chloride	aluminium chloride	phosphorus pentachloride
melting point/^{o}C	714	178	161

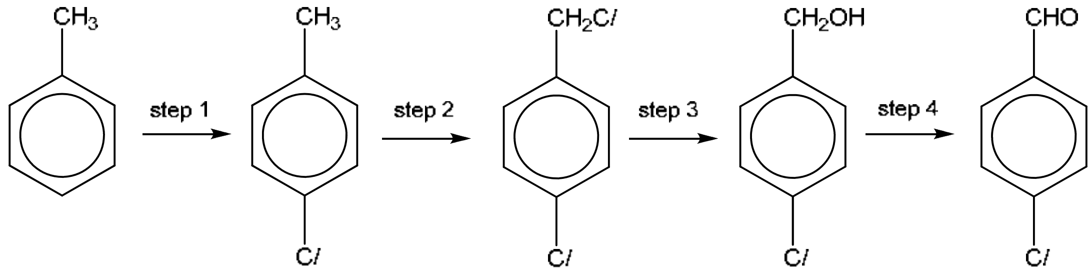
(i) Draw the Lewis structure of phosphorus pentachloride.

[1]

(ii) $AlCl_3$ can undergo dimerisation to form Al_2Cl_6. Draw the dot-and-cross diagram for $AlCl_3$ and Al_2Cl_6. Hence, or otherwise, deduce, with reasoning, whether the dimerisation reaction is endothermic or exothermic.

[3]

(c) Chlorine has landed its use in Organic Chemistry as shown in the reaction scheme below.



(i) Suggest suitable reagents and conditions for steps 1, 2 and 4.

[3]

(ii) State the type of reaction for step 3.

[1]

(d) The following results were obtained when chloroalkane, RC*l* reacted with aqueous sodium hydroxide.

Expt	Initial [NaOH] / mol dm^{-3}	Initial [RC*l*] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.02	0.0150	4.0×10^{-4}
2	0.02	0.0225	6.0×10^{-4}
3	0.03	0.0225	9.0×10^{-4}

(i) Deduce the orders of reaction with respect to each of the reactants. Hence, write the rate equation for the reaction.

[3]

(ii) In Expt 4, the initial concentrations of NaOH and RC*l* are 0.06 mol dm^{-3} and 0.03 mol dm^{-3} respectively. Calculate the initial rate for Expt 4.

[1]

(iii) Describe and explain, with an appropriate diagram, how the rate of this reaction is affected when the experiment is repeated at a higher temperature.

[4]

[Total: 20]

6 **(a)** Carbonates, CO_3^{2-} and hydrogencarbonates, HCO_3^{2-} react with acids in the following manner.

Reaction **A** $CO_3^{2-}(aq) + 2H^+(aq) \longrightarrow H_2O(l) + CO_2(g)$
Reaction **B** $HCO_3^-(aq) + H^+(aq) \longrightarrow H_2O(l) + CO_2(g)$

A student mixed 40.0 cm^3 of 1.0 mol dm^{-3} of an unknown solution and 40.0 cm^3 of 1.0 mol dm^{-3} of nitric acid, HNO_3 (aq). The temperature fell by 1.5 ºC.

The unknown solution is either sodium carbonate, Na_2CO_3 or sodium hydrogencarbonate, $NaHCO_3$.

(i) Use the standard enthalpy change of formation values in the table below to calculate the standard enthalpy change for reactions **A** and **B**.

	ΔH_f^θ / kJ mol^{-1}
$H_2O(l)$	– 285.8
$CO_2(g)$	– 393.5
$HCO_3^-(aq)$	– 692
$CO_3^{2-}(aq)$	– 677
$H^+(aq)$	0.0

[2]

(ii) Use your answer in **(a)(i)** to determine which of the two equations, **A** or **B**, represents the reaction that has occurred. Explain your answer.

[3]

(b) Using the energy cycle provided, calculate the enthalpy change, ΔH_r^θ for the following reaction.

$$\begin{array}{ccc} 2HCO_3^-(aq) & \xrightarrow{\Delta H_r^\theta} & CO_3^{2-}(aq) + H_2O(l) + CO_2(g) \\ + 2H^+(aq) \searrow & & \swarrow + 2H^+(aq) \\ & 2H_2O(l) + 2CO_2(g) & \end{array}$$

[2]

(c) Propanoic acid, CH_3CH_2COOH, can also react with carbonates and hydrogencarbonates.

(i) Explain in terms of its structure why 2-chloropropanoic, $CH_3CH(Cl)COOH$ acid is more acidic than propanoic acid.

[2]

(ii) Describe how you would convert propanoic acid to propan-1-ol, $CH_3CH_2CH_2OH$. Include the reagents and equation in your answer.

[2]

(d) How will propanal, CH_3CH_2CHO react with the following reagents?

In each case, write an equation to illustrate your answer and state what type of reaction is taking place.

(i) hydrogen cyanide, HCN, in the presence of sodium hydroxide,

[2]

(ii) 2,4-dintirophenylhydrazine reagent,

[2]

(ii) sodium borohydride, $NaBH_4$

[2]

(e) Describe one simple chemical test that could distinguish between propanoic acid and propan-1-ol.

[3]

[Total: 20]

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INNOVA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME

CLASS

INDEX NUMBER

CHEMISTRY

8872/02

Paper 2 Structured Questions

24 Aug 2017

Candidates answer on the question paper.

2 hours

Additional Materials: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

Write your index number, name and civics group on all the work you hand in.
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 **2 out of 3** questions on writing paper 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.

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

For Examiner's Use	
Section A	
1	**15**
2	**9**
3	**16**
Section B	
4	**20**
5	**20**
6	**20**
Significant Figures and Units	
Handwriting and Presentation	
Total	**80**

This document consists of **18** printed pages and **1** blank page.

Answer ALL questions on the space provided.

1 **(a)** The element potassium can exist as a number of isotopic species

Complete the table below for two isotopic species of potassium.

Isotopic species	protons	neutrons	electrons	electronic configuration
$^{39}_{19}K$	19	20	19	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
$^{40}_{19}K^+$	19	21	18	$1s^2 2s^2 2p^6 3s^2 3p^6$

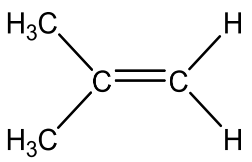
[4]

(b) The structure of an alkene can be determined by identifying the products formed when it undergoes a type of reaction that involves the breakage of the C=C double bond.

In **(i)** and **(ii)** use the products shown to determine the structure of the original alkene.

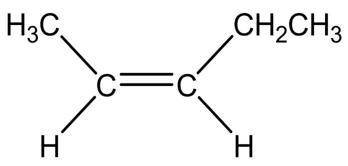
(i) products: CO_2 and $(CH_3)_2CO$

Original alkene:



(ii) products: CH_3CO_2H and $CH_3CH_2CO_2H$

Original alkene (accept cis-isomer)



[2]

(c) State the reagent(s) and condition(s) required for the reactions in **(b)(i)** and **b(ii)**.

$KMnO_4$, dilute H_2SO_4 heat with reflux (Accept heat)

[1]

(d) State the type of reaction in **(b)(i)** and **b(ii)**.

Oxidative cleavage (Accept Oxidation)

[1]

(e) Alkenes can be prepared in the laboratory by heating alcohols with **excess** concentrated sulfuric acid. The set up shown below can be used to prepare a sample of ethene.

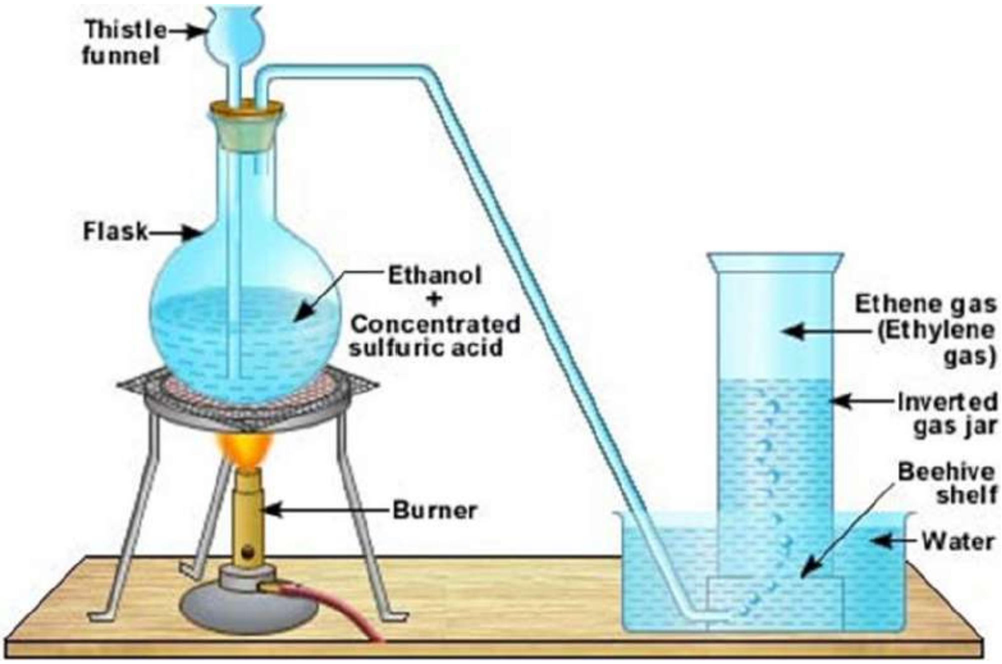


Figure 1.1

From the set up in **Figure 1.1**, the ethene gas collected in the inverted gas jar can be further purified by first bubbling it through another solution **A** and then passing it through a test tube containing anhydrous calcium chloride.

(i) Suggest an identity for solution **A** and explain its purpose.
Aqueous NaOH or Na_2CO_3.
To neutralize any sulfuric acid that remains

[2]

(ii) Suggest why anhydrous calcium chloride is required to obtain pure ethene
To remove water

[1]

Ethane-1,2-diol, $CH_2(OH)CH_2(OH)$ may be formed instead of ethene if the water in **Figure 1.1** is replaced with reagent **B**.

(iii) Suggest an identity of reagent **B** and state the condition to be used.
Cold $KMnO_4$, in dilute $H_2SO_4(aq)$ or NaOH(aq)

[1]

(iv) What changes do you expect to observe to reagent **B**?
Purple $KMnO_4$ solution turns colourless
and a brown precipitate is observed (if alkaline medium is used)

[1]

(v) Suggest one simple chemical test that could be used to distinguish between ethane–1,2–diol and ethanol, and state the observation expected for each compound.

Add I_2, NaOH(aq) to each compound, warm
(Accept aqueous alkaline iodine)
Ethanol: yellow precipitate.
Ethane-1,2-diol: no precipitate.
OR
Add $KMnO_4(aq)$, dil $H_2SO_4(aq)$ to each compound, heat
Ethanol: Purple $KMnO_4$ turns colourless

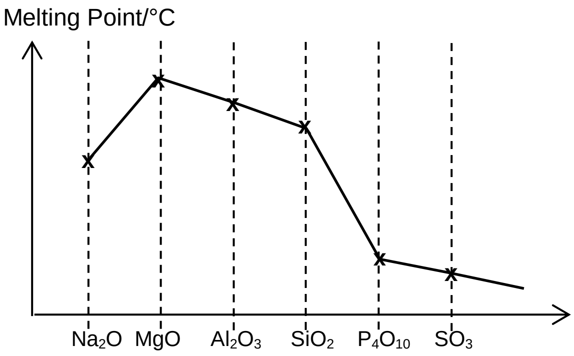
Ethane-1,2-diol: Purple $KMnO_4$ turns colourless. Effervescence is observed, when evolved gas is reacted with aqueous $Ca(OH)_2$, a white precipitate is observed.

[2]

[Total: 15]

2 **(a)** **(i)** The oxides Na_2O, MgO, Al_2O_3, SiO_2, P_4O_{10} and SO_3 differ considerably in their physical properties.

In the space provided below, sketch a graph of the **melting point** of these oxides.



*Axes will be given in question paper

- Graph should peak at MgO
- Increase from Na_2O to MgO then starts to drop
- Na_2O should be lower in m.p. than SiO_2
- P_4O_{10}/P_4O_6 and SO_3/SO_2 should have low m.p. with a decreasing trend

[2]

(ii) Explain, as fully as you can, why the melting point varies in the way shown.

Na_2O, MgO and Al_2O_3 has high melting point as it exists as giant ionic structure with strong electrostatic forces of attraction between the oppositely charged ions. Increase melting point from Na_2O to MgO is due to the increasing ionic bond stength of the compound. Al_2O_3 has ionic bond with covalent character hence the decrease in melting point.

SiO_2 has high melting point as it exists as giant covalent structure. Large amount of energy is required to break the strong and extensive covalent bonds between carbon atoms.

P_4O_{10} and SO_3 exist as simple molecular structure with instantaneous dipole induced dipole forces of attraction between molecules, hence less energy is required to overcome it. P_4O_{10} has a larger electron cloud size which is more easily polarised as compared to SO_3 hence a higher melting point.

[4]

(b) Both aluminium and phosphorus can form chlorides.

PCl_5 hydrolyses in water to produce hydrochloric acid and phosphoric acid, H_3PO_4(aq).

$AlCl_3$ also hydrolyses in water to produce an acidic solution.

(i) Write a balanced equation to show the reaction between PCl_5 and water.

$PCl_5 + 4H_2O \longrightarrow 5HCl + H_3PO_4$

[1]

(ii) Explain using equation(s) why $AlCl_3$ undergoes hydrolysis with water to produce an acidic solution.

Al^{3+} has high polarising power due to its high charge density. The O –H bond in the water molecule is polarised and broken to produce H^+ ions.

$[Al(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H_3O^+(aq)$

[2]

[Total: 9]

3 Carbonic acid-bicarbonate buffer is the most important buffer for maintaining acid-base balance in our blood. The equilibrium reactions involved are as follows.

$$H^+(aq) + HCO_3^-(aq) \overset{K_1}{\rightleftharpoons} H_2CO_3(aq)$$

$$H_2CO_3(aq) \overset{K_2}{\rightleftharpoons} H_2O(l) + CO_2(g)$$

(a) Carbonic acid-bicarbonate can acts as a buffer because they are ***conjugate acid-base pair.***

(i) Using H_2CO_3 as an example, what do you understand by do you understand by the term ***conjugate acid-base pair***.
When H_2CO_3 loses its proton, its conjugate base HCO_3^- is formed. Hence, H_2CO_3 and HCO_3^- are conjugate acid-base pair.
OR
H_2CO_3 and HCO_3^- differs only by the addition/removal of H^+

[1]

(ii) Define the term *buffer*.
A buffer solution is one which resist changes in pH when small amounts of acid and base is added.

[1]

(iii) Explain how carbonic acid-bicarbonate acts as buffer using relevant equations.

When small amount of H^+ is added, H^+ reacts with the conjugate base HCO_3^-.

$$HCO_3^- + H^+ \longrightarrow H_2CO_3$$

$[H^+]$ remains relatively constant/ pH remains fairly constant.

When base amount of OH^- is added, OH^- reacts with the acid H_2CO_3.

$$H_2CO_3 + OH^- \longrightarrow HCO_3^- + H_2O$$

$[OH^-]$ remains relatively constant/ pH remains fairly constant.

[3]

(b) During exercise, our body expends the energy in glucose and produces large amounts of CO_2 and H^+. This causes the pH of our blood to drop and may lead to a medical condition known as acidosis. Increased breathing during exercise will help to reverse this drop in pH.

(i) Describe how increase breathing alters the carbonic acid-bicarbonate buffer equilibrium leading to the removal H^+ from the blood.

When breathing, CO_2 is removed (from the lung and reduced [CO_2] in the blood) By Le Chatelier's Principle, equilibrium position of this $H_2CO_3(aq) \rightleftharpoons H_2O(l) + CO_2(g)$ to shift to the right to increase the concentration of CO_2. This decreases the concentration of H_2CO_3 will then cause the equilibrium position of $H^+(aq) + HCO_3^-(aq) \rightleftharpoons H_2CO_3(aq)$ to the right to increase in conceration of H_2CO_3.and decrease concentration of H^+ (from the blood).

[3]

(c) With reference to the equilibrium below, answer the following questions.

$$H^+(aq) + HCO_3^-(aq) \overset{K_1}{\rightleftharpoons} H_2CO_3(aq)$$

.

(i) Write an expression for the equilibrium constant of this reaction, K_1, stating clearly its units.

$K_1 = \dfrac{[H_2CO_3]}{[HCO_3^-][H^+]}$

Units: $mol^{-1}\ dm^3$

[2]

(ii) In our kidney, HCO_3^- is removed from the body. Predict what will happen to the value of K_1.

K_1 remains constant (as equilibrium constant only changes with temperature).

[1]

(d) pH of blood is carefully maintained at 7.4 for our body to function optimally. pH of a carbonic acid-bicarbonate buffer solution can be calculated using modified Henderson-Hasselbalch equation.

$$pH = pK - \log_{10}\left(\frac{[HCO_3^-]}{[CO_2]}\right)$$

Where pK is the negative logarithm of K (where $K = K_1.K_2$).

(i) Given the value of pK is 6.1, calculate the ratio of [CO_2] and [HCO_3^-] in our blood.

$7.4 = 6.1 - \log\left(\dfrac{[HCO_3^-]}{[CO_2]}\right)$

$\log\left(\dfrac{[HCO_3^-]}{[CO_2]}\right) = -1.3$

$\left(\dfrac{[HCO_3^-]}{[CO_2]}\right) = 0.0501$

OR $\dfrac{[CO_2]}{[HCO_3^-]} = 19.95 = 20.0$

[1]

(ii) The desired concentration of HCO_3^- in the blood is 12 millimole per litre. Using your answer in **(d)(i)**, what is the corresponding concentration of CO_2 in mol dm^{-3}?

$[HCO_3^-]$ = 12 millimole per litre = 12 x 10^{-3} mol dm^{-3}

$[CO_2] = \dfrac{12 \times 10^{-3}}{0.0501}$

= 0.239 mol dm^{-3}

OR $[CO_2]$ = 19.95 x $[HCO_3^-]$

[1]

(iii) Calculate the mass of $NaHCO_3$ that needs to be dissolved in 1 dm^3 of water to obtain the desired concentration of HCO_3^- in a lab setting.

No. of mol. Of HCO_3^- needed = 12 x 10^{-3} mol
Mass of $NaHCO_3$ needed = 84.0 (Mr of $NaHCO_3$) x 12 x 10^{-3}
= 1.01 g

[1]

(e) Besides exercise, alcohol beverage consumption can also lead to acidosis. This occurs when lactic acid, 2-hydroxypropanoic acid, is formed when ethanol is metabolised in the body.

The main component in alcohol beverages is ethanol.

(i) Ethanol can be converted to ethanoic acid. State the reagent (s) and condition (s) for this reaction in a lab setting.

Reagent (s) and condition (s)

$K_2Cr_2O_7$, dilute H_2SO_4 and heat (with reflux).
OR
$KMnO_4$, dilute H_2SO_4 and heat (with reflux) [1]

(ii) Explain why lactic acid cannot be formed using its corresponding alcohol in the lab setting.

The corresponding alcohol of lactic acid is $CH_3CH(OH)CH_2OH$, when it is subjected to the reagent(s) and condition(s) in part (e)(i), both alcohol present in the molecule will be oxidised. [1]

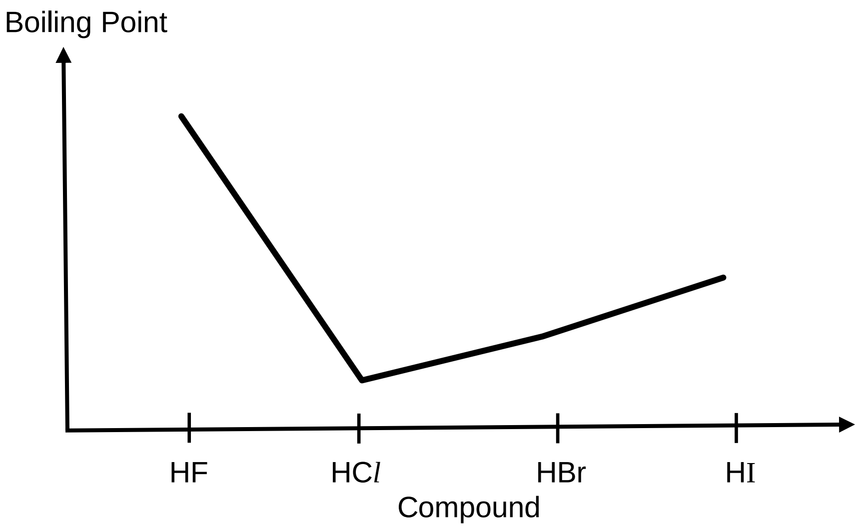
[Total:16]

SECTION B (Free Response Questions)

Answer **two** questions from this section on separate answer paper.

4 Hydrogen halides are diatomic inorganic compounds with the formula HX where X is one of the halogen atoms: fluorine, chlorine, bromine, iodine, or astatine. They exist as gases that dissolve in water to give acids which are commonly known as hydrohalic acids.

The boiling points of hydrogen halides are shown in the graph below.



(a) **(i)** Explain why the boiling point of HF is the highest.

[2]

The hydrogen halides have simple molecular structures.
The unusually high boiling point of HF is due to the intermolecular hydrogen bonds between HF molecules which are stronger than the permanent dipole permanent dipole OR instantaneous dipole induced dipole interactions between HC*l* HBr and HI molecules .

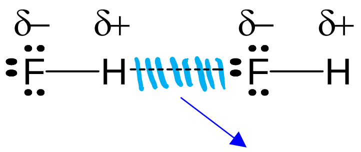
(ii) Explain why the boiling points of hydrogen halides increase from HC*l* to HI.

[2]

The size of electron cloud increases from HC*l* to HI. Polarisability of the electron cloud of the molecules increase and strength of instantaneous dipole–induced dipole between molecules also increases from HC*l* to HI. More energy is required to overcome the intermolecular attractions between HI.

(b) With the aid of a diagram, draw the type of bonding present between HF molecules.

[2]



Hydrogen bonding

- correct set of dipole on both molecules
- at least one lone pair of electrons on F used for bonding
- bonding from H to lone pair of electrons

- labelling of hydrogen bonding

(c) Explain if hydrohalic acids are able to conduct electricity when dissolved in water. [1]

Hydrohalic acids are able to conduct electricity as the hydrogen halides dissociate/ ionise in water to form free moving / mobile H^+ and X^- ions which can conduct electricity.

At high temperature, hydrogen iodide partially dissociates into hydrogen and iodine according to the equation:

$$2HI\,(g) \rightleftharpoons H_2\,(g) + I_2\,(g) \qquad \Delta H > 0$$

At 500K, the equilibrium constant, K_c, for the dissociation reaction is 6.25 x 10^{-3}. Some pure HI is placed into an evacuated glass tube and heated to 500K. In the equilibrium sample, the concentration of I_2 is 3.10 x 10^{-5} mol dm^{-3}.

(d) **(i)** Determine the concentrations of HI (g) in this equilibrium mixture at 500K. [1]

$[H_2] = [I_2] = 3.1 \times 10^{-5}$ mol dm^{-3}

$K_c = \frac{[H_2][I_2\}}{\{HI\}^2}$

$[HI] = 3.92 \times 10^{-4}$ mol dm^{-3}

(ii) Hence, calculate the initial concentration of HI added originally. [1]

	2HI (g)	H_2 (g)	I_2 (g)
Initial conc	?	0	0
Change in conc	$- 2 \times (3.1 \times 10^{-5})$	$+ 3.1 \times 10^{-5}$	$+ 3.1 \times 10^{-5}$
Eqm conc	3.92×10^{-4}	3.1×10^{-5}	3.1×10^{-5}

$[HI]_{initial} = 3.92 \times 10^{-4} + 2(3.10 \times 10^{-5})$
$= 4.54 \times 10^{-4}$ mol dm^{-3}

(iii) Suggest and explain how the value of K_c would change if the temperature of the glass tube was raised. [2]

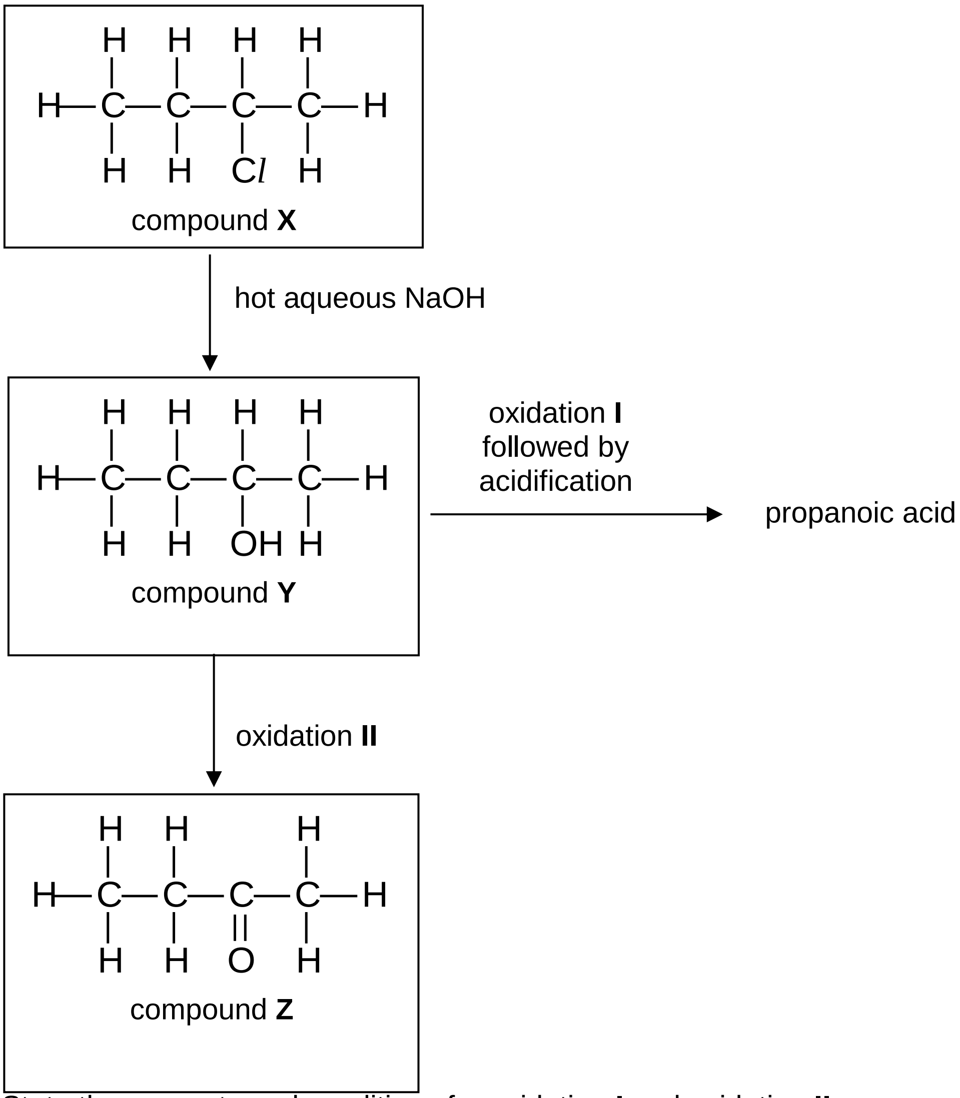
When the temperature was raised, the system will remove the additional heat by favouring the endothermic reaction which will shift the equilibrium to the right. This will increase the value of K_c.

(e) Compound **X** is a halogenoalkane with molecular formula C_4H_9Cl. When heated under reflux with aqueous NaOH, compound **Y** is formed.

Compound **Y** is able to undergo oxidation with two different sets of reagents and conditions. Using the first set of reagents and conditions, followed by acidification, propanoic acid is formed. However, when compound **Y** is oxidised using the second set of reagents and conditions, product **Z** is formed. Compound **Z** reacts with 2,4 - dinitrophenylhydrazine but not with Tollens' reagent.

(i) Using the information given above, deduce and draw the structures of compounds **X**, **Y** and **Z** in the flowchart below.

[3]



(ii) State the reagents and conditions for oxidation **I** and oxidation **II**. [2]

Oxidation **I**: NaOH(aq), I_2(aq), warm
Oxidation **II**: $KMnO_4$ OR $K_2Cr_2O_7$, H_2SO_4(aq), heat

(iii) Predict the shape and bond angle about C*l* – C – H in compound **X**, C_4H_9Cl. [2]

Shape : tetrahedral   Bond angle : 109.5°

(iv) State and explain whether compound **X**, C_4H_9Cl is polar or non-polar. [2]

C_4H_9Cl is polar/ C – C*l* bond is polar due to the difference in electronegativity between carbon and chlorine atoms. The dipole moments do not cancel each other out OR there is a net dipole moment.

[Total: 20m]

5 This question is about chlorine.

(a) Due to its toxic nature, chlorine was used as an offensive weapon in World War I in Flanders. It was first deployed in 1915 when the German army released the gas from hundreds of cylinders. The threat of causing many men dying in agony was eventually countered by issuing gas masks, termed the "hypo helmet", which was a hood that was dipped in aqueous sodium thiosulfate, $Na_2S_2O_3$.

(i) When chlorine gas was absorbed by sodium thiosulfate found in the "hypo helmet", chlorine was reduced to chloride while thiosulfate ions, $S_2O_3^{2-}$ was oxidised to sulfate ions, SO_4^{2-}.

Write a balanced equation for the reaction between chlorine and thiosulfate ions in an acidic medium.

$4\ Cl_2\ (g) + S_2O_3^{2-}\ (aq) + 5\ H_2O\ (l) \rightarrow 8\ Cl^-\ (aq) + 2\ SO_4^{2-}\ (aq) + 10\ H^+\ (aq)$

Ignore state symbols

[1]

(ii) Assuming that each treated "hypo helmet" effectively absorbed 500 cm^3 of chlorine gas during a battle at room temperature and pressure, and the production of each "hypo helmet" required 700 cm^3 of aqueous sodium thiosulfate, calculate the concentration in mol dm^{-3} of sodium thiosulfate required.
[You may assume the mole ratio between Cl_2 and $S_2O_3^{2-}$ to be 2 : 3 if you are not able to write the equation between Cl_2 and $S_2O_3^{2-}$]

No. of moles of chlorine in 500 cm^3 = $(500 \times 10^{-3})/ 24 = 0.0208$ mol

No. of moles of thiosulfate needed = $0.0208 / 4 = 5.208 \times 10^{-3}$ mol [ECF from wrong mole ratio]

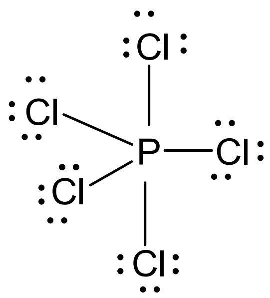
Conc of thiosulfate = mole/vol = $(5.208 \times 10^{-3}) / (700 \times 10^{-3})$
$= 7.44 \times 10^{-3}$ mol dm^{-3}

[3]

(b) Chlorine reacts with the Period 3 elements magnesium to phosphorus to form their chlorides. The melting point of these chlorides are given in the table below.

compound	magnesium chloride	aluminium chloride	phosphorus pentachloride
melting point/°C	714	178	161

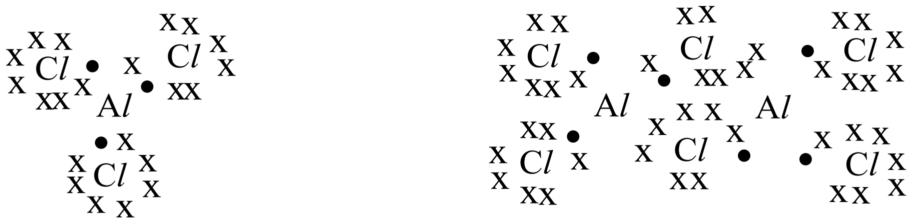
(i) Draw the Lewis structure of phosphorus pentachloride.



Must show correct axial and equatorial position
Must show lone pair of electrons on chlorine

[1]

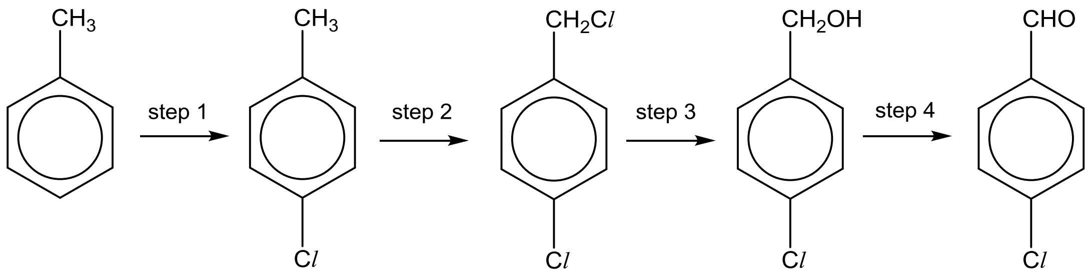
(ii) $AlCl_3$ can undergo dimerisation to form Al_2Cl_6. Draw the dot-and-cross diagram for $AlCl_3$ and Al_2Cl_6. Hence, or otherwise, deduce, with reasoning, whether the dimerisation reaction is endothermic or exothermic.



The dimerization involves forming bond between two $AlCl_3$ molecules. Hence, the reaction is exothermic.

[3]

(c) Chlorine has landed its use in Organic Chemistry as shown in the reaction scheme below.



(i) Suggest suitable reagents and conditions for steps 1, 2 and 4.

Step 1: Cl_2(g), or Cl_2 in CCl_4, anhydrous $FeCl_3$ catalyst, room temp in the dark (to prevent FRS) (For catalyst, can use Fe or $AlClX_3$)

Step 2: Cl_2(g), or Cl_2 in CCl_4, uv light

Step 4: $K_2Cr_2O_7$, dil H_2SO_4, heat with immediate distillation

[3]

(ii) State the type of reaction for step 3.

Substitution

Do not accept hydrolysis.

[1]

(d) The following results were obtained when chloroalkane, RC*l* reacted with aqueous sodium hydroxide.

Expt	Initial [NaOH] / mol dm^{-3}	Initial [RC*l*] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.02	0.0150	4.0×10^{-4}
2	0.02	0.0225	6.0×10^{-4}
3	0.03	0.0225	9.0×10^{-4}

(i) Deduce the orders of reaction with respect to each of the reactants. Hence, write the rate equation for the reaction.

Comparing expt 2 & 3

When [NaOH] increases by 1.5 times, keeping [RC*l*] constant, rate increases by 1.5 time. Order wrt NaOH is 1.

Comparing expt 1 & 2
When [RC*l*] increases by 1.5 times, keeping [NaOH] constant, rate increases by 1.5 time. Order wrt RC*l* is 1.

Rate = k [NaOH][RC*l*] [ECF based on order]

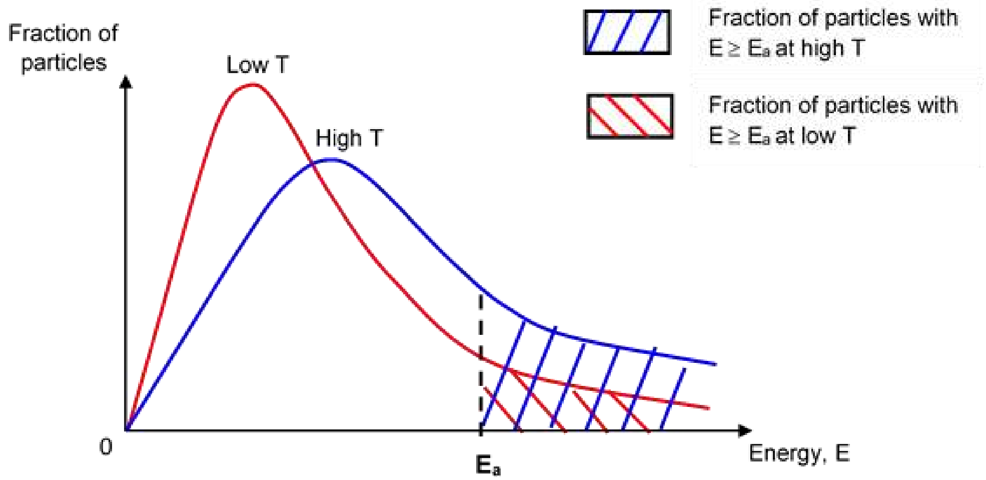
[3]

(ii) In Expt 4, the initial concentrations of NaOH and RC*l* are 0.06 mol dm^{-3} and 0.03 mol dm^{-3} respectively. Calculate the initial rate for Expt 4.
Comparing expt 1 & 4
[NaOH] increases by 3 and [RCl] increases by 2
Therefore rate increases by 6

$\boldsymbol{x} = (3 \times 2 \times 4.0 \times 10^{-4})$
$= 2.4 \times 10^{-3}$ mol dm^{-3} s^{-1}

[1]

(iii) Describe and explain, with an appropriate diagram, how the rate of this reaction is affected when the experiment is repeated at a higher temperature.



- ✓ Correct axes & origin
- ✓ Correct shape of both graphs with correct label & start at origin
- ✓ Ea & correct shading
- ✓ Correct legend & corresponding shading

At a higher temperature, the average kinetic energy of the particles increases. There is an increase in the fraction of particles with energy equal to or greater than the activation energy, E_a.
This result in an increase in the frequency of effective collisions, hence the reaction increases as rate of reaction is proportional to frequency of effective collision.

[4]

[Total: 20m]

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(a) Carbonates, CO_3^{2-} and hydrogencarbonates, HCO_3^{2-} react with acids in the following manner.

Reaction A $CO_3^{2-}(aq) + 2H^+(aq) \longrightarrow H_2O(l) + CO_2(g)$
Reaction B $HCO_3^-(aq) + H^+(aq) \longrightarrow H_2O(l) + CO_2(g)$

A student mixed 40.0 cm^3 of 1.0 mol dm^{-3} of an unknown solution and 40.0 cm^3 of 1.0 mol dm^{-3} of nitric acid, HNO_3(aq). The temperature fell by 1.5 ºC.

The unknown solution is either sodium carbonate, Na_2CO_3 or sodium hydrogencarbonate, $NaHCO_3$.

(i) Use the standard enthalpy change of formation values in the table below to calculate the standard enthalpy change for reactions **A** and **B**.

	ΔH_f^θ / kJ mol^{-1}
$H_2O(l)$	– 285.8
$CO_2(g)$	– 393.5
$HCO_3^-(aq)$	– 692
$CO_3^{2-}(aq)$	– 677
$H^+(aq)$	0.0

[2]

Using the ΔH_f^θ values (theoretical data):

ΔH_{rxn}^θ of **A** = $\sum n\Delta H_f^\theta$ **(products)** **–** $\sum m\Delta H_f^\theta$ **(reactants)**

= (-285.8 -393.5) – (-677)

= (-679.3) + 677 = – 2.30 kJ mol^{-1}

ΔH_{rxn}^θ of **B** = $\sum n\Delta H_f^\theta$ **(products)** **–** $\sum m\Delta H_f^\theta$ **(reactants)**

= (– 679.3) – (– 692) = – 679.3 + 692 = +12.7 kJ mol^{-1}

(ii) Use your answer in **(a)(i)** to determine which of the two equations, **A** or **B**, represents the reaction that has occurred. Explain your answer.

[3]

Using the ΔH_f^θ values (theoretical data):

ΔH_{rxn}^θ of **A** = – 2.30 kJ mol^{-1}

ΔH_{rxn}^θ of **B** = +12.7 kJ mol^{-1}

Heat absorbed = mcΔT = (80)(4.18)(1.5) = 501.6 J

Moles of H^+ = $\frac{40}{1000} \times 1.0$ = 0.04 mol

Moles of CO_3^{2-} or HCO_3^- = $\frac{40}{1000} \times 1.0$ = 0.04 mol

In both cases, H^+ is the limiting reagent. (Note that this is not a marking point)

ΔH^{θ}_{rxn} of A = $+\frac{501.6}{0.02}$ = +25080 J mol^{-1} = +25.1 kJ mol^{-1}

ΔH^{θ}_{rxn} of B =$+\frac{501.6}{0.04}$ = +12540 J mol^{-1} = +12.5 kJ mol^{-1}

Since the experimental value of the ΔH^{θ}_{rxn} of B is similar to the theoretical value, equation **B** has occurred.

2 – 1mark

Alternative answer

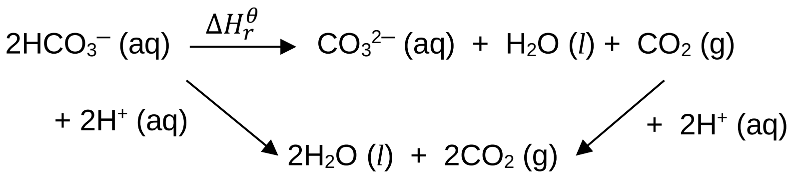
Using the ΔH^{θ}_{f} values (theoretical data):

ΔH^{θ}_{rxn} of **A** = – 2.30 kJ mol^{-1}

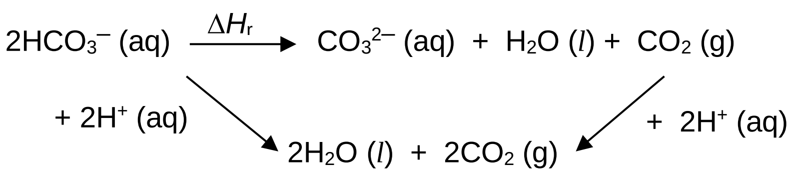
ΔH^{θ}_{rxn} of **B** = +12.7 kJ mol^{-1}

Since the enthalpy change of reaction of **B** is **positive** and the reaction is observed to be an **endothermic** one where **temperature has dropped**, equation **B** has occurred.

(b) Using the energy cycle provided, calculate the enthalpy change, ΔH^{θ}_{r} for the following reaction.



[2]



ΔH^{θ}_{rxn} of A = -2.3 kJ mol^{-1}

ΔH^{θ}_{rxn} of B = +12.7 kJ mol^{-1}

From the energy cycle, using Hess' law,

ΔH^{θ}_{rxn} = 2 x ΔH^{θ}_{rxn} of B - ΔH^{θ}_{rxn} of A

= 2 x + 12.7 – (– 2.3) = +27.7 kJ mol^{-1}

Sign must be seen for answer.

ECF if the student's calculation for ΔH^{θ}_{rxn} of A and ΔH^{θ}_{rxn} of B are wrong in part (a).

(c) Propanoic acid, CH_3CH_2COOH, can also react with carbonates and hydrogencarbonates.

(i) Explain in terms of its structure why 2-chloropropanoic, $CH_3CH(Cl)COOH$ acid is more acidic than propanoic acid.

[2]

Compare $CH_3CH(Cl)COOH$ vs CH_3CH_2COOH

$CH_3C(Cl)HCOOH$ is more acidic than CH_3CH_2COOH because the electron withdrawing Cl atom is present. The negative charge on O atom of anion is more dispersed and hence the anion $CH_3CH(Cl)COO^-$ is more stabilised than the $CH_3CH_2COO^-$ anion.

(ii) Describe how you would convert propanoic acid to propan-1-ol, $CH_3CH_2CH_2OH$. Include the reagents and equation in your answer.

[2]

React propanoic acid with $LiAlH_4$ with dry ether at room temperature.

Equation: $CH_3CH_2COOH + 4[H] \longrightarrow CH_3CH_2CH_2OH + H_2O$

(d) How will propanal, CH_3CH_2CHO react with the following reagents?

In each case, write an equation to illustrate your answer and state what type of reaction is taking place.

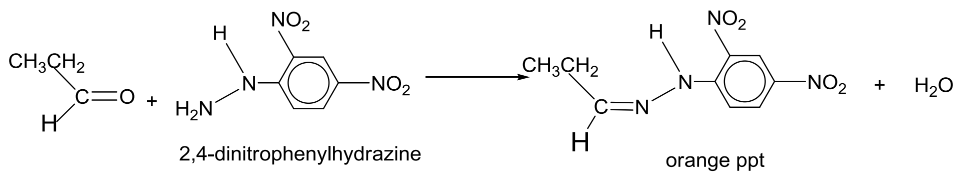
(i) hydrogen cyanide, HCN, in the presence of sodium hydroxide, [2]

Type of reaction: addition

$CH_3CH_2CHO + HCN \longrightarrow CH_3CH_2CH(CN)OH$

(ii) 2,4-dintirophenylhydrazine reagent, [2]

Type of reaction: condensation



(ii) Sodium borohydride, $NaBH_4$ [2]

Type of reaction: reduction

$CH_3CH_2CHO + 2[H] \longrightarrow CH_3CH_2CH_2OH$

(e) Describe one simple chemical test that could distinguish between propanoic acid and propan-1-ol.

[3]

Test: add Na_2CO_3(aq) to each sample at room temp

Observation:
For propanoic acid, effervescence seen & gas evolved gives white ppt with $Ca(OH)_2$ (aq) but no effervescence is seen for propanol.

OR

Test: add $KMnO_4$ followed by dilute H_2SO_4 into each sample & heat.

Observation:
For propanol, purple $KMnO_4$ is decolourised but purple $KMnO_4$ remains for ethanoic acid.

[Total: 20]

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JURONG JUNIOR COLLEGE

JC 2 PRELIMINARY EXAMINATION

Higher 1

CHEMISTRY 8872/01

Paper 1 Multiple Choice

14 September 2017

50 minutes

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, class and shade your exam index 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 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.

A *Data Booklet* is provided. Do not write anything on the *Data Booklet*.

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

SECTION A

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

1 Three half-equations are given below.

$$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$$
$$2CO_2 + 2e^- \rightleftharpoons C_2O_4^{2-}$$
$$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$$

Acidified MnO_4^- ions can oxidise both ions in iron(II) ethandioate, FeC_2O_4.

What is the mole ratio of MnO_4^-: FeC_2O_4 in a complete oxidation?

	MnO_4^-	FeC_2O_4
A	2	5
B	3	5
C	5	2
D	5	3

2 A compound is made up of two elements, **Y** and **Z**.
Each atom of **Y** and of **Z** has exactly 2 unpaired electrons in its outermost p orbitals.

What could the compound be?

A CO_2 **B** CF_4 **C** NF_3 **D** NO_2

3 What is the electronic configuration of vanadium atom, proton number 23?

A $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 4s^1$ **B** $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4p^3$

C $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$ **D** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$

4 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 statement helps to explain this?

A Nitrogen is less electronegative than phosphorus.

B Nitrogen cannot have an oxidation state of +5.

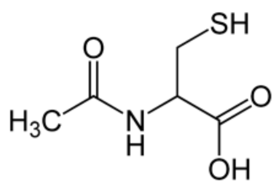
C Nitrogen's outer shell cannot contain more than eight electrons.

D Nitrogen only has three unpaired electrons in the valence shell.

5 Which compound has more than one type of chemical bond?

A Ammonium nitrate
B Calcium chloride
C Silicon(IV) oxide
D Diamond

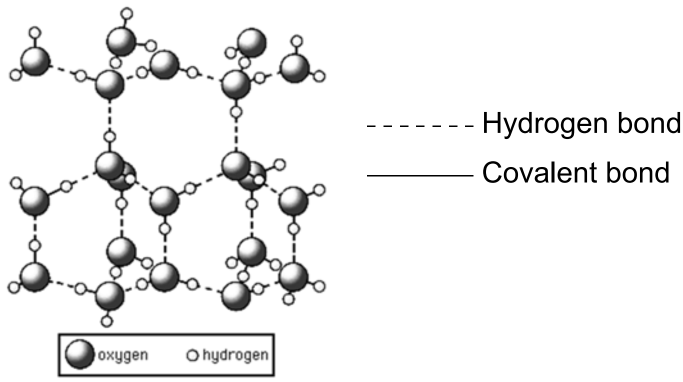
6 Fluimucil is a medicine used to loosen thick mucus in individuals with chronic obstructive pulmonary disease. Its structure is shown below.



How many lone pair of electrons are present in one molecule of fluimucil?

A 5
B 6
C 8
D 9

7 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 The hydrogen bonds are stronger than the O-H covalent bond.

8 Which set of bond angles are present in the molecule shown below?

A 90 °, 109 ° and 120 ° only
B 105 ° and 120 ° only
C 107 ° and 180 ° only
D 109 °, 120 ° and 180 ° only

9 The standard enthalpy change of formation of nitrogen(II) oxide, NO, is +90 kJ mol^{-1}.
What is the enthalpy change of the reaction shown below?

$$2NO(g) \rightarrow N_2(g) + O_2(g)$$

A –180 kJ mol^{-1} **B** –90 kJ mol^{-1} **C** +90 kJ mol^{-1} **D** +180 kJ mol^{-1}

10 In an experiment to measure the enthalpy change for the reaction between hydrochloric acid and calcium carbonate, 20 cm^3 of solution containing 0.04 mol of HC*l* is placed in a plastic cup of negligible heat capacity. When 2.0 g (0.02 mol) of calcium carbonate was added, the temperature rises by 15 K.

Given that the heat capacity per volume of the final solution is 4.2 J K^{-1} cm^{-3}, what is the magnitude of the enthalpy change for the reaction given below?

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

A $\dfrac{(20 + 2) \times 4.2 \times 15}{0.02}$ J mol^{-1}

B $\dfrac{(20 + 2) \times 4.2 \times 15}{0.04}$ J mol^{-1}

C $\dfrac{20 \times 4.2 \times 15}{0.04}$ J mol^{-1}

D $\dfrac{20 \times 4.2 \times 15}{0.02}$ J mol^{-1}

11 Given the following information:

ΔH_c of C(s) = –394 kJ mol^{-1}
ΔH_f of $H_2O(l)$ = –286 kJ mol^{-1}
ΔH_f of $CH_3OH(l)$ = –239 kJ mol^{-1}

Which one of the following is the correct enthalpy change of combustion of liquid methanol, CH_3OH, in kJ mol^{-1}?

A –441 **B** –727 **C** –919 **D** –1205

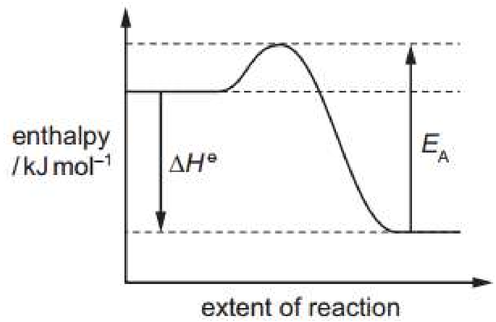
12 Nitric oxide, NO, and bromine vapour react together according to the following equation.

$$2NO(g) + Br_2(g) \rightarrow 2NOBr(g) \qquad \Delta H^{\ominus} = -23\ kJ\ mol^{-1}$$

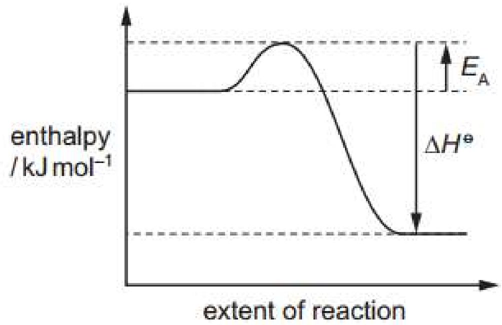
The reaction has an activation energy of +5.4 kJ mol^{-1}.

What is the correct reaction pathway diagram for the above reaction?

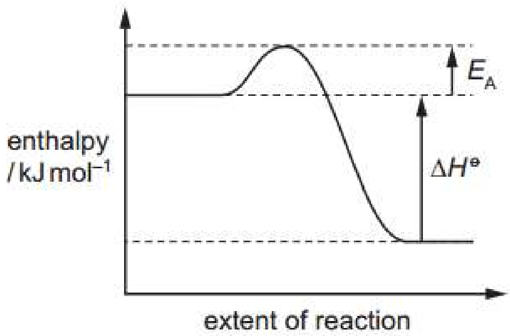
A



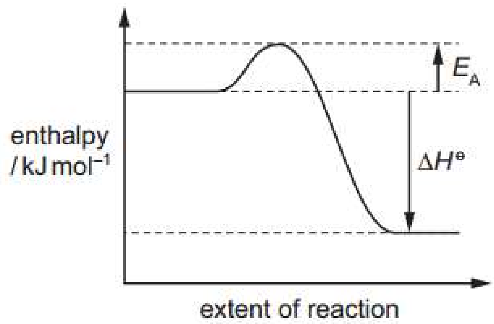
B



C



D



13 A piece of magnesium ribbon was added to 25 cm^3 of dilute hydrochloric acid. The magnesium was completely dissolved and the total volume of hydrogen gas evolved was measured.

In a second experiment, an identical piece of magnesium ribbon of the same mass was used. This was added to another 50 cm^3 of the same dilute hydrochloric acid. The total volume of hydrogen gas evolved was measured.

How will the initial rate of reaction and total volume of hydrogen evolved in the second experiment compare to the first experiment?

	Initial rate of reaction	Total volume of hydrogen evolved
A	Increase	Increase
B	Increase	No change
C	No change	Increase
D	No change	No change

14 The following reaction has a first-order kinetics.

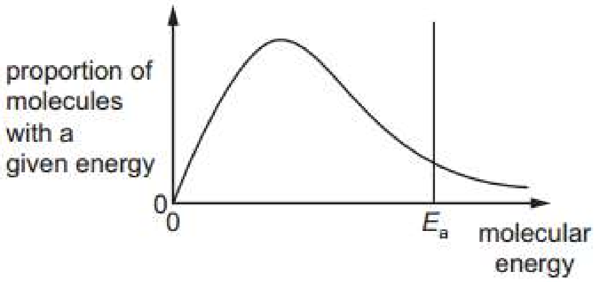
$$XY(g) \rightarrow X(g) + Y(g)$$

It takes 64 seconds for 4 g of XY to decompose till 2 g of XY was left.

How long will it take for 0.25 g of XY to react till 0.125 g?

A 4 s **B** 8 s **C** 64 s **D** 320 s

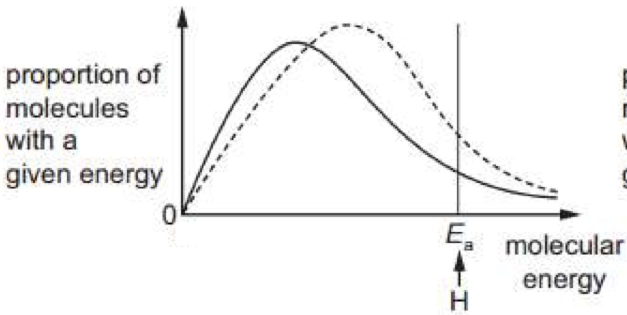
15 The diagram represents, for a given temperature, the Boltzmann distribution of the kinetic energies of the molecules in a mixture of two gases that react together. The activation energy for the reaction, E_a, is marked.



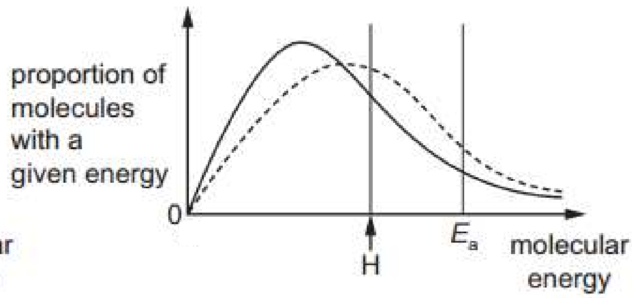
The dotted curves below show the Boltzmann distribution for the same reaction at a higher temperature. On these diagrams, H represents the activation energy at the higher temperature.

Which diagram is correct? C

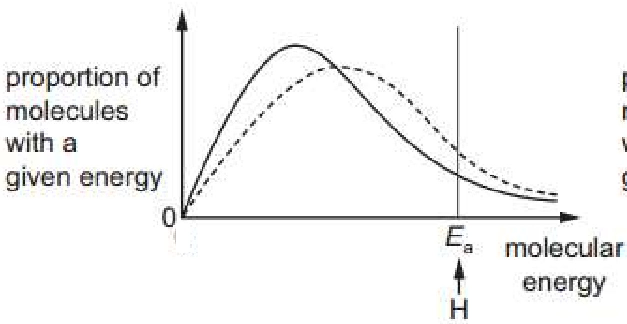
A



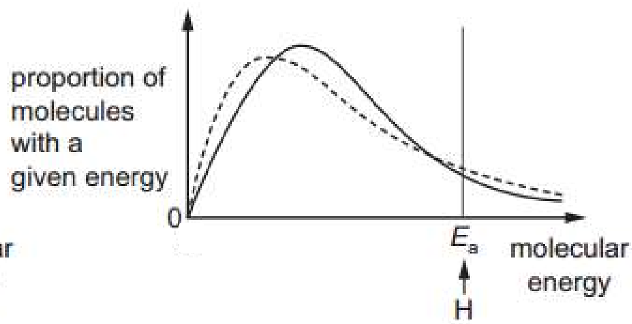
B



C



D



16 Which series is correctly arranged in order of increasing values?

A Atomic radius of P, S, C*l*

B Lattice energy of NaF, MgF_2, AlF_3

C First ionisation energy of Na, Mg, A*l*

D Melting point of P, S, C*l*

17 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 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 only **B** 1 and 2

C 2 only **D** Neither 1 or 2

18 What is meant by the term *dynamic equilibrium*?

A an equilibrium that is constantly changing its position

B an equilibrium where the forward and reverse reactions are taking place at different rates

C an equilibrium where the forward and reverse reactions are taking place at the same rates

D an equilibrium which has not yet settled to a constant state

19 Hydrogen and nitrogen react to produce ammonia.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92.4 \text{ kJ mol}^{-1}$$

Which statement is correct?

A Increasing pressure increases the value of the equilibrium constant.

B Increasing the amount of iron catalyst increases the equilibrium yield of ammonia.

C Condensing the gaseous ammonia product shifts the equilibrium position to favour the formation of more ammonia.

D Lowering the volume of the reaction vessel does not affect the rate of reaction and equilibrium yield of ammonia.

20 Which property of benzene results from the stability associated with the ring of delocalised π electrons?

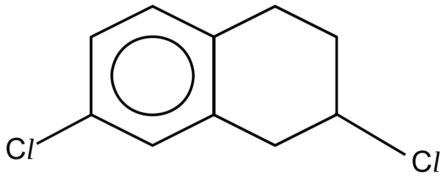
A It does not conduct electricity.

B It is susceptible to attack by electrophiles.

C It undergoes electrophilic substitution instead of electrophilic addition.

D All the carbon-carbon bonds have exactly the same bond length.

21 Which statement about the molecule below is correct?



A It has an empirical formula of C_6H_6Cl.

B It has an molecular formula of $C_{10}H_{10}Cl_2$.

C It has six sp^3 and six sp^2 carbon atoms.

D It is a tertiary alkyl halide.

22 A 0.050 mol dm^{-3} solution of strong acid **R** has a pH of 1.00.

Which acid is **R**?

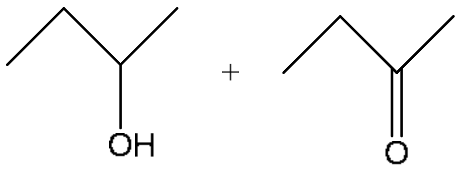
A HCl **B** HNO_3 **C** H_2SO_4 **D** H_3PO_4

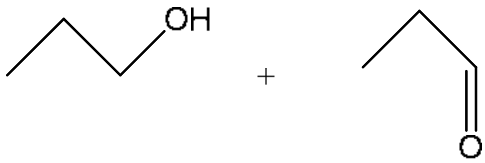
23 10 cm^3 of aqueous silver nitrate was added to two separate samples of bromopropane and chloropropane. The resulting mixtures were allowed to stand.

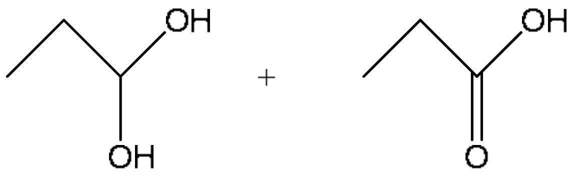
Which of the following shows the correct observation?

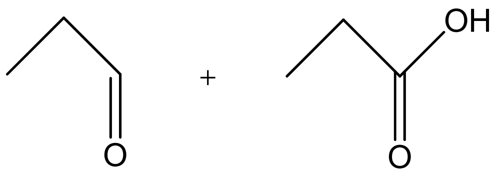
	bromopropane	chloropropane
A	white ppt formed immediately	cream ppt formed immediately
B	cream ppt formed after 2 hours	white ppt formed after 20 minutes
C	cream ppt formed after 20 minutes	white ppt formed after 2 hours
D	white ppt formed after 20 minutes	cream ppt formed after 2 hours

24 Which two compounds can react to produce an ester?

A 

B 

C 

D 

25 Compound **Q** was refluxed with aqueous sodium hydroxide and the resulting mixture was then distilled. The distillate gave a positive tri-iodomethane test. The residue in the distillation flask, after acidification, gave a white precipitate.

Which of these could be **Q**?

A $CH_3CH_2OCOC_6H_5$

B $CH_3CH_2OCOCH_3$

C $CH_3CH_2COOCH_2CH_3$

D $C_6H_5COOCH_3$

SECTION B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct.

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 Which molecules have an overall dipole moment?

1 carbon monoxide, CO

2 dichloromethane, CH_2Cl_2

3 phosphine, PH_3

27 Boron is a non-metallic element which is found above aluminium in Group 13 of the Periodic Table. It forms a compound with nitrogen known as boron nitride which has a graphite structure.

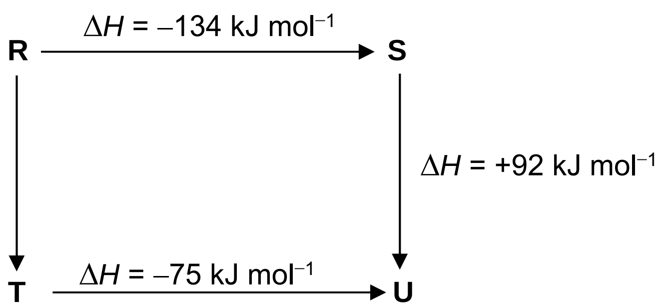
Which conclusions can be drawn from this information?

1 The empirical formula of boron nitride is BN.

2 Boron nitride has a layer structure with instantaneous dipole-induced dipole interactions between the layers.

3 The boron and nitrogen atoms in a layer are likely to be arranged alternately in a hexagonal pattern.

28 The diagram illustrates the enthalpy changes of a set of reactions.



Which statements are correct?

1 The enthalpy change for the transformation **U** → **R** is +42 kJ mol^{-1}.

2 The enthalpy change for the transformation **T** → **S** is endothermic.

3 The enthalpy change for the transformation **R** → **T** is –33 kJ mol^{-1}.

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

29 Which of the following gives the compounds in order of decreasing K_a?

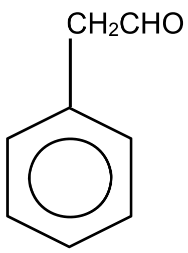
	highest K_a		lowest K_a
1	FCH_2CO_2H	$ClCH_2CO_2H$	$BrCH_2CO_2H$
2	$CH_3CF_2CO_2H$	FCH_2CHFCO_2H	$F_2CHCH_2CO_2H$
3	$CH_3CH(OH)CO_2H$	$CH_3CH_2CO_2H$	$CH_3CH(CH_3)CO_2H$

30 Compound **Z** was subjected to the following tests and the results are recorded below.

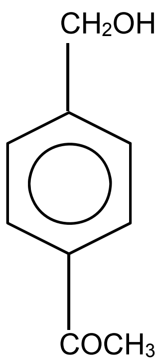
Reagents & Conditions	**Observations**
Acidified $K_2Cr_2O_7$, heat	Orange $K_2Cr_2O_7$ turns green.
Acidified $KMnO_4$, heat	Purple $KMnO_4$ decolourise. A colourless gas formed.
Fehling's reagent, heat	Red brown precipitate formed.

What could be the identity of **Z**?

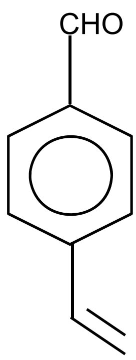
1



2



3



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Answers for 2017 JJC Prelim Paper 1 (8872/01)

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

JURONG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME			
CLASS		EXAM INDEX NUMBER	

CHEMISTRY **8872/02**

Paper 2 Structured Questions

29 August 2017

2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Answer Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and 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 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 **two** questions on separate answer paper.

A *Data Booklet* is provided. Do not write anything on the *Data Booklet*.

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

Section A		Section B	
1		7	
2		8	
3		9	
4			
5			
6			
Total			

This document consists of **14** printed pages.

Section A

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

1. **(a)** Complete the table to show the composition and identity of some ions.

name of element	Nucleon number	Atomic number	Number of protons	Number of neutrons	Number of electrons	Overall charge
beryllium	9	4				2+
helium				1	1	

[3]

(b) When passed through an electric field, a beam of protons is deflected by 2°.

The beam of beryllium ions in the table in **1(a)** is made to pass through the same electric field. Calculate the angle of deflection for the beam of beryllium ions.

[1]

(c) Radiochemical reactions such as radioactive decay of isotopes, can be represented by equations in which the nucleon numbers and atomic numbers must be balanced.

In the first stage of the radioactive decay of $^{232}_{92}\text{Th}$, the products are an isotope of element **E** and two alpha particles $^{4}_{2}\text{He}$.

$$^{232}_{92}\text{Th} \rightarrow \, ^{y}_{x}\mathbf{E} + 2\,^{4}_{2}\text{He}$$

What is the nucleon number, y, of **E**? ………………………………….

What is the proton number, x, of **E**? ………………………………….. [1]

[Total: 5]

2. The fifth to eighth ionisation energies of an element in the third period of the Periodic Table are given. The symbol used for reference is **not** the actual symbol of the element.

	Ionisation energies, kJ mol^{-1}			
	fifth	sixth	seventh	eighth
G	6274	21269	25398	29855

(a) State and explain the group number of element **G**.

Group number …………………………….

Explanation…………………………………………..…………………………

…………………………………………………………………..…………………

…………………………………………………………………...……………. [2]

(b) Explain why the seventh IE of **G** is higher than its sixth IE.

……………………………………………………………………………………….

……………………………………………………………………………………….

………………………………………………………………………………………. [1]

(c) How would the first ionisation energy of **G** compare with that of the element on its right in the Periodic Table? Explain your answer.

………………………………………………………………………………………..

………………………………………………………………………………………..

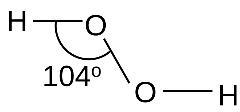
………………………………………………………………………………………..

………………………………………………………………………………………..

……………………………………………………………………………………….. [2]

[Total: 5]

3. Hydrogen peroxide, H_2O_2, is a colourless liquid with the structure shown below.



(a) Determine the oxidation number of O in hydrogen peroxide.

……………………………………………………………………………………... [1]

(b) By considering the number of electron pairs around the O atom in H_2O_2, explain why the H-O-O bond angle in H_2O_2 molecule is 104°.

……………………………………………………………………………………...

……………………………………………………………………………………...

……………………………………………………………………………………...

……………………………………………………………………………………... [2]

(c) Volume strength is a term used to indicate the concentration of hydrogen peroxide solution.

It may be defined as the volume of O_2 produced, in cm^3 at s.t.p, when 1 cm^3 of the H_2O_2 solution decomposes according to the following equation.

$$H_2O_2\,(aq) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$

Calculate the volume strength of a 0.250 mol dm^{-3} aqueous solution of H_2O_2. [2]

(d) Excess KI(aq) is added to another aqueous solution containing 0.008 mol H_2O_2 and brown iodine solution is produced.

$$2I^- + 2H_2O_2 + 2H^+ \rightarrow I_2 + 2H_2O$$

The resulting iodine solution is then titrated with 0.400 mol dm^{-3} $Na_2S_2O_3$.

(i) Write an equation for the reaction between I_2 and $Na_2S_2O_3$.

……………………………………………………………………………………

[1]

(ii) Calculate the volume of $Na_2S_2O_3$ solution required for the titration.

[1]

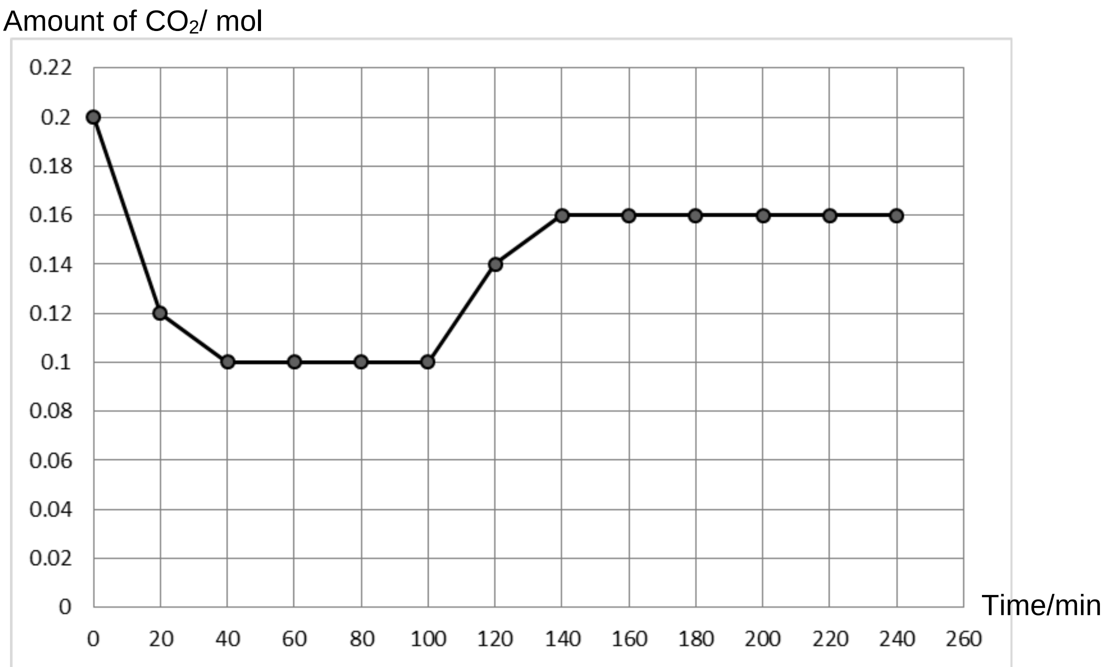
[Total: 7]

4. Growing concerns about global climate change have increased researchers' attention on the various approaches to reduce CO_2 emissions. A widely studied approach is the Sabatier reaction.

$$CO_2(g) + 4H_2(g) \rightleftharpoons CH_4(g) + 2H_2O(g)$$

(a) One researcher did some experiments to investigate the optimum temperature for the Sabatier reaction.

First, he mixed 0.2 mol of CO_2(g) and 0.8 mol of H_2(g) in a 3 dm^3 vessel at 350 ^oC. At every 20 minutes interval, he monitored the amount of CO_2 present in the mixture using a gas chromatography. At 100th min, he raised the temperature to 500 ^oC and continued to monitor the amount of CO_2. The results are shown graphically below.



(i) Determine the amount of CO_2, H_2, CH_4 and H_2O in the mixture at the 80th minute.

[1]

(ii) Hence, calculate the value of the equilibrium constant, K_C for the Sabatier reaction at 350 ^oC, stating its units.

[2]

4. **(a)** **(iii)** Use the graph to determine whether the CO_2 content in the equilibrium mixture increases or decreases when temperature is raised to 500 ^{o}C.

…………………………………………………………………………………… [1]

(iv) Using your answer in **(a)(iii)**, predict and explain whether the Sabatier reaction is exothermic or endothermic.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [2]

(b) The Sabatier reaction is also widely studied by NASA because water and methane are regenerated from the carbon dioxide produced by the cabin crew.

Some of the water produced by the reaction is then electrolysed to generate oxygen gas, a life support consumable, and hydrogen gas which is then passed into the Sabatier reactor to further produce more water and methane.

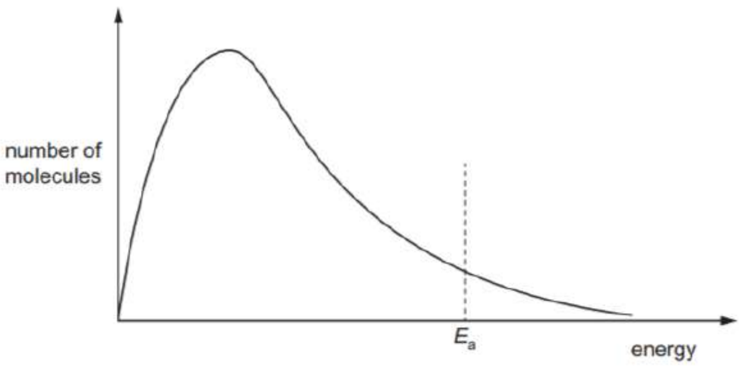
Research by NASA also shows that Ru is the most efficient catalyst for the Sabatier reaction.

(i) Explain the term *catalyst*.

……………………………………………………………………………………

…………………………………………………………………………………… [1]

(ii) The Boltzmann distribution curve shows the distribution of energies in a mixture of CO_2 and H_2 at 350 ^{o}C.



Add a suitable label to the horizontal axis and use it to explain why a catalyst is used in the Sabatier reaction.

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [2]

4. **(c)** Methane produced from the Sabatier reaction can be stored and used as a rocket propellant.

(i) Write an equation for the complete combustion of methane.

………………………………………………………………………………… [1]

(ii) Using appropriate bond energies from the *Data Booklet*, calculate the amount of energy evolved when 1 mole of methane is completely burnt in oxygen.

[1]

[Total: 11]

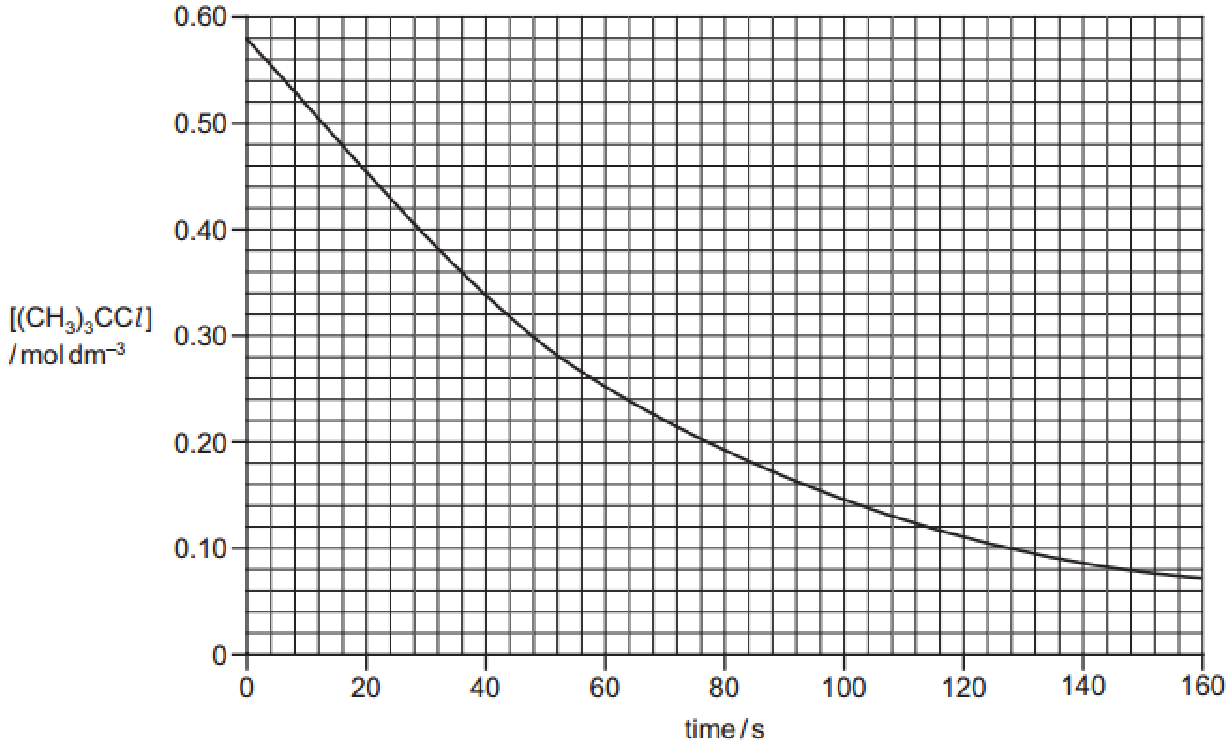
5. In aqueous solution, 2-chloro-2-methylpropane reacts with potassium hydroxide to form 2-methylpropan-2-ol.

(a) Write a balanced equation for the above reaction.

………………………………………………………………………………………... [1]

The rate of this reaction was investigated using a **large excess** of sodium hydroxide.

(b) The graph below shows the results of the experiment.



The reaction is first order with respect to $[(CH_3)_3CCl]$. This can be confirmed from the graph using half-lives.

(i) Explain what is meant by the *half-life* of a reaction?

…………………………………………………………………………………….

…………………………………………………………………………………….

……………………………………………………………………………………. [1]

(ii) Determine the half-life for this reaction. Show all your working and show clearly any construction lines on the graph.

[1]

5. **(b)** **(iii)** It is known that the reaction is zero order with respect to [KOH].

Using your answer in **(b)(ii)**, calculate the value of the rate constant, *k*, for this reaction and give its units.

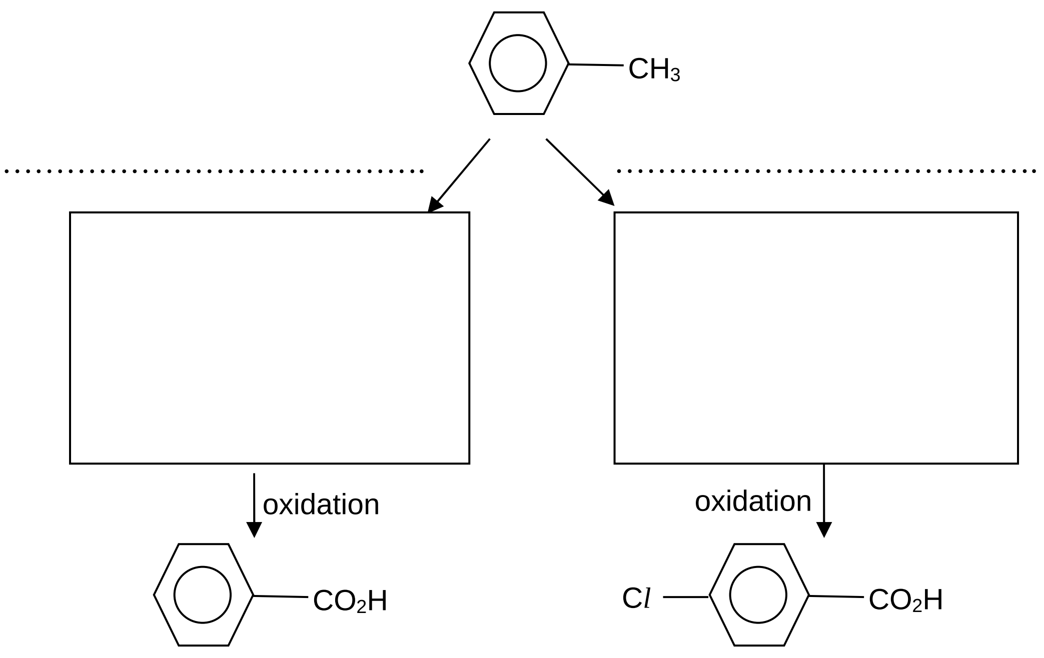
[2]

(iv) What would be the effect on the half-life of this reaction if the initial concentration of 2-chloro-2-methylpropane was doubled.

……………………………………………………………………………………. [1]

[Total: 6]

6. **(a)** Methylbenzene undergoes monochlorination under two different conditions to form two isomers. These two isomers then undergo oxidation to form carboxylic acids.



Benzoic acid

4-chlorobenzoic acid

In the boxes and space provided above, draw the structural formula of the monochlorinated products formed and state the reagent and conditions needed. [4]

(b) Compare and explain the relative acidity of benzoic acid and 4-chlorobenzoic acid formed in **(a)**.

……………………………………………………………………………………..

……………………………………………………………………………………..

…………………………………………………………………………………….. [2]

[Total: 6]

Section B

Answer **two** questions from this section on separate answer paper.

7. This question is about aluminium and its compounds.

(a) **(i)** State and describe the structure and bonding of solid aluminium. [2]

(ii) A common use of aluminium is to make the electrical cables in long distance overhead power lines.

Suggest **two** properties of aluminium that make it suitable for this use. [2]

(b) Aluminium reacts with chlorine to form a white solid chloride that contains 79.7% chlorine and sublimes at 180 ^{o}C.

(i) Determine the empirical formula of the chloride, showing your working clearly. [2]

(ii) Given that the molar mass of the chloride is 267 g mol^{-1}, determine the molecular formula of the chloride. Draw a labelled diagram to illustrate the bonding in the chloride. [2]

(iii) Explain, in terms of structure and bonding, why this chloride has a low sublimation temperature. [2]

(iv) When water is added to the solid chloride, it dissolves to form an acidic solution. However, when water is added to solid Na*Cl*, a neutral solution is obtained.

Using relevant data from the *Data Booklet*, explain why this solid chloride forms an acidic solution but not Na*Cl*. Write equation to illustrate the reaction that occurred.

You may use the empirical formula determined in **(b)(i)** to write the equation. [3]

(c) $LiAlH_4$ is a reducing agent commonly used in organic synthesis. It reacts vigorously with water to produce H_2, LiOH and an amphoteric hydroxide. Hence $LiAlH_4$ must be stored under dry condition and its reaction must be carried out in anhydrous organic solvents such as diethyl ether, $CH_3CH_2OCH_2CH_3$.

(i) Write a balanced equation for the reaction between $LiAlH_4$ and water. [1]

(ii) The above reaction produced an amphoteric hydroxide.

Write two equations to show that it is amphoteric [2]

(d) From the following compounds, identify the compounds that can be reduced by $LiAlH_4$ to form ethanol.

CH_3CHO $\quad$ CH_3CO_2H $\quad$ $CH_2{=}CHOH$ [1]

7. **(e)** Reactions involved $LiAlH_4$ are carried out in anhydrous organic solvents such as diethyl ether, $CH_3CH_2OCH_2CH_3$.

Diethyl ether can be prepared from ethanol in two steps as shown.

$$CH_3CH_2OH \xrightarrow[\text{Step 1}]{\text{Na}} \mathbf{W} \xrightarrow[\text{Step 2}]{} CH_3CH_2OCH_2CH_3$$

(i) State the type of reaction that occurred in Step 1. [1]

(ii) Draw the displayed formula of **W**. [1]

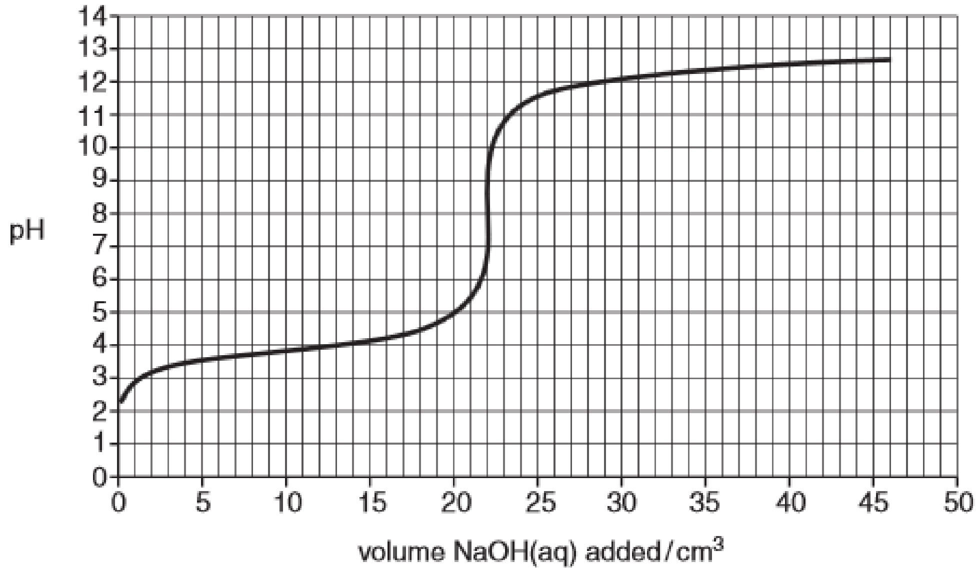
(iii) Given that **W** acts as a nucleophile in Step 2, draw the structural formula of the organic reactant required in Step 2. [1]

[Total: 20]

8. **(a)** Compound **R** is a weak monobasic acid.

A student dissolved 2.29 g of **R** in 250 cm^3 of deionised water and pipetted 25.0 cm^3 of this solution into a conical flask. He 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.

The pH curve obtained by the student is shown below.



(i) Using the data provided below, choose the most suitable indicator for the above titration. State the colour change of the solution at endpoint.

Indicator	**pH at which colour changes**	**Acid colour**	**Base colour**
Tetrabromophenol blue	3 – 5	yellow	blue
Methyl red	5 – 6	yellow	red
phenolphthalein	8 – 10	colourless	red

[2]

(ii) Use the titration curve above to calculate the amount of NaOH required to completely neutralise 25.0 cm^3 of solution **R**. [1]

(iii) Hence, calculate M_r of **R**. [2]

(b) Three weak monobasic acids are shown below.

S	**T**	**U**
$CH_3CH{=}CHCO_2H$	$CH_3CH(OH)CH(OH)CO_2H$	$CH_3CH(OH)CH_2CO_2H$

It is possible to convert **S**, **T** or **U** into one another **in a single step.**

State the reagents and conditions that would be used for the following conversions.

(i) **S** into **T** [1]

(ii) **S** into **U** [1]

(iii) **U** into **S** [1]

8. **(c)** State the type of reaction that occur in the following conversion.

(i) **S** into **U** [1]

(ii) **U** into **S** [1]

(d) **(i)** The acid **S** shows cis-trans isomerism. Draw diagrams to illustrate this type of isomerism, labelling each isomer clearly. [2]

(ii) Draw the skeletal formula of the organic product formed when acid **S** reacts with H_2 in the presence of Pt. [1]

(iii) With the aid of an equation, explain why **S** is miscible with water. [2]

(e) **(i)** Acid **T** reacts with dry PCl_5. Draw the structural formula of the organic product formed. [1]

(ii) Explain, with the aid of an equation, why the reaction must be carried out using **dry** PCl_5. [1]

(f) When **U** is heated with ethanoic acid and a small amount of concentrated sulfuric acid, an organic product, $C_6H_{10}O_4$, is obtained.

(i) State the type of reaction that occurred. [1]

(ii) Write a balanced equation for this reaction. Include the structural formula of the organic product in the equation. [2]

[Total: 20]

9. Oxygen-containing compounds, both organic and inorganic, are essential to our life.

(a) One example is the phosphate buffer system that operates in biological cells. The buffer contains dihydrogen phosphate, $H_2PO_4^-$, which acts as a weak acid.

(i) Write an equation to show that $H_2PO_4^-$ is a weak Bronsted acid. [1]

(ii) Explain the term *buffer* solution and write **two** equations to show how a solution containing $H_2PO_4^-$ and HPO_4^{2-} function as a buffer. [3]

(iii) The pH in many living cells is 7.40.

Given that the K_a of $H_2PO_4^-$ is 6.31×10^{-8} mol dm^{-3}, calculate the value of $[HPO_4^{2-}]/[H_2PO_4^-]$ needed to give a pH of 7.40 in the cells. [2]

(b) The α-amino acids $RCH(NH_2)COOH$ are essential building blocks for proteins in our body.

The simplest α-amino acids is glycine, H_2NCH_2COOH.

One student proposed the following reaction scheme to synthesis glycine from methanal.

$$\underset{\text{methanal}}{HCHO} \xrightarrow{\textbf{Step 1}} HOCH_2CN \xrightarrow{\textbf{Step 2}} HOCH_2CO_2H \xrightarrow{\textbf{Step 3}} ClCH_2CO_2H \xrightarrow{\textbf{Step 4}} \underset{\text{glycine}}{H_2NCH_2CO_2H}$$

(i) What is the state of hybridisation of the C atom in methanal? [1]

(ii) Describe the bonding in methanal in terms of orbital overlap. Draw diagram to illustrate your answer. [2]

(iii) For each step, state the reagents and conditions required. [4]

(iv) Give a reason to explain why **Step 4** gives a poor yield of glycine. [1]

(c) Compound **X** has the molecular formula $C_7H_{14}O$. **X** decolourises brown Br_2(aq).

Treating **X** with hot concentrated acidified $KMnO_4$(aq) produces two compounds **Y**, C_4H_8O, and **Z**, $C_3H_4O_3$.

Both **Y** and **Z** forms an orange precipitate with 2,4-dinitrophenylhydrazine and a yellow precipitate with alkaline aqueous iodine.

Z fizzes when added to aqueous sodium carbonate.

Deduce the structures of **X**, **Y** and **Z**. Include in your answers, the type of reaction that occurred and the functional groups deduced. [6]

[Total: 20]

JURONG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME			
CLASS		EXAM INDEX NUMBER	

CHEMISTRY 8872/02

Paper 2 Structured Questions

29 August 2017

2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Answer Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and 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 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 **two** questions on separate answer paper.

A *Data Booklet* is provided. Do not write anything on the *Data Booklet*.

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

Section A		Section B	
1		7	
2		8	
3		9	
4			
5			
6			
Total			

This document consists of **14** printed pages.

Section A

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

1. **(a)** Complete the table to show the composition and identity of some ions.

name of element	Nucleon number	Atomic number	Number of protons	Number of neutrons	Number of electrons	Overall charge
	Diff isotopes diff mass number (diff from PT)	**Same in all isotopes (same as PT)**	**Same as atomic number**			
beryllium	9	4	**4 ✓**	**5 ✓**	**2 ✓**	2+
helium	**3 ✓**	**2 ✓**	**2 ✓**	1	1	**1+ ✓**

7 ✓: [3] 6 - 4 ✓: [2] 3 - 2 ✓: [1] [3]

(b) When passed through an electric field, a beam of protons is deflected by 2°.

The beam of beryllium ions in the table in **1(a)** is made to pass through the same electric field. Calculate the angle of deflection for the beam of beryllium ions.

Charge/mass of protons (which is H^+) = 1

Charge/ mass of Be^{2+}= 2/9

Angle of deflection by Be^{2+}= 2/9 × 2 = <u>**0.444°**</u> **[1]**

[1]

(c) Radiochemical reactions such as radioactive decay of isotopes, can be represented by equations in which the nucleon numbers and atomic numbers must be balanced.

In the first stage of the radioactive decay of $^{232}_{92}$Th, the products are an isotope of element **E** and two alpha particles $^{4}_{2}$He.

$$^{232}_{92}\text{Th} \rightarrow {}^{y}_{x}\mathbf{E} + 2\,{}^{4}_{2}\text{He}$$

What is the nucleon number, y, of **E**? <u>**224**</u>

What is the proton number, x, of **E**? <u>**88**</u>. **[1]** [1]

[Total: 5]

2. The fifth to eighth ionisation energies of an element in the third period of the Periodic Table are given. The symbols used for reference is **not** the actual symbols of the elements.

	Ionisation energies, kJ mol^{-1}			
	fifth	sixth	seventh	eighth
G	6274	21269	25398	29855

(a) State and explain the group number of element **G**.

Group number : **15 or V** **[1]**

Explanation **From 5th to 6th IE**, **drastic increase** in IE. This implies G has **5 valence electrons**. Hence Group 15. **[1]** [2]

(b) Explain why the seventh IE of **G** is higher than its sixth IE.

6th IE: $G^{5+}(g) \rightarrow G^{6+} + e$
(electronic config of G^{5+}: $1s^2 2s^2 2p^6$) $\Rightarrow$2p e removed during 6th IE
7th IE: $G^{6+}(g) \rightarrow G^{7+} + e$
(electronic config of G^{6+}: $1s^2 2s^2 2p^5$) $\Rightarrow$2p e removed during 7th IE

More energy is needed to **remove electron from an increasingly positive ion**. **[1]**

Or

More energy is needed to **remove electron from G^{6+} than from G^{5+} ion** **[1]** [1]

(c) How would the first ionisation energy of **G** compare with that of the element on its right in the Periodic Table? Explain your answer.

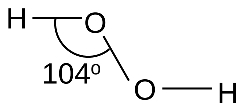
G is phosphorus. Element on the right is sulfur.

1st IE of P is higher than that of S **[1]**

because **in S**, the **inter-electronic repulsion between the paired 3p electrons makes it easier to remove one of them**. **[1]** [2]

[Total: 5]

3. Hydrogen peroxide, H_2O_2, is a colourless liquid with the structure shown below.



(a) Determine the oxidation number of O in hydrogen peroxide.

-1 **[1]** [1]

(b) By considering the number of electron pairs around the O atom in H_2O_2, explain why the H-O-O bond angle in H_2O_2 molecule is 104°.

Each O atom has **2 bond pairs and 2 lone pairs of electrons** **[1]**. **Since lp-lp repulsion > lp-bp repulsion > bp-bp repulsion, the bond angle is reduced from 109.5° to 104°** **[1]** (bond angle in tetrahedral shape) [2]

(c) Volume strength is a term used to indicate the concentration of hydrogen peroxide solution.

It may be defined as the volume of O_2 produced, in cm^3 at s.t.p, when 1 cm^3 of the H_2O_2 solution decomposes according to the following equation.

$$H_2O_2\,(aq) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$

Calculate the volume strength of a 0.250 mol dm^{-3} aqueous solution of H_2O_2. [2]

Amount of H_2O_2 in 1cm^3 0.250 mol dm^{-3} H_2O_2 solution

= 1/1000 × 0.250

= **2.50×10^{-4} mol** **[1]**

Amount of O_2 produced = ½ × 2.50×10^{-4} = 1.25×10^{-4} mol

Volume of O_2 produced = $1.25 \times 10^{-4} \times 22400$ = **2.80** cm^3 **[1]**

(d) Excess KI(aq) is added to another aqueous solution containing 0.800 mol H_2O_2 and brown iodine solution is produced.

$$2I^- + 2H_2O_2 + 2H^+ \rightarrow I_2 + 2H_2O$$

The resulting iodine solution is then titrated with 0.400 mol dm^{-3} $Na_2S_2O_3$.

(i) Write an equation for the reaction between I_2 and $Na_2S_2O_3$.

$\mathbf{I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}}$ **[1]** [1]

(ii) Calculate the volume of $Na_2S_2O_3$ solution required for the titration.

$\mathbf{2H_2O_2 \equiv I_2 \equiv 2S_2O_3^{2-}}$

Amount of $S_2O_3^{2-}$ needed = 0.008 mol

Volume of $S_2O_3^{2-}$ needed = 0.008 ÷ 0.400 × 1000 = 20 cm^3 **[1]**

[1]

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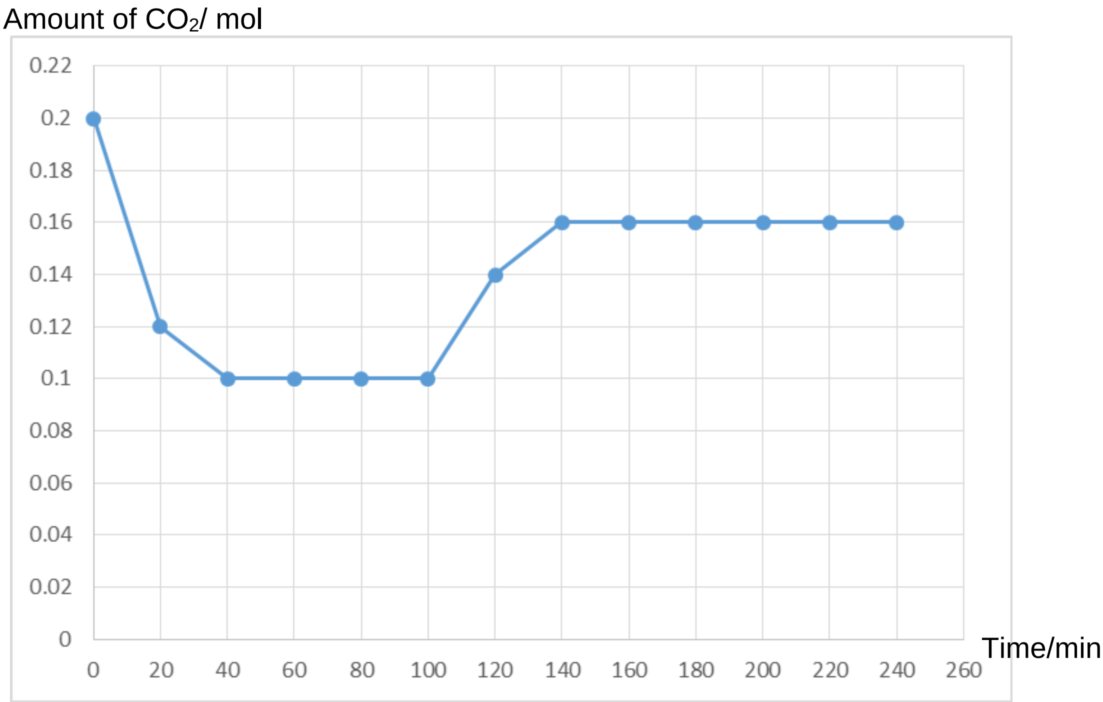
4. Growing concerns about global climate change have increased researchers' attention on the various approaches to reduce CO_2 emissions. A widely studied approach is the Sabatier reaction.

$$CO_2(g) + 4H_2(g) \rightleftharpoons CH_4(g) + 2H_2O(g)$$

(a) One researcher did some experiments to investigate the optimum temperature for the Sabatier reaction.

First, he mixed 0.2 mol of CO_2(g) and 0.8 mol of H_2(g) in a 3 dm^3 vessel at 350 ^oC. At every 20 minutes interval, he monitored the amount of CO_2 present in the mixture using a gas chromatography. At 100th min, he raised the temperature to 500 ^oC and continued to monitor the amount of CO_2. The results are shown graphically below.



(i) Determine the amount of CO_2, H_2, CH_4 and H_2O in the mixture at the 80th minute.

	$CO_2(g)$	+	$4H_2(g)$	$\rightleftharpoons$	$CH_4(g)$	+	$2H_2O(g)$
Initial amount/ mol	0.2		0.8		0		0
Change	0.1		0.4		0.1		0.2
Eqm amount/mol	**0.1**		**0.4**		**0.1**		**0.2**

[1]

(ii) Hence, calculate the value of the equilibrium constant, K_C for the Sabatier reaction at 350 ^oC, stating its units.

$$K_C = \frac{[CH_4][H_2O]^2}{[CO_2][H_2]^4}$$ [1]

$$= \frac{(0.1/3)(0.2/3)^2}{(0.1/3)(0.4/3)^4} = \underline{\mathbf{14.1\ mol^{-2}dm^6}}$$ [1]

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[2]

4. **(a)** **(iii)** Use the graph to determine whether the CO_2 content in the equilibrium mixture increases or decreases when temperature is raised to 500 °C at 100th min.

Increase **[1]** [1]

(iv) Use your answer in **(a)(iii)**, predict and explain whether the Sabatier reaction is exothermic or endothermic.

When temperature is raised, CO_2 content increases. This means that when **temperature is raised, backward reaction is favoured to favour the endothermic reaction to use up some heat**. **[1]**

Thus the **forward reaction is exothermic**. **[1]** [2]

(b) The Sabatier reaction is also widely studied by NASA because water and methane are regenerated from the carbon dioxide produced by the cabin crew.

Some of the water produced by the reaction is then electrolysed to generate oxygen gas, a life support consumable, and hydrogen gas which is then passed into the Sabatier reactor to further produce more water and methane.

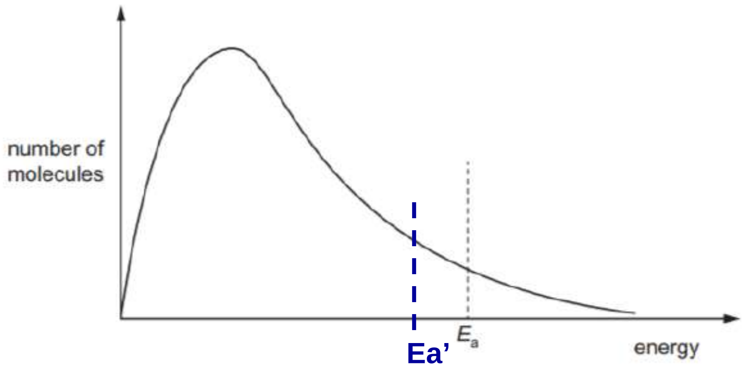
Research by NASA also shows that Ru is the most efficient catalyst for the Sabatier reaction.

(i) Explain the term *catalyst*.

A catalyst is a substance which increases the rate of reaction by providing an alternative pathway of lower activation energy, without itself undergoing any permanent chemical change. **[1]**

[1]

(ii) The Boltzmann distribution curve shows the distribution of energies in a mixture of CO_2 and H_2 at 350 °C.



Add a suitable label to the horizontal axis and use it to explain why a catalyst is used in the Sabatier reaction.

A catalyst provides an alternative reaction path of lower activation energy than that of the uncatalysed reaction. Thus, the **number of molecules with energy greater than Ea'** **increases**. **Frequency of effective collisions** **increases** and hence rate of reaction **increases**. **[1]** [2]

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4. **(c)** Methane produced from the Sabatier reaction can be stored and used as a rocket propellant.

(i) Write an equation for the complete combustion of methane.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ **[1]** [1]

(ii) Using appropriate bond energies from the *Data Booklet*, calculate the amount of energy evolved when 1 mole of methane is completely burnt in oxygen.

ΔH_c(methane)

= Amt of energy evolved by the complete combustion of 1 mol CH_4

= energy to break bonds – energy released when bonds formed

= **4E(C-H) + 2E(O=O) – [2E(C=O) + 4E(O-H)]** **[1]**

= 4(410) + 2(496) – [2(740) + 4(460)]

= –688 kJ mol^{-1}

Amount of energy evolved = 688 kJ **[1]** [1]

Q4 total [12] max [11]

[Total: 11]

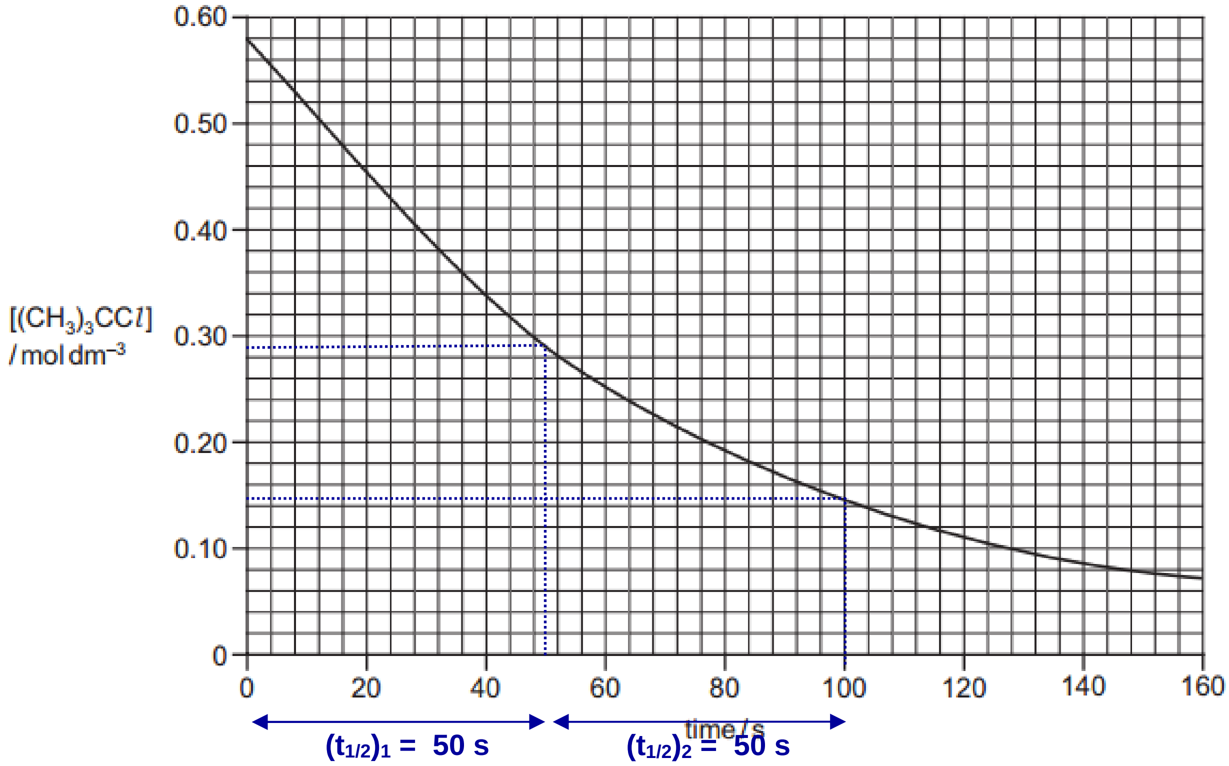
5. In aqueous solution, 2-chloro-2-methylpropane reacts with potassium hydroxide to form 2-methylpropan-2-ol.

(a) Write a balanced equation for the above reaction.

$(CH_3)_3CCl + KOH \rightarrow (CH_3)_3COH + KCl$ **[1]** [1]

The rate of this reaction was investigated using a **large excess** of sodium hydroxide.

(b) The graph below shows the results of the experiment.



The reaction is first order with respect to $[(CH_3)_3CCl]$. This can be confirmed from the graph using half-lives.

(i) Explain what is meant by the *half-life* of a reaction?

Half life is the **time taken for the concentration (or amount) of the reactant to reduce to half of its original concentration (or amount)**. **[1]** [1]

(ii) Determine the half-life for this reaction. Show all your working and show clearly any construction lines on the graph.

$t_{1/2}$ = **50 s** **[1] with units and workings on graph**

[1]

5. **(b)** **(iii)** It is known that the reaction is zero order with respect to [KOH].

Using your answer in **(b)(ii)**, calculate the value of the rate constant, *k*, for this reaction and give its units.

rate = k[$(CH_3)_3Cl$]

Since it is a first order reaction, $k = \dfrac{\ln 2}{t_{1/2}}$ = **<u>0.0139 s^{-1}</u>**

[1]: value **[1]: unit**

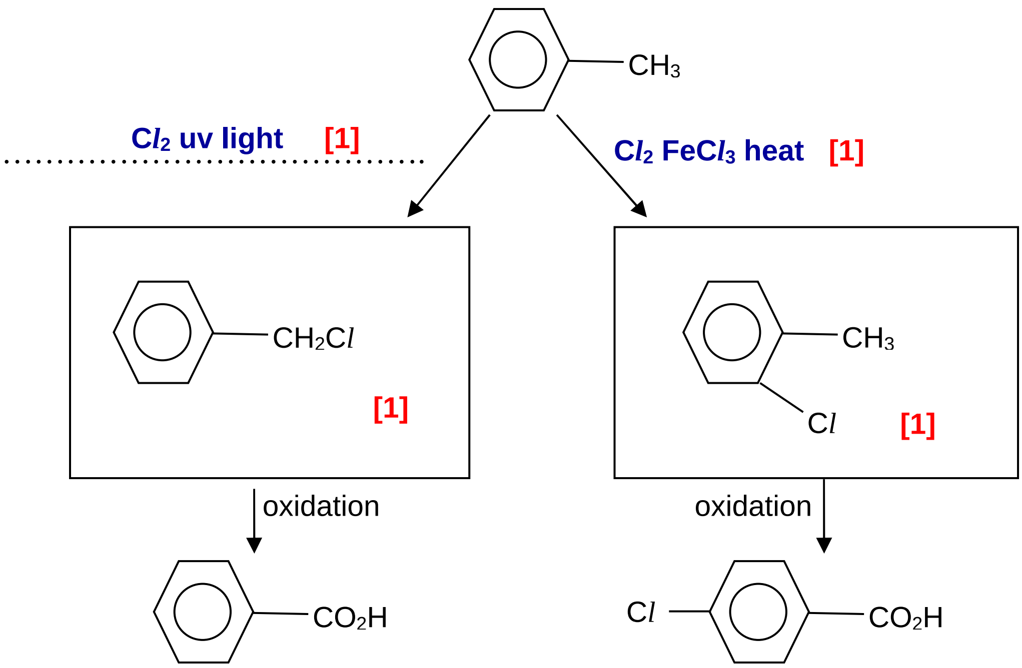
[2]

(iv) What would be the effect on the half-life of this reaction if the initial concentration of 2-chloro-2-methylpropane was doubled.

<u>Remains the same</u>. **[1]** [1]

[Total: 6]

6. **(a)** Methylbenzene undergoes monochlorination under two different conditions to form two isomers. These two isomers then undergo oxidation to form carboxylic acids.



Benzoic acid 4-chlorobenzoic acid

In the boxes and space provided above, draw the structural formula of the monochlorinated products formed and state the reagent and conditions needed. [4]

(b) Compare and explain the relative acidity of benzoic acid and 4-chlorobenzoic acid formed in **(a)**.

<u>4-chlorobenzoic acid is the stronger acid.</u> **[1]**

<u>C*l* is electron withdrawing</u>. It helps to <u>disperse the negative charge on the O^-</u> <u>of $C_6H_4ClCOO^-$</u> . Thus <u>$C_6H_4ClCOO^-$ is more stable</u> than $C_6H_5COO^-$. [1] [2]

[Total: 6]

Section B

Answer **two** questions from this section on separate answer paper.

7. This question is about aluminium and its compounds.

(a) **(i)** State and describe the structure and bonding of solid aluminium. [2]

Giant metallic structure. [1]

Al^{3+} and mobile valence electrons are held by strong electrostatic forces of attraction [1]

(ii) A common use of aluminium is to make the electrical cables in long distance overhead power lines.

Suggest **two** properties of aluminium that make it suitable for this use. [2]

Good electrical conductor

Highly corrosion resistant

low density

ductile

$\left.\right\}$ **Any one [1]. Two reasons needed.**

(b) Aluminium reacts with chlorine to form a white solid chloride that contains 79.7% chlorine and sublimes at 180 °C.

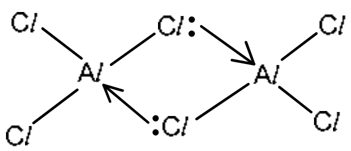
(i) Determine the empirical formula of the chloride, showing your working clearly. [2]

	C*l*	A*l*
mass	79.7	20.3
mol	79.7 ÷ 35.5 = 2.24	20.3 ÷ 27.0 =0.752
ratio	3	1

Empirical formula is **$AlCl_3$** **[1]** **working [1]**

(ii) Given that the molar mass of the chloride is 267 g mol^{-1}, determine the molecular formula of the chloride. Draw a labelled diagram to illustrate the bonding in the chloride. [2]

Molecular formula is **Al_2Cl_6** **[1] with working**



[1] must show dative bond

(iii) Explain, in terms of structure and bonding, why this chloride has a low sublimation temperature. [2]

It has a simple covalent structure ✓. Small amount of energy ✓ needed to overcome the weak intermolecular forces /instantaneous dipole-induced dipole interactions between the molecules ✓.

1-2 ✓: [1] 3 ✓: [2]

7 **(b)** **(iv)** When water is added to the solid chloride, it dissolves to form an acidic solution. However, when water is added to solid Na*Cl*, a neutral solution is obtained.

Using relevant data from the *Data Booklet*, explain why this solid chloride forms an acidic solution but not Na*Cl*. Write equation to illustrate the reaction that occurred.

You may use the empirical formula determined in **(b)(ii)** to write the equation. [3]

Charge density of Al^{3+} α 3/ 0.050 = 60.0

Charge density of Na^{+} α 1/ 0.095 = 10.5 **both correct [1]**

Al^{3+} has high charge density. Hence it hydrolyses in water to form acidic solution. **[1]**

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

$$Al(H_2O)_6]^{3+}(aq) \rightleftharpoons [Al(H_2O)_5OH]^{2+}(aq) + H^+(aq) \quad \textbf{[1]}$$

(c) $LiAlH_4$ is a reducing agent used commonly in organic synthesis. It reacts vigorously with water to produce H_2, LiOH and an amphoteric hydroxide. Hence $LiAlH_4$ must be stored under dry condition and its reaction must be carried out in anhydrous organic solvents such as diethyl ether, $CH_3CH_2OCH_2CH_3$.

(i) Write a balanced equation for the reaction between $LiAlH_4$ and water. [1]

$LiAlH_4 + 4H_2O \rightarrow 2H_2 + LiOH + Al(OH)_3$ **[1]**

(ii) The above reaction produced an amphoteric hydroxide.

Write two equations to show that it is amphoteric [2]

$Al(OH)_3 + OH^- \rightarrow Al(OH)_4^-$ **[1]**

$Al(OH)_3 + 3H^+ \rightarrow Al^{3+} + 3H_2O$ **[1]**

(d) CH_3CHO CH_3CO_2H $CH_2{=}CHOH$

From the above compounds, identify the compounds that can be reduced by $LiAlH_4$ to form ethanol.

CH_3CHO CH_3CO_2H **both correct [1]** [1]

7. (e) Reactions involved $LiAlH_4$ are carried out in anhydrous organic solvents such as diethyl ether, $CH_3CH_2OCH_2CH_3$.

Diethyl ether can be prepared from ethanol in two steps as shown below.

$$CH_3CH_2OH \xrightarrow[\text{Step 1}]{\text{Na}} \mathbf{W} \xrightarrow[\text{Step 2}]{} CH_3CH_2OCH_2CH_3$$

(i) State the type of reaction that occurred in Step 1. [1]

Redox reaction [1]

(ii) Draw the displayed formula of **W**. [1]

$CH_3CH_2O^-Na^+$ in displayed formula [1]

(iii) Given that **W** acts as a nucleophile in Step 2, draw the structural formula of the organic reactant required in Step 2. [1]

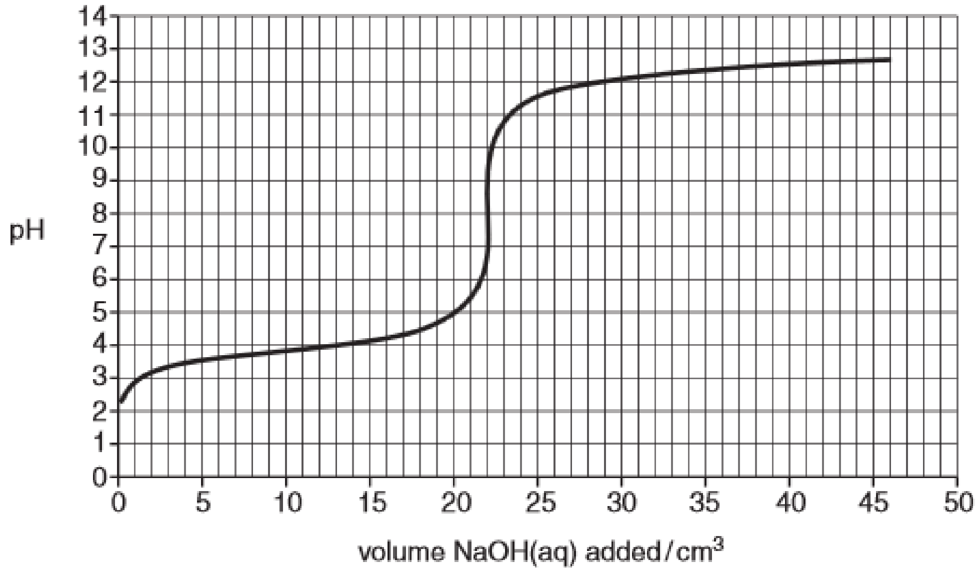
CH_3CH_2Br or any ethyl halide [1]

[Total: 20]

8. **(a)** Compound **R** is a weak monobasic acid.

A student dissolved 2.29 g of **R** in 250 cm^3 of deionised water and pipetted 25.0 cm^3 of this solution into a conical flask. He 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.

The pH curve obtained by the student is shown below.



(i) Using the data provided below, choose the most suitable indicator for the above titration. State the colour change of the solution at endpoint.

Indicator	pH at which colour changes	Acid colour	Base colour
Tetrabromophenol blue	3 – 5	yellow	blue
Methyl red	5 – 6	yellow	red
phenolphthalein	8 – 10	colourless	red

[2]

phenolphthalein [1]

colourless to PALE pink [1]

(ii) Use the titration curve above to calculate the amount of NaOH required to completely neutralise 25.0 cm^3 of solution **R**. [1]

Vol of NaOH needed to completely neutralise R = 22 cm^3

Amount of NaOH needed to completely neutralise R

= 22/1000 × 0.100 = **2.20×10^{-3} mol** **[1]**

(iii) Hence, calculate the M_r of **R**. [2]

Amount of **R** present in 250 cm^3 = **2.20×10^{-2} mol** **[1] ecf from (ii)**

M_r of R = 2.29 ÷ 2.20 × 10^{-2} = **104** **[1] ecf from (ii)**

(b) Three monobasic weak acids are shown below.

S	**T**	**U**
$CH_3CH{=}CHCO_2H$	$CH_3CH(OH)CH(OH)CO_2H$	$CH_3CH(OH)CH_2CO_2H$

It is possible to convert **S**, **T** or **U** into one another **in a single step.**

State the reagents and conditions that would be used for the following conversions.

(i) **S** into **T** [1]

Cold alkaline/acidic/dilute $KMnO_4$ **[1]**

(ii) **S** into **U** [1]

H_2O(g), H_3PO_4 catalyst, 300°C, 65 atm **[1]**

(iii) **U** into **S** [1]

Excess conc H_2SO_4, heat **[1]**

(c) State the type of reaction that occur in the following conversion.

(i) **S** into **U** [1]

Electrophilic addition **[1]**

(ii) **U** into **S** [1]

Elimination **[1]**

(d) **(i)** The acid **S** shows cis-trans isomerism. Draw diagrams to illustrate this type of isomerism, labelling each isomer clearly. [2]

[1] for each correct structure and label

(ii) Draw the skeletal formula of the organic product formed when acid **S** reacts with H_2 in the presence of Pt. [1]

$CH_3CH_2CH_2CO_2H$ in skeletal formula **[1]**

(iii) With the aid of an equation, explain why **S** is miscible with water. [2]

[1] for diagram to show hydrogen bonding btw S and H_2O

S is soluble in water because it can form hydrogen bonding with water molecules. [1]

(e) **(i)** Acid **T** reacts with dry PCl_5. Draw the structural formula of the organic product formed. [1]

$CH_3CH(Cl)CH(Cl)COCl$ **[1]**

(ii) Explain, with the aid of an equation, why the reaction must be carried out using **dry** PCl_5. [1]

With limited water: **$PCl_5(s) + H_2O(l) \rightarrow POCl_3(l) + 2HCl(g)$** **[1]**

Compare with the equations below:
With excess hot water: $PCl_5(s) + 4H_2O(l) \rightarrow H_3PO_4(aq) + 5HCl(aq)$
With excess cold water: $PCl_5(s) + H_2O(l) \rightarrow POCl_3(aq) + 2HCl(aq)$

(f) When **U** is heated with ethanoic acid and a small amount of concentrated sulfuric acid, an organic product, $C_6H_{10}O_4$, is obtained.

(i) State the type of reaction that occurred. [1]

Condensation **[1]**

(ii) Write a balanced equation for this reaction. Include the structural formula of the organic product in the equation. [2]

$CH_3CH(OH)CH_2CO_2H + CH_3COOH$

$= CH_3CH(OCOCH_3)CH_2CO_2H + H_2O$ **[1] eqn**

[1] structure of product

[Total: 20]

9. Oxygen-containing compounds, both organic and inorganic, are essential to our life.

(a) One example is the phosphate buffer system that operates in biological cells. The buffer contains dihydrogen phosphate, $H_2PO_4^-$, which acts as a weak acid.

(i) Write an equation to show that $H_2PO_4^-$ is a weak Bronsted acid. [1]

$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$ **[1]**

(ii) Explain the term *buffer* solution and write **two** equations to show how a solution containing $H_2PO_4^-$ and HPO_4^{2-} function as a buffer. [3]

A buffer is a solution that **resists pH changes when a small amount of acid or alkali is added.** **[1]**

$H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_2O$ **[1]**

$HPO_4^{2-} + H^+ \rightarrow H_2PO_4^-$ **[1]**

(iii) The pH in many living cells is 7.40.

Given that the K_a of $H_2PO_4^-$ is 6.31×10^{-8} mol dm^{-3}, calculate the value of $[HPO_4^{2-}]/[H_2PO_4^-]$ needed to give a pH of 7.40 in the cells. [2]

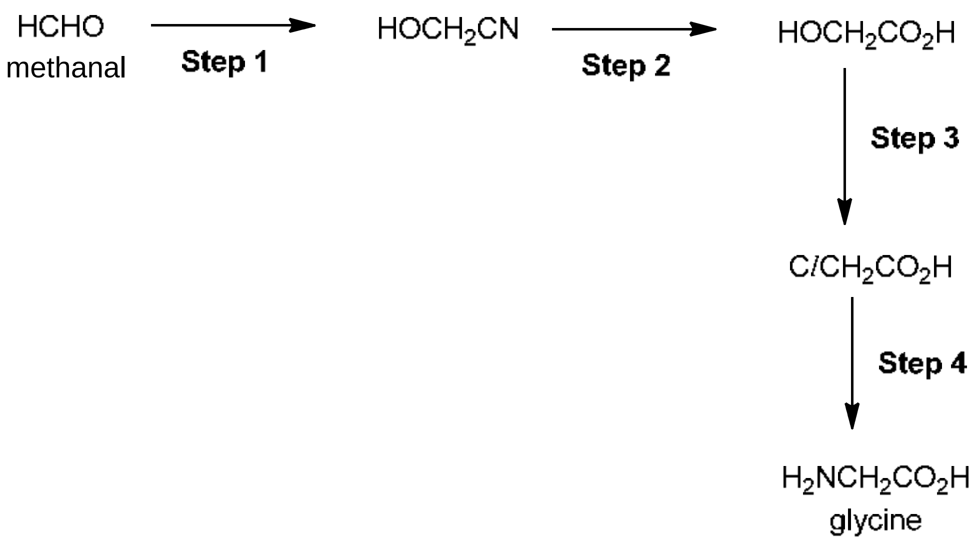
$[H^+] = 3.98 \times 10^{-8}$ mol dm^{-3} **[1]**

$[HPO_4^{2-}]/[H_2PO_4^-] = K_a/[H^+] = 6.31 \times 10^{-8} \div 3.98 \times 10^{-8} =$ **1.59** **[1]**

(b) The α-amino acids $RCH(NH_2)COOH$ are essential building blocks for proteins in our body.

The simplest α-amino acids is glycine, H_2NCH_2COOH.

One student proposed the following reaction scheme to synthesis glycine from methanal.



(i) What is the state of hybridisation of the C atom in methanal? [1]

sp^2 **[1]**

(ii) Describe the bonding in methanal in terms of orbital overlap. Draw diagram to illustrate your answer.

[2]

σ bond formed by head-on overlap of orbitals

π bond formed by side-way overlap of p orbitals **[1]**

Diagram [1]

(iii) For each step, state the reagents and conditions required. [4]

Step 1: **HCN, trace amount of NaCN** **[1]**

Step 2: **dilute H_2SO_4 or HC*l*(aq), heat** under reflux **[1]**

Step 3: **HC*l*, ZnC*l*$_2$ catalyst, heat** **[1]**

Step 4: **excess NH_3, ethanol, heat in sealed tube** **[1]**

(iv) Give a reason to explain why **Step 4** gives a poor yield of glycine. [1]

Glycine may act as nucleophile and react with $ClCH_2COOH$, giving secondary amine, tertiary amine and even quarternary ammonium salt.

Or NH_3, being a base, will react with glycine to form $NH_2CH_2COO^-NH_4^+$

[1]

9. **(c)** Compound **X** has the molecular formula $C_7H_{14}O$. **X** decolourises brown Br_2(aq).

Treating **X** with hot concentrated acidified $KMnO_4$(aq) produces two compounds **Y**, C_4H_8O, and **Z**, $C_3H_4O_3$.

Both **Y** and **Z** forms an orange precipitate with 2,4-dinitrophenylhydrazine and a yellow precipitate with alkaline aqueous iodine.

Z fizzes when added to aqueous sodium carbonate.

Deduce the structures of **X**, **Y** and **Z**. Include in your answers, the type of reaction that occurred and the functional groups deduced. [6]

Test	Functional group deduced	Type of reaction
X decolourises brown Br_2(aq).	**X** is an alkene ✓	Electrophilic addition ✓
X + $KMnO_4$(aq) produces **Y**, C_4H_8O, and **Z**, $C_3H_4O_3$.	Y is ketone Z has –COOH group	Oxidation ✓
Y and **Z** forms an orange precipitate with 2,4-DNPH	**Y** is ketone ✓ **Z** has ketone group (cannot be aldehyde bcos Z is a product of oxidation) ✓	Condensation ✓
Y and **Z** forms yellow precipitate with alkaline aqueous iodine	Y and Z has CH_3CO- group ✓	Iodoform test ✓
Z fizzes when added to aqueous sodium carbonate	Z has –COOH group ✓	Acid-carbonate reaction ✓

10 ✓ : [4] 9-7 ✓ :[3] 6-4✓ : [2] 3-2✓ :[1]

Z: CH_3COCO_2H [1]

Y: $CH_3COCH_2CH_3$ [1]

X: $CH_3(CH_2OH)C=C(CH_3)CH_2CH_3$ [1]

Total [21] max [20]

[Total: 20]

Class	Reg Number

Candidate's Name: ______________________________

MERIDIAN JUNIOR COLLEGE
JC 2 Preliminary Examination
Higher 1

Chemistry **8872/01**

22 September 2017

Paper 1 Multiple Choice

50 minutes

Additional Materials: OMR Sheet and *Data Booklet*

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 section. 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.

Section A

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 relative abundances of the isotopes of a sample of zirconium are shown in the table below.

relative isotopic mass	90	91	92	94	96
relative abundance (%)	51.3	11.3	17.2	17.4	2.8

What is the relative atomic mass of zirconium in this sample?

A 91.21

B 91.22

C 91.31

D 91.32

2 Hydrocarbon **E** consists of ~~84.3~~ 85.7% carbon. What could hydrocarbon **E** be?

A hexane

B hexene

C cyclohexene

D benzene

3 When 7.5 x 10^{-3} mole of gaseous chlorine at room temperature and pressure is reacted with 50 cm^3 hot excess aqueous sodium hydroxide, the following reaction occurs.

$$3Cl_2\,(g) + 6OH^-\,(aq) \rightarrow 5Cl^-\,(aq) + ClO_3^-\,(aq) + 3H_2O\,(l)$$

The resulting solution is diluted to 250 cm^3. It was found that 25.0 cm^3 of this resulting solution required 21.00 cm^3 of 0.10 mol dm^{-3} aqueous hydrochloric acid for complete reaction.

What is the initial concentration of the hot aqueous sodium hydroxide used?

A 0.12 mol dm^{-3}

B 0.36 mol dm^{-3}

C 0.57 mol dm^{-3}

D 0.72 mol dm^{-3}

4 Ions of vanadium with different oxidation states can exhibit various colours as shown in the following table.

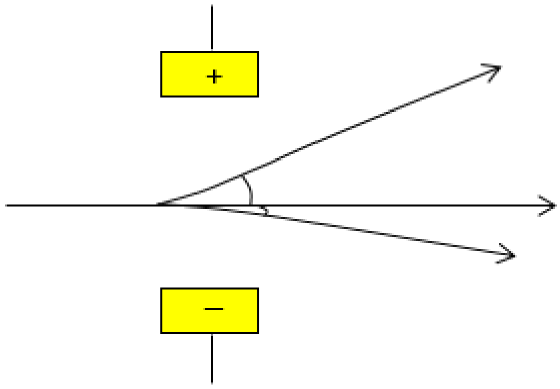
Ions	V^{2+}	V^{3+}	VO^{2+}	VO_2^+	VO_3^-
Colours	violet	green	blue	yellow	yellow

A sample of 0.015 mole of zinc powder reacts exactly with 0.010 mole ammonium vanadate(V), NH_4VO_3.

What is the final colour seen for the solution?

A violet **B** green **C** blue **D** yellow

5 A beam of particles containing $^{27}Al^{2+}$, ^{35}Cl atoms and $^{35}Cl^{3-}$ was passed through an electric field. The angle of deflection for $^{35}Cl^{3-}$ is 4.5˚.



Which of the following statements is correct?

A Both ^{35}Cl atoms and $^{35}Cl^{3-}$ ions will deflect towards the positive terminal.

B The ^{35}Cl atoms will deflect towards both the positive and negative terminals.

C The $^{27}Al^{2+}$ ions have an angle of deflection of 3.9˚.

D The $^{27}Al^{2+}$ ions will have a larger angle of deflection than $^{35}Cl^{3-}$ ions.

6 Which of the following statements is true for Cr^+?

A There are a total of six p orbitals being occupied.

B There are a total of three d orbitals being occupied.

C There are a total of four s subshells being occupied.

D There are a total of seven s, p and d subshells being occupied.

7 Four substances **F**, **G, H** and **I** have physical properties as shown.

substance	melting point/ °C	boiling point/ °C	electrical conductivity	
			of solid	of liquid
F	17	45	Poor	Poor
G	64	759	Good	Good
H	1132	1950	Poor	Good
I	3550	3825	Good	Unknown

What could be the identities of **F**, **G**, **H** and **I**?

	F	**G**	**H**	**I**
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)

8 Which pair of compounds below satisfy the following conditions?

- The first compound has a larger bond angle than the second compound.
- The first compound is more polar than the second compound.

	first compound	second compound
A	NF_3	SF_6
B	$AlCl_3$	PCl_3
C	CO_2	SO_2
D	ICl_5	PCl_5

9 The enthalpy changes for two reactions are given below.

$$2Cr\,(s) + \frac{3}{2}O_2\,(g) \rightarrow Cr_2O_3\,(s) \qquad \Delta H_f = -1120 \text{ kJ mol}^{-1}$$

$$C\,(s) + \frac{1}{2}O_2\,(g) \rightarrow CO\,(g) \qquad \Delta H_f = -110 \text{ kJ mol}^{-1}$$

What is the quantity of heat absorbed when 19.2 moles of chromium is obtained from the reduction of chromium(III) oxide using excess carbon?

$$3C\,(s) + Cr_2O_3\,(s) \rightarrow 2Cr\,(s) + 3CO\,(g)$$

A 82 kJ

B 7 580 kJ

C 15 200 kJ

D 22 800 kJ

10 In aqueous solution, dichromate (VI) ions exist in equilibrium with chromate (VI) ions.

$$\underset{\text{orange}}{Cr_2O_7^{2-}\,(aq)} + H_2O\,(l) \rightleftharpoons \underset{\text{yellow}}{2CrO_4^{2-}\,(aq)} + 2H^+\,(aq) \qquad \Delta H > 0$$

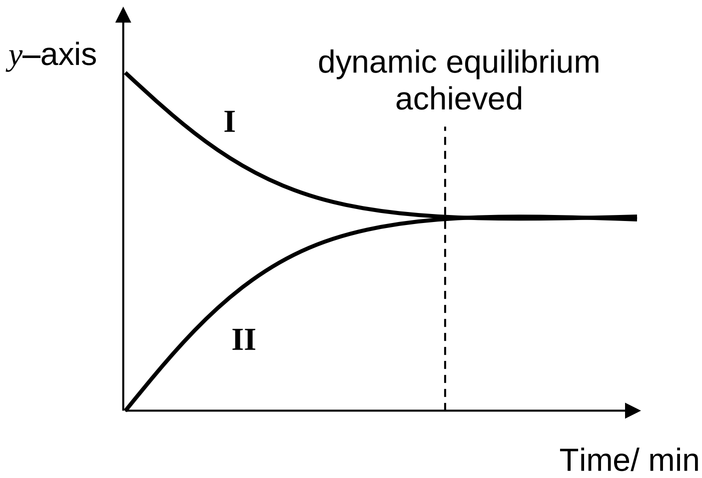
What is the colour of the solution under the following conditions?

	high temperature	high pH
A	yellow	orange
B	yellow	yellow
C	orange	yellow
D	orange	orange

11 At 250 °C, NOC*l* readily dissociates into NO and C*l*$_2$.

$$2\ NOCl\,(g) \rightleftharpoons 2\ NO\,(g) + Cl_2\,(g)$$

The following plot is obtained during the dissociation of NOC*l*.



Which of the following best describes the *y*–axis and the labels **I** and **II**?

	y–axis	**I**	**II**
A	concentration	[NOC*l*]	[NOC*l*] + [C*l*$_2$]
B	concentration	[NOC*l*] + [C*l*$_2$]	[NOC*l*]
C	rate	rate of forward reaction	rate of backward reaction
D	rate	rate of backward reaction	rate of forward reaction

12 The reaction between concentrated sulfuric acid and concentrated nitric acid occurs in the following steps.

$$H_2SO_4 + HNO_3 \rightleftharpoons HSO_4^- + H_2NO_3^+$$
$$H_2NO_3^+ \rightleftharpoons H_2O + NO_2^+$$
$$H_2O + H_2SO_4 \rightleftharpoons HSO_4^- + H_3O^+$$

Which of the following species is a conjugate acid in these reactions?

A $H_2NO_3^+$

B HSO_4^-

C NO_2^+

D H_2O

13 Some data on two acid–base indicators are shown in the table below:

Indicator	Approximate working range	Colour in	
		Acid	Alkali
methyl orange	3.2 – 4.4	red	yellow
cresol red	7.5 – 8.8	yellow	purple

Which one of the following conclusions can be drawn about a solution in which both methyl orange and cresol red is yellow?

A It is weakly acidic.

B It is weakly basic.

C It is neutral.

D No conclusion can be drawn.

14 Elements **X** and **Y** react vigorously with chlorine to form compounds **P** and **Q** respectively. Element **Z** reacts slowly with chlorine to form compound **R**.

When dissolved in water, **P** gives a neutral solution while **R** gives a strongly acidic solution. **Q** reacts with a few drops of water to give off white fumes and a white solid.

Given that elements **X**, **Y** and **Z** are Period 3 elements, what are the possible identities for **X**, **Y** and **Z**?

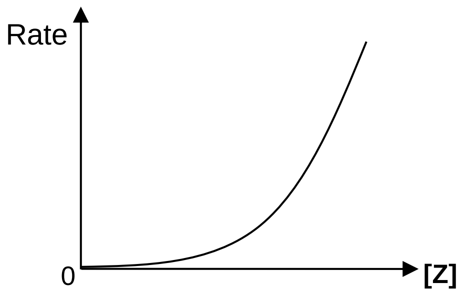
	X	**Y**	**Z**
A	Na	A*l*	P
B	Na	Si	P
C	Mg	A*l*	P
D	Mg	Si	A*l*

15 The rate equation for the following reaction is rate = k[**Y**]^2[**Z**].

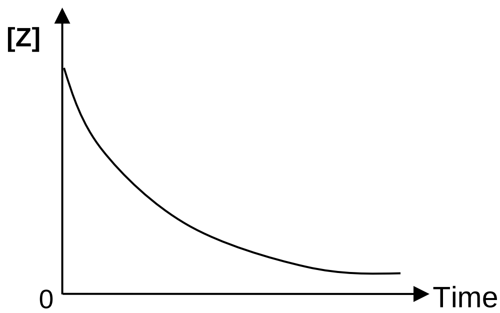
$$\mathbf{X}(aq) + 2\mathbf{Y}(aq) + \mathbf{Z}(aq) \rightarrow 2\mathbf{W}(aq) + \mathbf{U}(aq)$$

Which of the following graphs is correct when **Y** is in large excess?

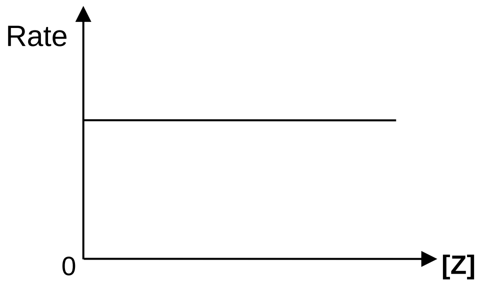
A



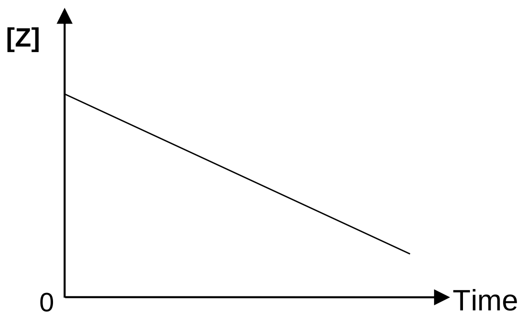
B



C



D



16 **L** and **M** are Period 3 elements. **M** has a larger atomic number than **L**.

The number of moles of chlorine that react with 1 mole of **M** is twice the number of moles of chlorine that react with 1 mole of **L**.

L burns vigorously in oxygen with a bright white flame.

Which of the following statement is **incorrect**?

A **M** is a solid at room temperature which is a poor conductor of electricity.

B Oxide of **M** is insoluble in water.

C **L** can form a basic oxide.

D **L** is in Group 13.

17 Which property generally decreases from sodium to aluminum?

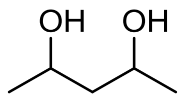
A Electrical conductivity

B Electronegativity

C Ionic radius

D First ionisation energy

18 Compound **X** reacts with two moles of H_2O (g) according to the following reaction:

Compound **X** + $2H_2O$ $\longrightarrow$ 

Given that there are no adjacent carbon–carbon double bonds in **X**, what is the total number of cis–trans isomers that **X** can exhibit?

A 1 **B** 2 **C** 3 **D** 4

19 At gas stations, there are 4 different grades of gasoline for choice. The grade of the gasoline is dependent on the percentage by mass of octane (e.g. Grade 92 indicates 92% by mass of octane).

It was determined that 1 kg of a certain grade of gasoline requires 2.58 m^3 of oxygen for complete combustion at room temperature and pressure according to the following equation.

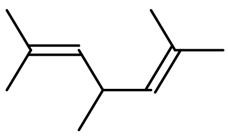
$$C_8H_{18} + \frac{25}{2}O_2 \rightarrow 8\ CO_2 + 9\ H_2O$$

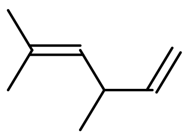
What is the grade of this particular gasoline?

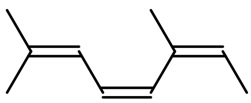
A 90 **B** 92 **C** 95 **D** 98

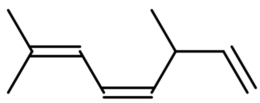
20 Hydrocarbon **W** produces ~~carbon dioxide,~~ CH_3COCH_3 and $CH_3CH(CO_2H)_2$ as the only organic products on heating with an excess of hot concentrated acidic $KMnO_4$.

Which of the following **cannot** be **W**?

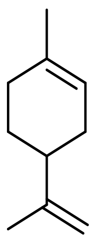
A 

B 

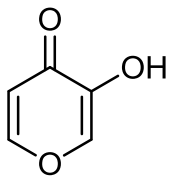
C 

D 

21 *Limonene* and *maltol* are some flavouring agents commonly used in food products.



limonene



maltol

Which of the following reagents, when added separately to the two compounds, would enable them to be distinguished from one another, assuming that the ether group, R–O–R, is unreactive?

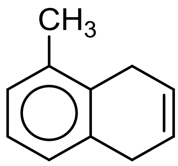
A hot acidified $KMnO_4$

B cold alkaline $KMnO_4$

C hot acidified $K_2Cr_2O_7$

D aqueous Br_2

22 Compound **Z** has the following structure as shown.



compound **Z**

Z undergoes both substitution and addition reactions with excess bromine in the presence of iron.

Which of the following statements is **false** about compound **Z**?

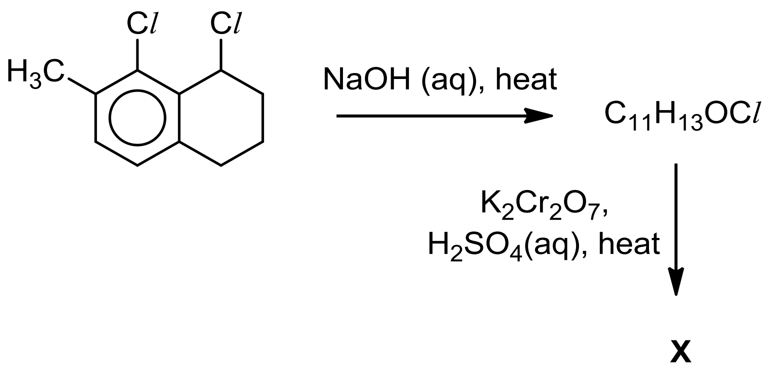
A All carbon atoms lie on the same plane.

B The π–bonding electrons are localised between two carbon atoms in the alkene.

C The π–electrons of benzene ring are delocalised throughout the ring, which makes the benzene ring very stable.

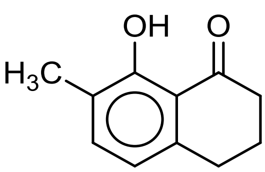
D Benzene would undergo substitution but not addition reaction to preserve the stable aromatic benzene ring structure.

23 The reaction scheme below shows the synthesis of compound **X**.

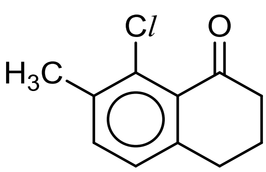


Which of the following shows the structural formula of **X**?

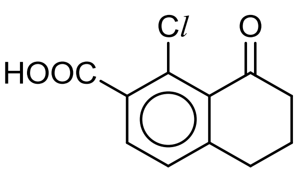
A



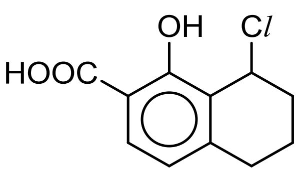
B



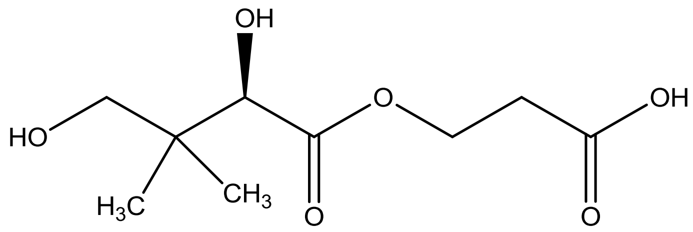
C



D



24 Vitamin B5 has the following structure.



Which of the following statement is correct?

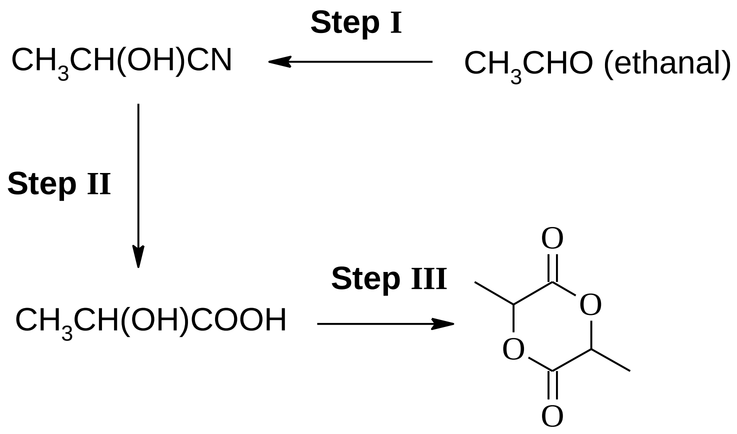
A One mole of Vitamin B5 reacts with three moles of Na.

B One mole of Vitamin B5 reacts with three moles of cold KOH (aq).

C One mole of Vitamin B5 after heating with HC*l* (aq), reacts with two moles of Na_2CO_3.

D One mole of Vitamin B5 reacts with two moles of 2,4–DNPH.

25 Ethanal, CH_3CHO, undergoes the reactions in the following reaction scheme.



Which are the types of reaction for steps **I, II** and **III**?

	Step I	Step II	Step III
A	addition	hydrolysis	addition
B	addition	hydrolysis	substitution
C	reduction	acidification	addition
D	reduction	acidification	substitution

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to place a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 What factors contribute to the lattice energy of $MgCl_2$ being numerically greater than that of NaBr?

1 The radius of the chloride ion is smaller than that of the bromide ion.

2 The charge on the magnesium ion is greater than that on the sodium ion.

3 Chlorine is more electronegative than bromine.

27 $AlCl_3$ dimerises to form Al_2Cl_6.

Which statements about Al_2Cl_6 are correct?

1 It is an ionic compound.

2 It contains coordinate (dative) bonding between the A*l* and C*l* atom.

3 The bonds around A*l* atoms are tetrahedrally arranged.

28 Which of the following reactions have only one pi–bond broken in the organic reactant?

1 Reaction of propanone with hot alkaline I_2.

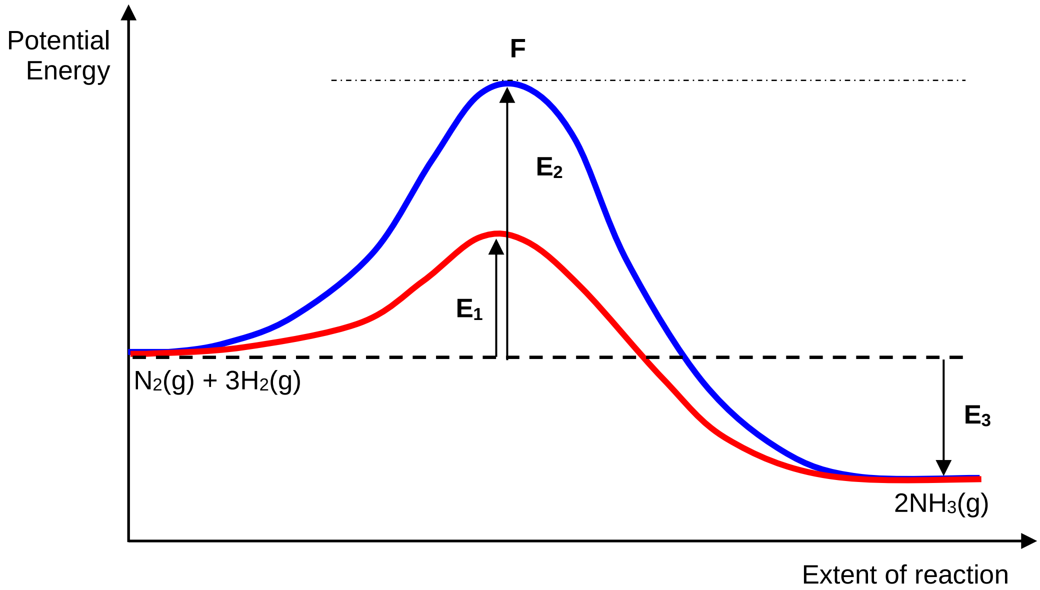
2 Reaction of propene with cold, alkaline $KMnO_4$.

3 Reaction of propanal with HCN with trace NaCN.

29 The diagram below illustrates the energy profile diagram for the Haber Process in the presence of iron catalyst.

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

Which of the following statements are true about the energy profile diagram below?



1 **E_1** corresponds to the activation energy of the reaction pathway of the catalysed reaction.

2 The reaction is exothermic.

3 **F** is the intermediate formed.

30 Compound **R** undergoes the following reaction scheme.

$$\mathbf{R} \xrightarrow{\text{ethanolic KOH}} C_5H_{10} \xrightarrow{KMnO_4/H_2SO_4} CH_3COCH_2CH_3 + CO_2$$

Which reagents can be used in a chemical test to confirm that all reactants and intermediates have been converted to products?

1 2,4–DNPH

2 aqueous NaOH with $AgNO_3$

3 aqueous Br_2

End of Paper 1

Paper 1 Answers

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

Section A

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

1 Vitamins and minerals are essential nutrients that perform many roles in the body. They help to build bones, heal wounds, bolster the immune system and convert food into energy. Young children require many essential minerals such as calcium, magnesium, iodine, iron and zinc to develop and grow.

Table 1.1 shows the recommended daily intake of some essential minerals for children.

Table 1.1

mineral	recommended daily intake for children / mg	
	age group	
	1 – 3 years	4 – 8 years
Calcium	500	700
Iodine	0.090	0.090
Iron	9	10
Magnesium	80	130
Phosphorus	460	500
Zinc	3	4

Table 1.2 shows part of a nutrition label on a tin of powdered milk formula.

Table 1.2

Nutrition Information Standard Dilution (per 100 mL)	
Nutrients:	
Protein	2.2 g
Fat	5.1 g
Carbohydrate	11.2 g
Minerals:	
Sodium	39 mg
Potassium	106 mg
Chloride	79 mg
Calcium	119 mg
Phosphorus	69 mg
Magnesium	7.8 mg
Iron	1.03 mg
Zinc	0.7 mg
Copper	0.056 mg
Manganese	0.0094 mg
Iodine	0.011 mg

(a) Zinc helps the immune system to fight off invading bacteria and viruses.

A 2–year old child takes an average of 3 feeds of milk formula per day, with a quantity of 180 mL per feed.

Using the information provided, determine if the zinc obtained from the milk formula meets the recommended quantity for daily intake and comment if there is a need for the child to supplement his diet with zinc from other sources.

[2]

Many of the minerals in formula milk are compounds of the elements found in the Periodic Table.

(b) **L** and **M** are unknown elements of increasing atomic number in Period 3 of the Periodic Table. Each of these elements has an atomic number below 20.

(i) The successive ionisation energies, in kJ mol^{-1}, of element **L** are given below.

494 4560 6940 9540

Deduce which Group element **L** belongs to.

[2]

(ii) Hence, write the full electronic configuration of element **L** in its ground state.

[1]

(iii) The oxide of **M** dissolves partially in water to give an alkaline solution while its chloride readily dissolves in water to give a slightly acidic solution.

1. Identify element **M**.

[1]

2. State the pH of the resultant solution when the oxide and chloride of **M** are added to water separately. Write appropriate equations to support your answer.

[3]

	equations for reaction with water	pH of resultant solution
oxide of **M**		
chloride of **M**		

(c) Aluminium and sulfur are elements in Period 3.

(i) Their oxides show different behaviours in acids and bases.

With the aid of appropriate equations, describe the acid–base nature of Al_2O_3 and SO_3.

[3]

(ii) State and explain the difference in the *first* ionisation energy between aluminium and sulfur.

[2]

[Total: 14]

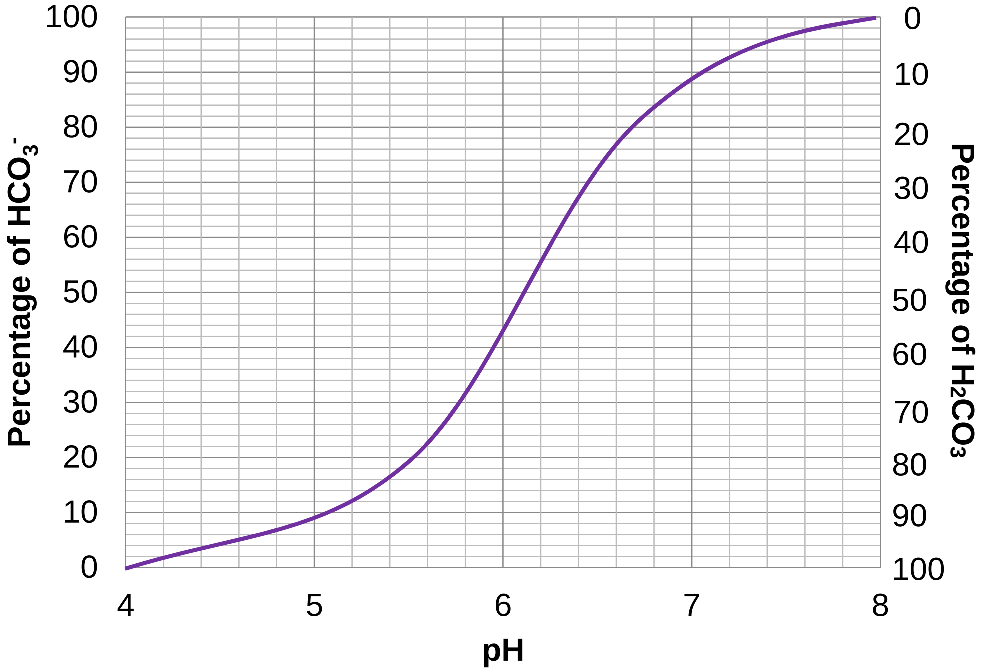
2 Many of the chemical reactions that occur in living systems are extremely sensitive to changes in pH. As a result, the human body maintains a remarkably intricate system of buffers, both within tissue cells and in the fluids that transport blood cells.

The buffer system that is used to control the pH of blood is the carbonic acid–hydrogen carbonate buffer system in the blood plasma.

$$HCO_3^- + H^+ \rightleftharpoons H_2CO_3$$

(a) **Graph 2.1** shows how the percentage of carbonic acid and hydrogen carbonate in blood plasma responds to changes in pH.

Graph 2.1



(i) Using information from the graph above, calculate the ratio of $\frac{[HCO_3^-]}{[H_2CO_3]}$ in the blood plasma for the body to function properly at a pH of 7.4.

[1]

(ii) Explain with the aid of equations, how the buffer system in blood plasma helps to control pH.

[3]

(b) Plasma contains mostly water, which accounts for 91.5% of the plasma content. Salts such as sodium, potassium, and hydrogen carbonate which are soluble in plasma can perform many important biological processes.

(i) Draw the dot–and–cross diagram for HCO_3^-.

[1]

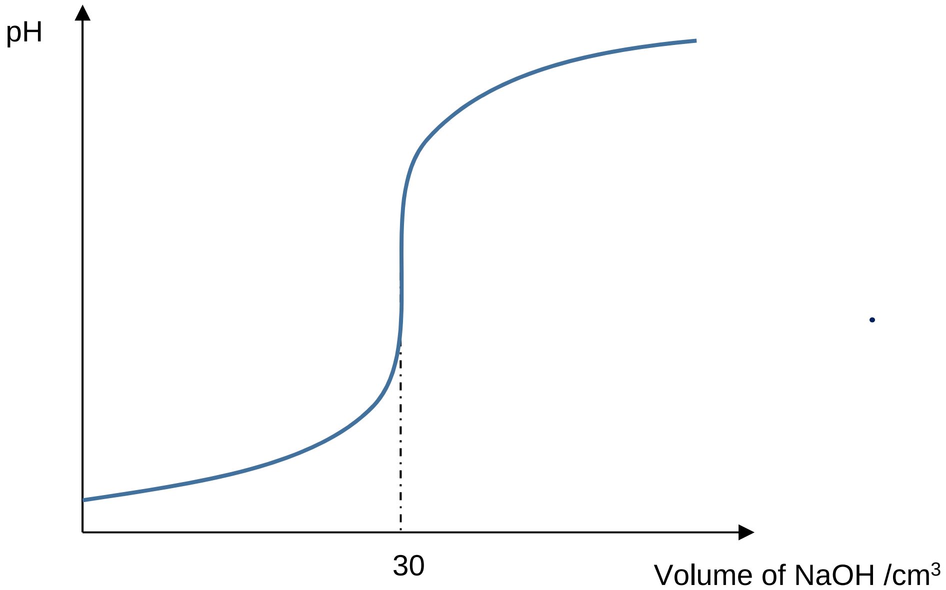
(ii) Explain why HCO_3^- is soluble in plasma. Support your answer using a labelled sketch of the interactions present.

[2]

(c) Both sulfuric acid, H_2SO_4, and carbonic acid, H_2CO_3, are dibasic acids which undergo neutralisation with sodium hydroxide.

(i) 25 cm^3 of sulfuric acid was titrated against 0.25 mol dm^{-3} sodium hydroxide. The change in pH during the titration is shown in **Graph 2.2**.

Graph 2.2



Calculate the initial pH of the sulfuric acid that is used in this experiment.

[2]

(ii) The pH of two separate samples of carbonic acid and sulfuric acid of identical concentrations are measured using a pH meter.

Explain why the sample of carbonic acid registers a higher pH value than that of sulfuric acid.

[2]

[Total: 11]

3 The Contact process is the current method of producing sulfuric acid in the industry. The key reaction in the process is as follows.

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)$$

When a 2:1 ratio of SO_2 and O_2 at a total initial amount of 3 moles is passed over V_2O_5 catalyst in a closed 5.00 dm^3 reaction chamber at 430 ^oC, 1.9 moles of SO_3 is formed at equilibrium.

(a) Calculate the concentrations of SO_2 and O_2 formed at equilibrium.

[2]

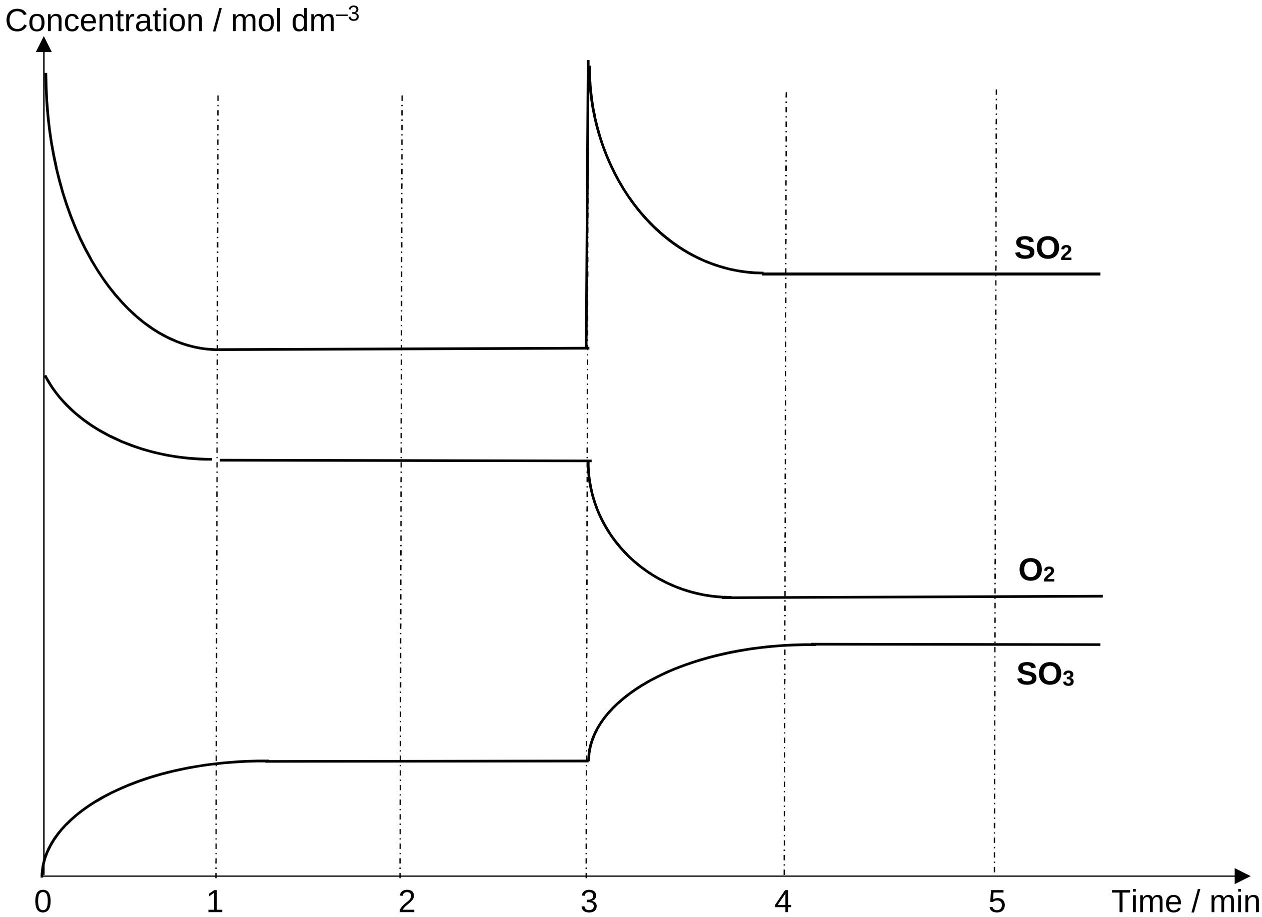
(b) Write an expression for the equilibrium constant, K_c' of the **reverse reaction** for the formation of SO_2 and O_2 at 430 ^oC. Calculate the value of K_c', stating its units.

[2]

(c) When a sample of SO_2 and O_2 were was in a closed vessel, the system was allowed to reach equilibrium.

The concentrations of all gases were measured at one minute intervals. At t = 3 min, one of the operating conditions was altered. The effects are shown graphically below.

Graph 3.1

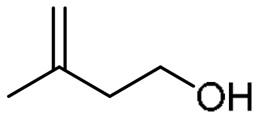


What change to the operating condition of the system has been made at t = 3 min? Account for the observed changes in the concentrations of the gases as a result of this change.

[3]

[Total: 7]

4(a) Ylang–ylang essential oil and lemongrass are often used as insect repellents. 3–methyl–3–buten–1–ol is a constituent of Ylang–ylang oil.



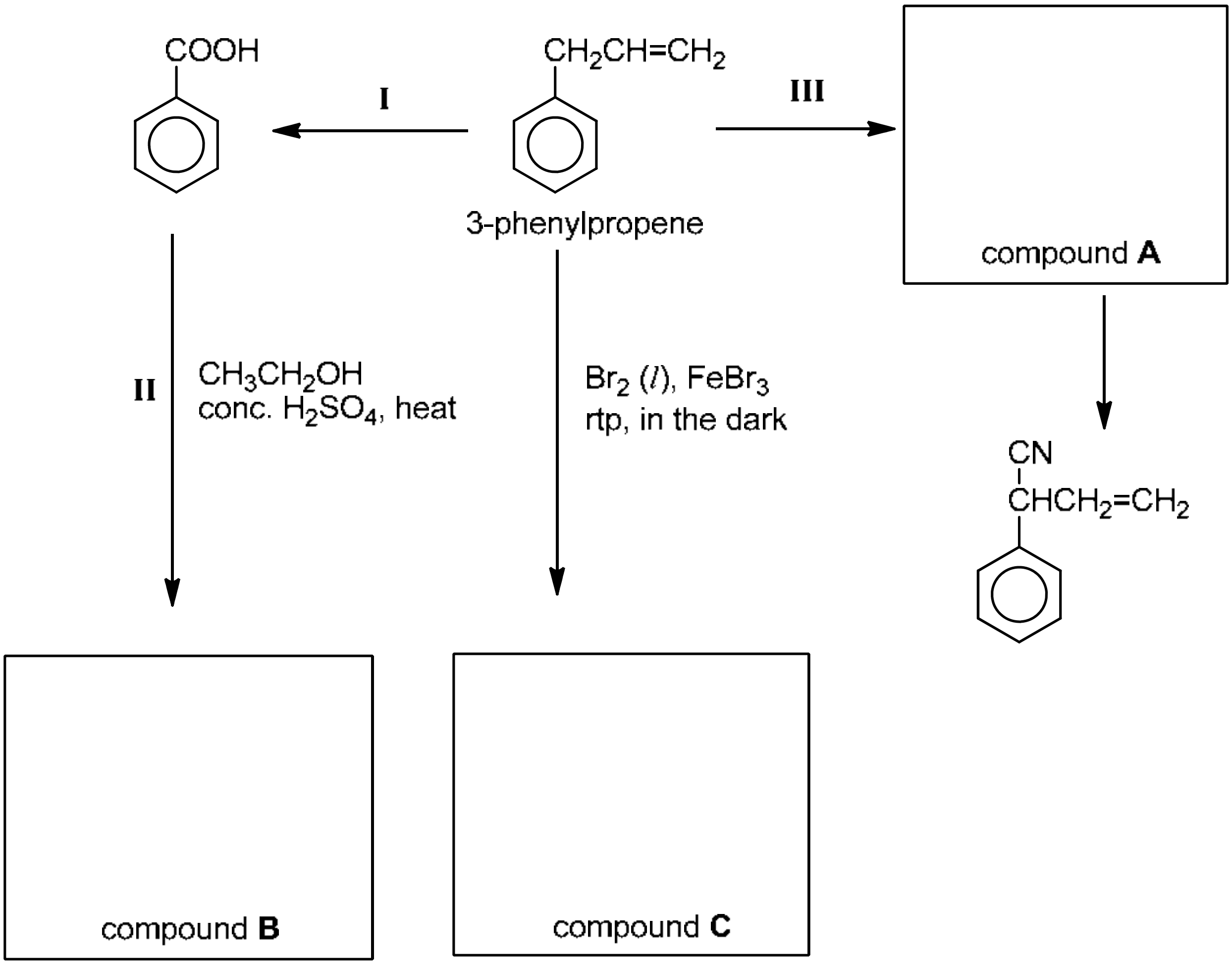
3–methyl–3–buten–1–ol

Draw the structure of the organic products formed when 3–methyl–3–buten–1–ol reacts with each of the following reagents.

reagents and conditions	organic product(s) formed
cold alkaline $KMnO_4$	
excess concentrated H_2SO_4, heat	

[2]

(b) Another ingredient that can be found in insecticides is 3–phenylpropene. It can be converted to various products as shown below.



(i) Draw the structures of compounds **A**, **B** and **C** in the boxes provided. [3]

(ii) State the reagents and conditions for the conversion in reactions **I** and **III.** [2]

Reaction **I**:

Reaction **III**:

(iii) Name the type of reaction for **II**. [1]

[Total: 8]

End of Section A

Section B: Free Response Questions

Answer two questions from this section on separate answer papers.

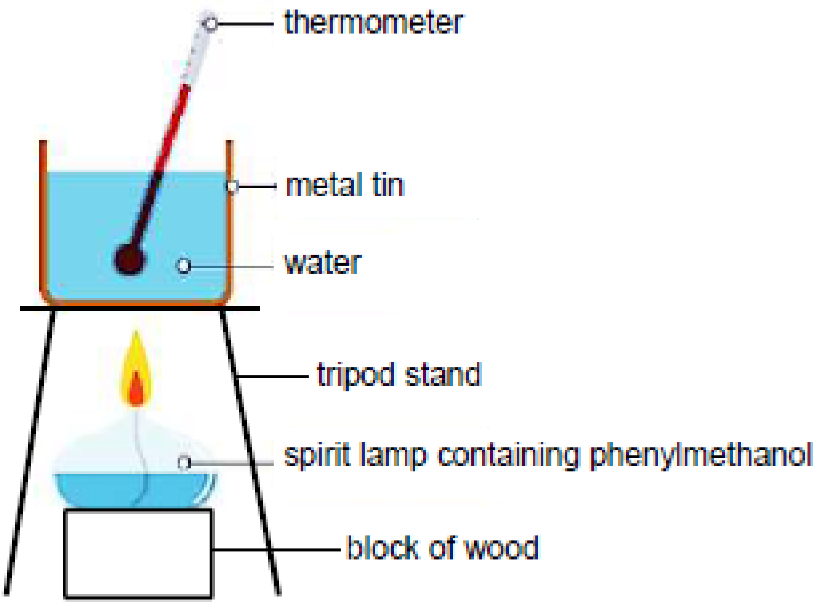
5 The *Cannizzaro* reaction which produces phenylmethanol and a benzoate salt is first discovered in 1853 by Stanislao Cannizzaro.

$$\underset{\text{benzaldehyde}}{2C_6H_5CHO} + KOH \rightarrow \underset{\text{phenylmethanol}}{C_6H_5CH_2OH} + \underset{\text{benzoate salt}}{C_6H_5CO_2K}$$

(a) In the *Cannizzaro* reaction, benzaldehyde is simultaneously reduced and oxidised when reacted with a strong base. Name the type of reaction taking place.

[1]

(b) A sample of phenylmethanol in a spirit lamp is used to heat 200 cm^3 of water in a metal tin.



The data for the experiment are as shown below.

mass of spirit lamp with phenylmethanol before heating	= 113.25 g
mass of spirit lamp with phenylmethanol after heating	= 112.22 g
temperature of water before heating	= 27.8 °C
temperature of water after heating	= 40.6 °C
molar mass of phenylmethanol	= 108 g mol^{-1}

(i) Define what is meant by *standard enthalpy change of combustion*.

[1]

(ii) Calculate the standard enthalpy change of combustion of phenylmethanol. The reaction is known to be only 30% efficient.

[2]

(iii) State one assumption you have made in your calculation.

[1]

(c) Another value for the enthalpy change of combustion of phenylmethanol can be calculated using the following energy cycle.

$$\begin{tikzcd}
C_6H_5CH_2OH(l) + \frac{17}{2}O_2(g) \arrow[r, "\Delta H_1"'] \arrow[d, "\Delta H_2"] & 7CO_2(g) + 4H_2O(l) \arrow[d, "\Delta H_3"] \\
C_6H_5CH_2OH(g) + \frac{17}{2}O_2(g) \arrow[r, "\Delta H_4"] & 7CO_2(g) + 4H_2O(g)
\end{tikzcd}$$

(i) Using relevant data from the *Data Booklet*, calculate a value for ΔH_4.

[3]

(ii) Enthalpy change of vapourisation, ΔH_{vap}, of a substance is the energy absorbed when one mole of the substance is vapourised from the liquid to the gaseous state. Using the following enthalpy changes of vapourisation, your answer in **(c)(i)** and the given energy cycle above, calculate the enthalpy change of combustion of phenylmethanol, ΔH_1.

[2]

$\Delta H_{vap}(C_6H_5CH_2OH) = +63\ kJ\ mol^{-1}$

$\Delta H_{vap}(H_2O) = +41\ kJ\ mol^{-1}$

(iii) Sketch a clearly labelled reaction pathway diagram for the combustion reaction of phenylmethanol.

[2]

(d) The two products of the *Cannizzaro* reaction, $C_6H_5CH_2OH$ and $C_6H_5CO_2K$, can be used for ester formation. The benzoate salt is first converted to benzoic acid before esterification takes place.

(i) The acid dissociation constant, K_a, of benzoic acid and phenylmethanol are given in **Table 5.1**.

Table 5.1

compound	acid dissociation constant, K_a / mol dm^{-3}
benzoic acid, $C_6H_5CO_2H$	6.3×10^{-5}
phenylmethanol, $C_6H_5CH_2OH$	4.0×10^{-16}

Explain the large difference in the K_a values between benzoic acid and phenylmethanol.

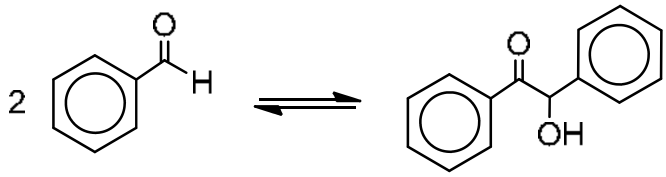
[3]

(ii) Isotope labelling is employed such that the oxygen atom in phenylmethanol is oxygen–18 (i.e. $C_6H_5CH_2{}^{18}OH$), while that in benzoic acid is oxygen–16.

Draw the structure of the organic product of the esterification reaction, labelling clearly the oxygen–18 in the product.

[1]

(e) Besides the *Cannizaro* reaction, another reaction involving benzaldehyde is the benzoin condensation shown below.



compound **J**

(i) Describe a simple chemical test to distinguish between the benzaldehyde and compound **J**.

[2]

(ii) The molecular formula of compound **J** is $C_{14}H_{12}O_2$. Compound **K** is an aromatic structural isomer of compound **J**. Compound **K** can exhibit cis–trans isomerism. Draw and label the isomers of compound **K**.

[2]

[Total: 20]

6 This question is about aldehydes, a class of organic compounds.

(a) The *Hydroformylation* reaction is an industrial process in which an alkene combines directly with carbon monoxide and hydrogen under high temperature and pressure to form an aldehyde. The reaction with ethene is shown below.

$$CH_2{=}CH_2 + CO + H_2 \xrightarrow{\text{catalyst}} CH_3CH_2CHO$$

A series of experiments is carried out to investigate the kinetics of the *Hydroformylation* reaction with ethene. The following results are obtained.

Table 6.1

experiment	$[CH_2{=}CH_2]$ / mol dm^{-3}	[CO] / mol dm^{-3}	$[H_2]$ / mol dm^{-3}	time / s
1	0.100	0.200	1.000	250
2	0.200	0.400	0.250	250
3	0.200	0.400	0.500	125

It is determined that the *order of reaction* with respect to carbon monoxide is 1.

(i) Explain the meaning of *order of reaction*.

[1]

(ii) What is the relationship between the time taken for the reaction and the initial rate of the reaction?

[1]

(iii) Using data from the table above, determine the order of reaction with respect to $CH_2{=}CH_2$ and H_2.

[3]

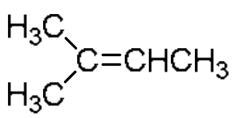
(iv) Hence, write the rate equation for the reaction.

[1]

(v) Explain quantitatively how the rate of reaction will change if the concentration of ethene is tripled while the concentration of carbon monoxide and hydrogen is each halved simultaneously.

[1]

(vi) Draw the structural formula of the product of the *Hydroformylation* reaction if the starting alkene used is 2–methylbut–2–ene instead.



[1]

(vii) The *Hydroformylation* reaction can be catalysed using platinum metal. Explain the catalytic effect on the rate of reaction with the aid of the Maxwell–Boltzmann distribution curve.

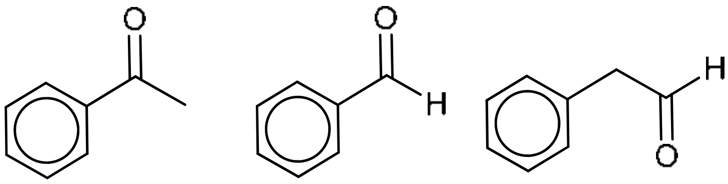
[3]

(b) Besides using the *Hydroformylation* reaction, propanal can be prepared from bromoethane, using propanoic acid as one of the intermediates.

Propose a reaction pathway, of **not more than 4 steps**, for this conversion. Your answer should include the reagents and conditions, as well as the structures of the intermediates formed.

[3]

(c) The labels of three test–tubes containing the individual compounds **P**, **Q** and **R** were mixed up.



compound **P** compound **Q** compound **R**

(i) Suggest how you can carry out two chemical tests to distinguish the three compounds. For each test, state the reagents, conditions and their observations.

[4]

(ii) One of the above three compounds reacts with $NaBH_4$ in ethanol to give compound **D**, C_7H_8O. Name the reaction and suggest the structure of compound **D**.

[1]

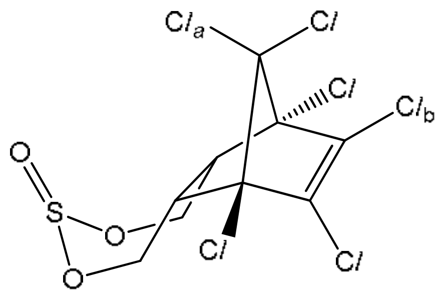
(iii) Compound **P** reacts with 2,4–DNPH to give an orange crystalline solid. Write the equation for this reaction.

[1]

[Total: 20]

7(a) *Endosulfan* is an off–patent organochlorine insecticide. It was recommended for use in India as a means of pest control against the *common lime caterpillar*, which has caused widespread damage to the agriculture in India. However, due to its threats to human health and the environment, a global ban on the manufacture and use of *endosulfan* was negotiated under the Stockholm Convention in April 2011**.**

The structure of *endosulfan* is shown below.



(i) *Endosulfan* has a solubility of 0.32 mg/L in water. However, it has a solubility of 2.40 mg/L in hexane.

Using structure and bonding, explain why *endosulfan* has a higher solubility in hexane but a lower solubility in water.

[3]

(ii) Predict and explain the bond angle and shape about the sulfur atom in *endosulfan*.

[5]

(iii) The reactivity of the organochlorine functional groups in *endosulfan* was investigated by treating separate samples of *endosulfan* with nitric acid, followed by silver nitrate solution. The results obtained were shown in **Table 7.1**.

Table 7.1

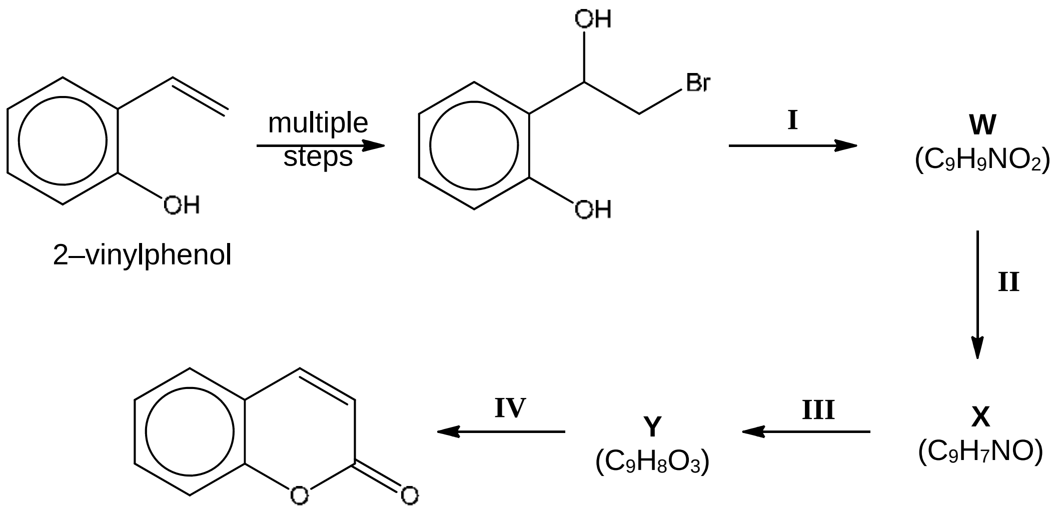
chlorine atom being reacted	time taken for white precipitate to form
Cl_a	≈ 1 hour
Cl_b	≈ 15 hours

Explain why the relative rate of formation of the white precipitate for Cl_b is much slower than Cl_a.

[2]

(b) *Cassia* is commonly used in traditional Chinese medicine.

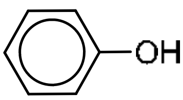
The organic compound **Z** shown below, is present in *cassia*, and may be toxic to humans if consumed in large amounts. Compound **Z** can be prepared using 2–vinylphenol as the starting material using the following synthetic scheme.



Z

(i) Chemical tests were conducted on compounds **X** and **Y**. It was found that compound **X** decolourises bromine water while effervescence was observed when solid sodium carbonate was added to compound **Y**.

Using the information given above, deduce the structural formula for compounds **W**, **X** and **Y** and explain the chemistry of the reaction involved.

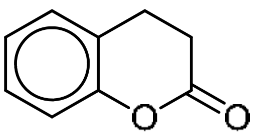
The phenol group,  may be considered to be unreactive from steps **I** to **III**.

[5]

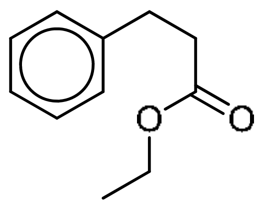
(ii) Hence, or otherwise, state the reagents and conditions needed for steps **I**, **II** and **III**.

[3]

(iii) Describe a chemical test that would allow you to distinguish between compounds **Z** and **A**, giving a positive result for compound **A**.



compound **Z**



compound **A**

[2]

[Total: 20]

End of Section B

MERIDIAN JUNIOR COLLEGE
JC 2 Preliminary Examination
H1 Chemistry Paper 2

1(a) Zn obtained from daily feed = 0.7 × (180/100) × 3 = 3.78 mg

It MEETS the recommended quantity for daily intake. There is no need for the child to supplement his / her diet with Zn from other sources.

(b) (i) Biggest increase is between 1st and 2nd ionization energy.

The 2nd electron is removed from the inner quantum shell.Hence, there is stronger electrostatic force of attraction between 2nd electron and nucleus.

Thus the element has 1 valence electron. The element belongs to Group 1

(ii) $1s^2 2s^2 2p^6 3s^1$

(iii) 1. Element M is Mg.
2.

	equations for reaction with water	pH of resultant solution
oxide of M	$MgO(s) + H_2O(\mathit{l}) \rightleftharpoons Mg(OH)_2(s)$	9
chloride of M	Hydration $MgCl_2(s) + 6H_2O(\mathit{l}) \rightarrow [Mg(H_2O)_6]^{2+}(aq) + Cl^-(aq)$ Slight Hydrolysis $[Mg(H_2O)_6]^{2+}(aq) \rightleftharpoons [Mg(H_2O)_5(OH)]^{+}(aq) + H^+(aq)$	6.5

(c) (i) Al_2O_3 is amphoteric due to its ionic with partial covalent character. It reacts with both acids and bases.

$Al_2O_3(s) + 6\ HCl(aq) \rightarrow 2\ AlCl_3(aq) + 3\ H_2O(\mathit{l})$
$Al_2O_3(s) + 2\ NaOH(aq) + 3\ H_2O(\mathit{l}) \rightarrow 2\ NaAl(OH)_4(aq)$

SO_3 is acidic and reacts only with bases.

$SO_3(g) + 2\ NaOH(aq) \rightarrow Na_2SO_4(aq) + H2O(\mathit{l})$

(ii) From aluminium to sulfur,

- Nuclear charge increases but shielding effect is relatively constant
- Effective nuclear charge increases.

- There is stronger electrostatic force of attraction between nucleus and valence electrons. More energy is required to remove the valence electron.

- Therefore, 1st I.E. of S is greater than A*l*.

2(a) (i)

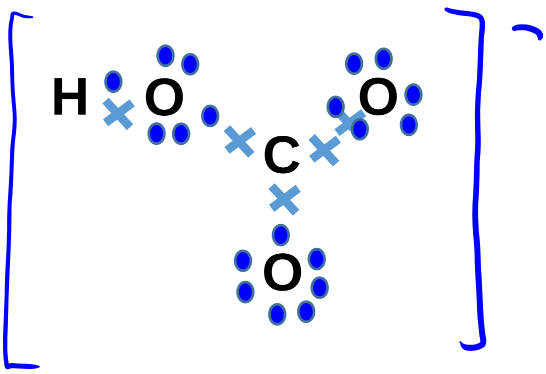
$$\frac{(96)}{(4)} = 24.0$$

(ii) $HCO_3^- + H^+ \rightarrow H_2CO_3$

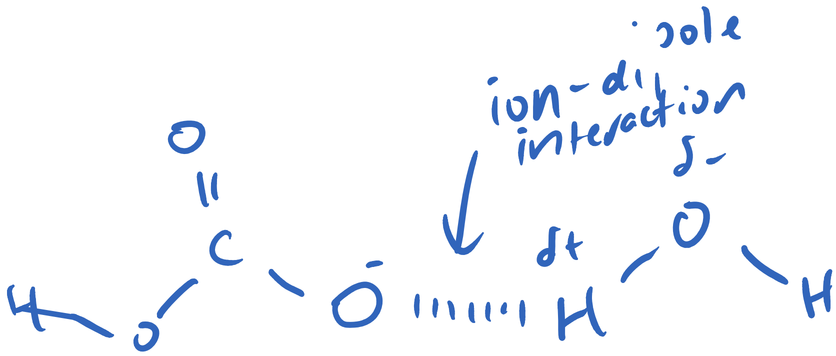
The added H^+ is removed as H_2CO_3.
[H^+] is slightly changed hence pH *remains* fairly *constant*.

$H_2CO_3 + OH^- \rightarrow HCO_3^- + H_2O$
The added OH^- is removed as HCO_3^- and H_2O.
[OH^-] is slightly changed hence pH *remains* fairly *constant*.

(b) (i)



(ii) There is the formation of ion-dipole interactions between HCO_3^- and water molecules.



(c) (i) No of mol of NaOH used = $\frac{30}{1000}$ x 0.25 = 7.50 x 10^{-3} mol

No of mol of H^+ present = 7.50 x 10^{-3} mol

Concentration of H^+ $= \dfrac{7.5 \times 10^{-3}}{\frac{25}{1000}}$ = 0.300 mol dm^{-3}

pH = 0.50

(ii) Carbonic acid is a weak acid and it dissociates partially. Sulfuric acid is a strong acid and it dissociates completely. Concentration of H^+ in the carbonic acid solution will be less than than the concentration of H^+ in sulfuric acid resulting in the pH to be higher

3(a)

	$2SO_2(g)$	+ $O_2(g)$ $\rightleftharpoons$	$2SO_3(g)$
Initial amount /mol	2	1	0
Change in amount /mol	-1.9	-0.95	+1.9
Amount at new equilibrium / atm	0.1	0.05	1.9

Concentration of SO_2 at equilibrium = $\dfrac{0.1}{5}$ = 0.02 $moldm^{-3}$

Concentration of O_2 at equilibrium = $\dfrac{0.05}{5}$ = 0.01 $moldm^{-3}$

(b) K_c' $= \dfrac{(0.02)^2(0.01)}{(0.38)^2}$

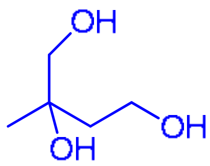
= 2.77 x 10^{-5} mol dm^{-3}

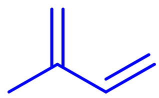
(c) At t = 3 min, concentration of SO_2 is increased.

By *Le Chatelier's Principle*, when concentration of SO_2 is increased, the equilibrium position shifts to the right to decrease the concentration of SO_2.

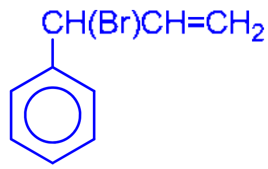
Overall, concentration of SO_2 still increases while concentration of O_2 is decreased as some O_2 reacted with the added SO_2 to form SO_3.

4(a)

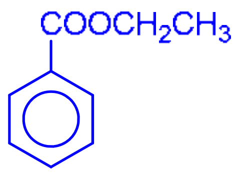




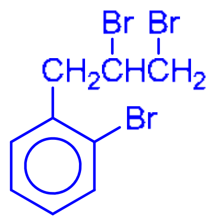
(b)



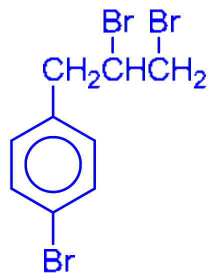
compound **A**



compound **B**



OR



compound **C**

(ii) Reaction **I**: $KMnO_4$, H_2SO_4 (aq) , heat

Reaction **III**: limited Br_2 , UV light

(iii) Substitution

5(a) disproportionation

(b) **(i)** Energy released when one mole of substance is completely burnt in excess oxygen under standard conditions.

(ii) Heat absorbed by water= 200 x 4.18 x (40.6 – 27.9) = 10701 J

Heat released by reaction = $\dfrac{10701}{30/100}$ = 35669 J

Amount of phenylmethanol burnt = $\dfrac{113.25 - 112.22}{108}$ = 9.538×10^{-3} mol

$\Delta H^{\ominus}_c(C_6H_5CH_2OH) = -\dfrac{35669}{9.538 \times 10^{-3}}$

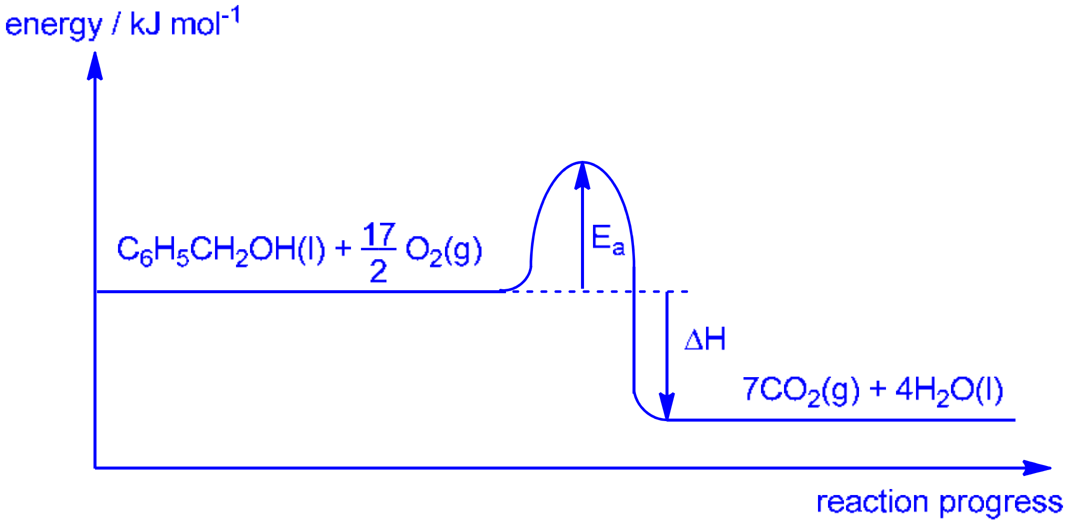
$= -3.74 \times 10^6$ J mol^{-1} or -3740 kJ mol^{-1}

(iii) density of water is 1.0 g cm^{-3} *other accurate reasons acceptable*

(c) **(i)** ΔH_1 $= 6(520) + 350 + 7(410) + 360 + 460 + 17/2(496) - 14(740) - 8(460)$
$= -2660$ kJ mol^{-1} (3 s.f.)

(ii) $-2660 + 63 = 164 + \Delta H_4$
$\Delta H_4 = -2660 + 63 - 164 = -2761$ kJ mol^{-1}

(iii)

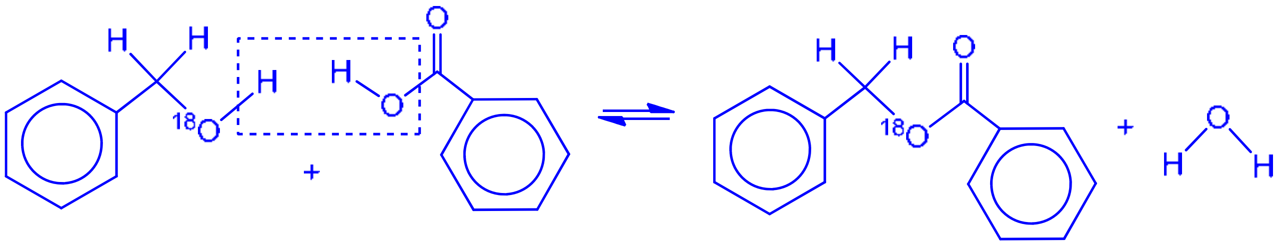


(d) **(i)** For alcohol / phenylmethanol: Electron-donating alkyl group increases the intensity of negative charge on oxygen atom of the alkoxide ion, destabilising the alkoxide ion.

For carboxylic acid / benzoic acid: Carboxylate ion is resonance stabilized; decreases intensity of negative charge on oxygen atom of the carboxylate ion, stabilising the carboxylate ion

Hence, K_a of carboxylic acid is higher because carboxylic acid is more acidic.

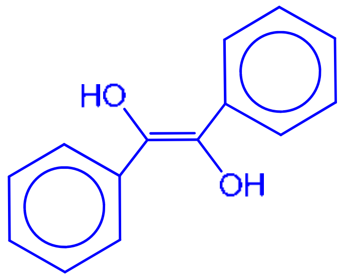
(ii)



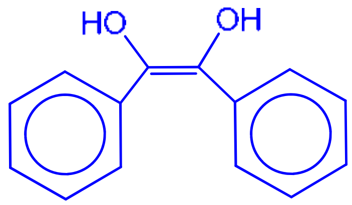
(e) **(i)**

Test (either one)	benzaldehyde	compound **J**
Tollens' reagent, heat	silver mirror formed	no silver mirror
PCl_5, r.t.p.	no white fumes	white fumes of HC*l* formed

(ii)



trans-isomer



cis-isomer

6(a) (i) Order of reaction is the power to which the concentration of a reactant is raised in the rate equation.

(ii) time taken α $\frac{1}{\textit{initial rate of reaction}}$

(iii) Comparing Experiment 2 and 3,
While keeping [CH_2=CH_2] and [CO] constant, when [H_2] doubles, rate of the reaction also doubles.

Hence it is 1st order of reaction with respect to H_2.

Comparing Experiment 1 and 3,

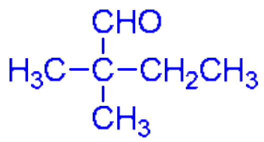
When [CH_2=CH_2] and [CO] doubles, [H_2] halves, rate of the reaction doubles. Since [CO] and [H_2] are 1st order, expected rate should be unchanged but doubling [CH_2=CH_2] doubles the rate of reaction.

Hence it is 1st order of reaction with respect to CH_2=CH_2.

(iv) rate = k[CH_2=CH_2][CO][H_2]

(v) The new rate will be ¾ times the original rate

(vi)



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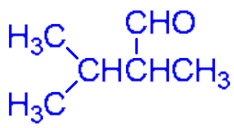
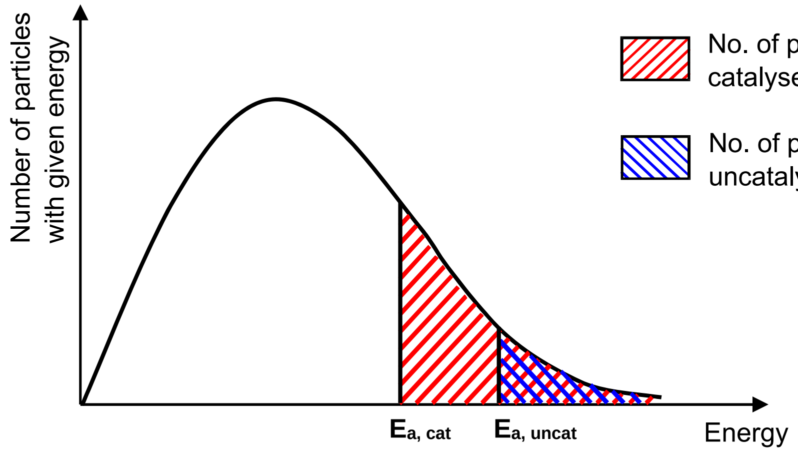
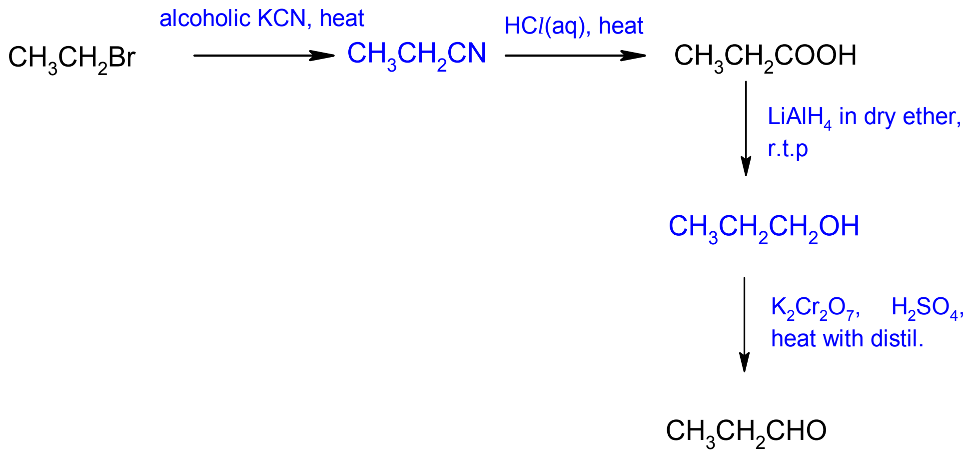


(vii)



Catalyst increases the rate of reaction by providing an alternative pathway of lower activation energy. Number of reactant particles with E ≥ E_a increases. Frequency of effective collisions increases. Since rate of reaction is proportional to the frequency of effective collisions, rate of reaction increases.

(b)



(c) **(i)** Test 1:

Add Tollens' reagent , heat.

Silver mirror is observed for compound Q and R.

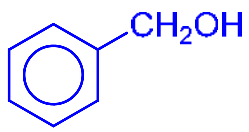
No silver mirror is observed for compound Q and R.

Test 2:

Add Fehling's solution , heat the mixtures.

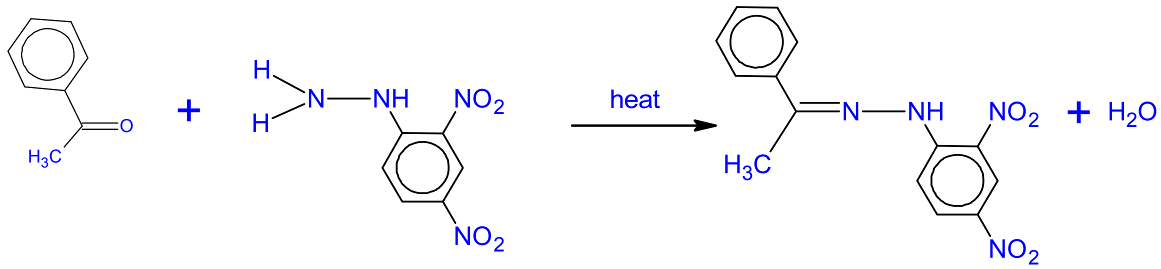
In the test tube containing compound R (the aliphatic aldehyde), a brick red ppt of Cu_2O is formed.In the test tube containing compound Q, no brick red ppt is formed.

(ii) Reduction



Compound **D**

(iii)



(Orange crystalline solid)

7(a) (i) *Endosulfan* has a simple molecular structure.

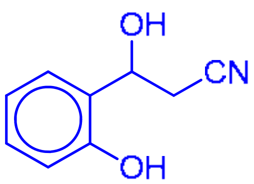
In water
- Strong hydrogen bonding between water molecules is not compatible to the weak van der Waals' forces between *endosulfan* molecules.
- *Endosulfan* is less soluble in H_2O.

In hexane
- Weak van der Waals' forces of attraction between *endosulfan* molecules is similar in strength / compatible to the weak van der Waals' forces of attraction between hexane molecules.
- *Endosulfan* is more soluble in hexane.

(ii) There are 3 bond pairs and 1 lone pair around the S atom.
- To minimise repulsion and maximise stability, the 4 electron pairs are directed to the corners of a regular tetrahedron.
- But lone pair–bond pair repulsion > bond pair–bond pair repulsion,
- Bond angle is 107°.
- Shape about the sulfur atom in *endosulfan* is trigonal pyramidal.

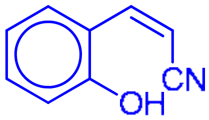
(iii)
- One lone electron pair of C*l*b atom is delocalised with the adjacent C=C.
- This strengthens the carbon-chlorine bond in the alkene due to presence of partial double bond character, hence substitution is difficult under normal conditions.

(b) (i) Structure of W:

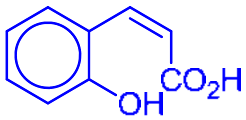


Structure of X:

- Compound X undergoes addition with bromine.
- X contains alkene functional group.



Structure of Y:
- Compound Y undergoes acid–carbonate with solid sodium carbonate.
- Y contains carboxylic acid functional group.



(ii) Step I: KCN in ethanol, heat

Step II: Excess concentrated H_2SO_4, 170^oC

Step III: HC*l* (aq) , heat

(iii) Reagents and condition: Aqueous alkaline iodine, heat
Compound A: Yellow precipitate of CHI_3 observed
Compound Z: No yellow precipitate of CHI_3 observed

Class | Adm No

Candidate Name: ____________________

Class	Adm No

H

millennia institute

2017 Preliminary Examination II
Pre-University 2

H1 CHEMISTRY **8872/01**

Paper 1 Multiple Choice **19th Sep 2017**

50 minutes

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)	

Section A

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

1 A sample of a rare ore containing iron and molybdenum was investigated. The composition of the sample is given in the table below.

mass number	55	56	95	96
% abundance	5	54	36	5

What is the A_r of Fe in this sample of Elinvar?

A 55.8 **B** 55.9 **C** 72.0 **D** 75.5

2 Perfluoroacetic acid is a structural analogue of ethanoic acid and is a stronger acid than ethanoic acid. The percentage composition by mass of perfluoroacetic acid is given as: C, 21.1%; H, 0.90%; O, 28.1%; F, 49.9%.

What is the empirical formula of perfluoroacetic acid?

A $CHOF_2$
B C_2H_2OF
C $C_2HO_2F_2$
D $C_2HO_2F_3$

3 Chalcopyrite is a common copper ore with the chemical formula $CuFeS_2$. Copper can be extracted from chalcopyrite through the roasting of the ore and undergoes the following reaction.

$$2CuFeS_2(s) + 5O_2(g) + 2SiO_2 \rightarrow 2Cu(l) + 4SO_2(g) + 2FeSiO_3(l)$$

What is the mass of chalcopyrite needed to produce 10 g of Cu?

A 28.9
B 51.6
C 57.8
D 103

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

Chloride ions can be oxidised to hypochlorous acid as shown below.

$$Cl^- + H_2O \rightleftharpoons HClO + H^+ + 2e^-$$

If 2 moles of acidified MnO_4^- were reacted with 1 mole of Cl^- ions, how many moles of hypochlorous acid would be obtained?

A 1
B 2
C 5
D 10

5 What is the change in oxidation number of chlorine and manganese in the following reaction?

$$5ClO_2^- + 6H^+ + 2MnO_4^- \rightleftharpoons 2Mn^{2+} + 5ClO_3^- + 3H_2O$$

	Chlorine	**manganese**
A	0	+3
B	+1	-5
C	+2	-5
D	+2	+3

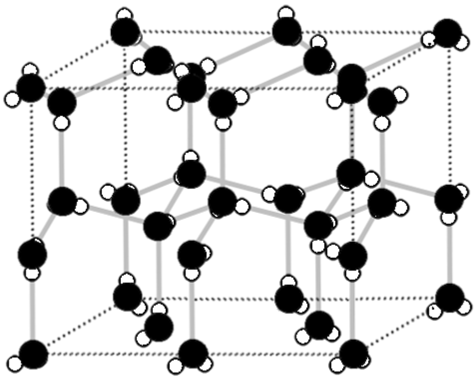
6 The first six ionisation energies of an element, **A**, in kJ mol^{-1} are given below.

947 1798 2735 4837 6043 12310

A forms an oxide. What is the empirical formula of the oxide?

A **A**O
B **A**$_2$O
C **A**O$_2$
D **A**$_2$O$_3$

7 The diagram below shows the structure of ice.



Which of the following statements about ice is correct?

A The bond angle about oxygen atom is 109.5°.

B There are strong covalent bonds between water molecules.

C A sample of ice occupies a smaller volume than a sample of water with the same mass.

D Ice has a giant covalent lattice.

8 Recycling metals are important to many countries. Which of the following statements does **not** explain why recycling is important?

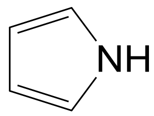
A It is energy intensive to extract metals from its ore.

B Natural resources are used up during the extraction of metals.

C It is expensive to dispose of waste produced in the extraction process.

D Recycling increases the consumption of non-renewable resources.

9 What is the number of sigma (σ) and pi (π) bonds in this molecule?



pyrrole

	σ	**π**
A	9	2
B	9	3
C	10	2
D	10	3

10 Which of the following compounds has the least exothermic lattice energy?

A barium oxide

B barium sulfide

C magnesium oxide

D magnesium sulfide

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

The water-gas shift reaction is used industrially to obtain hydrogen and is shown below.

$$CO + H_2O \rightleftharpoons CO_2 + H_2$$

The C≡O bond enthalpy is 1076 kJ mol^{-1}.

What is the enthalpy change for the reaction?

A +80 kJ mol^{-1}

B -80 kJ mol^{-1}

C +360 kJ mol^{-1}

D -360 kJ mol^{-1}

12 Methane and steam undergo a reaction as shown below.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

A mixture containing 4 moles of gas with methane and steam in 1:1 ratio is injected into a 5 dm^3 vessel. After some time, 1 mole of water is left.

What is the numerical value of the equilibrium constant, K_c, for the reaction?

A 27

B 9

C 1.08

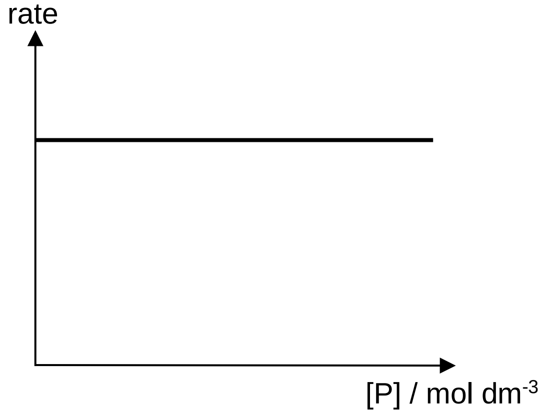
D 0.04

13 A reaction between **P** and **Q** is investigated and the following experimental results were obtained.

experiment	**initial concentration of P / mol dm^{-3}**	**initial concentration of Q / mol dm^{-3}**	**initial rate / mol dm^{-3} s^{-1}**
1	0.5	1.0	0.005
2	0.5	4.0	0.020
3	1.0	4.0	0.020

Which of the following correctly depicts the rate-concentration graph for the reaction?

A



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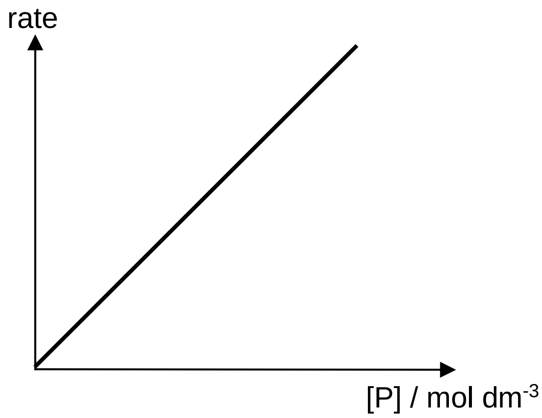
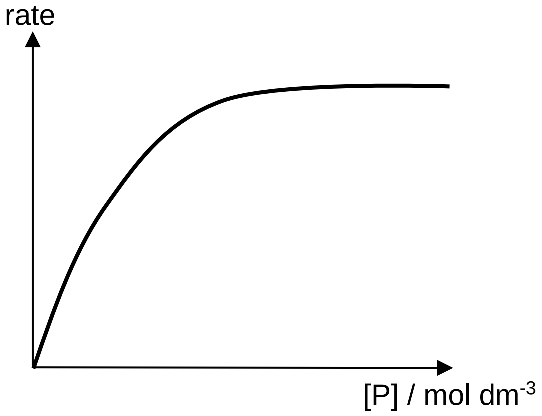
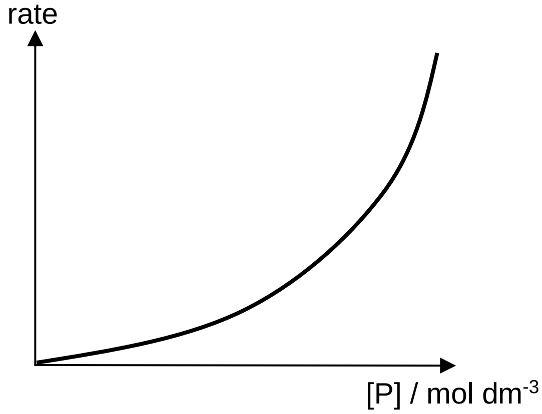


C



D



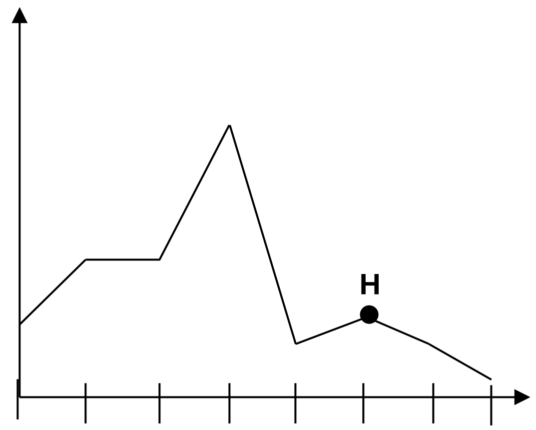
14 The decomposition of azomethane with time has the following rate equation. It takes 2000 s for 10 mol of azomethane to decay to 0.625 mol.

rate = k[azomethane]

What is the half-life for the decomposition of azomethane?

A 250 s **B** 500 s **C** 1000 s **D** 2000 s

15 The graph below shows a trend in the variation of a physical property of Period 3 elements.



Which of the following best describes the oxide of the element labelled **H**?

A It is amphoteric.

B It is an ionic compound with covalent character.

C It exists as discrete molecules.

D It turns universal indicator blue when dissolved in water.

16 The ionic radii of Period 3 metals decreases across the period.

Which of the following best explains this observation?

A More electrons are lost from the parent atom.

B There is less electronic shielding across the period.

C They are isoelectronic.

D The effective nuclear charge increases.

17 Element **J** is in Period 3 of the Periodic Table. It has a melting point of 660 °C and conducts electricity in the liquid state. The chloride of **J** is able to react with ammonia in a 1:1 ratio.

Which of the following correctly describes the structure of the chloride of **J**?

A Metallic

B Simple covalent

C Giant covalent

D Ionic

18 Which one of the following pairs of compounds does **not** have the same empirical formula?

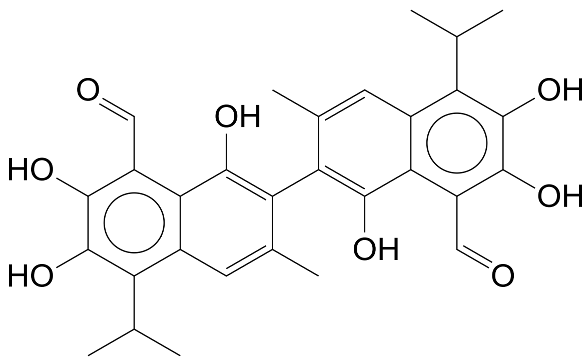
A $C_6H_{12}O_6$, CH_3COOH

B C_6H_{12}, C_3H_6

C $CHCl_3$, $Cl_3CHCHCl_3$

D CH_3COOCH_3, C_3H_5OH

19 Gossypol is a pigment found in cotton plants and has the following structure.



Which statement about this compound is **not** true?

A 1 mole of Gossypol will react with 2 moles of 2,4-dinitrophenylhydrazine.

B 1 mole of Gossypol will react with 2 moles of Fehling's solution.

C Gossypol will react with sodium metal.

D Gossypol will react with aqueous bromine.

20 R-124, C_2HClF_4, is a chlorofluorocarbon used as a refrigerant.

Which of the following statements is **not** true about R-124?

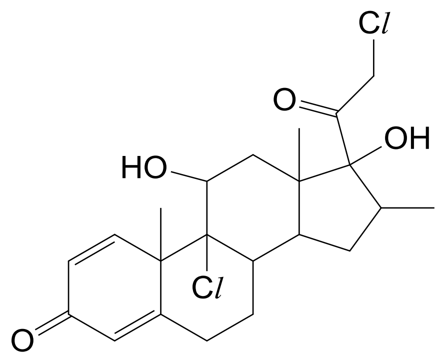
A Hydrogen bonds are formed between its molecules.

B It can deplete the ozone layer.

C It does not have π bonds within the molecule.

D The C–F bond requires a large amount of energy to break.

21 Mometasone is a corticosteroid that has functions similar to progesterone, an important hormone in the body.



Mometasone

Which of the following statements is **not** true about mometasone?

A The molecular formula is $C_{22}H_{28}ClO_4$

B After treatment with NaOH(aq), it reacts with $AgNO_3$(aq) readily.

C It can undergo reduction when reacted with $LiAlH_4$.

D It can be oxidised by acidified $K_2Cr_2O_7$(aq).

22 A sample of 2-chlorobutane is first treated with hot NaOH(aq) and then with acidified $KMnO_4$(aq).

What is the final organic product?

A CH_3COOH

B $CH_3CHCHCH_3$

C $CH_3COCH_2CH_3$

D $CH_3CH(COOH)CH_2CH_3$

23 Nitecapone is a drug that can be used to treat Parkinson's disease and has two carbonyl groups. It has the molecular formula of $C_{12}H_{11}NO_6$. When nitecapone reacts with HCN and trace amount of NaCN, a product is formed.

Which of the following is the molecular formula of the product?

A $C_{12}H_{11}N_2O_8$

B $C_{13}H_{11}N_2O_6$

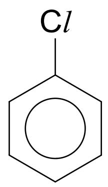
C $C_{14}H_{12}N_2O_6$

D $C_{14}H_{13}N_3O_6$

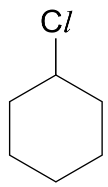
24 Compound **X** is subjected to NaOH(aq) followed by aqueous silver nitrate at room temperature but white precipitate does not form.

What is the structure of **X**?

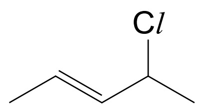
A



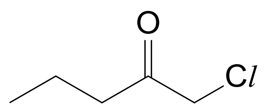
C



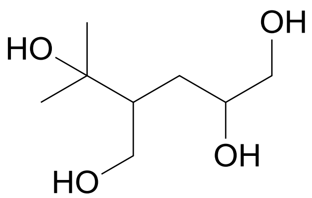
B



D



25 The compound below is heated with acidified potassium dichromate(VI) and forms an organic compound.



How many moles of sodium carbonate will react with 1 mole of the oxidised product?

A 0 **B** 1 **C** 1.5 **D** 2

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 Which of the following correctly define the relative molecular mass of a substance?

1 the mass of 1 mole of the substance compared to the mass of 1 mole of ^{12}C

2 the average mass of 1 mole of the substance compared to $\frac{1}{12}$ of the mass of 1 mole of ^{12}C atoms

3 the average mass of 1 molecule of the substance compared to $\frac{1}{12}$ of the mass of 1 atom of ^{12}C

27 Which of the following statements describe catalysts correctly?

1 Catalysts increase the number of molecules with energy more than activation energy.

2 Catalysts affect the rate constant.

3 At 40 °C, catalysts can increase the yield of a reaction.

28 Which of the following has a pH of 1?

1 0.05 mol dm^{-3} of sulfuric acid

2 0.10 mol dm^{-3} of nitric acid

3 0.05 mol dm^{-3} of hydrochloric acid

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

29 Element **G** is a Period 3 element and is a solid at room temperature and pressure. The oxide of **G** is soluble in water and forms a solution that turns blue litmus paper red.

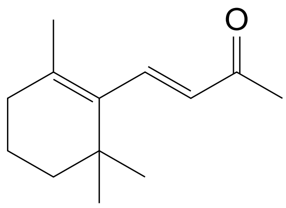
Which of the following describes the chloride of **G** correctly?

1 It is a gas at room temperature.

2 It has a formula of $\mathbf{G}Cl_5$.

3 It hydrolyses in water to form an acidic solution.

30 β-ionone is a compound that is known to have the aroma of roses.



β-ionone

Which reagents will react with β-ionone?

1 alkaline aqueous iodide

2 2,4-dinitrophenylhydrazine

3 potassium dichromate(VI)

END OF PAPER 1

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2017 Millennia Institute 8872 H1 Prelim Paper 1 MCQ Answers

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

Class	Adm No

Candidate Name: ____________________

H

millennia institute

2017 Promotional Examination II

Pre-university 2

H1 CHEMISTRY **8872/02**

Paper 2

11th Sep 2017

2 hours

Candidates answer Section A on the Question paper.

Additional materials: Answer Paper
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.

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.

Section A
Answer **all** the questions.

Section B
Answer **two** questions on separate answer paper.

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.

	Section A				Section B			Total
Question	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
Marks	**13**	**12**	**5**	**10**	**20**	**20**	**20**	**80**

Section A

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

1 **(a)** A sample of lead contains four stable isotopes with the following percentage abundances.

Isotope	Percentage abundance / %
^{204}Pb	1.4
^{206}Pb	24.1
^{207}Pb	22.1
^{208}Pb	**a**

(i) Define the term *relative atomic mass*.

……

…… [1]

(ii) Determine the value of **a**. Hence, calculate the relative atomic mass of lead. Give your answer to two decimal places.

[2]

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

Determine the number of protons, neutrons and electrons in one particle of $^{206}Pb^{2+}$.

Number of protons: ……… Number of neutrons: ……… Number of electrons: ………

[1]

(b) Another element in the same group as lead is germanium, Ge, which is chemically similar to silicon, Si. The common oxidation states of germanium in compounds is +2 and +4.

(i) Draw and label the orbital in which electrons are removed from Ge to form Ge^{2+}.

[1]

(ii) Draw and label the orbital in which electrons are removed from Ge^{2+} to form Ge^{4+}.

[1]

(iii) Explain why electrons are removed from the orbital you stated in **(b)(i)** before removing electrons from the orbital in **(b)(ii)** in the ionisation of germanium.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [1]

(iv) Describe the structure and bonding in germanium.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [2]

(v) Compare and explain briefly how the melting point of germanium differs from that of silicon.

………

………

……… [2]

(c) Pure lithium is highly reactive and reacts readily with water to form lithium hydroxide and hydrogen gas.

Write the ion-electron equations for the redox processes that are occurring in this reaction.

Oxidation: ……………………………………………………………………………………………..

Reduction: ……………………………………………………………………………………………

[2]

[Total: 13]

2 **(a)** In 1905, Fritz Haber succeeded in the atmospheric ‘fixing’ of nitrogen with hydrogen to produce ammonia, which is a precursor in the production of fertilisers. This process is now known as the Haber process, which can be described by the chemical equation below. Haber later went on to receive a Nobel prize in 1918 for this achievement.

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

(i) Describe the conditions and catalyst used in the Haber process.

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [1]

(ii) Explain how the addition of the catalyst in **(a)(i)** affects the position of the equilibrium for the equation above.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [2]

(b) In aqueous solution, ammonia is a *weak Brønsted base*.

Define what is meant by the term *weak Brønsted base.*

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [1]

(c) When excess bromoethane is reacted with limited ammonia, a multi-substituted product is produced.

Write an overall equation to for the reaction when ammonia is reacted with bromoethane in the molar ratio of 1 : 2. [1]

(d) 1,1,2-trichloroethane can undergo elimination to form an alkene which exhibits geometrical isomerism.

(i) Explain how geometrical isomerism arises in alkenes.

....

....

....

.... [2]

(ii) State the reagent and condition required for the elimination reaction.

.... [1]

(iii) Draw and name the structures of the two geometrical isomers.

[3]

(iv) State the number of σ and π bonds in each of the alkenes produced after elimination.

.... [1]

[Total: 12]

3 Use the third period of the modern Periodic Table, sodium to argon, to answer the following questions.

(a) Describe and explain how the atomic radii and first ionisation energies of these elements vary across the period.

....

....

....

....

....

.... [3]

(b) State the structure and bonding present in sodium, magnesium and aluminium. Explain how the bonding present affects the variation in electrical conductivity of these elements.

....

....

....

.... [2]

[Total: 5]

4 Rainwater has a pH of 5.6 instead of 7.0 at 25 °C. This is because carbon dioxide in the atmosphere dissolves in the rainwater and reacts to form an equilibrium with carbonic acid, H_2CO_3, with a K_c of 1.3×10^{-3} mol^{-1} dm^3. The carbonic acid then dissociates, acting as a weak Brønsted acid. Carbonic acid can be assumed to be a monoprotic acid with a K_a value of 4.27×10^{-7}.

Carbonic acid can also be found in the human blood stream as part of an acidic buffer system. When a person undergoes aerobic metabolism, the body uses oxygen to break down glucose to generate carbon dioxide and water as products. However, when a person exercises intensely, there could temporarily be insufficient oxygen for aerobic metabolism, hence producing a by-product called lactic acid, $CH_3CH(OH)COOH$. When lactic acid is built up in the muscles faster than it could be removed by the body, the person can suffer from a condition called lactic acidosis, in which the muscles feel a burning sensation. The lactic acid produced can be removed from the system by reacting with the acidic buffer system present in blood.

(a) Write an expression for the equilibrium constant, K_c, for the dissolution of carbon dioxide in rainwater.

[1]

(b) **(i)** Construct a balanced equation, including state symbols, for the dissociation of carbonic acid in rainwater. Hence, write an expression for the acid dissociation constant of carbonic acid, K_a, and state its units.

[3]

(ii) Calculate the concentration of H^+ ions in rainwater.

[1]

(iii) Using your answers in **(b)(i)** and **(b)(ii)**, calculate the equilibrium concentration of carbonic acid, H_2CO_3, in water. You may assume that the equilibrium concentration of H^+ ions in rainwater is the same as the concentration of HCO_3^- ions.

[1]

(c) Write a balanced equation to show how small amounts of lactic acid, $CH_3CH(OH)COOH$ can be removed by the buffer system present in blood.

…………………………………………………………………………………………………… [1]

(d) Lactic acid can be synthesised in the laboratory from ethanal, CH_3CHO, in two steps.

State the reagents and conditions for both steps and draw the structure of the intermediate organic compound in the space below.

Structure of intermediate:

Reagents and conditions for

Step 1: ……………………………………………………………………………………………..

Step 2: ……………………………………………………………………………………………. [3]

[Total: 10]

Section B

Answer **two** questions from this section on separate answer paper.

5 **(a)** The boiling points of the halogens show the following trend.

Element	boiling point / °C
Cl_2	–35
Br_2	59
I_2	184

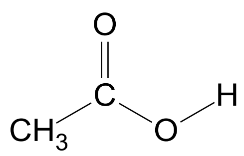
Explain, in terms of structure and bonding, the trend in the boiling point. [2]

(b) The table shows the melting points of magnesium chloride and magnesium oxide respectively.

compound	**melting point / °C**
$MgCl_2$	714
MgO	2852

Account for the difference in the melting point of the two compounds in terms of their structure and bonding. [3]

(c) The structural formula of ethanoic acid is given below.



Explain, with the aid of a diagram, why ethanoic acid has a M_r of 120 in organic solvent. [2]

(d) **(i)** Define, with the aid of an equation, the standard enthalpy change of combustion of propane, C_3H_8. [2]

(ii) Calculate the enthalpy change of formation of propane, given the following data.

Standard enthalpy change of combustion of propane	–2220 kJ mol^{-1}
Standard enthalpy change of formation of water	–285 kJ mol^{-1}
Standard enthalpy change of formation of carbon dioxide	–394 kJ mol^{-1}

[1]

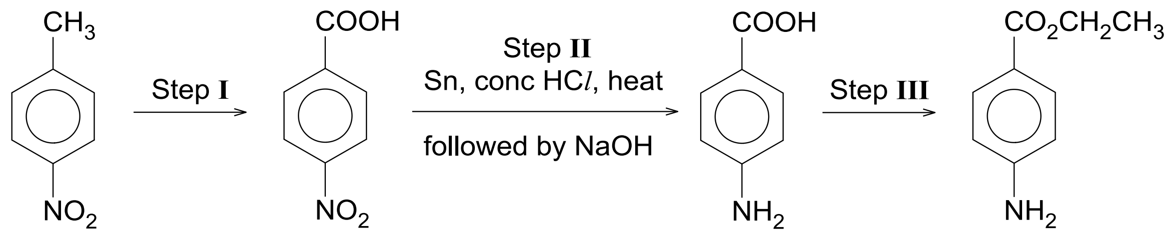
(iii) Propane is combusted under an open copper container with 2 dm^3 of water at 29.0 °C.

Using the data given below and in **(d)(ii)**, calculate the change in temperature of the water if 11.0 g of propane is combusted. Assume that the efficiency of heat transfer is 75%.

Specific heat capacity of water = 4.20 J g^{-1} K^{-1}
Density of water = 1.0 g cm^{-3} [3]

(iv) Suggest a reason to explain why the efficiency of heat transfer is not 100%. [1]

(e) Benzocaine is a topical anaesthetic used in first aid creams and sunburn remedies. It can be produced from 4-nitrotoluene in a series of steps.



4-nitrotoluene　Compound **B**　Compound **C**　Benzocaine

(i) State the reagents and conditions used for steps **I** and **III**. [2]

(ii) State the type of reaction for steps **I** and **III**. [2]

(iii) Explain why the NaOH in step **II** needs to be added carefully in order to obtain compound **C**. [1]

(iv) Write a balanced equation for step **III**. [1]

[Total: 20]

6 **(a)** 2.78 g of a metallic oxide, represented by $\mathbf{M}_2O$ (where **M** is an unknown metal), was added to 43.7 cm^3 of 1.50 mol dm^{-3} hydrochloric acid. The resulting solution then required 13.0 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide for neutralisation.

Construct two balanced equations for the reactions that occur. Hence, determine the relative atomic mass of **M**. [4]

(b) The reaction of ethanoic anhydride, $(CH_3CO)_2O$, with ethanol, C_2H_5OH, can be represented by the equation:

$$(CH_3CO)_2O + C_2H_5OH \rightarrow CH_3CO_2C_2H_5 + CH_3CO_2H$$

The table below shows the initial concentrations of the two reactants and the initial rates of reaction.

Experiment	**$[(CH_3CO)_2O]$ /mol dm^{-3}**	**$[C_2H_5OH]$ /mol dm^{-3}**	**Initial rate /mol dm^{-3} s^{-1}**
1	0.800	0.400	1.20×10^{-3}
2	0.800	0.800	2.40×10^{-3}
3	1.60	0.800	4.80×10^{-3}

(i) Deduce the order of the reaction with respect to each of ethanoic anhydride and ethanol. [2]

(ii) Write an expression for the rate equation. [1]

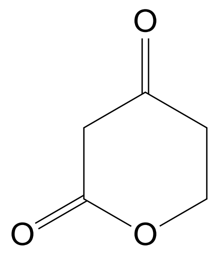
(iii) Calculate the value, with units, for the rate constant, k. [1]

(iv) With the aid of a diagram, explain how a catalyst increases the rate of a chemical reaction. [3]

(c) On heating a neutral compound **D** (shown below) with dilute sulfuric acid, a single compound **E** ($C_5H_8O_4$) is produced. Both compounds **D** and **E** give an orange precipitate with 2,4-dinitrophenylhydrazine but do not react with Fehling's solution.

Upon treating **E** with HCN with a trace of NaCN, **F** ($C_6H_9O_4N$) is produced.

F gives **G** ($C_6H_{15}O_3N$) on reacting with lithium aluminum hydride in dry ether. **G** forms **H** ($Na_2C_6H_9O_5N$) when reacted with hot $KMnO_4$ in dilute NaOH.



Compound **D**

Suggest the structures of **E** to **H**, explaining the chemistry of the reactions described.
Write a balanced equation for the reaction of **D** with 2,4-dinitrophenylhydrazine.

[9]

[Total: 20]

7 **(a)** Bromine trifluoride auto-ionises in the liquid state according to the equation.

$$2BrF_3 \rightleftharpoons BrF_2^+ + BrF_4^-$$

Draw the 'dot-and-cross' diagrams to show the outer shell electron arrangement of BrF_3 and BrF_4^-. Hence, predict the shapes of the two structures. [2]

(b) Boron forms simple trihalides of formula BX_3 with all the halogens. BF_3 and BCl_3 are commonly used as catalyst in chemical reactions since they readily react with electron pair donors.

(i) Using VSEPR theory, explain the shape and state the bond angle of BF_3. [3]

(ii) BF_3 and trimethylamine, $(CH_3)_3N$ react in a 1:1 ratio to give a white crystalline compound. Draw a diagram to illustrate and explain the type of bonding involved in the formation of the compound. [3]

(c) Pure hydrogen iodide, HI, is a gas, which at high temperatures, partially decomposes into hydrogen and iodine, according to the equation:

$$2HI\,(g) \rightleftharpoons H_2\,(g) + I_2\,(g)$$

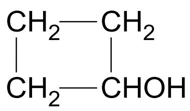
At 500 K, the equilibrium constant, K_c, for the decomposition reaction is 6.25×10^{-3}. Some pure HI is placed into an evacuated 2.0 dm^3 glass tube and heated to 500 K. In the equilibrium sample, the concentration of I_2 is 3.10×10^{-5} mol dm^{-3}.

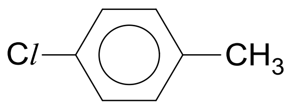
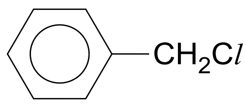
(i) Calculate the concentrations of H_2 (g) and HI (g) in this equilibrium mixture at 500 K. [2]

(ii) Calculate the amount of HI that must have been placed in the 2.0 dm^3 glass tube originally. [2]

(iii) At 600 K, the K_c for dissociation of HI is 1.56×10^{-2}. Deduce whether the forward reaction is endothermic or exothermic. [2]

(d) Suggest simple one-step test-tube reactions by which the following pairs of isomers can be distinguished from each other. You should state the reagents and conditions for each test, and describe the observations for each of the isomers in the pair.

(i)  and $CH_3CH{=}CHCH_2OH$ [2]

(ii)  and  [2]

(iii) $CH_3CH(OH)CH_3$ and $CH_3CH_2CH_2OH$ [2]

[Total: 20]

END OF PAPER 2

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	Class	Adm No
Candidate Name: ____________________		

H

millennia institute

2017 Promotional Examination II
Pre-university 2

H1 CHEMISTRY **8872/02**

Paper 2

11th Sep 2017

2 hours

Candidates answer Section A on the Question paper.

Additional materials: Answer Paper
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.

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.

Section A
Answer **all** the questions.

Section B
Answer **two** questions on separate answer paper.

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	Section A				Section B			Total
	1	2	3	4	5	6	7	
Marks	13	12	5	10	20	20	20	80

Section A

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

1 **(a)** A sample of lead contains four stable isotopes with the following percentage abundances.

Isotope	**Percentage abundance / %**
^{204}Pb	1.4
^{206}Pb	24.1
^{207}Pb	22.1
^{208}Pb	**a**

(i) Define the term *relative atomic mass*.

....

.... [1]

Relative atomic mass is the weighted average isotopic mass of one atom of an element compared to $^{1}/_{12}$ the mass of a ^{12}C atom. ;

(ii) Determine the value of **a**. Hence, calculate the relative atomic mass of lead. Give your answer to two decimal places.

[2]

% abundance of ^{208}Pb, a = 100 – 1.4 – 24.1 – 22.1 = 52.4% ;

Relative atomic mass of lead
= (204 × 1.4%) + (206 × 24.1%) + (207 × 22.1%) + (208 × 52.4%)
= 207.24 (2 d.p.) ;

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

Determine the number of protons, neutrons and electrons in one particle of $^{206}Pb^{2+}$.

Number of protons: .... Number of neutrons: .... Number of electrons: ....

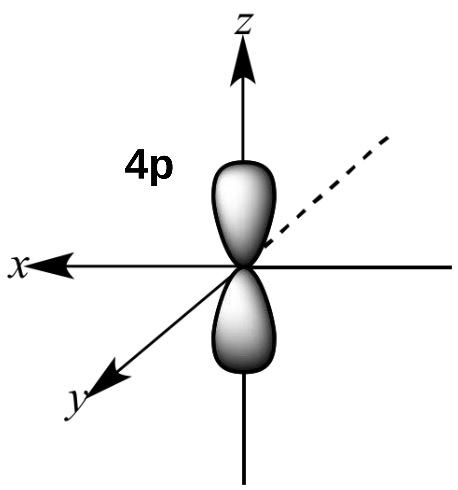
[1]

Number of protons: **82** Number of neutrons: **124** Number of electrons: **80** ;

(b) Another element in the same group as lead is germanium, Ge, which is chemically similar to silicon, Si. The common oxidation states of germanium in compounds is +2 and +4.

(i) Draw and label the orbital in which electrons are removed from Ge to form Ge^{2+}.

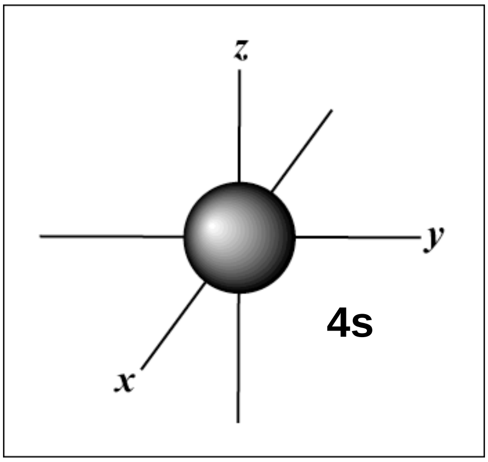
[1]



(axis not required)

(ii) Draw and label the orbital in which electrons are removed from Ge^{2+} to form Ge^{4+}.

[1]



(iii) Explain why electrons are removed from the orbital you stated in **(b)(i)** before removing electrons from the orbital in **(b)(ii)** in the ionisation of germanium.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [1]

The electrons in the 4p orbital are <u>further from nucleus</u> and <u>experiences additional shielding</u> from the 4s electrons. Less energy is required and it is easier to remove from a valence electron from the 4p than 4s orbital ;

(iv) Describe the structure and bonding in germanium.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [2]

Germanium has a <u>giant covalent structure</u> with <u>strong covalent bonds between atoms / strong electrostatic forces of attraction between positive Ge nuclei and the shared pair of electrons.</u>

(v) Compare and explain briefly how the melting point of germanium differs from that of silicon.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [2]

The melting point of germanium will be <u>lower than silicon.</u> ;

Atomic radius of Ge is larger than Si OR Ge has longer bond length than Si and less effective overlap of orbitals resulting in weaker covalent bonds. ;

(c) Pure lithium is highly reactive and reacts readily with water to form lithium hydroxide and hydrogen gas.

Write the ion-electron equations for the redox processes that are occurring in this reaction.

Oxidation: ……………………………………………………………………………………………..

Reduction: ………………………………………………………………………………………………

[2]

[Total: 13]

Oxidation: $Li \rightarrow Li^{+} + e^{-}$

Reduction: $2H_2O + 2e^{-} \rightarrow H_2 + 2OH^{-}$

2 **(a)** In 1905, Fritz Haber succeeded in the atmospheric 'fixing' of nitrogen with hydrogen to produce ammonia, which is a precursor in the production of fertilisers. This process is now known as the Haber process, which can be described by the chemical equation below. Haber later went on to receive a Nobel prize in 1918 for this achievement.

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

(i) Describe the conditions and catalyst used in the Haber process.

………………………………………………………………………………………………

……………………………………………………………………………………………… [1]

450 °C, 200-300 atm, finely divided Fe catalyst (and Al_2O_3 promoter) ;

(ii) Explain how the addition of the catalyst in **(a)(i)** affects the position of the equilibrium for the equation above.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

……………………………………………………………………………………………… [2]

The equilibrium position does not change as the catalyst increases the rate of the forward and backward reactions to the same extent. ;

(b) In aqueous solution, ammonia is a *weak Brønsted base*.

Define what is meant by the term *weak Brønsted base.*

....

.... [1]

A weak Bronsted base **dissociates partially in water to accept H^+ ions / protons**

(c) When excess bromoethane is reacted with limited ammonia, a multi-substituted product is produced.

Write an overall equation to for the reaction when ammonia is reacted with bromoethane in the molar ratio of 1 : 2. [1]

$NH_3 + 2\ CH_3CH_2Br \rightarrow (CH_3CH_2)_2NH + 2HBr$;

(d) 1,1,2-trichloroethane can undergo elimination to form an alkene which exhibits geometrical isomerism.

(i) Explain how geometrical isomerism arises in alkenes.

....

....

....

.... [2]

There is restricted rotation about the π bond ;

and the two groups attached to each adjacent carbon are different. ;

(ii) State the reagent and condition required for the elimination reaction.

.... [1]

ethanolic KOH, heat under reflux ;

(iii) Draw and name the structures of the two geometrical isomers.

[3]

***cis*-1,2-dichloroethene** ***trans*-1,2-dichloroethene ; (both names)**

(iv) State the number of σ and π bonds in each of the alkenes produced after elimination.

.... [1]

[Total: 12]

5 σ bonds and 1 π bond. ;

3 Use the third period of the modern Periodic Table, sodium to argon, to answer the following questions.

(a) Describe and explain how the atomic radii and first ionisation energies of these elements vary across the period.

....

....

....

....

....

.... [3]

Atomic radius generally **decrease** while first ionisation energies generally **increase** across the period. ;

Across the period, nuclear charge increases (as proton no. increases) while the increase in shielding effect is negligible. Effective nuclear charge increases ;

Hence, attraction for the valence electrons increases, distance of valence electrons from nucleus decreases. More energy is required remove a valence electron from the outer shell. ;

(b) State the structure and bonding present in sodium, magnesium and aluminium. Explain how the bonding present affects the variation in electrical conductivity of these elements.

....

....

....

.... [2]

[Total: 5]

Sodium, magnesium and aluminium have giant metallic lattice structure with strong electrostatic forces of attraction between positively charged cations and negatively charged delocalised electrons. ;

As the number of delocalised electrons increases from sodium to aluminium, there are more mobile charge carriers. Hence electrical conductivity increases from sodium to aluminium. ;

4 Rainwater has a pH of 5.6 instead of 7.0 at 25 °C. This is because carbon dioxide in the atmosphere dissolves in the rainwater and reacts to form an equilibrium with carbonic acid, H_2CO_3, with a K_c of 1.3×10^{-3} mol^{-1} dm^3. The carbonic acid then dissociates, acting as a weak Brønsted acid. Carbonic acid can be assumed to be a monoprotic acid with a K_a value of 4.27×10^{-7}.

Carbonic acid can also be found in the human blood stream as part of an acidic buffer system. When a person undergoes aerobic metabolism, the body uses oxygen to break down glucose to generate carbon dioxide and water as products. However, when a person exercises intensely, there could temporarily be insufficient oxygen for aerobic metabolism, hence producing a by-product called lactic acid, $CH_3CH(OH)COOH$. When lactic acid is built up in the muscles faster than it could be removed by the body, the person can suffer from a condition called lactic acidosis, in which the muscles feel a burning sensation. The lactic acid produced can be removed from the system by reacting with the acidic buffer system present in blood.

(a) Write an expression for the equilibrium constant, K_c, for the dissolution of carbon dioxide in rainwater.

[1]

$$K_c = \frac{[H_2CO_3]}{[H_2O][CO_2]} \quad ;$$

(b) **(i)** Construct a balanced equation, including state symbols, for the dissociation of carbonic acid in rainwater. Hence, write an expression for the acid dissociation constant of carbonic acid, K_a, and state its units.

[3]

$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ or $H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$;

$$K_a = \frac{[H^+][HCO_3^-]}{[H_2CO_3]} \quad ;$$

Units: mol dm^{-3} ;

(ii) Calculate the concentration of H^+ ions in rainwater.

[1]

$[H^+] = 10^{-5.6} = 2.512 \times 10^{-6} = 2.51 \times 10^{-6}$ mol dm^{-3} (3 s.f.)

(iii) Using your answers in **(b)(i)** and **(b)(ii)**, calculate the equilibrium concentration of carbonic acid, H_2CO_3, in water. You may assume that the equilibrium concentration of H^+ ions in rainwater is the same as the concentration of HCO_3^- ions.

[1]

$$K_a = \frac{[H^+][HCO_3^-]}{[H_2CO_3]} = \frac{[H^+]^2}{[H_2CO_3]}$$

$[H_2CO_3] = (2.512 \times 10^{-6})^2 \div (4.266 \times 10^{-7})$

$= 1.479 \times 10^{-5} = \underline{1.48 \times 10^{-5}\ \text{mol dm}^{-3}\ (3\ \text{s.f.})}$;

(do not penalise units here. Marks awarded for units in (b)(i))

(c) Write a balanced equation to show how small amounts of lactic acid, $CH_3CH(OH)COOH$ can be removed by the buffer system present in blood.

.... [1]

$CH_3CH(OH)COOH + HCO_3^- \rightarrow CH_3CH(OH)COO^- + H_2CO_3$;

Also accept $CH_3CH(OH)COOH + HCO_3^- \rightarrow CH_3CH(OH)COO^- + H_2O + CO_2$

(d) Lactic acid can be synthesised in the laboratory from ethanal, CH_3CHO, in two steps.

State the reagents and conditions for both steps and draw the structure of the intermediate organic compound in the space below.

Structure of intermediate:

Reagents and conditions for

Step 1: ....

Step 2: .... [3]

[Total: 10]

Intermediate: $CH_3CH(OH)CN$

Step 1: HCN, trace NaOH / NaCN / KCN, 10-20 °C ;

Step 2: dilute H_2SO_4, heat under reflux ;

Section B

Answer **two** questions from this section on separate answer paper.

5 **(a)** The boiling points of the halogens show the following trend.

Element	boiling point / °C
Cl_2	–35
Br_2	59
I_2	184

Explain, in terms of structure and bonding, the trend in the boiling point. [2]

Halogens have simple molecular structures, consisting of non-polar molecules held together by weak van der Waals' forces between molecules.

Down the group, the molecules becomes larger and the no. of electrons to be polarized increases / electron cloud size to be polarised increases. Thus, van der Waals' forces of attraction become stronger. More energy required to overcome the intermolecular forces of attraction. Hence, boiling points increase.

(b) The table shows the melting points of magnesium chloride and magnesium oxide respectively.

compound	**melting point / °C**
$MgCl_2$	714
MgO	2852

Account for the difference in the melting point of the two compounds in terms of their structure and bonding. [3]

MgO and $MgCl_2$ are have giant ionic lattice structure with strong electrostatic forces of attraction between oppositely charged ions. [1]

$$|\text{ lattice energy }| \propto \left|\frac{q_+ \times q_-}{r_+ + r_-}\right|$$

Both compounds have the same cation, but charge of O^{2-} is greater than that Cl^- and ionic radius of O^{2-} is smaller than that of Cl^-. [1]

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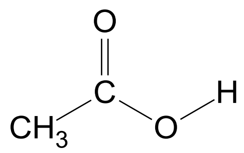
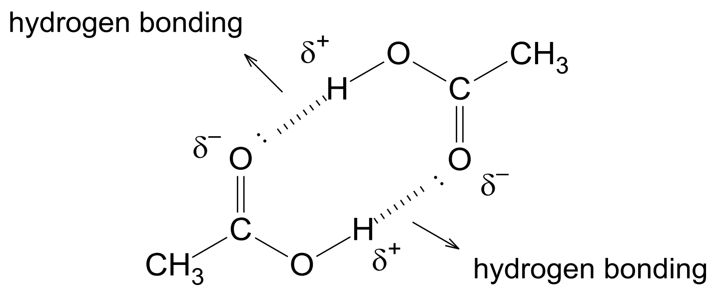
Thus, the magnitude of lattice energy of MgO is greater than that of $MgCl_2$, indicating that the ionic bonds of MgO is stronger. Hence more energy is required to break the stronger ionic bonds in MgO compared to $MgCl_2$. [1]

(c) The structural formula of ethanoic acid is given below.



Explain, with the aid of a diagram, why ethanoic acid has a M_r of 120 in organic solvent. [2]

The apparent M_r is 120 which is twice that of M_r of ethanoic acid. Ethanoic acid dimerises in organic solvent through the formation of intermolecular hydrogen bonding .



(Must have partial positive and negative signs, lone pair of electron on the oxygen and label the hydrogen bonds.)

(d) **(i)** Define, with the aid of an equation, the standard enthalpy change of combustion of propane, C_3H_8. [2]

Standard enthalpy change of combustion, ΔH_c^{θ}, of propane is the enthalpy change when *1 mole of the propane* is completely burnt in excess oxygen under standard conditions of 298K and 1 atm. [1]

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ (state symbols req) [1]

(ii) Calculate the enthalpy change of formation of propane, given the following data.

Standard enthalpy change of combustion of propane	-2220 kJ mol^{-1}
Standard enthalpy change of formation of water	-285 kJ mol^{-1}
Standard enthalpy change of formation of carbon dioxide	-394 kJ mol^{-1}

[1]

Let x be the enthalpy change of formation of propane.

ΔH_c^θ = sum of ΔH_f^θ (products) - sum of ΔH_f^θ (reactants) OR energy cycle

– 2220 = [3(–394) + 4(–285)] – (x)

x = -102 kJ mol^{-1} [1]

(iii) Propane is combusted under an open copper container with 2 dm^3 of water at 29.0 °C.

Using the data given below and in **(d)(ii)**, calculate the change in temperature of the water if 11.0 g of propane is combusted. Assume that the efficiency of heat transfer is 75%.

Specific heat capacity of water = 4.20 J g^{-1} K^{-1}

Density of water = 1.0 g cm^{-3} [3]

Mr of propane, C_3H_8 = 3 × 12.0 + 8 × 1.0 = 44.0

Amt of propane = 11.0 ÷ 44.0 = 0.25 mol **;**

Heat transferred to 2 dm^3 water

= Heat released by combustion of propane × 75%

= (2220 X 10^3)(0.25) × 75 %= 416.25 kJ = 416 250 J **;**

Q = mcΔT

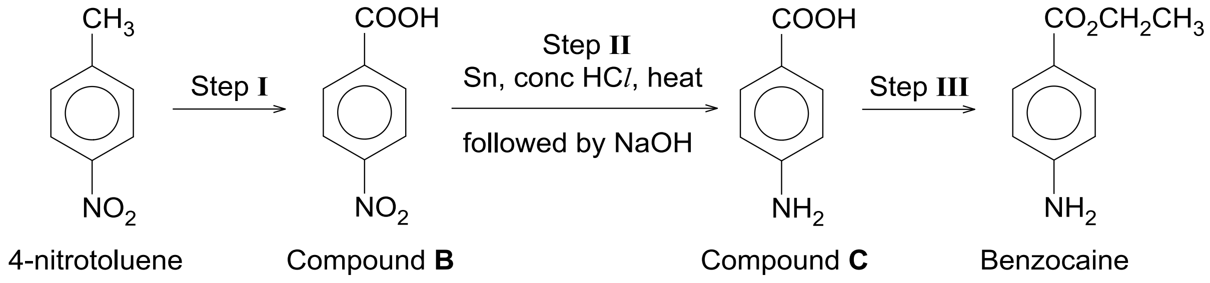
416 250 = (2000)(4.20) ΔT

ΔT = **49.6 °C (3 s.f.) ;**

(iv) Suggest a reason to explain why the efficiency of heat transfer is not 100%. [1]

Heat is lost to the surroundings [1]

(e) Benzocaine is a topical anaesthetic used in first aid creams and sunburn remedies. It can be produced from 4-nitrotoluene in a series of steps.



(i) State the reagents and conditions used for steps **I** and **III**. [2]

Step **I**: $KMnO_4$, dil. H_2SO_4, heat with reflux [1]

Step III: CH_3CH_2OH, conc H_2SO_4, heat with reflux [1]

(ii) State the type of reaction for steps **I** and **III**. [2]

Step **I**: Oxidation [1]

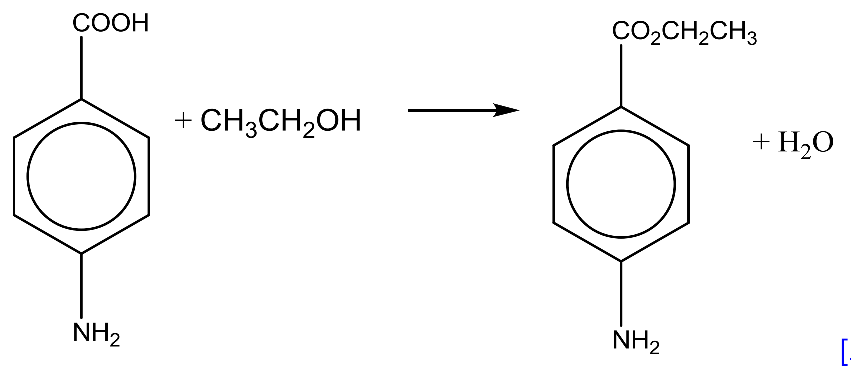
Step **III**: Substitution/Condensation/Esterification [1]

(iii) Explain why the NaOH in step **II** needs to be added carefully in order to obtain compound **C**. [1]

If too much NaOH is added, the carboxylic acid may exist as a carboxylate salt. [1]

(iv) Write a balanced equation for step **III**. [1]

[Total: 20]



[1]

6 **(a)** 2.78 g of a metallic oxide, represented by $\mathbf{M}_2O$ (where **M** is an unknown metal), was added to 43.7 cm^3 of 1.50 mol dm^{-3} hydrochloric acid. The resulting solution then required 13.0 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide for neutralisation.

Construct two balanced equations for the reactions that occur. Hence, determine the relative atomic mass of **M**. [4]

$NaOH + HCl \rightarrow NaCl + H_2O$

$2HCl + \mathbf{M}_2O \rightarrow 2\mathbf{M}Cl + H_2O$ [1]

No of moles of NaOH = 13.0/1000 x 0.5 = 6.5 x 10^{-3} mol

No of moles of HC*l* in the resulting solution = 6.5 x 10^{-3} mol

No of moles of HC*l* that has reacted with $\mathbf{M}_2O$ = (43.7/1000 x 1.50) – (6.5 x 10^{-3})

= 0.05905 mol [1]

No of moles of $\mathbf{M}_2O$ = 0.05905/2 = 0.029525 mol [1]

Mr of $\mathbf{M}_2O$ = 2.78/0.029525 = 94.2

Ar of M = (94.2 – 16)/2 = 39.1 [1]

(b) The reaction of ethanoic anhydride, $(CH_3CO)_2O$, with ethanol, C_2H_5OH, can be represented by the equation:

$$(CH_3CO)_2O + C_2H_5OH \rightarrow CH_3CO_2C_2H_5 + CH_3CO_2H$$

The table below shows the initial concentrations of the two reactants and the initial rates of reaction.

Experiment	**$[(CH_3CO)_2O]$ /mol dm^{-3}**	**$[C_2H_5OH]$ /mol dm^{-3}**	**Initial rate /mol dm^{-3} s^{-1}**
1	0.800	0.400	1.20 x 10^{-3}
2	0.800	0.800	2.40 x 10^{-3}
3	1.60	0.800	4.80 x 10^{-3}

(i) Deduce the order of the reaction with respect to each of ethanoic anhydride and ethanol. [2]

Rate = k $[(CH_3CO)_2O]^x[C_2H_5OH]^y$

Comparing experiment 1 and 2

Rate = k $[(CH_3CO)_2O]^x[C_2H_5OH]^y$

Comparing experiment 2 and 3

When $[C_2H_5OH]$ doubles, initial rate doubles, therefore
y =1
order with respect to C_2H_5OH = 1 **;**

When $[(CH_3CO)_2O]$ doubles, initial rate doubles, therefore
x =1
order with respect to $CH_3CO)_2O$ = 1 **;**

(ii) Write an expression for the rate equation. [1]

Rate = k $[CH_3CO)_2O][C_2H_5OH]$ **;**

(iii) Calculate the value, with units, for the rate constant, k. [1]

Using values from experiment 1:
$1.20 \times 10^{-3} = k\,(0.800)(0.400)$
$k = 3.75 \times 10^{-3}\ mol^{-1}\ dm^{3}\ s^{-1}$ **;**

(iv) With the aid of a diagram, explain how a catalyst increases the rate of a chemical reaction. [3]

- Catalyst increases the rate of reaction by providing an alternative pathway of lower activation energy
- Number of reactant particles with E ≥ Ea increases
- Frequency of effective collisions increases, rate increases

[all 3 points: 2m ; 1-2 points: 1m]

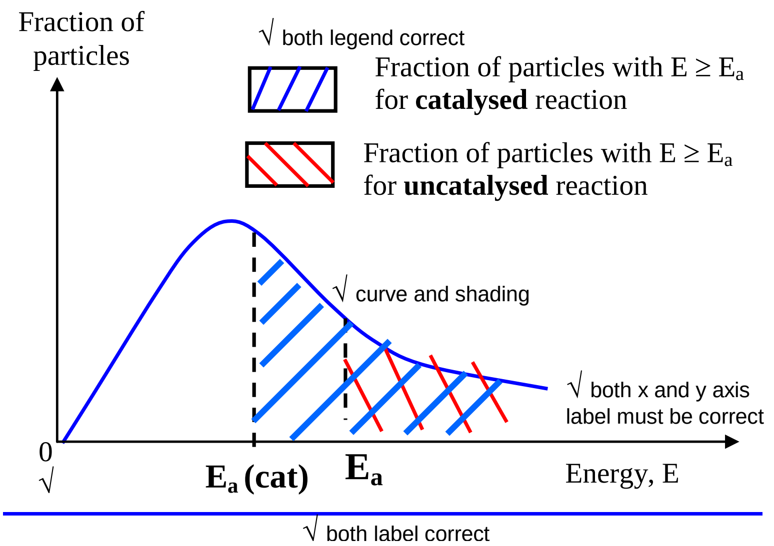
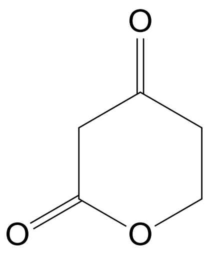


Diagram and legend [1m]
Must be correct graph to award any marks.

(c) On heating a neutral compound **D** (shown below) with dilute sulfuric acid, a single compound **E** ($C_5H_8O_4$) is produced. Both compounds **D** and **E** give an orange precipitate with 2,4-dinitrophenylhydrazine but do not react with Fehling's solution.

Upon treating **E** with HCN with a trace of NaCN, **F** ($C_6H_9O_4N$) is produced.

F gives **G** ($C_6H_{15}O_3N$) on reacting with lithium aluminum hydride in dry ether. **G** forms **H** ($Na_2C_6H_9O_5N$) when reacted with hot $KMnO_4$ in dilute NaOH.



Compound **D**

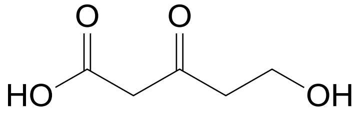
Suggest the structures of **E** to **H**, explaining the chemistry of the reactions described.
Write a balanced equation for the reaction of **D** with 2,4-dinitrophenylhydrazine.

[9]

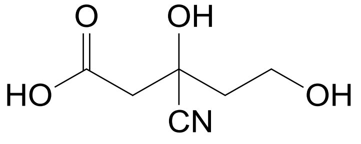
[Total: 20]

- **D** undergoes acid hydrolysis to form **E**
- **D** and **E** give orange ppt with 2,4 DNPH → condensation, carbonyl group present
- **D** and **E** does not react with Fehling's → absence of aliphatic aldehyde group
- **E** undergoes addition with HCN to form **F**
- **F** undergoes reduction/hydrogenation to give **G**.
- **G** undergoes oxidation with alkaline $KMnO_4$ to form H

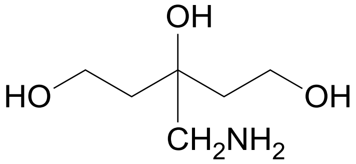
(capped at maximum of 4m, 8 ticks)

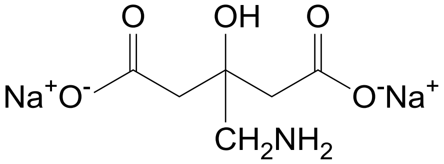
E: 

(COOH)$CH_2COCH_2CH_2OH$

F: 

(COOH)$CH_2C(OH)(CN)CH_2CH_2OH$

G: 

H: 

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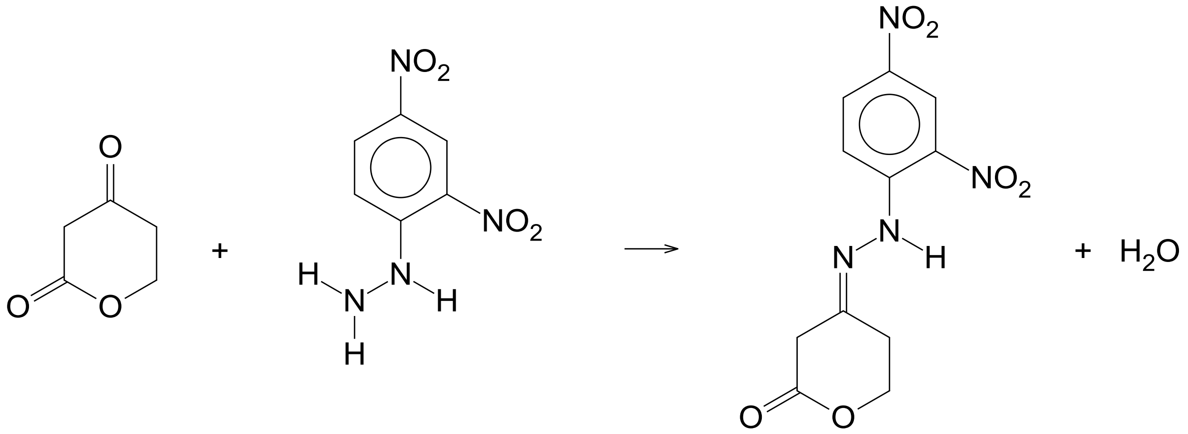
$CH_2OHCH_2C(OH)(CH_2NH_2)CH_2CH_2OH$ $(COO^-Na^+)CH_2C(OH)(CH_2NH_2)CH_2COO^-Na^+$

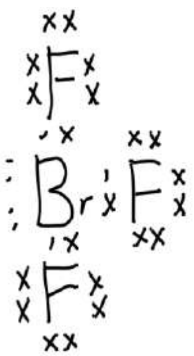


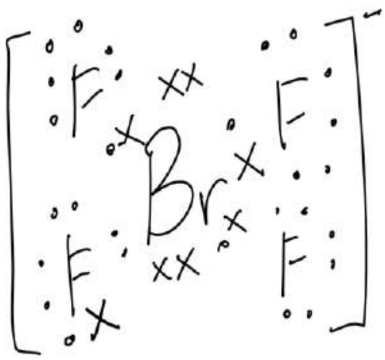
(each structure and equation 1 mark)

7 **(a)** Bromine trifluoride auto-ionises in the liquid state according to the equation.

$$2BrF_3 \rightleftharpoons BrF_2^+ + BrF_4^-$$

Draw the 'dot-and-cross' diagrams to show the outer shell electron arrangement of BrF_3 and BrF_4^-. Hence, predict the shapes of the two structures. [2]





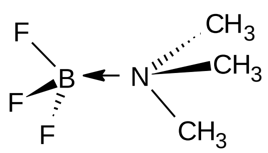
T-shaped (3bp 2lp) (Square Planar (4bp 2lp)

(b) Boron forms simple trihalides of formula BX_3 with all the halogens. BF_3 and BCl_3 are commonly used as catalyst in chemical reactions since they readily react with electron pair donors.

(i) Using VSEPR theory, explain the shape and state the bond angle of BF_3. [3]

BF_3 molecule has trigonal planar [1m] shape because to minimise repulsion the 3 bond pairs will be arranged as far apart as possible. [1m]
Bond angle is 120° [1m]

(ii) BF_3 and trimethylamine, $(CH_3)_3N$ react in a 1:1 ratio to give a white crystalline compound. Draw a diagram to illustrate and explain the type of bonding involved in the formation of the compound. [3]



;

In BF_3, there are only six electrons around the central atom hence, B is electron deficient. B in BF_3 has an energetically accessible vacant orbital to accept a lone pair of electrons ; from N to form a dative bond. ;

(c) Pure hydrogen iodide, HI, is a gas, which at high temperatures, partially decomposes into hydrogen and iodine, according to the equation:

$$2HI\,(g) \rightleftharpoons H_2\,(g) + I_2\,(g)$$

At 500 K, the equilibrium constant, K_c, for the decomposition reaction is 6.25×10^{-3}. Some pure HI is placed into an evacuated 2.0 dm^3 glass tube and heated to 500 K. In the equilibrium sample, the concentration of I_2 is 3.10×10^{-5} mol dm^{-3}.

(i) Calculate the concentrations of H_2 (g) and HI (g) in this equilibrium mixture at 500 K. [2]

$[H_2] = [I_2] = 3.10 \times 10^{-5}$ mol dm^{-3} [1]

$$K_c = \frac{[H_2][I_2]}{[HI]^2}$$

$$6.25 \times 10^{-3} = \frac{(3.10 \times 10^{-5})^2}{[HI]^2}$$

$[HI] = 3.92 \times 10^{-4}$ mol dm^{-3} [1]

(ii) Calculate the amount of HI that must have been placed in the 2.0 dm^3 glass tube originally. [2]

	2HI (g)	$\rightleftharpoons$ H_2 (g)	+ I_2 (g)
Initial / $moldm^{-3}$	*x*	0	0
change / $moldm^{-3}$	$-2(3.1 \times 10^{-5})$	$+3.1 \times 10^{-5}$	$+3.1 \times 10^{-5}$
equil / $moldm^{-3}$	3.92×10^{-4}	3.1×10^{-5}	3.1×10^{-5}

Initial [HI] = $3.92 \times 10^{-4} + 2(3.1 \times 10^{-5}) = 4.54 \times 10^{-4}$ mol dm^{-3} [1]

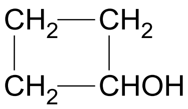
Initial amount of HI = $2(4.54 \times 10^{-4})$ mol

= 9.08×10^{-4} mol [1]

(iii) At 600 K, the K_c for dissociation of HI is 1.56×10^{-2}. Deduce whether the forward reaction is endothermic or exothermic. [2]

As temperature increases, by Le Chatelier's Principle, the system will respond in a way to decrease the temperature. Since K_c increases, this implies that the position of equilibrium shifts to the right (products). ; favoring endothermic reaction, which is the forward reaction. ;

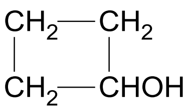
(d) Suggest simple one-step test-tube reactions by which the following pairs of isomers can be distinguished from each other. You should state the reagents and conditions for each test, and describe the observations for each of the isomers in the pair.

(i) 

and $CH_3CH{=}CHCH_2OH$ [2]

Test: Add aqueous bromine to each sample [1]

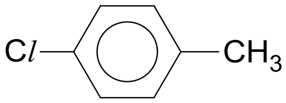
Observation:

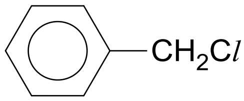


: orange colour of aqueous bromine remains

$CH_3CH{=}CHCH_2OH$: orange aqueous bromine decolourises

Both observation correct: [1]

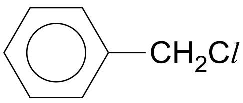
(ii) 

and 

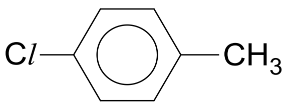
[2]

Test: NaOH and heat. Add HNO_3, followed by $AgNO_3$. [1]

Obs:



: white precipitate of AgCl observed



: No white precipitate of AgCl observed

Both observation correct: [1]

(iii) $CH_3CH(OH)CH_3$ and $CH_3CH_2CH_2OH$ [2]

[Total: 20]

Test: add aqueous I_2 in aqueous NaOH, warm. [1]

Obs:

$CH_3CH(OH)CH_3$: yellow ppt of CHI_3 formed

$CH_3CH_2CH_2OH$: No yellow ppt

Both observation correct: [1]

END OF PAPER 2

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NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CHEMISTRY 8872/01

Paper 1 Multiple Choice **25 Sep 2017**

50 minutes

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, CT and NRIC / FIN on the Answer Sheet in the spaces provided.

There are **thirty** questions in 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.

Section A

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 compound S_2O_7 is hydrolysed by water to produce sulfuric acid and oxygen.

What volume of oxygen, measured at room temperature and pressure, is evolved when 0.352 g of S_2O_7 is hydrolysed?

A 12 cm^3 **B** 24 cm^3 **C** 48 cm^3 **D** 96 cm^3

2 Tanzanite is used as a gemstone for jewellery. It is a hydrated calcium aluminium silicate mineral with a chemical formula of $Ca_2Al_aSi_bO_{12}(OH).6½H_2O$. Tanzanite has M_r of 571.5.

Its chemical composition is 14.04% calcium, 14.17% aluminium, 14.75 % silicon, 54.59% oxygen and 2.45% hydrogen.

What are the values of a and b?

	a	b
A	1	1
B	2	3
C	3	3
D	6	1

3 Ammonium nitrate, NH_4NO_3, can decompose explosively when heated.

$$NH_4NO_3 \rightarrow N_2O + 2H_2O$$

What are the changes in the oxidation numbers of the two nitrogen atoms in NH_4NO_3?

A −2, −4 **B** +2, +6 **C** +4, −6 **D** +4, −4

4 Tritium is the isotope of hydrogen ^{3}H.

Which of the following is the same for a ^{4}He atom and a ^{3}H atom?

A the relative atomic mass

B the number of electrons

C the number of protons

D the number of neutrons

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

What could be the proton number of an element that has three unpaired electrons in each of its atoms?

A 5 **B** 13 **C** 15 **D** 21

6 Why does aluminium chloride, Al_2Cl_6, sublime at a relatively low temperature of 180 °C?

A The intermolecular forces between the Al_2Cl_6 molecules are weak.

B The co-ordinate bonds between aluminium and chlorine are weak.

C The covalent bonds between aluminium and chlorine are weak.

D The ionic bonds between aluminium and chlorine are weak.

7 Which of these statements cannot be explained by hydrogen bonding?

A At 0 °C, ice floats on water.

B At 20 °C, propanone and propanal are miscible.

C The relative molecular mass of ethanoic acid in benzene is 120.

D The boiling point of propan-2-ol and propanone are 82 °C and 56 °C respectively.

8 Silica, SiO_2 has many industrial uses, including the manufacture of glass, ceramic and cement.

In the structure of solid SiO_2

- each silicon atom is bonded to x oxygen atoms,
- each oxygen atom is bonded to y silicon atoms,
- each bond is a z bond.

What is the correct combination of x, y and z in these statements?

	x	y	z
A	2	1	covalent
B	2	1	ionic
C	4	2	covalent
D	4	2	ionic

9 Ethanol, commonly made from biomass such as sugarcane is increasingly being used as a green fuel due to its lower greenhouse gas emissions as compared to burning fossil fuels.

The appropriate enthalpy changes of formation are given in the table.

Compound	$\Delta H_f^\ominus$ / kJ mol^{-1}
Carbon dioxide	−393
Water	−286
Ethanol	−277

What is the enthalpy change of combustion of ethanol?

A $\Delta H_c^\ominus = -1921$ kJ mol^{-1}

B $\Delta H_c^\ominus = -1367$ kJ mol^{-1}

C $\Delta H_c^\ominus = -956$ kJ mol^{-1}

D $\Delta H_c^\ominus = -402$ kJ mol^{-1}

10 A student mixed 30.0 cm^3 of 0.350 mol dm^{-3} sodium hydroxide solution with 25.0 cm^3 of 0.350 mol dm^{-3} hydrochloric acid. The temperature rose by 2.5 °C. Assume that 4.20 J is required to raise the temperature of 1 cm^3 of the solution by 1 K.

Which is the enthalpy change of neutralisation?

A $\Delta H_n^\ominus = -330$ kJ mol^{-1}

B $\Delta H_n^\ominus = -66$ kJ mol^{-1}

C $\Delta H_n^\ominus = -55$ kJ mol^{-1}

D $\Delta H_n^\ominus = -30$ kJ mol^{-1}

11 $Na_2S_2O_3$ reacts with dilute HCl to give a pale yellow precipitate. If 1 cm^3 of 0.1 mol dm^{-3} HCl is added to 10 cm^3 of 0.02 mol dm^{-3} $Na_2S_2O_3$, the precipitate forms slowly.

If the experiment is repeated with 1 cm^3 of 0.1 mol dm^{-3} HCl and 10 cm^3 of 0.05 mol dm^{-3} $Na_2S_2O_3$, the precipitate forms more quickly.

Why is there a difference in observation when 0.05 mol dm^{-3} $Na_2S_2O_3$ is used?

A The reactant particles collide more frequently.

B The reaction proceeds by a different pathway.

C The activation energy of the reaction is lower.

D The collisions between reactant particles are more violent.

12 Which statement about dynamic equilibrium is always correct?

A Equal amounts of reactants and products are present.

B Concentrations of reactants and products remain constant.

C The rates of the forward and reverse reactions are equal to zero.

D The rate constant for the forward reaction equals the rate constant for the reverse reaction.

13 The following equilibrium is set up in a mixture of concentrated nitric acid and sulfuric acid.

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

Which row correctly describes the behaviour of each substance in the reaction mixture?

	HNO_3	H_2SO_4	$H_2NO_3^+$	HSO_4^-
A	acid	acid	base	base
B	acid	base	acid	base
C	base	acid	acid	base
D	acid	base	base	acid

14 The table gives the concentrations and pH values of the aqueous solutions of two compounds, F and G. Either compound could be an acid or a base.

	F	G
concentration	2 mol dm^{-3}	2 mol dm^{-3}
pH	6	9

Student P concluded that G is a weak base.

Student Q concluded that the extent of dissociation is lower in F(aq) than in G(aq).

Which of the students are correct?

A both P and Q

B neither P nor Q

C P only

D Q only

15 The value of the ionic product, 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 Water is not a neutral liquid at 62 °C.

B The ionic dissociation of water is an endothermic process.

C Hydrogen bonding between water molecules increases as temperature rises.

D The ionic dissociation of water increases by a factor of 5 between 25 °C and 62 °C.

16 Elements X and Y are both in Period 3. Element X has the smallest atomic radius in Period 3. There are only two elements in Period 3 which have a lower melting point than element Y. Elements X and Y react together to form compound Z.

Which compound could be Z?

A $MgCl_2$ **B** SCl_2 **C** Na_2S **D** PCl_5

17 The electrical conductivities of two compounds, H and I, are shown in the table.

Electrical conductivity	H	I
conductivity of the compound in the liquid state	good	does not conduct
conductivity of the mixture obtained by adding the compound to water	good	good

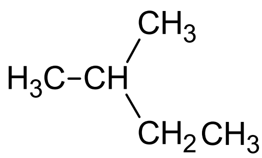
What could compounds H and I be?

	H	I
A	NaF	$SiCl_4$
B	NaF	Al_2O_3
C	Al_2O_3	$SiCl_4$
D	$SiCl_4$	Al_2O_3

18 Alcohols can be classified into primary, secondary and tertiary alcohols. How many structural isomers are there for each type with the formula $C_5H_{12}O$?

	primary	secondary	tertiary
A	3	3	2
B	4	2	2
C	4	3	1
D	5	2	1

19 When 2-methylbutane reacts with limited chlorine gas in the presence of uv light, monochlorinated compounds are formed.



2-methylbutane

Which of the following statements is **not** correct?

A H_2 molecule is a by-product of the reaction.

B Four different monochlorinated isomers may be formed.

C The reaction can take place if heat is used instead of uv light.

D The colour in the reaction vessel changes from yellow-green to white.

20 S and T are isomers of $C_4H_6Br_2$.

S T

Which of the following are three **different** possible products formed when S and T isomers react with HBr?

A	$(CH_3)_2CHCBr_3$	$(CH_3)_2CBrCHBr_2$	$CH_3CHBrCHBrCH_3$
B	$(CH_3)_2CBrCHBr_2$	$CHBr_2CBr(CH_3)_2$	$CH_3CHBrCBr_2CH_3$
C	$(CH_3)_2CBrCBr_3$	$(CH_3)_2CHCBr_3$	$CH_3CBr_2CHBrCH_3$
D	$(CH_3)_2CHCBr_3$	$(CH_3)_2CBrCHBr_2$	$CH_3CBr_2CHBrCH_3$

21 A catalytic converter is part of the exhaust system of many modern cars. Which reactions occur in a catalytic converter?

A $2CO + 2NO \rightarrow 2CO_2 + N_2$

B $2SO_2 + 2NO \rightarrow 2SO_3 + N_2$

C $C_6H_{14} \rightarrow C_2H_4 + C_4H_{10}$

D $CO_2 + NO \rightarrow CO + NO_2$

22 Sodium hydroxide reacts with chloropropane in a series of steps to produce propanal.

$$CH_3CH_2CH_2Cl \longrightarrow \longrightarrow CH_3CH_2CHO$$

Which of the following terms describe the first step of this reaction?

A addition

B elimaintion

C oxidation

D substitution

23 Which of the following reagents can be used to differentiate the two alcohols?

$CH_3CH_2CH_2CH(OH)CH_3$ $CH_3CH_2CH(OH)CH_2CH_3$

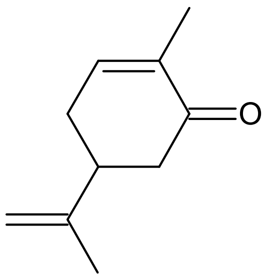
A Acidified $K_2Cr_2O_7$

B Acidified $KMnO_4$

C Tollens' reagent

D I_2 (aq), NaOH

24 Carvone is used to give the flavour of spearmint in chewing gums.



Carvone

Prolonged heating of carvone with hot concentrated acidified potassium manganate(VII) produces compound L.

What is the maximum number of molecules of 2,4-dinitrophenylhydrazine that will react with one molecule of L?

A 1 **B** 2 **C** 3 **D** 4

25 Butanedioic acid may be synthesised in two steps from 1,2-dibromoethane.

$$BrCH_2CH_2Br \xrightarrow{\text{step 1}} X \xrightarrow{\text{step 2}} HO_2CCH_2CH_2CO_2H$$

Which of the following reagents can be used for this synthesis?

	step 1	step 2
A	HCN and KCN	HC*l*
B	$HCO_2^-Na^+$	HC*l*
C	NaOH	$K_2Cr_2O_7$ and H_2SO_4
D	KCN in ethanol	H_2SO_4

Section B

For each of the questions in this section one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements which you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 Methanol is manufactured industrially by the catalytic reaction shown.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H < 0$$

The operating conditions are:

- 250 °C
- a pressure between 50 atm and 100 atm
- a copper-based catalyst

Which factor influences the choice of these conditions?

1 The catalyst increases the equilibrium yield of methanol

2 At high pressures, the rate of formation of methanol increases.

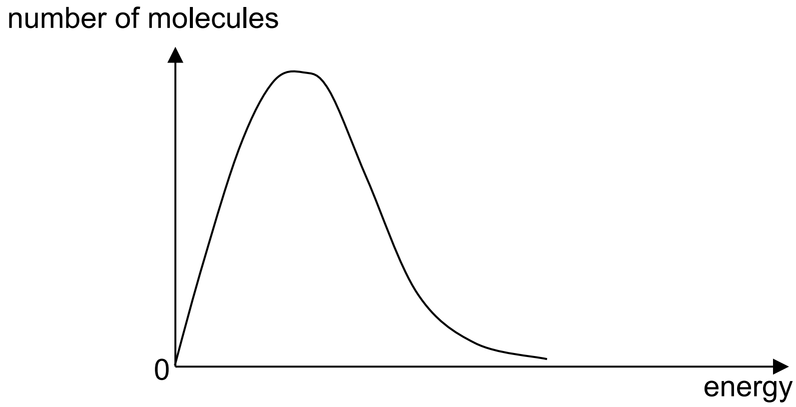
3 At lower temperatures, the equilibrium yield of methanol increases.

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

27 The graph below shows the Boltzmann distribution of molecular energies.



Which of the following statements are correct?

1 Raising the temperature increases the spread of molecular energies.

2 The area under the curve is proportional to the number of molecules present.

3 Raising the temperature always increases the number of molecules with a given energy.

28 A little water is added to each of the following compounds and the mixture warmed. For which compounds will an acidic gas be evolved?

1 aluminium chloride

2 silicon chloride

3 phosphorus pentachloride

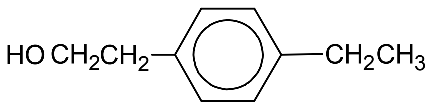
The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

29 Which of the following structures will give benzene–1,4–dicarboxylic acid as the only organic product when heated with acidified $KMnO_4$ under reflux?

1



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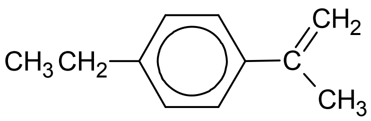

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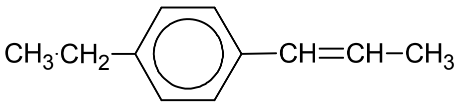

30 Bromoethane reacts with NaOH in different ways depending on the solvent used. Which of the following are correct?

	solvent	main organic product
1	water	ethane-1,2-diol
2	ethanol	ethene
3	water	ethanol

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

H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME			
CLASS		TUTOR'S NAME	

CHEMISTRY **8872/02**

Paper 2

11 Sep 2017

2 hours

Candidates answer Section A on the Question Paper

Additional Materials: Answer Paper
Data Booklet
Graph paper

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, graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section **A**
Answer **all** the questions.

Section **B**
Answer **two** questions on separate answer paper.

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	
Section A	
B5	
B6	
B7	
Total	**/80**

This document consists of **16** printed pages.

Section A

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

1 (a) (i) The bond energy of the carbon-carbon single bond in the ethane molecule is 350 kJ mol^{-1}. It was expected that bond energy of the carbon-carbon double bond in the ethene molecule to be twice that of the carbon-carbon single bond in the ethane. However, actual bond energy of the carbon-carbon double bond in the ethene molecule is only 610 kJ mol^{-1}. Account for the difference.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………[2]

(ii) Ethanol is miscible in water because of interactions between molecules of ethanol and water. Draw a labelled diagram to show the interaction between a molecule of ethanol and a molecule of water.

[1]

(iii) Explain why unlike ethanol, butanol is immiscible in water.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………[1]

For Examiner's Use

(b) The molecule of benzene, C_6H_6, is a regular hexagon in which the π electrons are described as being delocalised.

(i) Draw a diagram to illustrate the delocalisation of π electrons in benzene.

[1]

(ii) The delocalised π electrons results in characteristic chemical properties of benzene. Explain why benzene undergo substitution rather than addition reactions.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………......[1]

(iii) Compare the relative ease of oxidation of benzene and methylbenzene. State the reagents and conditions necessary for oxidation to take place.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………......[2]

For Examiner's Use

(c) Free chlorine atoms, initially formed in the upper atmosphere by the action of ultraviolet light on chlorofluorocarbons, CFCs, are believed to be responsible for the destruction of the ozone layer.

By reference to the Data Booklet, suggest why industrial use of CFCs such as CF_2Cl_2 were replaced by flurohydrocarbons such as $C_2H_2F_4$.

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....

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.... [2]

[Total: 10]

For Examiner's Use

2 **(a)** Lead(II) chromate, $PbCrO_4$, has a vivid yellow colour and is insoluble in water. It is used in paints under the name chrome yellow. However when exposed to atmosphere containing sulfur dioxide, SO_2, the yellow colour slowly changes due to formation of Cr^{3+}.

(i) Write the half equation for the reaction of CrO_4^{2-} to form Cr^{3+}.

……………………………………………………………………………………........[1]

(ii) In an experiment, 0.0150 mol of CrO_4^{2-} reacted with 0.0225 mol of SO_2. Determine the new oxidation number of sulfur.

[2]

(iii) Hence predict identity of the sulfur product from the table of sulfur-containing compounds.

Compound	S^{2-}	HSO_3^{2-}	SO_3^{2-}	SO_4^{2-}

Identity of sulfur-containing product: …………………….

[1]

(b) 20.00 g of lead(II) chromate is dissolved in 100 cm^3 of acid solution and allowed to stand for a long time to reach equilibrium according to the equation below:

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O\,(l)$$

K_c = 7.55 x 10^{12} mol^{-3} dm^9

(i) Write a K_c expression for the above equilibrium.

[1]

For Examiner's Use

(ii) Calculate initial concentration of CrO_4^{2-}(aq).

[1]

(iii) At equilibrium, only **one-fifth** of the original amount of CrO_4^{2-}(aq) remain, determine the equilibrium concentration of CrO_4^{2-}(aq) and $Cr_2O_7^{2-}$(aq).

[2]

(iv) Hence calculate pH of the solution.

[1]

(v) Given that aqueous CrO_4^{2-} solution is yellow in colour while aqueous $Cr_2O_7^{2-}$ solution is orange in colour, predict and explain what will be observed when aqueous NaOH is added to the above mixture in equilibrium.

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………………......[2]

[Total: 11]

3 An unknown compound X has the molecular formula C_3H_8O and is a liquid at room temperature.

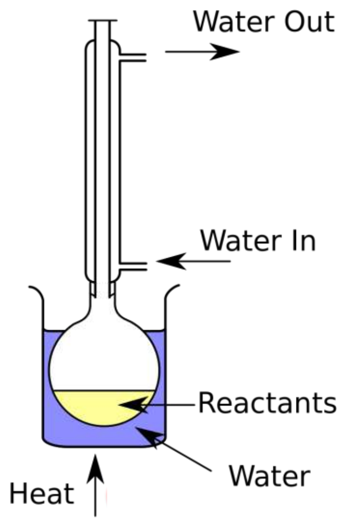
A student placed 5 cm^3 of X in a test tube and added a strip of sodium into the test tube. He observes bubbles forming vigorously at the surface of the sodium strip and floats to the surface. He suggest collecting the gas and devise a method to test it.

(a) Describe how the gas can be tested to confirm its identity, and what would be observed to confirm the identity of the gas.

……………………………………………………………………………………………..

……………………………………………………………………………………………..[2]

The following apparatus was assembled to carry out further experiment on X.



He first put 5 cm^3 of dilute sulfuric acid in the round bottom flask. He then added 5 drops of potassium dichromate(VI) solution followed by 2 cm^3 of X. The mixture was heated till it started boiling and a colour change was observed.

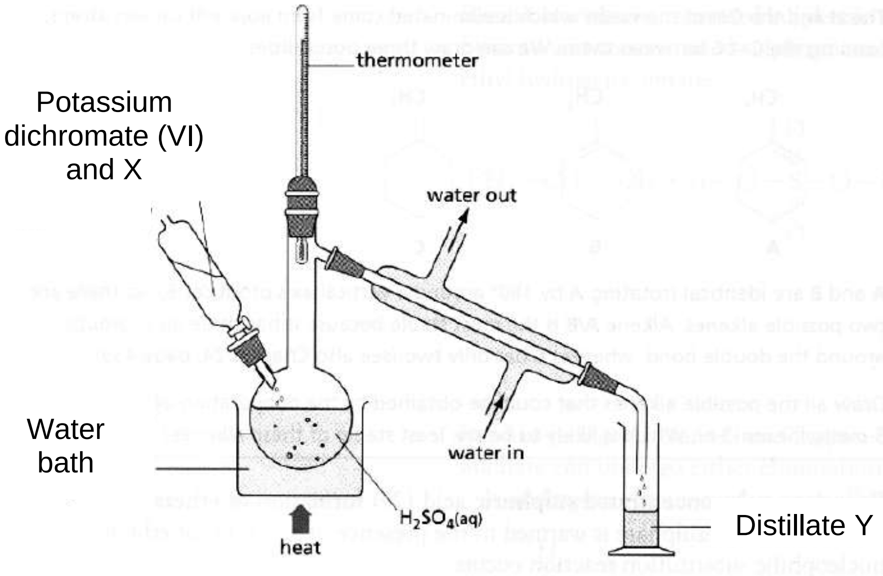
(b) **(i)** What colour change would the student see as the reaction is carried out?

………………………………………………………… [1]

(ii) Name the type of reaction that has occurred.

Type of reaction: …………………….………… [1]

The set-up was rearranged as shown.



He repeated the process of adding 5 cm^3 of dilute sulfuric acid into the round bottom flask, followed by 5 drops of potassium dichromate(VI) solution and 2 cm^3 of X. The distillate collected was labelled as Y.

The student observed reddish brown precipitate when he gently warmed a small sample of Y with Fehling's solution in a test tube.

(c) **(i)** Draw the structures of X and Y.

[1]

(ii) Write equation for reaction between Y and Fehling's solution.

…………..……………………………………………………………………….[1]

(iii) Suggest a simple chemical test to distinguish between X and Y. Describe clearly what will be observed. Do not repeat reagents that had been mentioned in this question.

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..[2]

[Total: 8]

4 The Paris Agreement, signed in 2015 by 195 countries, was aimed to slow down global warming by reducing human activities that generate emission of gases that cause harm to the environment.

Over the past decade, Singapore has adopted cleaner energy sources to fuel electricity demand, moving away from petroleum products such as diesel and fuel oil to the more environmentally-friendly fossil fuel alternative: natural gas (Methane, CH_4). It has been found that combustion of methane releases 890 kJ of heat and emits about 35 per cent less carbon dioxide than the petroleum-based oil that Singapore was using.

In many developing countries however, there is still heavy reliance on the use of coal to generate electricity. Combustion of carbon generates only 394 kJ of heat and is known to be much more polluting. The following table compares these two types of power generation.

Type of power station	Overall efficiency of power station	Amount of by-product produced per MJ of electrical energy (1MJ = 10^6J)	
		SO_2	NO_2
Coal	40%	0.31 g	0.64 g
Natural gas	51%	0.0015 g	0.11 g

For your calculations, assume that coal consists of 95% of carbon and 5% of non-combustible ash.

'Water-gas' is an equimolar mixture of hydrogen and carbon monoxide and in some cases is used in place of methane as an industrial gaseous fuel. It is produced when steam is blowing through white-hot coke in the following reaction.

$$H_2O\,(g) + C(s) \rightarrow H_2\,(g) + CO\,(g)$$

Complete combustion of hydrogen and carbon monoxide releases 242 kJ and 283 kJ of heat respectively.

(a) Define the term *enthalpy change of combustion*.

…………………………………………………………………………………………………

……………………………………………………………………………………………...[1]

(b) Write balanced equation with state symbols for the complete combustion of

(i) Carbon: ………………………………………………………………………………..

Methane: ……………………………………………………………………………..

[1]

(ii) Calculate how many moles of carbon and methane need to be burned in order to produce 1 MJ of **heat** energy.

[1]

(iii) Calculate how many moles of methane and carbon need to be burned in order to produce 1 MJ of **electrical** energy.

[1]

(c) Calculate the mass of ash that would be produced per MJ of electrical energy in a coal-fired power station.

[1]

(d) **(i)** Explain why it is important to cut down CO_2 emissions?

....

....

....[1]

For Examiner's Use

(ii) Despite the obvious environmental impact of generating electricity using coal, many countries continue using coal burning power station because it is cheaper and easier to operate. Suggest why this is so.

....

....

....[1]

(e) **(i)** Use answer from **(b)(ii)** to calculate the volume of methane required to produce 1 MJ of heat energy.

[1]

(ii) Calculate the volume of water gas required to produce 1 MJ of heat energy.

[2]

(iii) Based on your calculations, or on other considerations, suggest an advantage of using natural gas rather than water gas. Give reasons for your answers.

....

....

....[1]

[Total: 11]

Section B

Answer **two** questions from this section on separate answer paper.

5 **(a)** Spathose is an iron ore that contains iron(II) carbonate, $FeCO_3$. The percentage of iron(II) carbonate in spathose can be determined by titration with acidifed potassium manganate(VII) solution using a suitable indicator.

The ionic equation is shown below.

$$5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$$

A 5.00 g sample of spathose was reacted with sulfuric acid and then filtered.

The filtrate was made up to 250 cm^3 in a volumetric flask with distilled water.

A 25.0 cm^3 sample of the standard solution required 27.30 cm^3 of 0.0200 mol dm^{-3} potassium manganate(VII) solution for complete reaction.

Calculate the percentage by mass of iron(II) carbonate in the sample of spathose. [3]

(b) The following table compares the pK_a values of malonic acid, a dicarboxylic acid with that of propanol and propanoic acid.

acid	formula	pK_1	pK_2
malonic acid	$HO_2CCH_2CO_2H$	2.83	5.69
propanol	$CH_3CH_2CH_2OH$	16.1	–
propanoic acid	$CH_3CH_2CO_2H$	4.88	–

(i) Explain why the pK_a value for propanoic acid is smaller than the pK_a of propanol. [2]

(ii) Explain why the pK_1 value is smaller than the pK_2 for malonic acid. [1]

The monosodium salt of malonic acid is added to some foodstuffs as buffers.

(iii) Explain what is meant by the term *buffer solution*. [1]

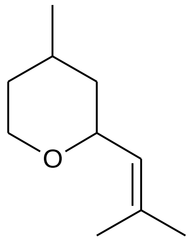
(iv) Write two equations to show how monosodium malonate, $HO_2CCH_2CO_2^-Na^+$, acts as a buffer. [2]

(c) Separate samples of Na_2O and P_4O_{10} were added to water.

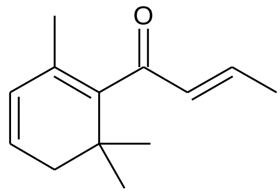
(i) For each oxide, write a balanced equation for its reaction with water and suggest a numerical value for the pH of the resulting solution. [4]

(ii) Construct a balanced equation for the reaction that occurs when a solution of Na_2O in water reacts with a solution of P_4O_{10} in water. [1]

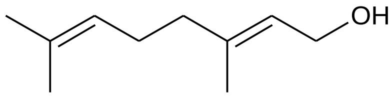
(d) Rose oil is extracted from the petals of various types of rose. It contains the following organic compounds.



rose oxide



damascenone



geraniol

Describe two chemical tests that would allow you to distinguish between separate unlabelled samples of rose oxide, damascenone, geraniol. State what you would observe in each test, for each compound. Write equations for each positive test. [6]

[Total: 20]

6 Iodine and chlorine are commonly used for chemical purification of water outdoors.

(a) Iodine treatment of water involves the use of iodine tincture. It is usually made up of 2-7% elemental iodine with sodium iodide, dissolved in a mixture of ethanol and water. When sodium iodide is added with elemental iodine in water, an equilibrium is established and triiodide ions are formed.

$$I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq)$$

Chlorine treatment of water involves the use of tablets that contain sodium chlorite(III), $NaClO_2$. When sodium chlorite(III) dissolves in water, chlorine dioxide, ClO_2, which is a radical is formed. It is an effective disinfectant against most waterborne pathogenic agents.

(i) Draw the dot-and-cross diagrams of I_3^- ion and ClO_2 molecule. Use the Valence Shell Electron Pair Repulsion (VSEPR) theory to state and explain the shape of the species. [4]

(ii) Elemental iodine has low solubility in water. Sodium iodide is added to increase its solubility.

Explain why the triiodide ion formed is more soluble in water. Draw a labelled diagram to show how a water molecule can be attached to a triiodide ion and the type of interaction involved. [2]

(iii) The enthalpy change of vaporisation of chlorine dioxide is less endothermic than elemental iodine. Explain why. [2]

(b) **(i)** Define, with an equation, the first ionisation energy of chlorine. [2]

(ii) Explain why the first ionisation energy of iodine is lower than the first ionisation energy of chlorine. [2]

(iii) Sketch the trend of first ionisation energy across Period 3 and account for any anomaly to the general trend. [5]

(c) Hydrocarbon undergoes reactions with chlorine under different conditions.

Suggest the structures of the products formed when the following hydrocarbons react under different conditions with chlorine.

(i) butane with chlorine gas in the presence of uv light [1]

(ii) but-1-ene with chlorine gas in the dark [1]

(iii) methylbenzene with chlorine gas and anhydrous aluminium chloride [1]

[Total: 20]

7 **(a)** **(i)** Using the chlorides of magnesium, silicon and phosphorus as examples, describe their reactions, if any, with water. Explain the trend in the pH of the solutions formed. Write balanced equations for any reactions that take place. [4]

(ii) Suggest how the type of bonding present in these three chlorides affect their reaction with water. [1]

(b) Hydrogen peroxide decomposes in the presence of iodide ions according to the following equation.

$$2H_2O_2(aq) \rightarrow O_2(g) + 2H_2O(l)$$

To study the kinetics of the above reaction, a 80 cm^3 mixture containing the following was prepared.

- 30 cm^3 of 0.100 mol dm^{-3} of H_2O_2
- 30 cm^3 of 1.00 mol dm^{-3} of iodide ions
- 20 cm^3 distilled water

At every five minutes interval, 10.0 cm^3 samples were removed and 50 cm^3 of cold water was added, followed by a titration against a solution of fixed concentration of potassium manganate(VII).

The experiment was repeated using 2.00 mol dm^{-3} of iodide ions.

The following results were obtained.

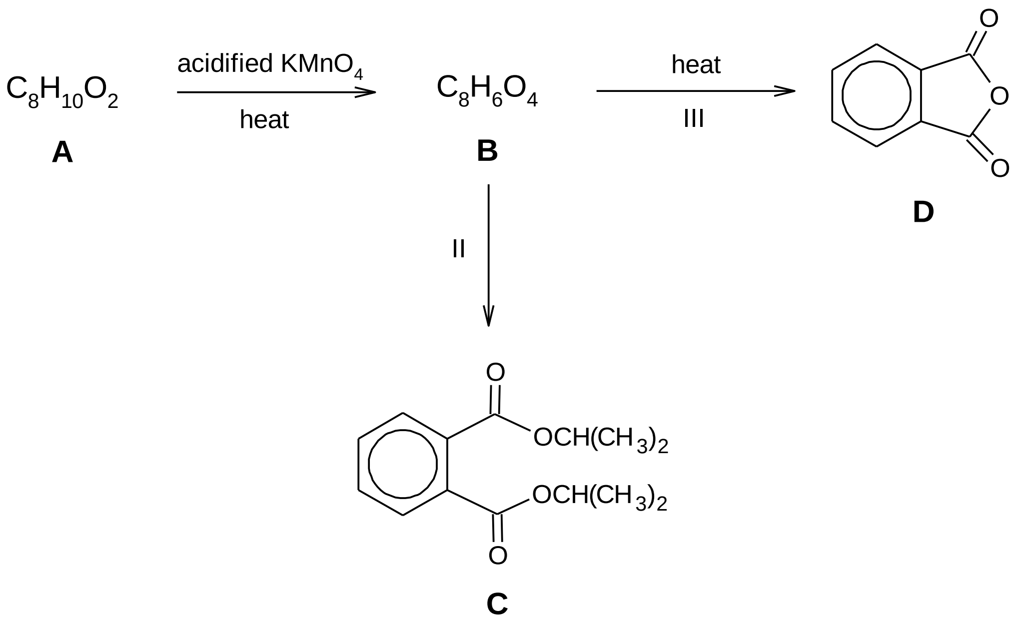
Experiment	Time/min	0	5	10	15	20	25
1	Volume of $KMnO_4$ / cm^3 when [iodide ions] = 1.00 mol dm^{-3}	30.00	20.00	15.00	11.00	7.50	5.00
2	Volume of $KMnO_4$ / cm^3 when [iodide ions] = 2.00 mol dm^{-3}	30.00	15.00	7.50	3.75	1.875	0.938

(i) Explain why 50 cm^3 of cold water was added prior to the titration. [1]

(ii) Plot a graph of these results, putting all the data on the same axes. Label each curve clearly. [1]

(iii) Use your graph to deduce the order of reaction with respect to hydrogen peroxide and iodide ions. Hence, write a rate equation for this reaction and state the units of the rate constant. [5]

(c) **(i)** Suggest structures for compounds **A** and **B** in the following scheme, explaining all the reactions involved. Hence, write a balanced equation for the conversion from **A** to **B**.



[4]

(ii) State the type of reaction, and reagents and conditions for reaction II. [2]

(iii) Describe a simple chemical test that would allow you to distinguish between compounds **C** and **D**. [2]

[Total: 20]

2017 J2 H1 Chemistry Prelim Answers

Paper 1 Answer Key

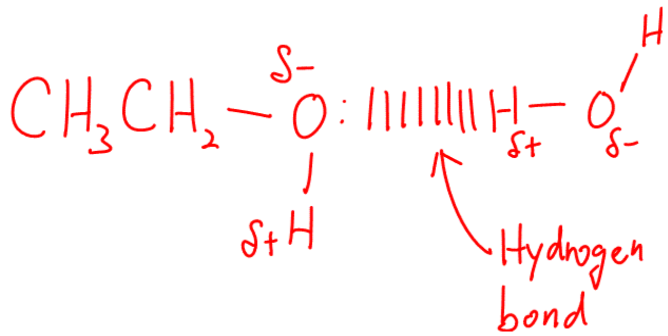
1	**B**	6	**A**	11	**A**	16	**D**	21	**A**	26	**C**
2	**C**	7	**B**	12	**B**	17	**A**	22	**D**	27	**B**
3	**D**	8	**C**	13	**C**	18	**C**	23	**D**	28	**A**
4	**D**	9	**B**	14	**A**	19	**A**	24	**C**	29	**B**
5	**C**	10	**B**	15	**B**	20	**D**	25	**D**	30	**C**

Paper 2 Section A Answers

1 **(a)** **(i)** The carbon-carbon single bond in the ethane molecule consists of 1 π bond. The carbon=carbon double bond in ethane molecule consists of 1 σ bond and 1 π bond.

A π bond is weaker than a σ bond due to less effective overlap, hence C=C bond is less than twice of C-C bond.

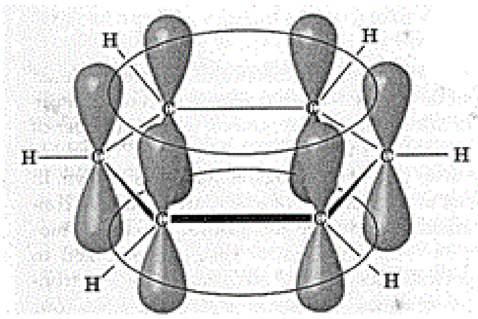
(ii)



(iii) Ethanol and butanol differs in the size of the non-polar hydrocarbon chain.

Butanol is insoluble in water even though it can form hydrogen bonds with water. Its <u>predominantly forms dispersion forces with water due to its long, non-polar hydrocarbon chain</u>. The energy released during formation of these dispersion forces is <u>not enough to overcome the hydrogen bonds between water molecules and the dispersion forces between butanol</u>.

(b) **(i)**



(ii) The delocalised π electron cloud results in stability, so the loss of this aromatic character is not energetically favored. Instead, benzene tends to undergo substitution reactions so that its <u>π electron cloud remains intact to maintain aromatic stability</u>.

(iii) Benzene do not undergo oxidation.

Methylbenzene is oxidized by heating with $KMnO_4$, H_2SO_4 (aq)

(c) Bond energy of C-H bond = 410 kJ mol^{-1}
Bond energy of C-Cl bond = 340 kJ mol^{-1}

As fluorine atom is smaller than chlorine, bond length of C-F bond is shorter than C-Cl bond. Therefore C-F bond is expected to be stronger than C-Cl bond, hence they do not break easily to form free fluorine atoms to attack the ozone layer.

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

(ii) Amount of electrons gained by 0.0150 mole of CrO_4^{2-} = 0.0450 mol
Amount of electrons lost by 0.0225 mole of SO_2 = 0.0450 mol
Therefore each mole of SO_2 lost = (0.0450/0.0225) = 2 mol of electron

Original oxidation number of sulfur = +4
New oxidation number of sulfur = +4 + 2 = +6

(iii) SO_4^{2-}

(b) (i) $$Kc = \frac{[Cr_2O_7^{2-}]}{[CrO_4^{2-}]^2[H^+]^2}$$

(ii) Amount of $PbCrO_4$ initiallly = 20.00/ (207.2+52.0 +16.0x4)
= 0.06188 mol
$[CrO_4^{2-}]$ initially = 0.06188/(100/1000) = 0.6188 ≈ 0.619mol dm^{-3}

(iii) $[CrO_4^{2-}]$ at equilibrium = 0.6188 / 5 = 0.1237 = 0.124 mol dm^{-3}

$[Cr_2O_7^{2-}]$ at equilibrium = $\frac{0.6188 - 0.1237}{2}$
= 0.2475 ≈ 0.248 mol dm^{-3}

(iv) Since $K_C = 7.55 \times 10^{12}$ mol^{-3} dm^9

$$[H^+] = \sqrt{\frac{[Cr_2O_7^{2-}]}{[CrO_4^{2-}]^2 \times Kc}} = \sqrt{\frac{0.2475}{0.1237^2 \times 7.55 \times 10^{12}}} = 1.463 \times 10^{-6} \text{ mol dm}^{-3}$$

pH = 5.8

(v) By Le Chatelier's Principle, the system will react to <u>reduce</u> the added amount of NaOH. <u>Backward</u> reaction is favoured and position of equilibrium shifts to the <u>left</u>. [1] The solution will <u>appear yellow in color</u> due to formation of aqueous CrO_4^{2-}.

3 **(a)** Place a lighted splint near the mouth of the test tube. A pop sound would be heard to confirm its identity as hydrogen gas.

(b) **(i)** From orange to green

(ii) Oxidation

(c) **(i)** X: $CH_3CH_2CH_2OH$ Y: CH_3CH_2CHO

(ii) $CH_3CH_2CHO + 2Cu^{2+} + 5OH^- \rightarrow CH_3CH_2CO_2^- + Cu_2O + 3H_2O$

(iii) Test: Add Tollens' to solution and warm.
Observation: Silver mirror observed with Y. No silver mirror with X.

Test: Add 2,4-DNPH to solution and warm
Observation: orange precipitate formed with Y. No orange precipitate with X.

4 **(a)** Energy change when one mole of a substance is completely burnt in excess oxygen under standard conditions.

(b) **(i)** Carbon: $C (s) + O_2 (g) \rightarrow CO_2 (g)$
Methane: $CH_4 (g) + 2O_2 (g) \rightarrow CO_2 (g) + 2H_2O (l)$

(ii) 1 MJ = 10^6 J = 1000 kJ

Since ΔH_C (C) = - 394 kJ mol^{-1}, amount of carbon need to be burned to produce 1 MJ of heat = 1000 / 394 = <u>2.54 mol</u>

Since ΔH_C (CH_4) = - 890 kJ mol^{-1}, amount of methane need to be burned to produce 1 MJ of heat = 1000 / 890 = <u>1.12 mol</u>

(iii) Since efficiency of coal power station = 40% , amount of carbon need to be burned to produce 1 MJ of heat = 2.538 / 0.40 = <u>6.35 mol</u>

Since efficiency of natural gas power station = 51% , amount of methane need to be burned to produce 1 MJ of heat = 1.124 / 0.51 = <u>2.20 mol</u>

(c) Mass of C (s) need to be burn to produce 1 MJ of electrical energy = 6.35 x 12.0 = 76.2 g
Mass of ash produced = 76.2 (5/95) = 4.01 g

(d) **(i)** CO_2 is a <u>greenhouse gas</u> that causes <u>global warming</u>, leading to <u>droughts and rising sea levels</u>.

(ii) Coal is found in the solid state, which is easier to store and transport. Hence it is easier and cheaper to operate power station that burn natural gas which is harder to store and transport.

(e) **(i)** Amount of methane need to be burned to produce 1 MJ of heat = 1.124 mol
Volume of methane at rtp = 1.124 x 24.0 = 27.0 dm^3

(ii) $CO + \frac{1}{2} O_2 \rightarrow CO_2$ ΔH_C = -283
$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$ ΔH_C = -242
Since 1 mole of water-gas contain ½ mole of CO and ½ mole of H_2, amount of heat energy produced by 1 mole of water-gas
= ½ (283) + ½ (242) = 262.5 kJ
Therefore amount of water-gas needed to produce 1 MJ of heat energy = 1000/262.5 = 3.810 mol
Volume of water-gas at rtp = 3.810 x 24.0 = 91.4 dm^3

(iii) - Volume of methane needed to be burn to produce 1 MJ is lower, hence it is safer and easier to operate a power station using natural gas.

Paper 2 Section B Answers

5 **(a)** $n(MnO_4^-)$ = 0.0200 × 27.30 / 1000 = 5.46 × 10^{-4} mol

$n(Fe^{2+})$ in 25.0 cm^3 = 5.46 × 10^{-4} × 5 = 2.73 × 10^{-3} mol

$n(Fe^{2+})$ in 250 cm^3 = 2.73 × 10^{-3} × 250 / 25.0 = 2.73 × 10^{-2} mol

mass of $FeCO_3$ = 2.73 × 10^{-2} × 115.8 = 3.161 g

percentage by mass of $FeCO_3$ = 3.161 / 5.00 × 100% = 63.2%

(b) **(i)** $CH_3CH_2CH_2O^-$ is the least stable as the electron donating alkyl ($-CH_2CH_2CH_3$) group on the $CH_3CH_2CH_2O^-$ ion increases the electron density on the oxygen atom, making it even more negative, hence destabilising the $CH_3CH_2CH_2O^-$ ion. Thus propanol is less acidic than propanoic acid.

$CH_3CH_2COO^-$ is the most stable as the p orbital of the oxygen atom overlaps with the π electron cloud of the –C=O bond and the lone pair of electrons on the oxygen atom delocalise into the –C=O. The negative charge is dispersed over the carbon atom and the two electronegative oxygen atoms, stabilising the $CH_3CH_2COO^-$ ion. Thus propanoic acid is more acidic than propanol.

(ii) It is more difficult to remove a proton from an anion.

(iii) A buffer solution is a solution that is able to maintain a **fairly constant** pH when a **small** amount of acid or base is added.

(iv) $HO_2CCH_2CO_2Na + H^+ \rightarrow HO_2CCH_2CO_2H + Na^+$
$HO_2CCH_2CO_2Na + NaOH \rightarrow NaO_2CCH_2CO_2Na + H_2O$

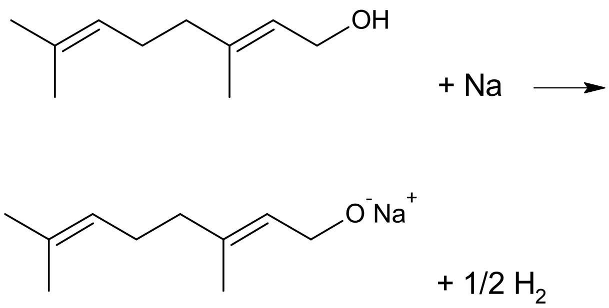
(c) **(i)** Na_2O (s) + H_2O (l) → 2NaOH (aq)
pH = 13

P_4O_{10} (s) + $6H_2O$ (l) → $4H_3PO_4$ (aq)
pH = 1-2

(ii) H_3PO_4 (aq) + 3NaOH (aq) → Na_3PO_4 (aq) + $3H_2O$ (l)

(d) 1. Sodium metal at room temp

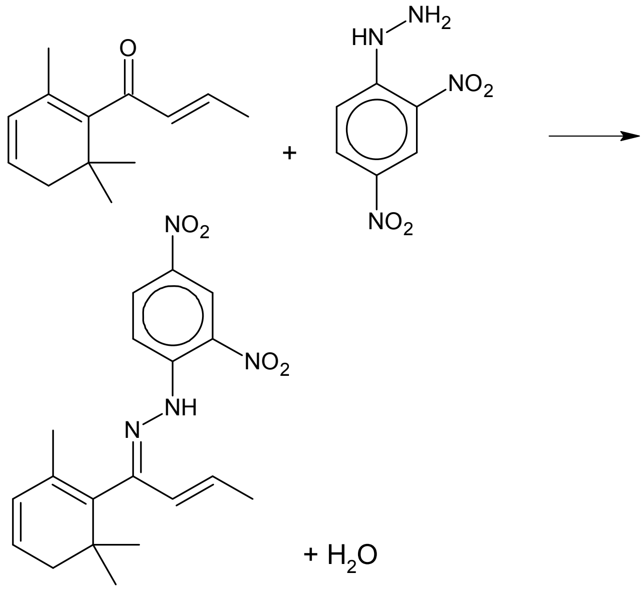
Geraniol will give effervescence. H_2 (g) evolved gives a 'pop' sound with a lighted splint.



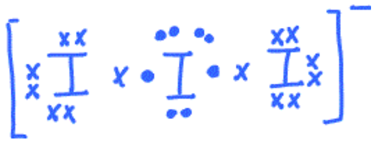
Rose oxide and damascenone will not give any effervescence. No 'pop' sound with a lighted splint observed.

2. 2,4-DNPH, warm

Damascenone will give an orange precipitate but not rose oxide, geraniol.



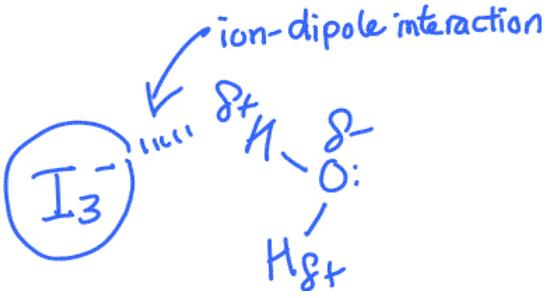
6 (a) (i)

	I_3^-	ClO_2
Dot-and-cross diagram		

I_3^- has 2 bond pairs and 3 lone pairs. The electron pairs will orientate as far as possible to minimise repulsion. Since the repulsion between lone pair – lone pair > bond pair – lone pair > bond pair – bond pair, the shape with respect to I atom is linear.

ClO_2 has 2 bond electron domains, 1 lone pair and 1 lone electron. The electron pairs will orientate as far as possible to minimise repulsion. Since the repulsion between lone pair – lone pair > bond pair – lone pair > bond pair – bond pair, the shape with respect to C*l* atom is bent.

(ii)



The energy released when the H_2O molecules formed the stronger ion-dipole interaction with I_3^- ions is sufficient to overcome the hydrogen bonds between the H_2O molecules.

(iii) Both I_2 and ClO_2 have simple molecular structure with weak dispersion forces between molecules . The size of electron cloud for ClO_2 is smaller, hence less polarisable. The dispersion forces between ClO_2 molecules is weaker. Less energy is needed to overcome the weaker dispersion forces, enthalpy change of vaporisation for ClO_2 is less endothermic.

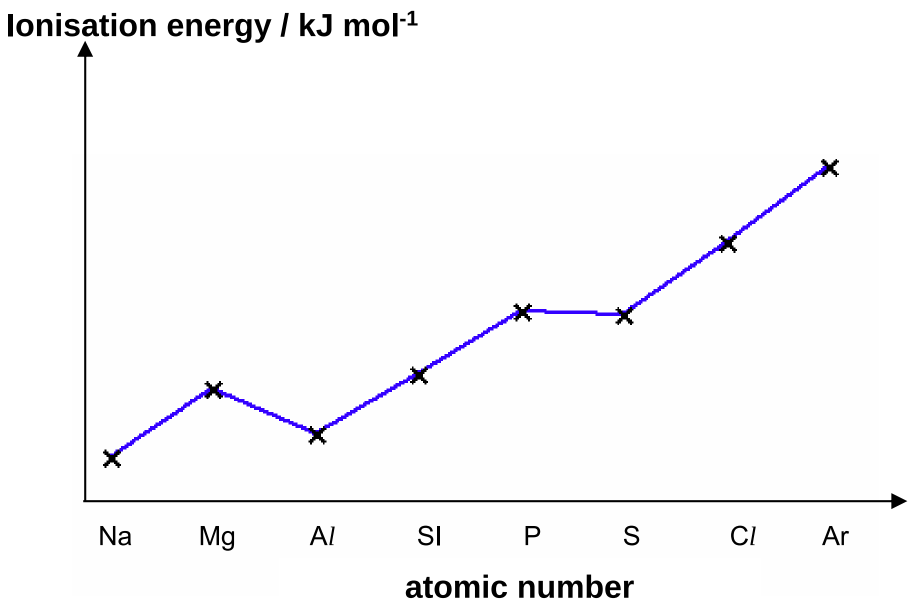
(b) (i) The first ionisation energy of chlorine is the energy required to remove one mole of electrons from one mole of gaseous C*l* atoms to form one mole of singly charged gaseous C*l* cations.

$Cl(g) \downarrow Cl^+(g) + e$

.

(ii) Down a group, the number of protons increases, the nuclear charge increases. As the number of electron shells increases, the shielding effect increases significantly for iodine. The increase in shielding effect outweighs the increase in nuclear charge, effective nuclear charge decreases. Less energy is needed to remove the outermost electron, hence iodine has a lower first ionisation energy.

(iii)



Between Mg (Group 2) and Al (Group 3)

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

A*l* $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

First ionisation of A*l* is lower than that of Mg.
Less energy is required to remove the 3p electron in A*l* as it experiences increased shielding by the filled 3s subshell.

Between P (Group 15) and S (Group 16)

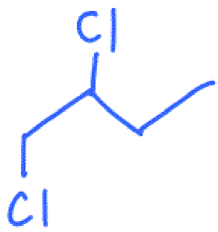
P $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^1\ 3p_y^1\ 3p_z^1$

S $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^2\ 3p_y^1\ 3p_z^1$

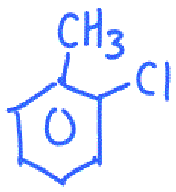
First ionisation of S is <u>lower</u> than that of P.
Less energy is required to remove the paired <u>$3p_x$ electron</u> in S as it experiences <u>interelectronic repulsion</u> arising from 2 electrons occupying the same <u>3p orbitals</u>.

(c) (i)

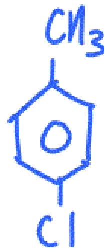
(ii)



(iii)



OR



7 (a) (i) $MgCl_2$ undergoes <u>hydration</u> with water to from aqueous Mg^{2+} and Cl^- ions.
$[Mg(H_2O)_6]^{2+}$ then undergoes <u>slight hydrolysis</u> with water to produce H_3O^+ hence a weakly acidic solution is formed. pH = 6.5
$MgCl_2\ (s) + 6H_2O(l) \rightarrow [Mg(H_2O)_6]^{2+}(aq) + 2Cl^-(aq)$
$[Mg(H_2O)_6]^{2+}\ (aq) + H_2O(l) \rightleftharpoons [Mg(H_2O)_5OH]^+\ (aq) + H_3O^+$

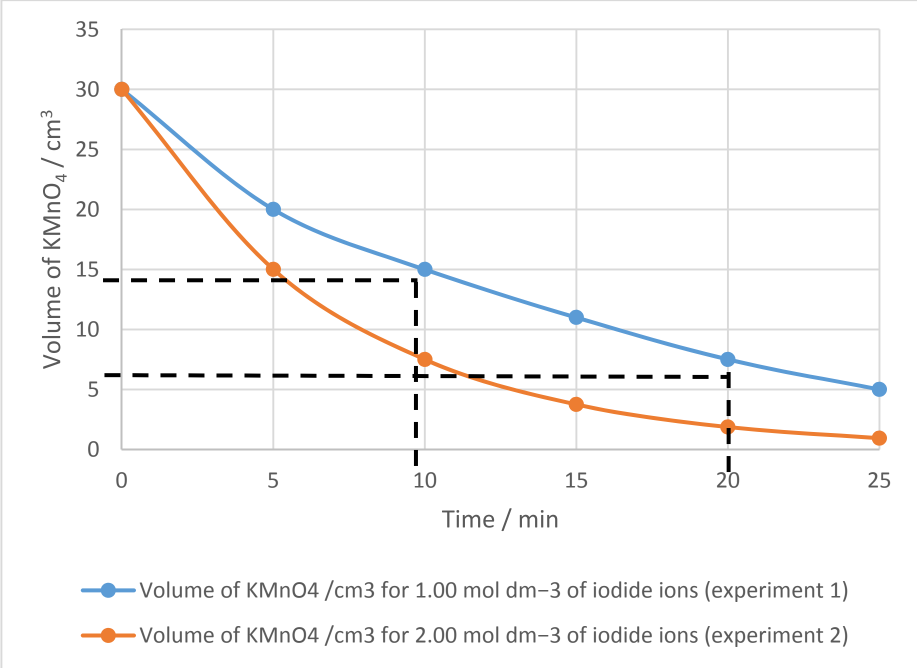
Both $SiCl_4$ and PCl_3 (or PCl_5) undergoes <u>hydrolysis with water</u> to from a strongly acidic solution, pH = 1 – 2.

$SiCl_4\ (l) + 2\ H_2O\ (l) \rightarrow SiO_2\ (s) + 4\ HCl\ (aq)$
$PCl_3\ (l) + 3\ H_2O\ (l) \rightarrow H_3PO_3\ (aq) + 3\ HCl\ (aq)$
OR $PCl_5\ (l) + 4\ H_2O\ (l) \rightarrow H_3PO_4\ (aq) + 5\ HCl\ (aq)$

(ii) $MgCl_2$ is an <u>ionic chloride</u> hence it undergoes <u>hydration</u> to form the ions readily while both $SiCl_4$ and PCl_3 (or PCl_5) are <u>covalent chlorides</u> which undergoes <u>hydrolysis</u> with water.

(b) (i) 50 cm^3 of cold water was added prior to the titration to <u>stop/slow down the reaction</u> so as to achieve a <u>more accurate titre value at that time</u> / <u>to find the concentration at that instance</u>.

(ii)



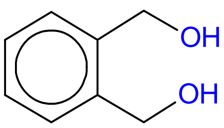
(iii) When volume of $KMnO_4$ decreases from 30 cm^3 to 15 cm^3, time taken is 10 min.
When volume of $KMnO_4$ decreases from 15 cm^3 to 7.5 cm^3, time taken is 10 min.
Since the 2 half lives are approximately constant at 10 min, reaction is first order to $KMnO_4$.

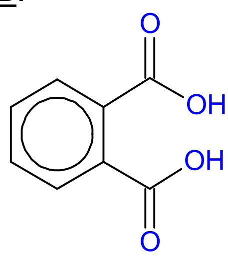
Since volume of H_2O_2 and concentration of $KMnO_4$ are constant, $[H_2O_2]$ is proportional to V($KMnO_4$). Reaction is thus first order with respect to H_2O_2.
When $[I^-]$ = 1.00 mol dm^{-3}, initial rate = 30/6.5 = 4.62 cm^3 min^{-1}
When $[I^-]$ = 2.00 mol dm^{-3}, initial rate = 30/11.5 = 2.61 cm^3 min^{-1}

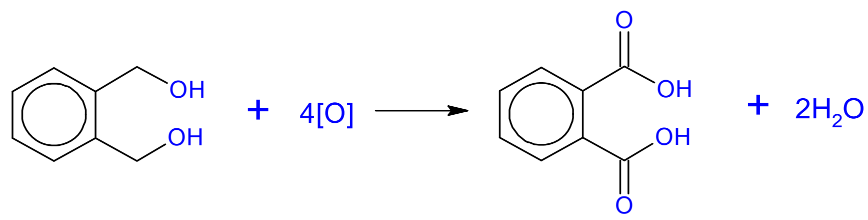
As $[I^-]$ doubles (2/1), initial rate also doubles (4.62/2.61 ≈ 2), hence order of reaction with respect to I^- is one.

Rate = $k[H_2O_2][I^-]$
Units for rate constant: mol^{-1} dm^3 min^{-1}

(c) (i) The primary alcohol in A undergoes oxidation with acidified KMnO4 to form carboxylic acid in B.

A:


B:




(ii) Type of reaction: Condensation
Reagents & conditions: $CH(CH_3)_2OH$, conc. H_2SO_4, heat under reflux

(iii) Reagent and condition: I_2(aq), NaOH(aq), warm
Observations for **C**: Yellow ppt of CHI_3 formed.
Observations for **D**: No yellow ppt of CHI_3 formed.

NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION

Higher 1

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY

8872/01

Paper 1 Multiple Choice

Thursday 14 Sept 2017
50 minutes

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, 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.

Instructions on how to fill in the Optical Mark Sheet


1. Enter your NAME (as in NRIC). TAN AH TECK
2. Enter the SUBJECT TITLE. CHEMISTRY
3. Enter the TEST NAME. SH2 Prelim
4. Enter the CLASS. 2cm1A

RUB OUT ERRORS THOROUGHLY

USE PENCIL ONLY
FOR ALL ENTRIES ON THIS SHEET

0	1	2	3	4	5	6
0	1	2	3	4	5	6
0	1	2	3	4	5	6

Example:

Shade the index number in a 5 digit format on the optical mark sheet:
2nd digit and the last 4 digits of the Registration Number.

Student	Examples of Registration No.	Shade:
	1605648	65648

Section A

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

1 How many molecules are present in 5 cm^3 of methane under room conditions?

A $\dfrac{5 \times 24000}{6.02 \times 10^{23}}$

B $\dfrac{5 \times 6.02 \times 10^{23}}{24000}$

C $5 \times 6.02 \times 10^{23} \times 24000$

D $\dfrac{24000}{5 \times 6.02 \times 10^{23}}$

2 Ions of the two most common isotopes of iron are shown below:

$$^{54}_{26}Fe^{2+} \qquad ^{56}_{26}Fe^{2+}$$

Which statement is true?

A Both of these Fe^{2+} ions have the same number of electrons but different number of protons.

B The $^{54}_{26}Fe^{2+}$ ion will be deflected more than the $^{56}_{26}Fe^{2+}$ ion when passing through an electric field of same strength.

C The $^{56}_{26}Fe^{2+}$ ion have more protons than the $^{54}_{26}Fe^{2+}$ ion.

D The electron arrangement of both these Fe^{2+} ions is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 4s^2$.

3 10 cm^3 of a hydrocarbon C_xH_y was exploded in 100 cm^3 of oxygen gas and cooled to room temperature. There was a contraction of 30 cm^3. When the resulting gas was passed through a solution of sodium hydroxide, there was a further contraction of 40 cm^3. All volumes measured are under room conditions.

What is the molecular formula of the hydrocarbon?

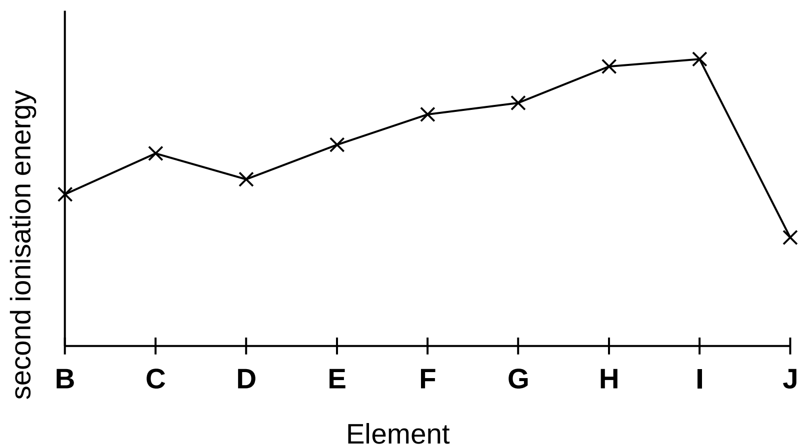
A C_4H_8

B C_4H_{10}

C C_3H_6

D C_3H_{10}

4 The following graph represents the second ionisation energy trend of 9 consecutive elements in Periods 3 and 4.



Which statement is correct?

A Element **C** is in Group 3.

B Element **F** has the lowest boiling point.

C The ionic radius of ion of **E** is greater than that of ion of **J**.

D The formula of the compound formed between elements **D** and **G** is $\mathbf{D_2G_3}$.

5 Two elements, **X** and **Y**, have the following properties.

- **X** and **Y** form ionic compounds Ca**X** and Ca**Y** respectively.
- Element **X** forms **X**F_6 molecule while **Y** is unable to do so.

Which options shows the correct electronic configuration of **X** and **Y**?

	X	**Y**
A	[Ne] $3s^2$ $3p^2$	[He] $2s^1$
B	[Ne] $3s^2$ $3p^4$	[He] $2s^1$
C	[Ne] $3s^2$ $3p^2$	[He] $2s^2$ $2p^4$
D	[Ne] $3s^2$ $3p^4$	[He] $2s^2$ $2p^4$

6 For which system does the equilibrium constant, K_c, have units of $mol^{-2}dm^6$?

A $CH_3CH_2OH(l) + CH_3COOH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$

B $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

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

D $2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$

7 Which compound is the most volatile?

A $CH_3CH_2CH_2CH_2NH_2$

B $CH_3CH(CH_3)CH_2NH_2$

C $CH_3CH(NH_2)CH_2CH_3$

D $CH_3C(CH_3)_2NH_2$

8 Which reaction has a positive ΔH value?

A $Na(s) \rightarrow Na(g)$

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

C $2\,Cl(g) \rightarrow Cl_2(g)$

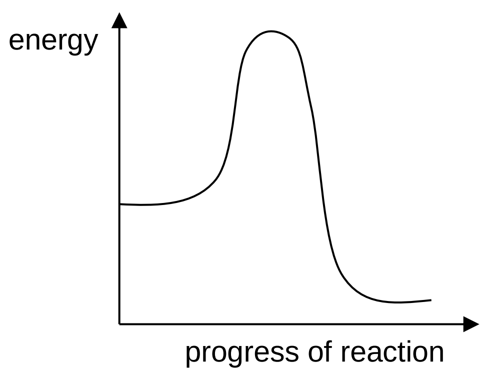
D $CH_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$

9 A series of reactions between 2**X** and **Y** to give **Z** is shown below, where the overall enthalpy change of reaction is negative.

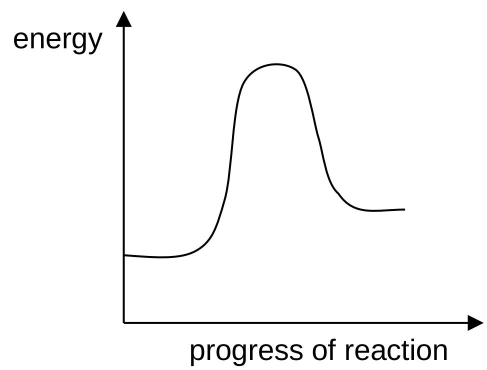
Step 1: **X** + **Y** → **U**
Step 2: **X** + **U** → **Z**

Which diagram represents the energy profile diagram of the reaction?

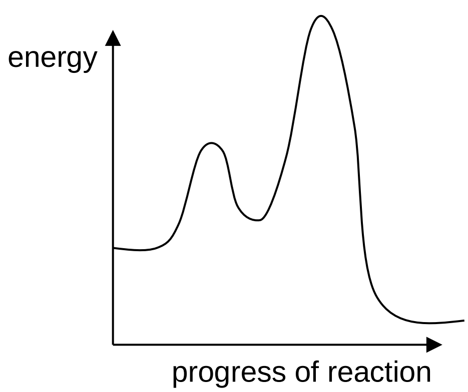
A



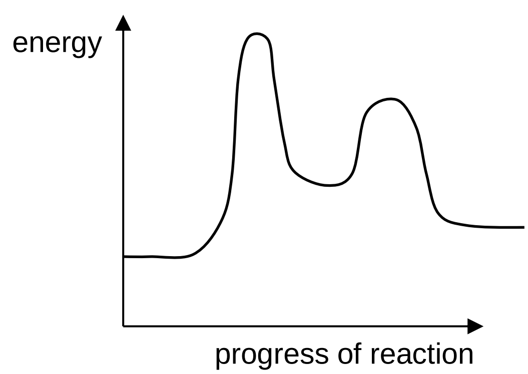
C



B



D



10 The bond dissociation energy of H–C*l* is +432 kJ mol^{-1}.

Which of the following processes have an enthalpy change of −432 kJ mol^{-1}?

A HC*l* (s) → H(g) + C*l*(g)

B HC*l* (g) → H(g) + C*l*(g)

C H(g) + C*l*(g) → HC*l* (s)

D H(g) + C*l*(g) → HC*l* (g)

11 The enthalpy change of neutralisation between 1 mole of HC*l* and 1 mole of NaOH is given below.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) \qquad \Delta H = -57.3 \text{ kJ mol}^{-1}$$

The enthalpy change of neutralisation between 1 mole of CH_3COOH and 1 mole of NaOH is less than −57 kJ mol^{-1}.

$$NaOH(aq) + CH_3CO_2H\ (aq) \rightarrow CH_3CO_2^-Na^+(aq) + H_2O(l) \qquad \Delta H = -54.7 \text{ kJ mol}^{-1}$$

Which statement best explains the difference between these two values?

A Heat is lost to the surroundings.

B The reaction between NaOH and CH_3CO_2H is incomplete.

C Dissociation of CH_3CO_2H is endothermic.

D CH_3CO_2H can form hydrogen bonds with water but not HC*l*.

12 Which indicator is suitable for use in a titration of 0.1 mol dm^{-3} H_2SO_4 with 0.1 mol dm^{-3} of NH_3?

A Methyl Orange (pH range 3.3 – 4.4)

B Bromothymol blue (pH range 6.0 – 7.6)

C Phenolphthalein (pH range 8.3 – 10.0)

D None of the above

13 Which mixtures, when mixed at equal volumes, would result in a buffer solution?

A 0.10 mol dm^{-3} CH_3CO_2Na and 0.05 mol dm^{-3} HCl

B 0.05 mol dm^{-3} CH_3CO_2H and 0.10 mol dm^{-3} NaOH

C 0.05 mol dm^{-3} CH_3CO_2H and 0.05 mol dm^{-3} $NaCl$

D 0.10 mol dm^{-3} HCl and 0.10 mol dm^{-3} NaOH

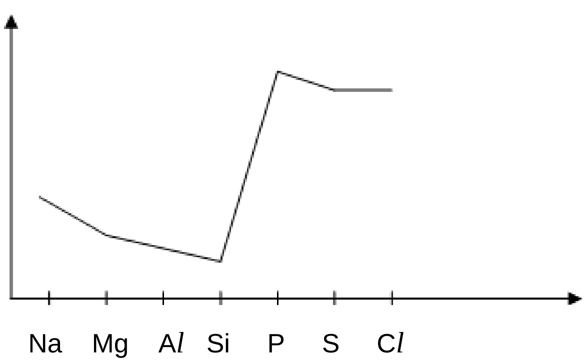
14 A theoretical reaction involves **X** + **Y** → **Z**

The rate equation is rate = $k[\mathbf{X}]^p[\mathbf{Y}]^q$ and the units of the rate constant, k, are (mol dm^{-3})^r min^{-1}.

Which set of the values of p, q and r fits the above information?

	P	*q*	*r*
A	2	0	−2
B	2	1	2
C	1	0	0
D	1	1	1

15 What property of Period 3 is shown by the graph below?



A Melting point

B Ionic radius

C Electrical conductivity

D pH of chlorides

16 Xenon is the final product formed by a series of changes in the radioactive decay of iodine 131. This radioactive decay is a *first-order reaction* with a half-life of 8 days.

What is the time period required for an iodine sample which was originally xenon free, to have a molar proportion of Iodine to Xenon in a 1:7?

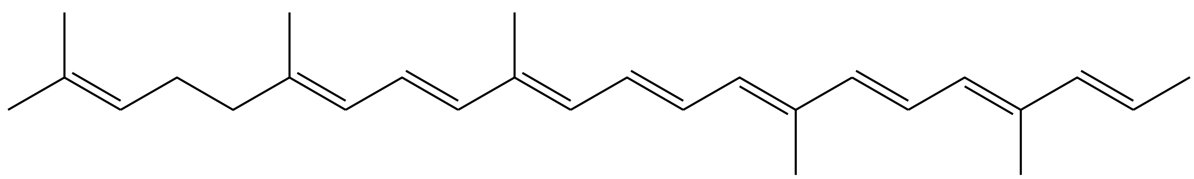
A 8 days

B 16 days

C 24 days

D 32 days

17 Determine the number of geometric isomers in the compound below:



A 2^6

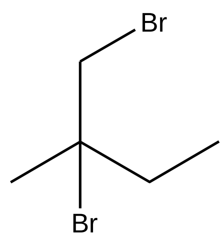
B 2^7

C 2^8

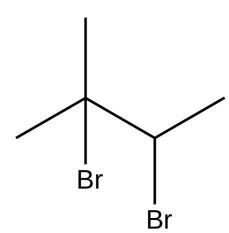
D 2^9

18 Which compound **could not** be formed by the action of bromine on an alkene of molecular formula C_5H_{10}?

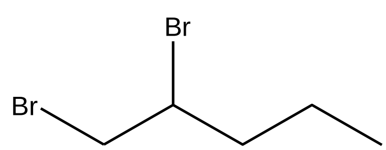
A



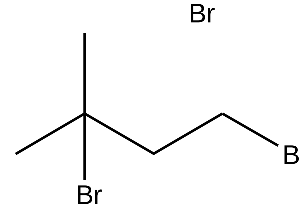
C



B



D



19 What is the structural formula of the alkene that undergoes mild oxidation to give a diol and further oxidation to give a diketone?

A $(C_2H_5)_2C=C(CH_3)_2$

B $CH_3CH=CHCH_3$

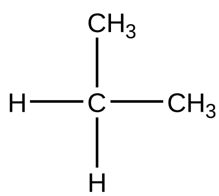
C $C_2H_5CH=C(CH_3)_2$

D $(CH_3)_2C=CHC_2H_5$

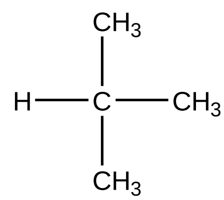
20 An alkane **Z** is reacted with chlorine gas in the presence of ultraviolet light to form two monochlorinated alkanes in an approximate molar ratio of 3 : 1.

Which of the following is a possible structure for **Z**?

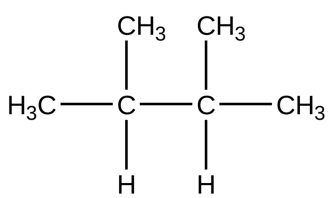
A



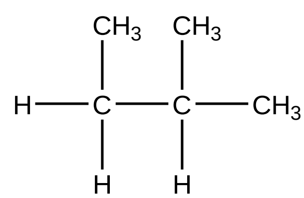
C



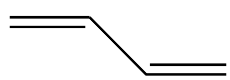
B



D

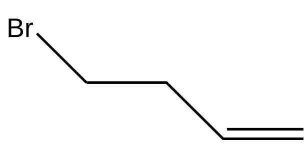


21 What is the major product formed when 1 mole of buta-1,3-diene reacts with 1 mole HBr(g)?

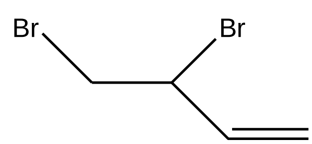


buta-1,3-diene

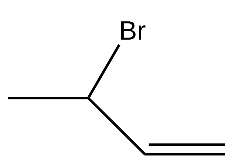
A



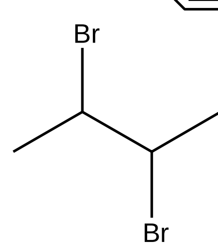
C



B



D



22 How many structural isomers of alcohol with the molecular formula, $C_4H_{10}O$, have?

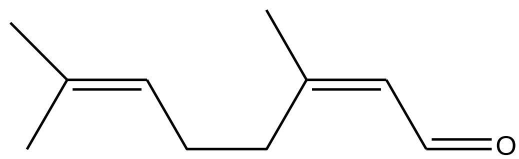
A 1

B 2

C 3

D 4

23 Which of the following is not a final product of the vigorous oxidation of citral?



citral

A CO_2

B CH_3COCH_3

C $CH_3COCH_2CH_2CO_2H$

D $(CO_2H)_2$

24 A company wants to create a perfume with an ester that has the formula. $C_2H_5CO_2CH(CH_3)_2$. In which of the following will the substances react together to produce this ester?

A C_2H_5OH and $(CH_3)_2CHCOOH$

B CH_3COOH and $CH_3CH(OH)CH_2CH_3$

C C_2H_5COOH and $(CH_3)_2CHOH$

D C_2H_5COOH and $C_2H_5CH_2OH$

25 A sample of propanal is treated with HCN in the presence of NaCN. The organic product is then refluxed with $LiAlH_4$ in dry ether.

What will be the final product?

A $CH_3CH_2CH(OH)CH_2NH_2$

B $CH_3CH_2CH(OH)CO_2H$

C $CH_3CH_2CH(OH)CONH_2$

D $CH_3CH_2COCO_2H$

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct. Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct.)

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1,**2**, and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 For which pairs does species **I** have a smaller bond angle than species **II**?

	Species **I**	Species **II**
1	H_2S	SO_2
2	CO_2	CH_4
3	NH_4^+	NH_3

27 In microwave ovens, the wave energy is absorbed by polar molecules.

Which molecules would absorb microwave energy?

1 CH_3Cl

2 CH_3CO_2H

3 SO_3

28 Which reactions **can** represent standard enthalpy changes at 298 K?

1 $2C(s) + 3H_2(g) \rightarrow C_2H_6(g)$

2 $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

3 $Ca(s) + C(s) + \frac{3}{2}O_2(g) \rightarrow CaCO_3(s)$

A	B	C	D
1,**2**, and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

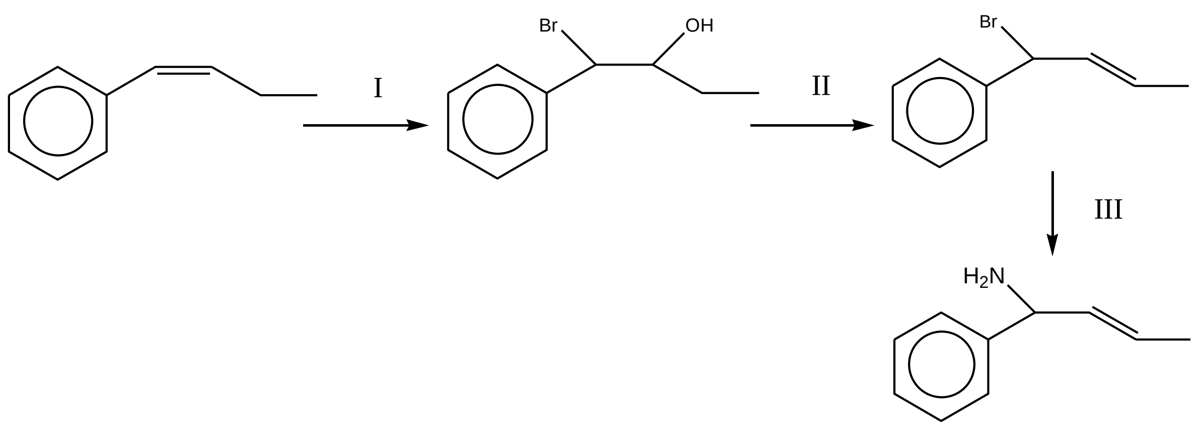
29 Which compounds yields only a single product upon heating with concentrated H_2SO_4?

1 $CH_3CH_2CH_2CH_2OH$

2 $CH_3C(OH)(CH_3)_2$

3 $CH_3CH_2CH(OH)CH_3$

30 Which types of reactions are involved in the reaction scheme below?



1 Addition

2 Substitution

3 Elimination

2017 NJC H1 Chemistry Prelim Paper 1 Suggested Answers

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

1 Amount of methane = $\frac{5}{24000}$

Hence, number of molecules = $\frac{5}{24000} \times 6.02 \text{ x } 10^{23}$

Ans: B

2 The two ions contain the same number of protons and electrons, but different number of neutrons. The electronic configuration of Fe^{2+} is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$. (Electrons are removed from 4s orbital first when forming cations.)

The angle of deflection by an ion in an electric field is inversely proportionate to its charge to mass ratio.

E.g the larger the charge to mass ratio, the greater the deflection.

${}^{54}_{26}\mathrm{Fe}^{2+}$ ion has a smaller charge to size ratio than ${}^{56}_{26}\mathrm{Fe}^{2+}$. Hence, ${}^{54}_{26}\mathrm{Fe}^{2+}$ will be deflected more.

Ans: B

3 2nd contraction of 40 cm^3 is due to that of CO_2 reacting with the NaOH.

For the first contraction,

initial total vol = 110 cm^3 of hydrocarbon + O_2

final total vol after cooling back to rtp = 40cm^3 of CO_2 + unreacted O_2

110 – (unreacted O_2 + 40) = 30

Vol of unreacted O_2 = 40 cm^3

	C_xH_y (g)	+ $(x+\frac{y}{4})$ O_2 (g) →	x CO_2 (g)	+ $\frac{y}{2}$ H_2O (l)
Initial vol / cm^3	10	100	0	-
Final vol / cm^3	0	40	40	-
Vol reacted/ produced/ cm^3	10	60	40	
Reacting mol ratio	1	6	4	

Comparing the mol ratio, x =4,

$x+\frac{y}{4} = 6$, y = 8

Hence, the formula of the hydrocarbon = C_4H_8

Ans: A

4 Making reference to the I.E. values from Data Booklet, we can conclude that **I** is potassium.

Element **C** is A*l*, it is in Group 13.

Element **F** is S and it exists as S_8 molecules. The lowest boiling point is Ar gas (element **H**).

Ion of **E** (P^{3-}, 0.212 nm) is larger than that of **J** (Ca^{2+}, 0.099nm)

Element **D** and **G** are Si and C*l* respectively. The compound formed is $SiCl_4$.

Ans: **C**

5 Given that both **X** and **Y** form ionic compounds with Ca, both are non-metals and are group 16.

For X to form **X**F_6 molecule while **Y** is unable to do so, that means that **X** has energetically accessible vacant d orbitals to expand beyond octet configuration while **Y** does not.

Ans: D

6 **A** $K_c = \frac{[CH_3COOCH_2CH_3][H_2O]}{[CH_3CH_2OH][CH_3COOH]}$ = no units

B $K_c = \frac{[NH_4^+][OH^-]}{[NH_3]}$ = mol dm^{-3}

C $K_c = \frac{[NH_3]}{[N_2][H_2]^3}$ = mol^{-2}dm^6

D $K_c = \frac{[Cr_2O_7^{2-}]}{[CrO_4^{2-}]^2[H^+]^2}$ = mol^{-3}dm^9

Ans: C

7 $CH_3C(CH_3)_2NH_2$ has the lowest boiling point among all the other molecules. All the molecules has 1 NH_2 group, which means they all have the same degree of hydrogen bonding between the molecules. Hence, the difference lies in the temporary dipole – induced dipole (td−id), where the $CH_3C(CH_3)_2NH_2$ is the most branched with least surface area of contact between molecules and experiences the weakest td−id among all the molecules.

Ans: D

8 **A** Refers to the enthalpy change of atomisation which is endothermic

B The neutralisation reaction between OH^- and H^+ to give H_2O is exothermic

C The formation of bonds between 2 C*l* to give C*l*$_2$ is exothermic

D Enthalpy change combustion is always exothermic

Ans: A

9 The reaction is a 2 step reaction, hence the reaction pathway must reflect 2 activation energy. Also, the overall enthalpy change is negative, which means the energy level of the product must be lower than the reactants.

Ans: B

10 Given Bond dissociation energy of H–C*l* is +432 kJ mol^{-1}

A Energy is taken in to change the state of HC*l* from (s) to (g) and then to break the H–C*l* bond. Hence energy change is more than + 432 kJ mol^{-1}

B Energy is taken in to to break the H–C*l* bond. Hence energy change is + 432 kJ mol^{-1}

C Energy is given off to form the H–C*l* bond and to change the state of HC*l* from (g) to (s). Hence energy change is less than − 432 kJ mol^{-1}

D Energy is given off to form the H–C*l* bond. Hence energy change is = − 432 kJ mol^{-1}

11 A weak acid dissociates partially in water according to the following equation:

$CH_3CO_2H \rightleftharpoons CH_3CO_2^- + H^+$

Some of the heat from the enthalpy change of neutralisation between H^+ and OH^- is compensated towards the dissociation for CH_3CO_2H. Hence less energy is released from the neutralisation reaction involving a weak acid and strong base.

Note that acid base reaction always go to completion.

Ans: C

12 Titration of a strong acid (H_2SO_4) with a weak base (NH_3). Equivalent point pH is less than 7 as NH_4^+ is a weakly acidic cation.

Methyl orange will be a suitable indicator as the working pH range of methyl orange coincides with the region of sharp pH change at equivalent point of this titration.

Ans: A

13 A buffer consists of a weak base and its conjugate acid, or a weak acid and its conjugate base.The conjugate acid-base pair differs from each other by one H^+.

A HC*l* is the limiting reagent, final solution mixture contains unreacted CH_3CO_2Na and CH_3CO_2H. They are conjugate acid-base pair and forms a buffer solution.

B CH_3CO_2H is the limiting reagent, final solution mixture contains unreacted NaOH and CH_3COO^-. This is not a buffer solution.

C No reaction between the two compounds. This is not a buffer solution.

D Both reactants react completely. Only NaC*l* is present in the solution. Not a buffer solution.

Ans: A

14 Substitute the values inside and see which one fits.

Ans: C

Units for rate = mol $dm^{-3}min^{-1}$

When p =1,q = 0, rate = k[**X**]

Units for rate constant, k = $\frac{\text{mol dm}^{-3}\text{min}^{-1}}{\text{mol dm}^{-3}}$ = min^{-1}. Hence r = 0.

15 **A** Melting point increases from Na to Si before decreasing to the non-metals.

B Ionic radius decreases from Na^+ to Si^{4+} and increases to the non-metals anions. (Check Data Booklet)

C Electrical conductivity increases from Na to A*l* and then decreases for Si and conductivity drop to zero for the non-metals.

D pH of chlorides decreases from Na to Si and remains low for the chlorides of non-metals.

Ans: B

16 Radioactive decay of iodine is a first-order reaction with half-life, $t_{½}$ = 8 days

$$\begin{array}{ccccccc} \text{I : Xe} & \xrightarrow{1^{st}\ t_{½}} & \text{I : Xe} & \xrightarrow{2^{nd}\ t_{½}} & \text{I : Xe} & \xrightarrow{3^{rd}\ t_{½}} & \text{I : Xe} \\ 1 : 0 & & ½ : ½ & & ¼ : ¾ & & {}^{1}/_{8}\ \ {}^{7}/_{8} \end{array}$$

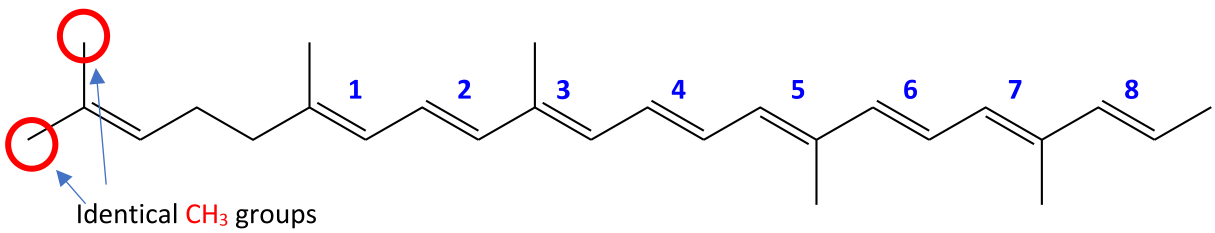
Time period = 3 × $t_{½}$ = 3 × 8 = 24 days

Ans: C

17 The <u>two conditions</u> required for geometric isomerism to exist:

(i) <u>restricted rotation</u> about a bond by the presence of a double bond (usually C=C bonds)

(ii) <u>two different groups</u> on **each of the carbon atoms** with restricted rotation.



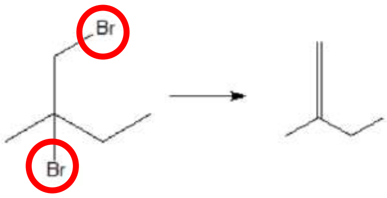
No. of geometric isomers: **2^n** = **2^8**

Ans: C

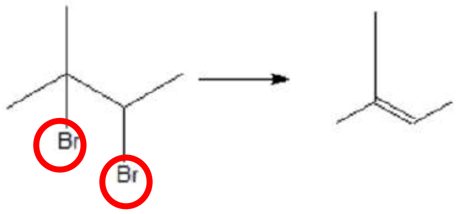
18 During the ***addition*** reaction, two Br atoms are added across the C=C bond when Br_2 reacts with alkene.

To obtain the alkene from the addition product, remove two Br atoms (circled) and reform the C=C as shown below.

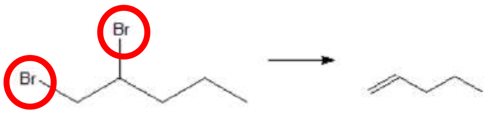
A



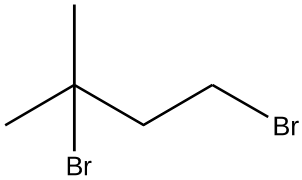
C



B

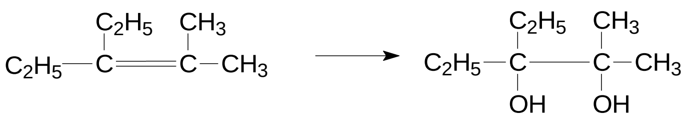


D



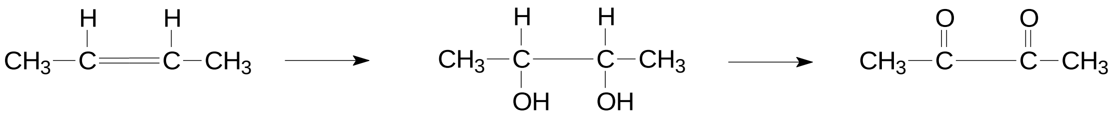
Ans: D

19 **A**



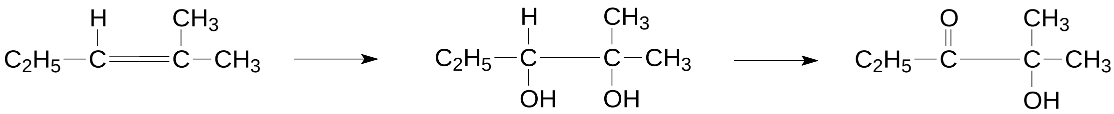
(3°) (3°) (No further oxidation for 3° alcohol)

B



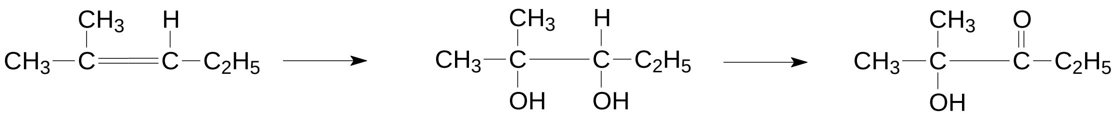
(2°) (2°) (diketone)

C



(2°) (3°)

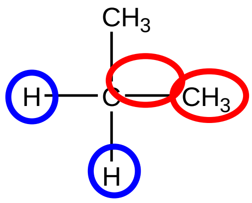
D



(3°) (2°)

Ans: B

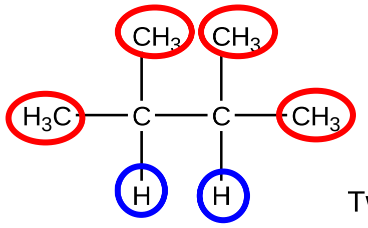
20 **A**



Two different types of H in the ratio of 2 : 6 (1 : 3)

Product	CH_3 Cl—C—CH_3 H	CH_3 H—C—CH_2Cl H
Probability of forming	2	6

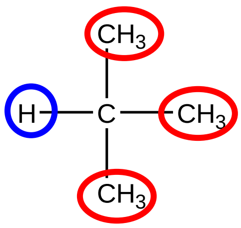
B



Two different types of H in the ratio of 2 :12 (1 : 6)

Product	CH_3 CH_3 CH_3—C—C—CH_3 Cl H	CH_3 CH_3 CH_3—C—C—CH_2Cl H H
Probability of forming	2	12

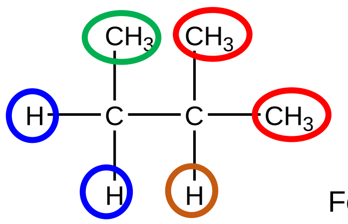
C



Two different types of H in the ratio of 1 : 9

Product	CH_3 H—C—CH_2Cl CH_3	CH_3 Cl—C—CH_3 CH_3
Probability of forming	9	1

D

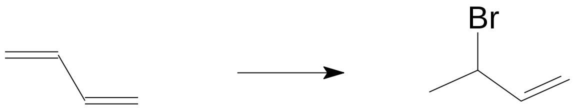


Four different types of H in the ratio of 2 : 3 : 1 : 6

Ans: A

21 During the addition of **H-X** to an alkene, the electrophile, hydrogen atom, is added to the carbon with the greater number of hydrogen atoms while the halogen atom is added to the carbon with the fewer number of hydrogen atoms to obtain the major product.

Since there are two C=C bonds in one buta-1,3-diene molecule, when 1 molecule of HBr is added, only 1 Br atom will be added to one of the two C=C bonds.

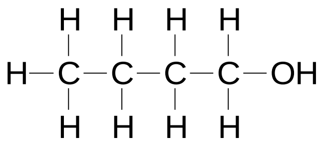


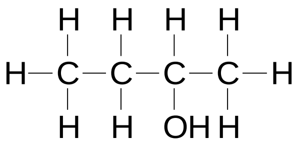
buta-1,3-diene

Ans: B

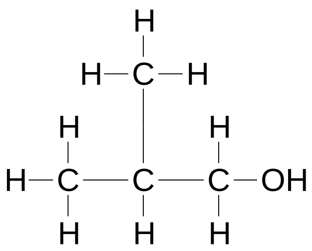
22 No. of structural isomers of alcohol with the molecular formula, $C_4H_{10}O$ = 4

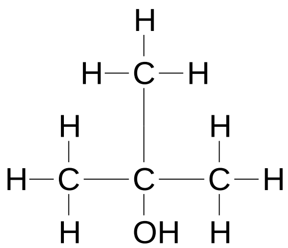
For 4 carbon chain:





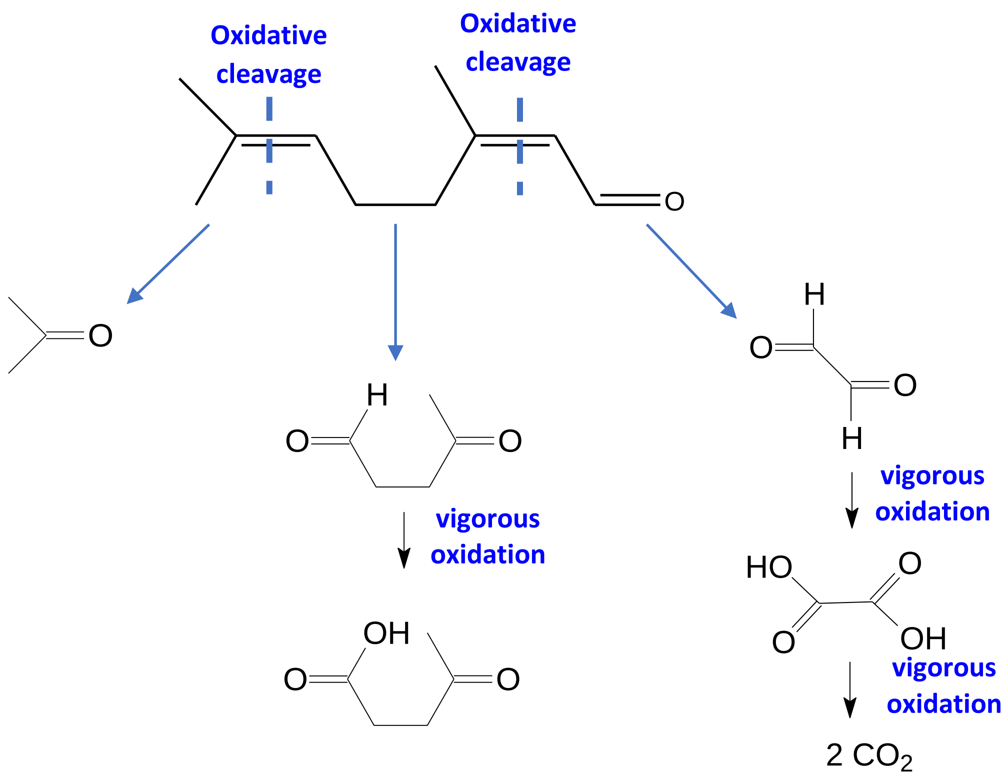
For 3 carbon chain





Ans: D

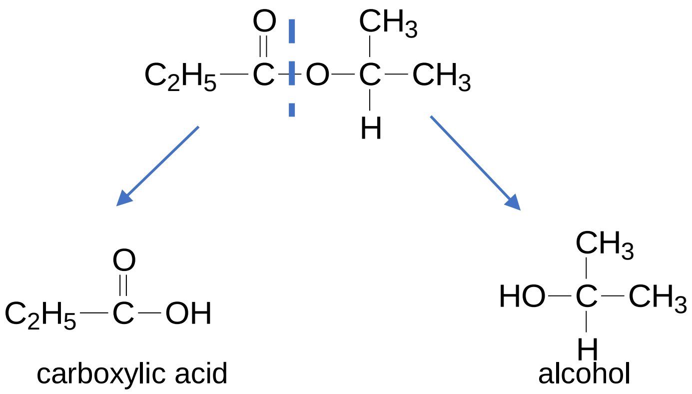
23



Therefore, $(CO_2H)_2$ is not the final product.

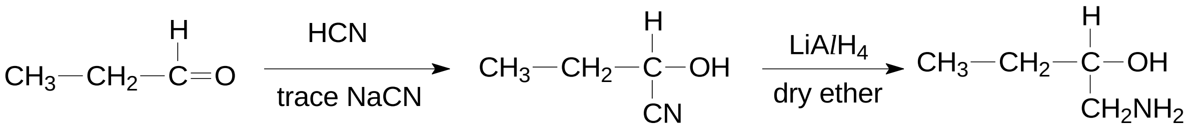
Ans: D

24 Ester has the formula. $C_2H_5CO_2CH(CH_3)_2$ with the following structure:



Ans: C

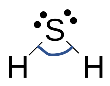
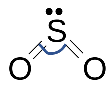
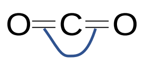
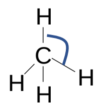
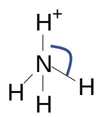
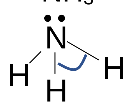
25



final product

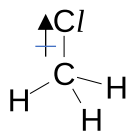
Ans: A

26

	Species **I**	Species **II**
1	H_2S  (107°)	SO_2  (118°)
2	CO_2  (180°)	CH_4  (109.5°)
3	NH_4^+  (109.5°)	NH_3  (107°)

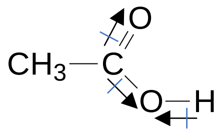
Ans: D (Option 1 only)

27 **1** CH_3Cl



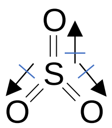
Net dipole moment (polar)

2 CH_3CO_2H



Net dipole moment (polar): dipole moments do not cancel out completely.

3 SO_3



No net dipole moment (Non-polar): dipole moments cancel out completely

Ans: B (Option 1 and 2 only)

28 **1** Standard enthalpy changes of formation of ethane

$2C(s) + 3H_2(g) \rightarrow C_2H_6(g)$

Standard enthalpy changes of formation is defined as the heat absorbed or evolved when one mole of a substance is formed from its constituent elements in their standard states at 298 K and 1 bar.

2 Standard enthalpy changes of combustion of methane

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

Standard enthalpy changes of combustion is defined as the heat evolved when one mole of a substance is completely burnt in excess oxygen at 298 K and 1 bar.

3 Standard enthalpy changes of formation of calcium carbonate

$Ca(s) + C(s) + \frac{3}{2}O_2(g) \rightarrow CaCO_3(s)$

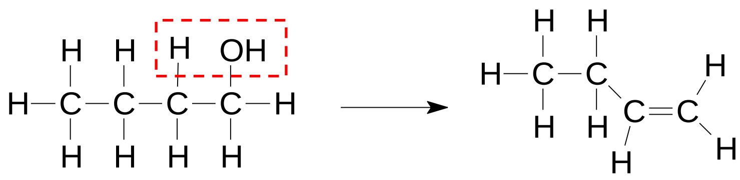
Standard enthalpy changes of formation is defined as the heat absorbed or evolved when one mole of a substance is formed from its constituent elements in their standard states at 298 K and 1 bar.

Ans: A (Option 1, 2 and 3)

29 Concentrated H_2SO_4 is a common reagent used for elimination reaction (elimination of H_2O).

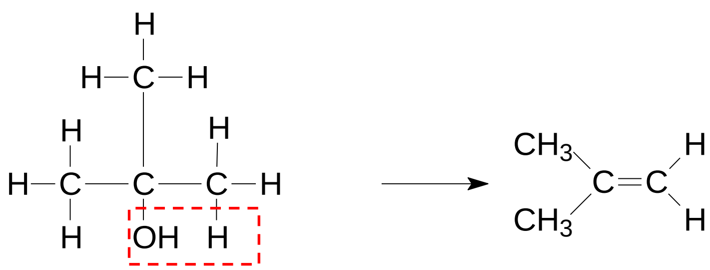
During the elimination reaction, OH and the H on the adjacent carbon atom is removed to form an alkene.

1 $CH_3CH_2CH_2CH_2OH$



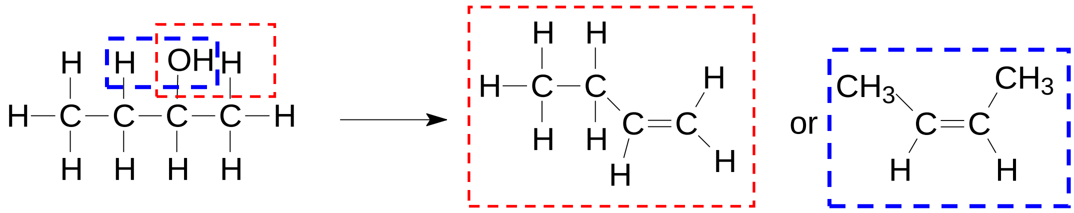
In this asymmetrical molecule, there is only one adjacent carbon atom next to the carbon atom with the OH group. Hence, there is only 1 product formed.

2 $CH_3C(OH)(CH_3)_2$



In this symmetrical molecule, there are three adjacent carbon atoms next to the carbon atom with the OH group. Hence, there is only 1 product formed.

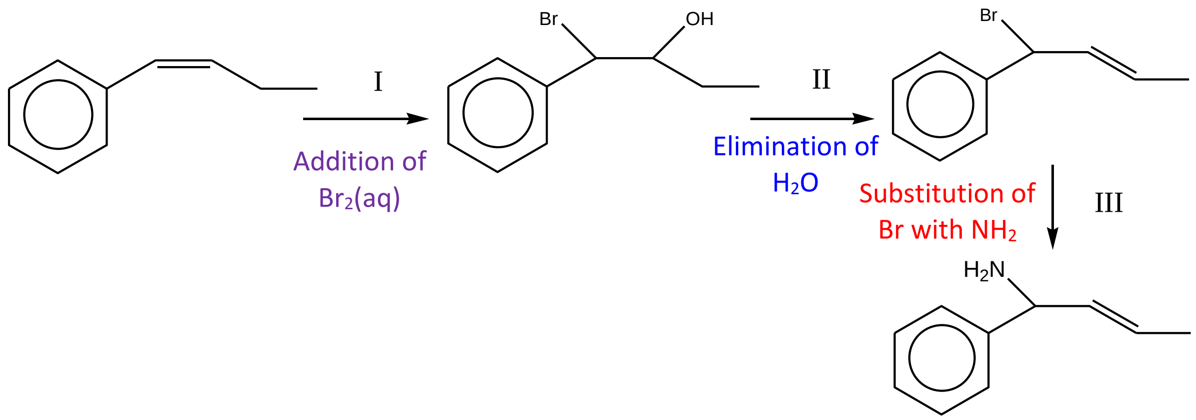
3 $CH_3CH_2CH(OH)CH_3$



In this asymmetrical molecule, there are two adjacent carbon atoms next to the carbon atom with the OH group. Hence, there are 2 products formed.

Ans: B (Option 1 and 2 only)

30



Ans: A (Option 1, 2 and 3)

NATIONAL JUNIOR COLLEGE

SH2 PRELIMINARY EXAMINATION

Higher 1

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY **8872/02**

Paper 2 Structured Questions

Thursday 24 Aug 2017
2 hours

Candidates answer **Section A** on the Question Paper.

Additional Materials: Data Booklet
Answer Paper
Graph paper (2sheets)

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 or rough working.
Do not use paper clips, highlighters, glue or correction fluid/tape.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answers **all** questions.

Section B
Answers **two** questions on separate answer paper.

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	/10
2	/7
3	/13
4	/10
5	/20
6	/20
7	/20
Paper 2	/80
Paper 1	/30
Paper 1 Percentage	/33
Paper 2 Percentage	/67
Overall Percentage	%

This document consists of **17** printed pages and **1** blank page.

For Examiner's Use

Section A

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

1 **(a)** Chlorine is a yellow-green gas and is the 2nd most abundant halogen after fluorine.

A mass spectrometer provides the following information about the relative abundances of the 2 isotopes.

isotope	relative abundance / %
^{35}Cl	75.76
^{37}Cl	24.24

(i) Define the term *relative isotopic mass*.

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....

.... [1]

(ii) Using the data above, calculate the relative atomic mass of chlorine and give your answer to 4 significant figures.

[1]

(b) The table below shows the boiling points of several halogenoalkanes.

compound	boiling point / °C
1–fluorobutane	32
1–chlorobutane	78
1–bromobutane	102
1–iodobutane	127
1–chloro–2–methylpropane	68

For Examiner's Use

(i) State and explain the trend in the boiling points from 1–fluorobutane to 1–iodobutane.

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.... [3]

(ii) Explain why the boiling point of 1–chloro–2–methylpropane is lower than that of 1-chlorobutane.

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.... [2]

(c) Suggest a synthetic route of not more than 2 steps to form butane–1,4–dioic acid, $HO_2C–CH_2CH_2–CO_2H$, from 1,2–dibromoethane. State the reagents and conditions for each step and show the structure of the organic intermediate compound.

[3]

[Total:10]

For Examiner's Use

2 **(a)** The mineral hydromagnesite is a hydrated carbonate of magnesium, with the formula $Mg_y(CO_3)_x(OH)_2.\mathbf{n}H_2O$ and a molar mass of 466 g mol^{-1}.

Hydromagnesite decomposes upon heating to form a white solid, magnesium oxide. The thermal decomposition of hydromagnesite can be expressed as follows:

$$Mg_y(CO_3)_x(OH)_2.\mathbf{n}H_2O \rightarrow \mathbf{y}MgO + \mathbf{x}CO_2 + (\mathbf{n}+1)H_2O$$

where **x**, **y** and **n** is a whole number.

(i) When 1.000 g of a pure sample of hydromagnesite is heated, it decomposes to give magnesium oxide, a white solid, till a constant mass is attained. During the decomposition, 0.378 g of carbon dioxide was given off, together with steam.

Using the above information, calculate the value of **x**.

[2]

(ii) The remaining white solid, magnesium oxide, from the above decomposition was completely dissolved in 50 cm^3 of a 1.0 mol dm^{-3} solution of hydrochloric acid and diluted to 250 cm^3.

25.0 cm^3 of the unreacted HC*l* was pipetted out from the resultant solution and required 28.50 cm^3 of a 0.10 mol dm^{-3} solution of sodium hydroxide for complete neutralisation.

I. Calculate the amount of unreacted HC*l* in 25.0 cm^3 of the resultant solution. Hence, calculate the total amount of unreacted HC*l* in 250 cm^3 of the diluted solution.

[1]

For Examiner's Use

II. Calculate the total amount of HC*l* in 50.0 cm^3 of 1.0 mol dm^{-3} of hydrochloric acid. Hence, calculate the amount of HC*l* used to react with magnesium oxide.

[1]

III. Calculate the amount of magnesium oxide obtained from the decomposition of hydromagnesite and hence, calculate the value of **y**.

[1]

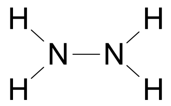
(iii) Using your answers from **a(i)**, **a(ii)** and the molar mass of hydromagnesite, deduce the value of **n** and hence, write the balanced equation for the thermal decomposition of hydromagnesite.

[2]

[Total: 7]

For Examiner's Use

3 **(a)** Hydrazine, N_2H_4, is useful as a rocket fuel.



Liquid hydrazine undergoes combustion according to the following equation.

$$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(l)$$

(i) Define standard enthalpy change of combustion, $\Delta H_c^{\ominus}$, of hydrazine.

....

....

....
[1]

(ii) A student conducted an experiment to determine the standard enthalpy change of combustion of hydrazine. 0.42 g of hydrazine was ignited in excess oxygen and combusted to heat up a beaker containing 200 cm^3 of water. The temperature of water rose by 8 ^{o}C. The heat transfer from the combustion of hydrazine is found to be 80 % efficient.
Calculate the enthalpy change of combustion, $\Delta H_c^{\ominus}$, of hydrazine.

[2]

For Examiner's Use

(iii) The bond energy of N≡N is found to be 945 kJ mol^{-1}.

Use the above bond energy of N≡N and the bond energy values from the *Data Booklet* to calculate the enthalpy change of combustion of hydrazine.

[2]

(iv) Suggest a reason why there is a discrepancy in the calculated value of the standard enthalpy change of combustion of hydrazine in **a(iii)** and **a(ii)**.

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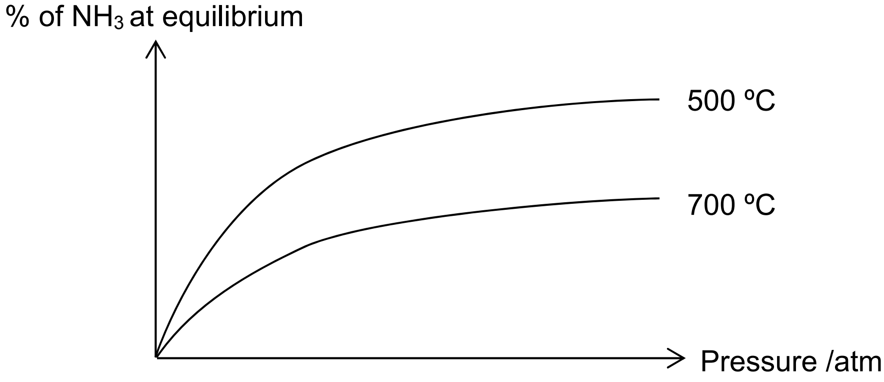
[1]

For Examiner's Use

(b) In the industry, ammonia, which is used to prepare hydrazine, is synthesised by the Haber process.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

(i) The figure below shows how percentage of ammonia in the equilibrium mixture varies with pressures at 500 °C and 700 °C respectively.



Use the above data to deduce whether the production of NH_3 is exothermic or endothermic process. Explain your answer.

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[2]

(ii) Describe and explain what would happen to the yield of NH_3 if more H_2 is added to the reaction vessel.

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[2]

For Examiner's Use

(iii) In an experiment, 2 moles of nitrogen and 7 moles of hydrogen are placed in a 2 dm^3 reaction vessel initially and allowed to reach equilibrium at 573 ^oC. The equilibrium mixture contains 3.2 moles of NH_3. Calculate the value of equilibrium constant, K_c, at this temperature. State the units of K_c.

[3]

[Total: 13]

4 Most of earth's crust consist of solid oxides that are formed as a result of the elements being oxidised by air.

The pH of the oxides of the elements from sodium to sulfur is given in the table below:

compound	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2
pH of solution	13	8	7	7	2	2
melting point / ^oC	1132	2852	2072	1700	24	–72

(a) Explain, in terms of structure and bonding, why MgO has a higher melting point than Na_2O.

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[3]

(b) **(i)** Suggest briefly, in terms of structure and bonding, why the pH of the solution containing SiO_2 is 7?

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[2]

For Examiner's Use

(ii) A sample of silicon dioxide has been contaminated with some aluminium oxide. Describe a method which can be used to obtain a pure sample silicon dioxide. Include equations for any reactions.

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....

....
[2]

(c) **(i)** Draw dot-and-cross diagram of SO_2.

[1]

(ii) Explain, with the aid of equations, the observed pH of solution when SO_2 dissolves in water.

....

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....

....
[2]

[Total:10]

Section B

Answer **two** questions from this section on separate answer paper.

5 **(a)** Compound **H**, $C_xH_yO_z$**,** is found to contain 62.1 % carbon and 10.3 % hydrogen by mass. The relative molecular mass, M_r, of **H** is 58.

(i) Prove that the empirical formula and molecular formula of **H** is C_3H_6O. [2]

Compound **H** does not react with sodium, but it gives orange precipitate when warmed with 2,4–dinitrophenylhydrazine.

(ii) Use your answer in **a(i)**, draw and name two structural isomers of compound **H** that satisfy the above reactions. [3]

(iii) Compound **H** does not decolourised hot acidified $KMnO_4$. Hence, write a balanced equation for the reaction between compound **H** and 2,4–dinitrophenylhydrazine and state the type of reaction. [2]

(b) Compound **M** is another isomer of compound **H** with the structural formula of CH_2=$CHCH_2$(OH).

(i) How will compound **M** reacts with

(I) cold, $KMnO_4$ in dilute NaOH

(II) PCl_5

(III) ICl

In **each** case, draw the structural formula of the organic product formed.[3]

(ii) Suggest a chemical test (not repeating the above-mentioned reagents and conditions in **b(i)** that can be used to distinguish compound **M** from propan–2–ol and state the expected observation for each compound. [2]

(c) Secondary fermentation of blackberries wine converts compound **J**, $C_4H_6O_5$, to compound **K**, $C_3H_6O_3$, to decrease the acidity of the wine.

Compounds **J** and **K** undergo the following reactions.

- Both **J** and **K** react with sodium carbonate and hot acidified $K_2Cr_2O_7$, but not with 2,4–dinitrophenylhydrazine.
- Both **J** and **K** react with excess hot concentrated H_2SO_4, but only **J** gives a mixture with a pair of cis-trans isomers.
- 0.234 g sample of **J** reacts completely with 35 cm^3 of 0.10 mol dm^{-3} NaOH(aq).
- **K** give a yellow precipitate with alkaline aqueous iodine.
- 7.5×10^{-4} mol of **K** produces 18 cm^3 H_2 gas at r.t.p. when excess Na is added.

Use the information above to deduce a structure for compounds **J** and **K** and explain all the reactions involved. [8]

[Total: 20]

6 Nitrogen monoxide, NO, is a by-product of the combustion of hydrocarbon fuels in internal engines.

(a) NO is considered to be involved in the formation of 'acid rain'. State one other undesirable consequence of the presence of NO in the atmosphere. [1]

(b) The reaction between H_2(g) and NO(g) was studied.

$$2H_2(g) + 2NO(g) \rightarrow 2H_2O(g) + N_2(g)$$

The rate of reaction was measured at different times at a constant temperature and the results are shown in the table below.

$[H_2]$ / mol dm^{-3}	2.20	2.00	1.80	1.50	1.25	0.80
rate / mol dm^{-3} s^{-1}	22.7×10^{-4}	21.1×10^{-4}	18.9×10^{-4}	15.7×10^{-4}	13.1×10^{-4}	8.3×10^{-4}

(i) Plot a graph of rate against $[H_2]$. [2]

(ii) Use your graph to find the order of reaction with respect to H_2. [1]

To determine the order of reaction with respect to NO, a series of experiments using different concentration of H_2 and NO were carried out at a constant temperature. The results are shown in the table below.

experiment	initial concentration of H_2(g) / mol dm^{-3}	initial concentration of NO(g) / mol dm^{-3}	initial rate / mol dm^{-3}s^{-1}
1	2.0×10^{-3}	2.0×10^{-3}	3.0×10^{-7}
2	4.0×10^{-3}	4.0×10^{-3}	2.4×10^{-6}

(iii) Use the data above, deduce the order of reaction with respect to NO. [2]

(iv) Write the rate equation for the reaction between H_2 and NO. [1]

(v) Calculate the value for the rate constant, *k*, using the data from the experiment 1 result. State the units for *k*. [3]

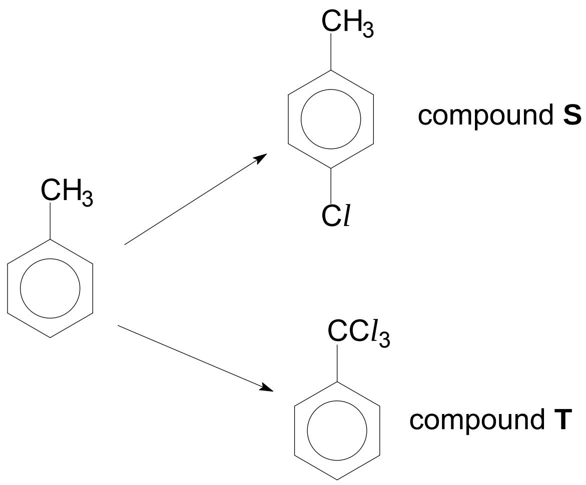
(c) Nitrogen monoxide, NO, is one of the atmospheric pollutants emitted from petrol car engines. It can be removed by passing the exhaust gases through a catalytic converter which has a platinum-rhodium mixture coated onto a fine-meshed aluminium alloy filter. The nitrogen monoxide is decomposed by excess carbon monoxide to form nitrogen and carbon dioxide.

(i) Write a balanced equation, with state symbols, to show how nitrogen monoxide is removed in the catalytic convertor. [1]

(ii) Suggest why the catalyst in the catalytic converter is in the form of a fine mesh? [1]

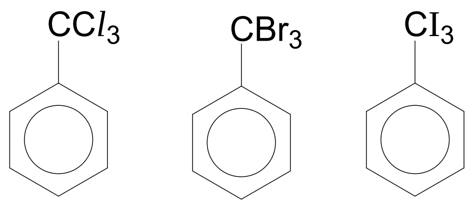
(iii) Explain why a catalyst is used in the catalytic converter with the aid of an energy distribution diagram to illustrate your answer. [3]

(d) Methylbenzene can undergo halogenation reaction with chlorine under different conditions to form two organic compounds, **S** and **T**.



(i) State the reagents and conditions for the formation of compounds **S** and **T**. [2]

(ii) Using your knowledge of the halogenoalkanes, arrange in increasing order of reactivity for the hydrolysis of the following three compounds. [1]



I **II** **III**

(iii) Hence, explain the difference in the reactivity for the above three compounds. [2]

[Total: 20]

7 (a) (i) Sketch a graph to show the variation in the first ionisation energy of the elements across Period 3 from Na to C*l*. [2]

(ii) Suggest explanation for the observed variation in the first ionisation energy of the elements across Period 3. [3]

Chloroethane can be formed from the reaction between ethane and chlorine. When chloroethane undergoes hydrolysis with sodium hydroxide, hydrogen chloride is produced and dissolves in water to form hydrochloric acid, which reacts with excess sodium hydroxide present in the solution.

(iii) State the type of reaction that has occurred between hydrochloric acid and sodium hydroxide and write a balanced equation. [2]

(iv) Hence, calculate the standard enthalpy change of reaction between hydrochloric acid and sodium hydroxide given the following enthalpies:

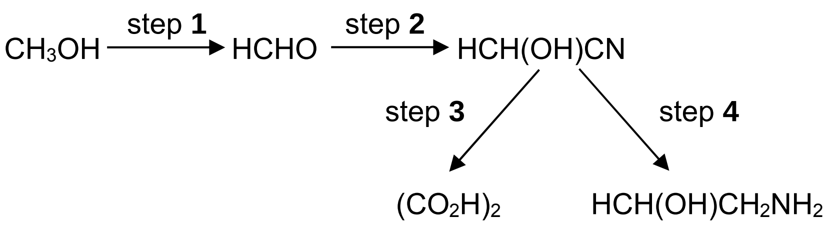
compound	$\Delta H^{\ominus}_f$ / kJ mol^{-1}
NaOH(aq)	–469.15
NaC*l*(aq)	–407.27
HC*l*(aq)	–167.20
H_2O(*l*)	–285.83

[2]

(v) Using your answer in **a(iv)**, suggest a value for the enthalpy change of neutralisation, $\Delta H^{\ominus}_{neu}$, of the reaction when barium hydroxide, $Ba(OH)_2$, which acts as a strong base, is reacted with hydrochloric acid instead. [1]

(b) (i) Calculate the oxidation number of carbon in methanol, CH_3OH. [1]

(ii) Methanol can undergo the following reaction scheme.



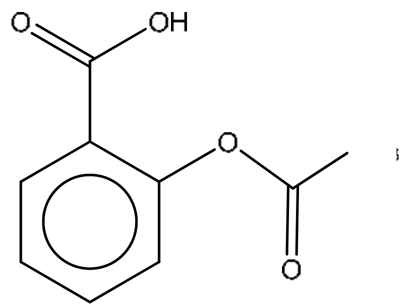
State the reagent and conditions for steps **1**, **2**, **3** and **4**. [4]

(c) In human body, carbon dioxide, that is produced, will dissolve in water present in the blood to form a carbonic acid–hydrogen carbonate (H_2CO_3/HCO_3^-) buffer system.

(i) Explain, with the aid of equations, how the buffer system helps to control and maintain the pH in the blood. [2]

(ii) Although the blood has a pH value of 7.4, the pH in the stomach is 2.5. Calculate the hydrogen ion concentration, [H^+], present in the stomach. [1]

(d) Aspirin is also known as acetylsalicylic acid and the structure of aspirin is as shown below.



Draw the organic products formed when aspirin reacts with HC*l* (aq) in the presence of heat. [2]

[Total: 20]

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2017 NJC H1 Chemistry Prelim Paper 2 Suggested Answers

1 **(a)** **(i)** The mass of an isotope of an element relative to $^1/_{12}$ the mass of one atom of ^{12}C.

(ii) relative atomic mass of chlorine
= (75.76/100) × 35 + (24.24/100) × 37
= 35.48 (4s.f.)

(b) **(i)** The boiling point **increases** from as 1–fluorobutane to 1–iodobutane. The halogenoalkanes are made up of **simple covalent molecules** held by **temporary dipole-induced dipole interactions**. There is an increase in M_r from 1–fluorobutane to 1–iodobutane and hence the **electron cloud size increases**, making it **more easily polarised** and leading to **increasingly stronger** temporary dipole induced dipole interactions. Hence, **more energy** is needed to overcome the increasingly stronger temporary dipole induced dipole interactions between the halogenoalkanes, leading to the increase in boiling point from 1–fluorobutane to 1–iodobutane.

(ii) Both are **simple covalent compounds** with **temporary dipole – induced dipole interactions**. 1-chloro–2-methylpropane is **branched while 1–bromobutane is a straight chain**. Thus, there is **greater surface of contact** between the 1–bromobutane molecules than 1–chloro–2–methylpropane, leading to **greater temporary dipole - induced dipole** interactions between 1–bromobutane that requires **more energy** to overcome.

(c)

$$BrCH_2CH_2Br \xrightarrow[\text{heat}]{\text{ethanol, NaCN}} NCCH_2CH_2CN \xrightarrow[\text{heat}]{H_2SO_4(aq)} HO_2CCH_2CH_2CO_2H$$

2 **(a)** **(i)** Amount of hydromagnesite = 1/466 = 2.146 × 10^{-3} mol

Amount of CO_2 given off = 0.378/44.0 = 8.591 × 10^{-3} mol

Mole ratio of hydromagnesite: CO_2 = 2.146 × 10^{-3} : 8.591 × 10^{-3}
= 1 : 4

x = 4

(ii) I
$NaOH + HCl \rightarrow NaCl + H_2O$

Amount of NaOH used to neutralise remaining HC*l* in 25 cm^3
= (28.50/1000) x 0.10
= 2.85 x 10^{-3} mol

Amt of remaining HC*l* in 250 cm^3 = (2.85 x 10^{-3}) x (250/25.0)
= 0.02850 mol

II
Amount of HC*l* used in 50 cm^3 of HC*l* solution
= (50/1000) x 1.0
= 0.05000 mol

Amt of HC*l* reacted with MgO
= 0.05000 – 0.02850
= 0.02150 mol

III
$MgO + 2HCl \rightarrow MgCl_2 + H_2O$

Amt of MgO formed = 0.02150/2 = 0.0107 mol

Mole ratio of hydromagnesite: MgO = 2.146×10^{-3} : 0.0107
= 1 : 5
y = 5

(iii) Molar mass of hdromagnesite = 466 g mol^{-1}

$Mg_5(CO_3)_4(OH)_2.\mathbf{n}H_2O$

Mass of water per mole of hdromagnesite
= 466 – [(5 x 24.3) + (4 x 12.0) + (14 x 16.0) + 2(1.0)]
= 70.5 g

n = 70.5/18.0 = 3.917 ≈ 4

Balanced equation: $Mg_5(CO_3)_4(OH)_2.4H_2O \rightarrow 5MgO + 4CO_2 + 5H_2O$

3 **(a)** **(i)** Standard enthalpy change of combustion of hydrazine is the heat liberated when 1 mole of hydrazine is completely burnt in excess oxygen at 298 K and 1 atm.

(ii) Amount of heat gained by water, $q = mc\Delta T$
$q = 200 \times 4.18 \times 8$
$= 6688$ J

Amount of heat evolved, $q = 6688 \times (100/80)$
$= 8360$ J

Amount of hydrazine = 0.42/32 = 0.01313 mol

$\Delta H_c^{\ominus}(\text{hydrazine}) = -q/n_{hydrazine}$
$= -8360/0.01313$
$= -\,637000$
$= -\,637$ kJ mol^{-1}

(iii)

bonds broken	bond energy/ kJ mol^{-1}	bonds formed	bond energy/ kJ mol^{-1}
1 N–N	+160	1 N≡N	–945
4 N–H	4(+390)	4 O–H	4(–460)
1 O=O	+496		

$\Delta H^{\ominus}_c$ (hydrazine) = BE(Bonds broken) + BE(Bonds formed)
= [160 + 4(390) + 496] + [(–945) + 4(–460)]
= – 569 kJ mol^{-1}

(iv) The bond energy values obtained from the Data booklet are average values which would differ from the actual bond energy in the molecule due to the different chemical environment. Therefore, there would be discrepancy in the calculated value.

Or

The bond energy values obtained from the Data booklet are used on gaseous molecules. However, in the balanced equation of combustion of hydrazine, both hydrazine and water are in liquid state and not in gaseous state. Therefore, there would be discrepancy in the calculated value.

(b) (i) The production of NH_3 is an exothermic reaction since at lower temperature, there is a higher percentage of NH_3 at equilibrium, implying that the forward exothermic reaction is favoured to counteract the decrease in temperature.

(ii) When more H_2 is added to the reaction vessel, by **Le Chatelier's principle**, position of **equilibrium shifts right** to **partially remove the increased concentration of H_2**, resulting in a **greater yield of NH_3.**

(iii)

	N_2 +	$3H_2$ $\rightleftharpoons$	$2NH_3$
Initial amount / mol	2	7	0
Change / mol	–x	–3x	+2x
Equilibrium amount / mol	2–(1.6) =0.4	7–3(1.6) =2.2	3.2
Equilibrium concentration / mol dm^{-3}	0.4/2 =0.2	2.2/2 = 1.1	3.2/2 = 1.6

2x = 3.2
x = 1.6

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

$$= \frac{[1.6]^2}{[0.2]1.1]^3}$$

K_c = 9.617
= 9.62 mol^{-2} dm^6

4 **(a)** Both MgO and Na_2O have giant ionic lattice structure with strong ionic bonds between the oppositely charged ions. Both compounds contain the same O^{2-} ion, but Mg^{2+} ion has a higher charge and smaller ionic radius than Na^+ ion. Since $|\text{L.E.}| \propto \dfrac{q^+q^-}{r^+ + r^-}$, MgO, therefore, has a higher magnitude of lattice energy than that of Na_2O and hence more energy is needed to overcome the stronger ionic bond in MgO than in Na_2O. Thus, MgO has higher melting point than Na_2O.

(b) **(i)** SiO_2 has a giant covalent lattice structure with covalent bonding between Si and O atoms. The covalent bond in SiO_2 are too strong to overcome. Hence, SiO_2 are insoluble in water.

(ii) $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$

Add hot HC*l*(aq) to the contaminated mixture to remove the Al_2O_3. Filter the mixture and keep the residue which contains the SiO_2.

(c) **(i)**

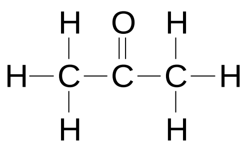
(ii) $SO_2 + H_2O \rightarrow H_2SO_3$
$H_2SO_3 \rightleftharpoons HSO_3^- + H^+$

5 **(a)** **(i)**

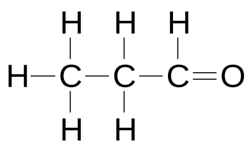
	C	H	O
Composition by mass	62.1	10.3	27.6
Divide by A_r	62.1/12 = 5.175	10.3/1 =10.3	27.6/16 =1.725
Divide by smallest number	5.175/1.725 =3	10.3/1.725 =6	1.725/1.725 =1
Simplest mole ratio	3	6	1

Molecular formula of **H** = Empirical formula of **H** = C_3H_6O (M_r = 58)

(ii)

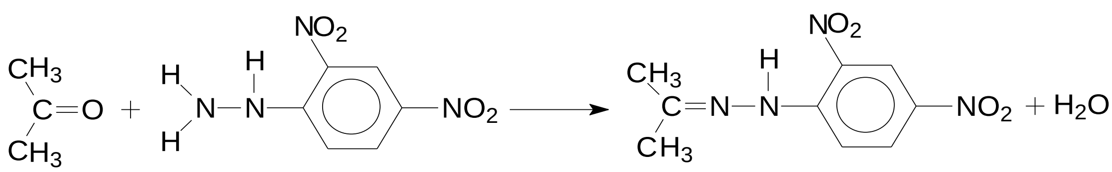


propanone



propanal

(iii)



Condensation

(b) **(i)** I: $CH_2(OH)CH(OH)CH_2(OH)$

II: $CH_2{=}CHCH_2Cl$

III: $CH_2(I)CH(Cl)CH_2(OH)$

(ii) *Test:* Add Br_2(aq) or Br_2 in CCl_4
Observation:
M: Decolourisation of orange Br_2(aq)/ reddish-brown Br_2 in CCl_4
propan–2–ol: orange Br_2(aq)/ reddish-brown Br_2 in CCl_4 remains.

OR

Test: $KMnO_4$, dilute H_2SO_4, heat
Observation:
M: Decolourisation of purple $KMnO_4$ and effervescence.
propan–2–ol: Decolourisation of purple $KMnO_4$.

OR

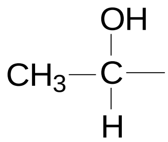
Test: cold, NaOH(aq), $KMnO_4$
Observation:
M: Decolourisation of purple $KMnO_4$, brown ppt of MnO_2 formed.
propan–2–ol: No decolourisation of purple $KMnO_4$/ Purple solution remains.

OR

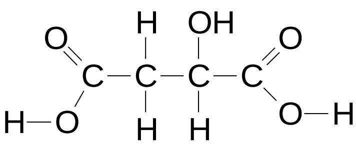
Test: I_2(aq), NaOH(aq), warm
Observation:
M: No yellow ppt of CHI_3
propan–2–ol: Yellow ppt of CHI_3 is formed.

(c)

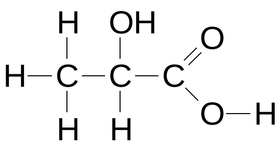
Information	Deduction
Both **J** and **K** react with sodium hydroxide	**J** and **K** undergoes acid base reaction with sodium hydroxide. ➔ Both compounds contain COOH group.
Both **J** and **K** react with acidified $K_2Cr_2O_7$, but not with 2,4–dinitrophenylhydrazine reagent.	**J** and **K** undergoes oxidation reaction with $K_2Cr_2O_7$. ➔ Both compounds are not carbonyl compound and contain OH group.

Both **J** and **K** react with excess hot concentrated H_2SO_4, but only **J** gives a mixture with a pair of cis-trans isomers.	**J** and **K** undergoes elimination of H_2O to form alkene. Alkenes obtained from **J** exhibited cis-trans isomerism, but not that of **K** (terminal alkene).
A 0.234 g sample of **J** reacts completely with 35 cm^3 of 0.10 mol dm^{-3} NaOH.	J undergoes neutralisation/acid base reaction with NaOH. Amt of **J**= $\frac{0.234}{134}$ =1.746 x10^{-3} mol Amt of NaOH = 3.5 x 10^{-3} mol Mole ratio of **J**: NaOH is 1:2 **J** is dibasic acid which contains two COOH groups.
K give a yellow precipitate with alkaline aqueous iodine.	**K** undergoes mild oxidation with alkaline aqueous iodine. **K** contains the following structure 
A 7.5 x 10^{-4} mol of **K** produces 18 cm^3 H_2 gas when excess Na is added.	**K** undergoes redox/ acid metal reaction with Na. Amt of H_2 liberated = 18/24000 =7.5 x 10^{-4} mol Mole ratio of **K**:H_2 is 1:1 **K** contains two OH groups (make up of 1 COOH and 1 OH group).

J:

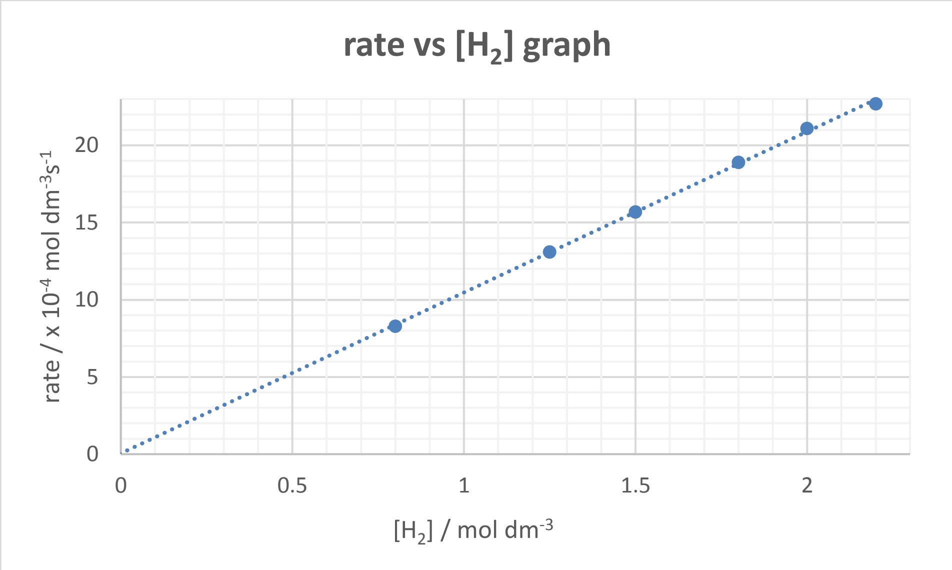


K:



6 **(a)** NO is one of the pollutants which causes photochemical smog. Such smog causes respiratory problems.

(b) **(i)**



Correct axes label with appropriate units and appropriate scale
Correct plotting of points and the graph must occupy at least half of the grid paper.

(ii) Since the graph is a straight line graph with constant gradient, this implies that the rate is directly proportional to [H_2], therefore it is 1st order reaction w.r.t H_2.

(iii)

$$\frac{\text{rate}_{\text{expt1}}}{\text{rate}_{\text{expt2}}} = \frac{[H_2]_{\text{expt1}}[NO]^n_{\text{expt1}}}{[H_2]_{\text{expt2}}[NO]^n_{\text{expt2}}}$$

$$\frac{3.0\times10^{-7}}{2.4\times10^{-6}} = \frac{(2.0\times10^{-3})(2.0\times10^{-3})^n}{(4.0\times10^{-3})(4.0\times10^{-3})^n}$$

$$\frac{3.0\times10^{-7}}{2.4\times10^{-6}} = \frac{(2.0\times10^{-3})}{(4.0\times10^{-3})}\left(\frac{2.0\times10^{-3}}{4.0\times10^{-3}}\right)^n$$

n = 2
Order of reaction w.r.t NO is 2.

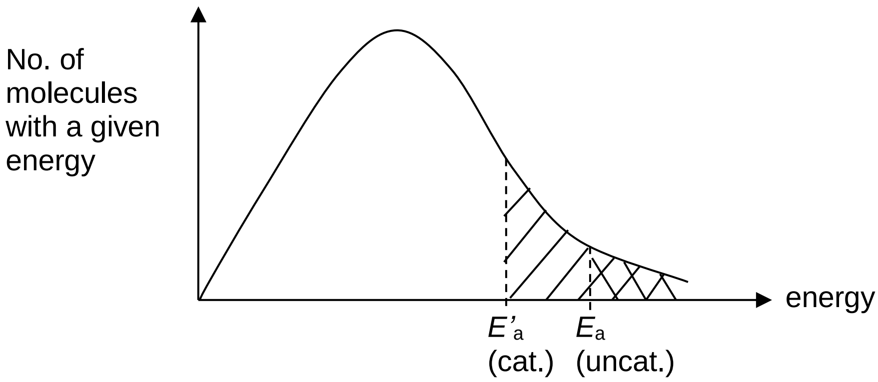
(iv) rate = k$[NO]^2[H_2]$

(v) k = rate/$[NO]^2[H_2]$
= $(3.0 \times 10^{-7})/(2.0 \times 10^{-3})^3$
= 37.5 $mol^{-2}\ dm^6\ s^{-1}$

(c) **(i)** $2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g)$

(ii) The fine mesh is used so as to maximise the surface area on which the catalytic reaction takes place.

(iii)



Correct axes label, graph start from origin, labels and shading for E_a for each catalysed and un catalysted reaction.

In the presence of a catalyst, the reaction proceeds via an alternative reaction pathway with a lower activation energy.

Hence, frequency of effective collisions increases as more reactant molecules possess sufficient energy to overcome the lowered activation energy, E_a' (shown by the greater shaded area under the curve) and rate of reaction increases.

(d) **(i)** Compound **S**: Cl_2 and anhydrous $AlCl_3$

Compound **T**: excess $Cl_2(g)$ and UV light or high temperature

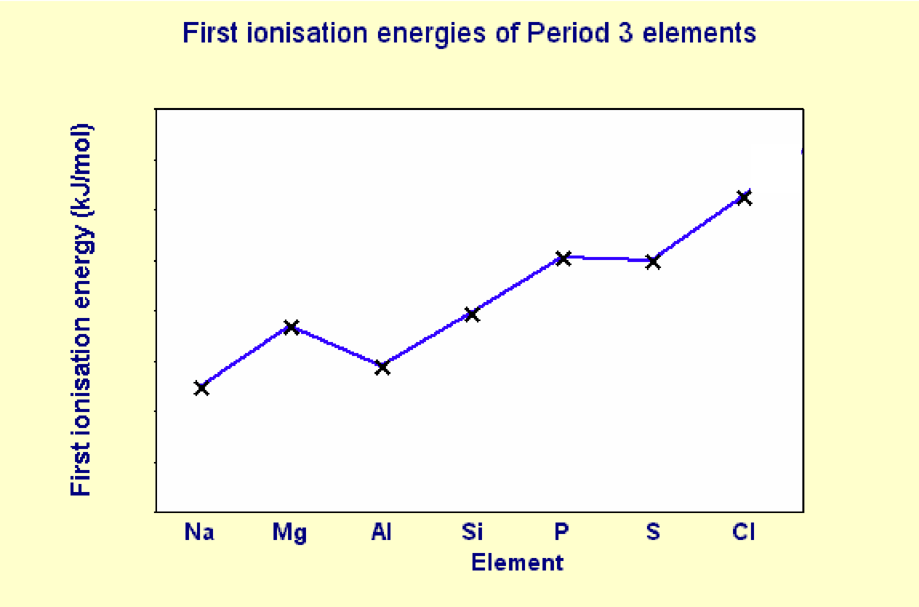
(ii) Reactivity: **I** < **II**< **III**

(iii) During hydrolysis, the C–X (where X = C*l*, Br & I) bond needs to be broken. Down the group, the atomic radius of the halogens increases from C*l* to I and hence the C–X bond length increases from C–C*l* to C– I. Thus, the C-X bond strength decreases down the group resulting in increasing ease of hydrolysis from C–C*l* to C– I.

Or

Quote the bond energy for C–X from Data booklet
BE(C–C*l*) = 340 kJ mol^{-1}
BE (C–Br) = 280 kJ mol^{-1}
BE (C–I) = 240 kJ mol^{-1}
Thus, the C-X bond strength decreases down the group resulting in increasing ease of hydrolysis from C–C*l* to C– I.

7 (a) (i)



(ii) There is a general increase in 1st ionization energy from Na to C*l*. Across the period, as the number of proton increases, **nuclear charge increases**. However, the number of inner core electrons remain the same, thus **shielding effect remains relatively constant**. Therefore, increasing ionisation energy is needed to remove the most loosely held electron from the increasing nuclear attraction.

There are two anomalies in 1st ionisation energy between.

(i) Mg vs A*l*

The most loosely held electron in A*l* is in the 3p orbital while the most loosely held electron in Mg is in the 3s orbital. **The 3p orbital is further away (at a higher energy level) from the nucleus than the 3s orbital. This outweighs the increase in nuclear charge,** resulting in a **weaker nuclear attraction for the most loosely held electron** and thus requires less energy to remove it, giving A*l* a lower first ionisation energy

(ii) P vs S

The most loosely held electron from S is from the paired electrons in 3p orbital whereas that of P comes from the singly filled 3p orbital. The **inter-electronic repulsion between the paired electrons in the same orbital outweighs the effect of increasing nuclear charge**, resulting in **weaker nuclear attraction for the *most loosely held electron***. Less energy is thus needed to remove it, giving S a lower first ionisation energy

(iii) Acid-base reaction/ Neutralisation

$NaOH + HCl \rightarrow NaCl + H_2O$

(iv) $\Delta H^{\ominus}_{rxn} = [\Delta H^{\ominus}_f(NaCl) + \Delta H^{\ominus}_f(H_2O)] - [\Delta H^{\ominus}_f(HCl) + \Delta H^{\ominus}_f(NaOH)]$

$= [(-407.27) + (-285.83)] - [(-167.20)+(-469.15)]$

$= -56.75$

$= -56.8 \text{ kJ mol}^{-1}$

(v) ΔH^{e}_{neu}= –56.8 kJ mol^{-1} as $Ba(OH)_2$ is a strong base.
ΔH^{e}_{neu} for strong acids + strong base reactions are the same.

(b) **(i)** –2

(ii) step **1**: $K_2Cr_2O_7$, H_2SO_4(aq), heat with immediate distillation

step **2**: HCN, trace amount of NaCN or NaOH, cold

step **3**: $K_2Cr_2O_7$, H_2SO_4(aq), heat

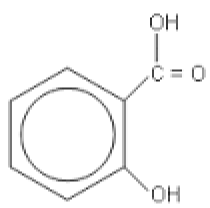
step **4**: $LiAlH_4$ in dry ether/ H_2, Pt / H_2, Ni, heat

(c) **(i)** Addition of H^+: $HCO_3^- + H^+ \rightarrow H_2CO_3$
Addition of OH^-: $H_2CO_3 + OH^- \rightarrow HCO_3^- + H_2O$
When small amount of H^+ or OH^- is added, the large reservoir of HCO_3^- and H_2CO_3 will neutralise H^+ and OH^- respectively. Hence pH is maintained.

(ii) pH = – log [H^+]

[H^+] = $10^{-2.5}$
= 3.162×10^{-3}
= 3.16×10^{-3} mol dm^{-3} (3 s.f.)

(d)



CH_3COOH

PIONEER JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
HIGHER 1

CANDIDATE NAME		
CT GROUP	1 6	INDEX NUMBER

CHEMISTRY **8872/01**

Paper 1 Multiple Choice **22 September 2017**
50 minutes

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, CT group and index number in the spaces provided.

Do not use staples, paper clips, highlighters, glue or correction fluid.

There are **thirty** questions in 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, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 20 cm^3 of a gaseous hydrocarbon was mixed with 100 cm^3 of oxygen and the mixture sparked so that the hydrocarbon was completely burnt. The volume of gas remaining at the end of the combustion was 70 cm^3. After passing over soda lime, this volume was reduced by 60 cm^3. All gases were measured at 25°C and at the same pressure.

Determine the molecular formula of the hydrocarbon.

A C_2H_4

B C_2H_6

C C_3H_6

D C_3H_8

2 Carbon monoxide, CO, is a colourless, odourless and toxic gas. It is formed as a result of partial oxidation of carbon-containing compounds. The maximum safe toleration level of CO in air is 50 ppm. (1 ppm = 1 mg kg^{-1})

How many molecules of CO gas are present in 1 kg of air at this toleration level?

A $\dfrac{50 \times 10^{-3} \times 6.02 \times 10^{23}}{28}$

B $50 \times 10^{-3} \times 28 \times 6.02 \times 10^{23}$

C $\dfrac{50 \times 6.02 \times 10^{-3}}{28}$

D $50 \times 28 \times 6.02 \times 10^{23}$

3 Equimolar amounts of ClO_2 and OH^- ions react to produce three products: water, chlorate(III) ions ClO_2^- and another chloro-oxy anion, ClO_x^-

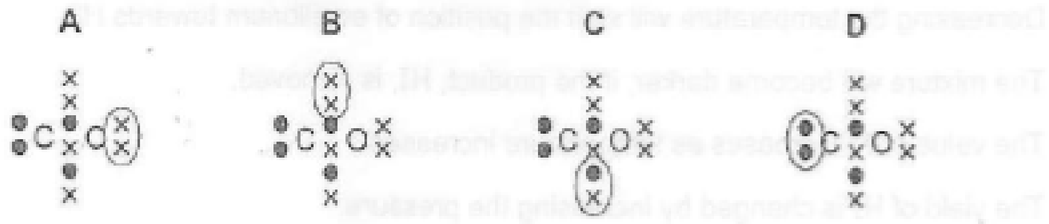
What is the oxidation state of chlorine in the chloro-oxy anion, ClO_x^- ?

A +1 **B** +2 **C** +5 **D** +7

4 Which of the following particles would, on losing an electron, have a half-filled set of p orbitals?

A O^+ B O^- C N D N^-

5 Which circled pair of electrons represents a co-ordinate bond?



6 Which molecules contain within their structure three atoms arranged in a straight line?

A ICl_3

B SO_4^{2-}

C CCl_4

D H_2S

7 Consider the following four isoelectronic compounds.

1 $(CH_3)_3CH$
2 $CH_3CH_2CH_2CH_3$
3 $CH_3CH_2CH_2OH$
4 CH_3CH_2Cl

What is the order of decreasing boiling point of these compounds?

A 1 → 2 → 4 → 3

B 3 → 4 → 1 → 2

C 3 → 4 → 2 → 1

D 4 → 3 → 2 → 1

8 Given the following thermochemical data, what is the standard enthalpy change of the reaction, $\Delta H_r^{\ominus}$.

$$\Delta H_r^{\ominus}$$
$$CH_2{=}CHCH{=}CH_2\,(g) \rightarrow CH_3C{\equiv}CCH_3\,(g)$$

Standard enthalpy change of combustion of $CH_3C{\equiv}CCH_3$ (g)	= –2577 kJ mol^{-1}
Standard enthalpy change of formation of carbon dioxide	= –394 kJ mol^{-1}
Standard enthalpy change of formation of water	= –286 kJ mol^{-1}
Standard enthalpy change of formation of $CH_2{=}CHCH{=}CH_2$(g)	= +110 kJ mol^{-1}

A – 253 kJ mol^{-1} **B** – 33 kJ mol^{-1}
C + 33 kJ mol^{-1} **D** + 253 kJ mol^{-1}

9 Which one of the following equations correctly represents the standard enthalpy change of formation of water?

A $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

B $H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l)$

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

D $2H(g) + O(g) \rightarrow H_2O(l)$

10 Chlorine dioxide, ClO_2, is a yellow gas which can be synthesised in the laboratory by the following reaction:

$$2AgClO_3(s) + Cl_2(g) \rightleftharpoons 2AgCl\,(s) + 2ClO_2(g) + O_2(g) \qquad \Delta H = 0$$

Which of the following statements about the above reaction is correct?

A Adding more $AgClO_3$ (s) increases the equilibrium yield of ClO_2.

B The equilibrium constant changes when temperature changes.

C Decreasing the pressure decreases the equilibrium yield of ClO_2.

D The addition of a catalyst increases the rates of both the forward and the reverse reactions.

11 The values for the ionic product of water, K_w, at two different temperatures are given below.

Temperature / ^oC	K_w / mol^2dm^{-6}
25	1.00×10^{-14}
30	$1 .44 \times 10^{-14}$

Which of the following is correct for pure water at 30^oC?

A $[H^+] = 1.44 \times 10^{-7}$ moldm^{-3}

B $[H^+] > [OH^-]$

C pH = 7

D pH < 7

12 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 at 25^oC?

A 12.0

B 11.7

C 11.5

D 11.0

13 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.

Which statement is true?

A It took 17 minutes for the amount of NO_2 to rise from 0 mol to 0.10 mol.

B There was 0.0625 mol of N_2O_5 left after 17 minutes.

C There was 0.0125 mol of N_2O_5 left after 68 minutes.

D The amount of NO_2 in the flask went up by four times in the first 34 minutes.

14 A piece of magnesium ribbon was added to $25cm^3$ of 0.100 $moldm^{-3}$ of dilute hydrochloric acid. The magnesium was completely dissolved and the total volume of hydrogen gas evolved was measured.

In a second experiment, an identical piece of magnesium ribbon was added to solution **X**. Solution **X** is prepared by adding $25cm^3$ of 0.100 $moldm^{-3}$ of dilute hydrochloric acid to $25cm^3$ of 0.0200 $moldm^{-3}$ of hydrochloric acid. The total volume of hydrogen evolved was measured.

How will the initial rate of reaction and total volume of hydrogen evolved in the second experiment compare to the first experiment?

	Initial rate of reaction	Total volume of hydrogen evolved
A	Decrease	Increase
B	Decrease	no change
C	Increase	Increase
D	Increase	no change

15 Water was poured into a mixture containing solid oxides of elements **A**, **B** and **C**. The mixture was filtered to obtain a colourless solution with a pH of 2 and a residue.

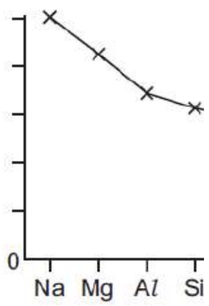
The residue was then treated with excess hot concentrated sodium hydroxide and all the residue dissolved.

What are the identities of elements **A**, **B** and **C**?

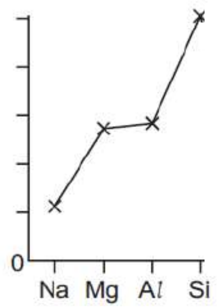
	Element **A**	Element **B**	Element **C**
A	aluminium	silicon	phosphorus
B	aluminium	silicon	sodium
C	magnesium	aluminium	sulfur
D	magnesium	silicon	phosphorus

16 The graphs below show the variation in two properties of the elements Na to Si.

Graph 1



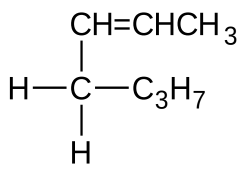
Graph 2



Which properties are illustrated in Graphs 1 and 2?

	Graph 1	**Graph 2**
A	electronegativity	melting point
B	electronegativity	electrical conductivity
C	atomic radius	melting point
D	atomic radius	electrical conductivity

17 The compound shown below has the following structure:



How many isomers does this compound have?

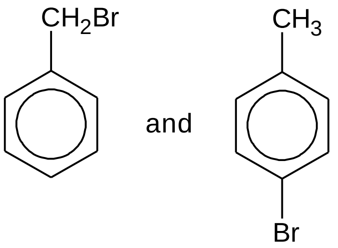
A 2 **B** 4 **C** 8 **D** 16

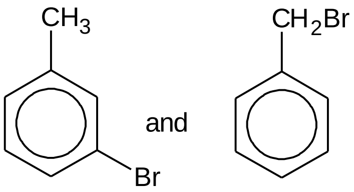
18 How many different alkenes, including geometric isomers, could be produced by the removal of HBr from $(CH_3)_2CBrCH_2CH_3$?

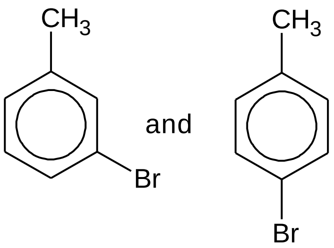
A 2 **B** 3 **C** 4 **D** 5

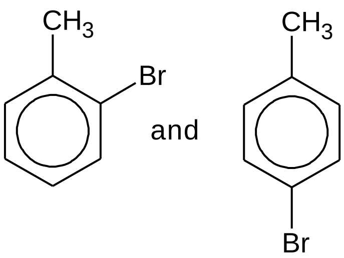
19 A student placed a stoppered conical flask containing iron powder, bromine and methylbenzene in cupboard. The flask was removed when no further change was observed.

Which of the following are likely to be the main products formed?

A 

B 

C 

D 

20 Chlorodifluoromethane, R-22, is a type of hydrochlorofluorocarbon. It is commonly used as a refrigerant and propellant. Its use is being phased out as it contributes to ozone depletion.

Which of the following statements about R-22 is **incorrect**?

A Ultraviolet rays can break down R-22 into chlorine radicals which will react with ozone

B R-22 is a gas at room temperature because of weak intermolecular forces

C Fluorine radicals are not formed because the C-F bond is very strong

D R-22 is very reactive and flammable

21 Which of the following reagents and conditions will **not** give a positive observation for ethanal?

A $LiAlH_4$ in dry ether

B $K_2Cr_2O_7$(aq), H_2SO_4(aq), heat

C $KMnO_4$(aq), H_2SO_4(aq), heat

D I_2(aq), NaOH(aq), warm

22 In an attempt to make propanoic acid, propan-2-ol was added to a solution of potassium dichromate(VI) dissolved in dilute sulfuric acid and the mixture was heated.

No propanoic acid was produced.

Which of the following statements explain this?

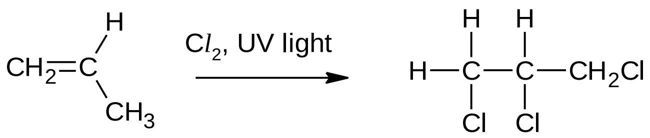
A The sulfuric acid dehydrates the propan-2-ol to form propene.

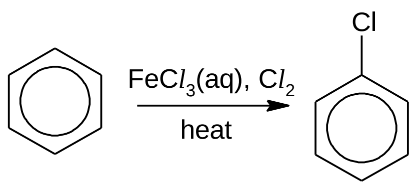
B The propan-2-ol forms propanal when oxidised.

C The propan-2-ol forms propanone when oxidised

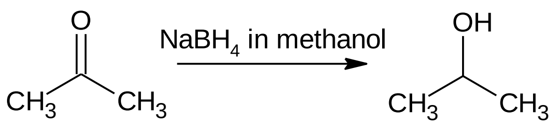
D Potassium dichromate(VI) will not oxidise propan-2-ol.

23 What of the following reactions will **not** result in the formation of the product?

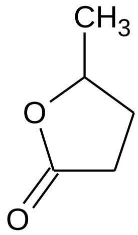
A 

B 

C $CH_3{\cdot}CH_2CH_2Cl \xrightarrow[\text{heat}]{NaOH(aq)} CH_3{\cdot}CH_2CH_2OH$

D 

24 The molecule shown below is a naturally occurring organic compound found in fruits and could be a possible bio-fuel alternative to ethanol.



Which statement about this compound is **not** correct?

A It can be prepared by warming 4-hydroxypentanoic acid, $CH_3CH(OH)CH_2CH_2CO_2H$, in the presence of an acid catalyst

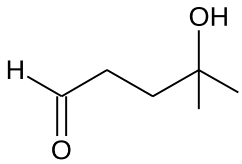
B It can decolourise hot acidified potassium manganate(VII)

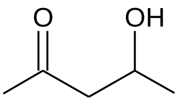
C It reacts readily with warm, aqueous alkali.

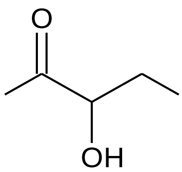
D It reacts with 2,4-dinitrophenylhydrazine solution to give an orange solution

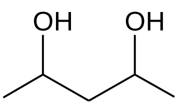
25 When treated with alkaline I_2(aq), 1 mol of compound **Y** forms 1 mol of CHI_3. Compound **Y** is formed when compound **X** is reacted with HCN(aq) with a trace amount of NaOH. 1 mol of compound **X** forms 12 dm^3 of gas when reacted with sodium metal but 1 mol of compound **Y** forms 24 dm^3 of gas.

Which of the following could be compound **X**?

A 

B 

C 

D 

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

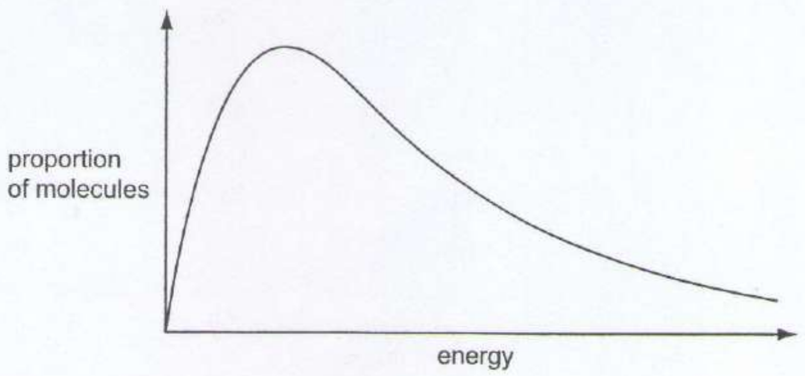
Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, 2 and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 The diagram represents the Boltzmann Distribution of molecular energies at a given temperature.



Which of the following statements are correct at a higher temperature?

1 The maximum of the curve is displaced to the right

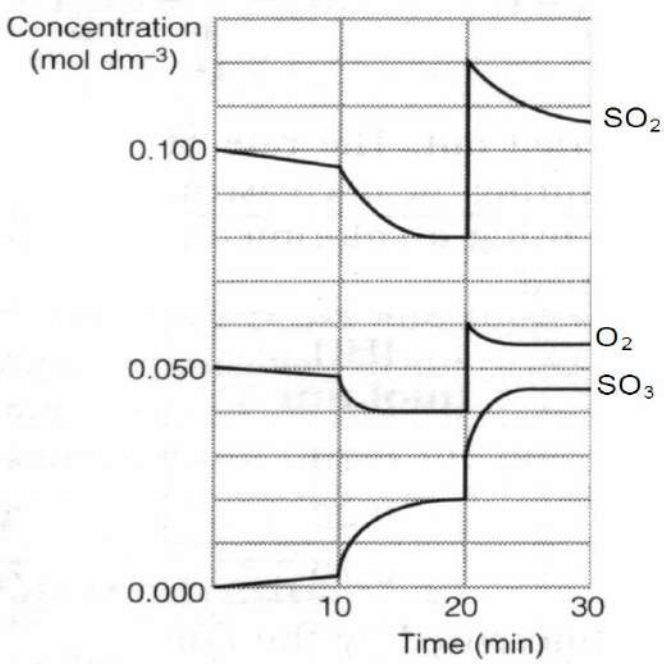
2 The proportion of molecules with energies **above** any given value increases.

3 The proportion of molecules **with** any given value increases

27 During the Contact process, sulfur dioxide is converted to sulfur trioxide as shown by the equation below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197 \text{ kJ mol}^{-1}$$

The following graph shows how the concentration of the three gases changed when a series of changes was made.



Which of the statements are correct?

1 At 20 minute, the numerical value of the equilibrium constant, K_c, is 1.56.

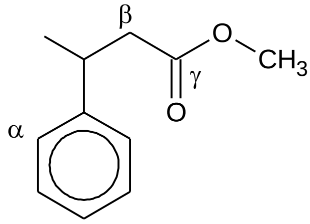
2 At 20 minute, the pressure of the system was increased by reducing the volume.

3 At 10 minute, heat was removed from the system.

28 Which of the reagents can be used to differentiate the pair of compounds given?

	Compound 1	Compound 2	Reagents
1	$AlCl_3$	$SiCl_4$	H_2O
2	$SiCl_4$	PCl_5	damp blue litmus paper
3	NaCl	MgO	dilute H_2SO_4

29 Which of the following statements on the given compound are true?



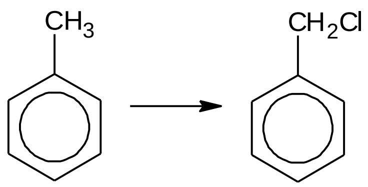
1 There are 14 hydrogen atoms

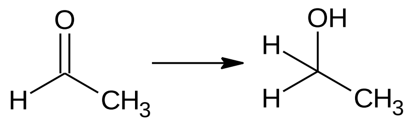
2 There are 7 sp^2 and 4 sp^3 hybridised carbons

3 The bond angles around carbons α, β, and γ are all 120°

30 Which of the following pairs of reactions require the same reagents and conditions?

1 

2 $CH_3CH_3 \longrightarrow CH_3CH_2Cl$ 

3 $CH_2{=}CH_2 \longrightarrow CH_3CH_3$ 

End of paper

2017 PJC H1 Chemistry Preliminary Exam Answer

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

H

PIONEER JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
HIGHER 1

CANDIDATE NAME								
CT GROUP	1	6				INDEX NUMBER		

CHEMISTRY **8872/02**

12 September 2017

2 hours

Additional Materials: Data Booklet
Writing Paper
Graph Paper

READ THESE INSTRUCTIONS FIRST

Write your name, CT group and index number in the spaces provided.
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.
The use of an approved scientific calculator is expected where appropriate.

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

Section B
Answer **two** questions on separate writing papers. If there is no answer to the question, a *blank sheet* of paper must still be submitted.
You are advised to show all working in calculations.
You may use a calculator.
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 B**	
Total	/ 30	Total	/ 40
Paper 2 Section A			
1	/ 10	4	/ 6
2	/ 10	5	/ 7
3	/ 7	Total	/ 40
Penalty	s.f. / units	**GRADE**	

This document consists of **19** printed pages

Section A (40 marks)

Answer **all** questions. Write your answers in the spaces provided.

1 (a) Burning sodium in air produces a mixture of sodium oxide, Na_2O, and sodium peroxide, Na_2O_2. The amount of sodium oxide in the mixture can be determined by the following method.

- The mixture is dissolved in water

$Na_2O_2 + 2H_2O \rightarrow 2NaOH + H_2O_2$ **reaction 1**

- The solution is acidified and an excess of potassium iodide solution is added, iodine is liberated by the following reaction.

$2KI + H_2O_2 + 2H^+ \rightarrow 2H_2O + 2K^+ + I_2$ **reaction 2**

- The iodine is titrated with standard sodium thiosulfate solution

$2Na_2S_2O_3 + I_2 \rightarrow Na_2S_4O_6 + 2NaI$ **reaction 3**

(i) When a sample of the mixed oxides, of mass 1.00 g was treated in this way, it was found that 33.40 cm^3 of 0.200 $mol dm^{-3}$ $Na_2S_2O_3$ was required to react with all the iodine released.

Calculate the amount of Na_2O in the oxide mixture. [4]

(ii) In terms of oxidation state, deduce all the changes in oxidation number that occurs for **reaction 3**, stating which element is involved in each change.

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..[2]

(b) Sodium oxide and aluminium oxide are white solids.

A student is tasked to add sodium oxide to water followed by a few drops of universal indicator to the resultant solution.

(i) Describe what will be observed when a few drops of universal indicator is added to the resultant solution prepared by adding sodium oxide to water. Write a balanced equation for this reaction.

………………………………………………………………………………………..

……………………………………………………………………………………… [1]

Equation: ……………………………………………………………........[1]

Another student is tasked to add aluminium oxide to hydrochloric acid and aqueous sodium hydroxide separately.

(ii) Write balanced equations to show the reaction between aluminium oxide with hydrochloric acid and aqueous sodium hydroxide

Equation for the reaction between aluminium oxide and hydrochloric acid.

…………………………………………………………………………………...[1]

Equation for the reaction between aluminium oxide and aqueous sodium hydroxide

…………………………………………………………………………………...[1]

[total:10]

2 **(a)** Chromium, potassium and sodium are common elements that are found in many compounds commonly used in the school laboratory.

(i) Give the full electronic configuration of chromium atom.

…………………………………………………………………………………………..

[1]

(ii) The first ionisation energy of potassium is lower than that of sodium. Explain why.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

[2]

(b) An aqueous sodium chromate (VI) contains yellow CrO_4^{2-} ions. An aqueous potassium dichromate (VI) contains orange $Cr_2O_7^{2-}$ ions. These chromate (VI) ions exist in equilibrium with dichromate (VI) ions as shown by the expression below:

$$\underset{\text{yellow}}{2\,CrO_4^{2-}\,(aq)} + 2H^+ \rightleftharpoons \underset{\text{orange}}{Cr_2O_7^{2-}\,(aq)} + H_2O\,(l)$$

(i) Write an expression for the equilibrium constant K_c, for this reaction.

[1]

(ii) A 2.0 dm^3 solution is prepared in which the initial amount of CrO_4^{2-} ions , H^+ ions and $Cr_2O_7^{2-}$ ions are 2.40 mol , 3.00 mol and 0.112 mol respectively. When equilibrium is reached, the pH of the mixture is 0 at 298 K.

Show relevant workings to calculate the amount of H^+ ions at equilibrium.

Amount of H^+ ions at equilibrium = …………………………………………

[1]

(iii) Using your answer in **(b)(ii)**, fill in the blanks with the correct values

	$2CrO_4^{2-}$ (aq)	$+2H^+$ (aq)	$\rightleftharpoons$	$Cr_2O_7^{2-}$(aq)	+ H_2O (*l*)
Initial/ mol					
Change/ mol					
Equilibrium/ mol					

[1]

(iv) Using your K_c expression in **b(i)**, calculate the numerical value of K_c for this equilibrium, stating its units.

[2]

(v) Describe and explain the colour changes when solid P_4O_6 was added into the equilibrium mixture containing the CrO_4^{2-}(aq) and $Cr_2O_7^{2-}$ (aq) ions.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

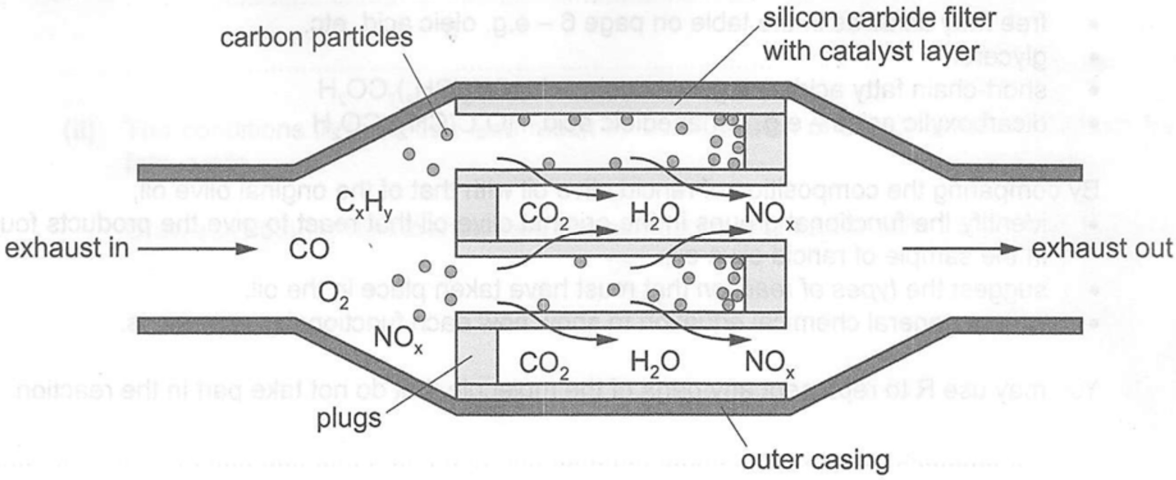
…………………………………………………………………………………………..

[2]

[Total: 10]

3 Nearly all petrol and diesel vehicles have some kind of catalytic converter fitted to the exhaust to reduce the amount of polluting substances emitted into the atmosphere.

For diesel engines the catalytic converter may also include a particle filter to remove solid particles of carbon. The diagram shows one design of diesel particle filter.



(a) The walls of the particle filter are made from silicon carbide, SiC. This is a hard solid that will not melt at the high temperatures of the exhaust.

Suggest how the structure and bonding in silicon carbide makes it resistant to melting, even at high temperatures.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..[2]

(b) CO pollutants react with oxygen and are removed from the exhaust. The reaction is as shown below:

$$CO\ (g) + \tfrac{1}{2}\ O_2\ (g) \rightarrow CO_2\ (g)$$

(i) Name the enthalpy change of reaction that is represented by the above reaction.

……………………………………………..……………………………………… [1]

(ii) The enthalpy change of reaction for this reaction, ΔH is **-283 kJ mol^{-1}**

$$CO\,(g) + \tfrac{1}{2}\,O_2\,(g) \rightarrow CO_2\,(g)$$

The catalyst from the catalytic converter helps to remove the CO pollutants from the exhaust more quickly.

Draw a reaction pathway diagram to represent the reaction. Draw labelled arrows to show ΔH, activation energy, E_a, of the reaction and activation energy of the catalysed reaction, E_a(catalysed) on your diagram.

[2]

(iii) Using bond energy data from the *D*ata *B*ooklet, calculate the enthalpy change of the reaction: $CO\,(g) + \tfrac{1}{2}\,O_2\,(g) \rightarrow CO_2\,(g)$

[Use a value of 1070 kJ mol^{-1} for the bond energy of CO bond in carbon monoxide and a value of 805 kJmol^{-1} for the bond energy of each C=O bond in CO_2 respectively.]

[1]

(iv) The theoretical value given in **b(ii)** is -283 kJmol^{-1}. Comment on the difference between your calculated value in **(b)(iii)** and the theoretical value in **(b)(ii).**

…………………………………………………………………………………………..

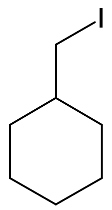
…………………………………………………………………………………..……

[1]

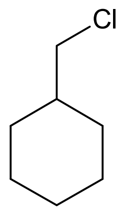
[total:7]

4 Suggest simple chemical tests to distinguish the following pairs of compounds. You are required to state the observations of each compound.

(a)



and



Compound **A** Compound **B**

Chemical test: ……………………………………………………………………………

……………………………………………………………………………………………

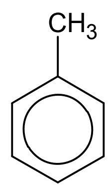
Observation for compound **A** ……………………………………………………………

……………………………………………………………………………………………

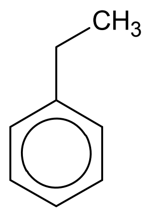
Observation for compound **B** ……………………………………………………………

……………………………………………………………………………………………
[3]

(b)



and



Compound **C** Compound **D**

Chemical test: ……………………………………………………………………………

……………………………………………………………………………………………

Observation for compound **C** ……………………………………………………………

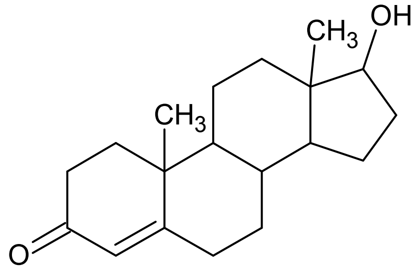
……………………………………………………………………………………………

Observation for compound **D** ……………………………………………………………

……………………………………………………………………………………………
[3]

[Total: 6]

5 (a) Androstanes are a group of compounds with a tetracyclic hydrocarbon ring structures. An example of an androstane is testosterone.



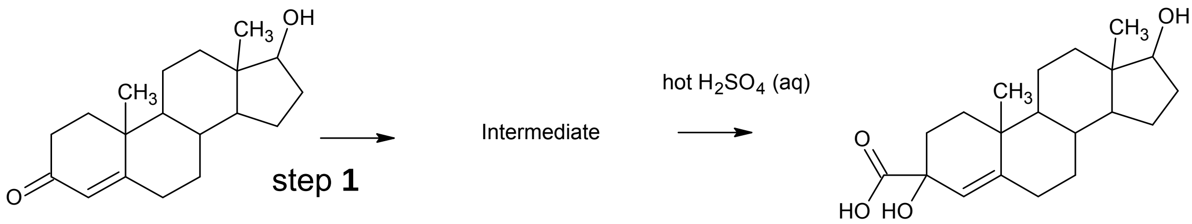
testosterone

(i) Name the functional groups present in testosterone.

……………………………………………………………………………………………

…………………………………………………………………………………………… [2]

Testosterone can be converted into the compound **A** as shown.



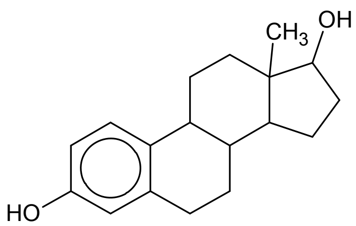
(ii) Give the reagents and conditions for step **1**. [1]

……………………………………………………………………………………………

(iii) Draw the structure of the intermediate formed. [1]

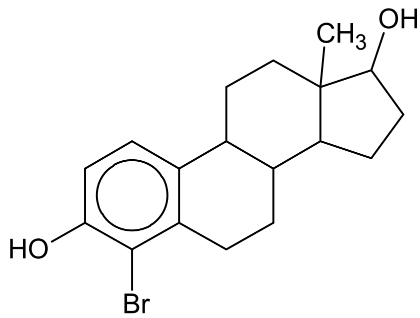
(iv) Draw the structure when testosterone undergoes addition reaction with aqueous bromine. [1]

(b) In the body, the enzyme aromatase can convert testosterone into estrogen.



Estrogen

The following product is obtained when estrogen undergoes substitution with bromine under suitable conditions.



Unlike Testosterone which undergoes addition reaction with aqueous bromine, explain why estrogen undergoes substitution with aqueous bromine instead of addition?

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…………………………………………………………………………………………..

[2]

[Total:7]

Section B (40 marks)

Answer **two** of the three questions in this section on separate paper.

1 **(a)** Sodium and silicon are elements in Period 3 of the Periodic Table.

Describe what will you see when both elements are burned separately in chlorine. Give an equation for each reaction. [4]

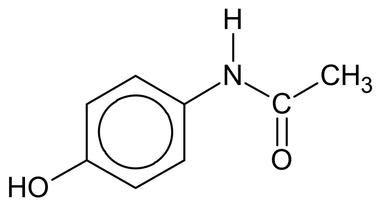
(b) Ethanol can be burned in an excess of oxygen as a fuel but in the body ethanol is partially oxidised. Complete combustion of ethanol to give carbon dioxide releases 1367 kJ mol^{-1} whilst the metabolism of ethanol in the human body leads to partial oxidation to give ethanoic acid, CH_3CO_2H, which releases 770 kJ mol^{-1}. Complete oxidation of ethanoic acid, CH_3CO_2H, to give carbon dioxide releases 873 kJ mol^{-1}

(i) Write an equation to represent the enthalpy change of combustion of ethanol. [1]

(ii) Calculate the energy released if one mole of ethanol in the body were to be oxidised to ethanoic acid and water only. [1]

(iii) Assuming in the body, ethanol is oxidised to a mixture of ethanoic acid and carbon dioxide, use the data to calculate the proportion of ethanol metabolised to form CH_3COOH. [2]

Paracetamol is a suitable analgesic for patients who regularly drink moderate to large amounts of alcohol. It is also used widely to treat fever and pain. Paracetamol is also commonly known as panadol.



paracetamol

Some information on paracetamol is provided in the table below.

Molecular Formula	$C_8H_9NO_2$
Density	1.263 g/cm^3
Melting Point	169 °C
Boiling Point	420 °C
Bioavailability	75% (oral) 100% (intravenous)
Biological half-life	2 hours

**Bioavailability refers to the percentage of a drug which enters the blood circulation system when introduced into the body and hence able to have an active and effective effect.*

**Biological half-life of a drug is the time taken for the drug to reduce to half its original amount in the body.*

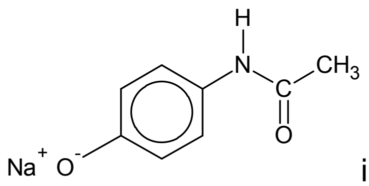
(c) Paracetamol can be produced from the reaction between 4-aminophenol and ethanoic anhydride as shown below.

C_6H_7NO	+	$C_4H_6O_3$	→	$C_8H_9NO_2$	+	$C_2H_4O_2$
4-aminophenol		ethanoic anhydride		paracetamol		
M_r = 109				M_r = 151		

Excess ethanoic anhydride is used in this reaction and it is known that the yield of this reaction is 60%.

(i) Calculate the minimum mass of the 4-aminophenol that are required to produce 10 g of paracetamol. [1]

(ii) Paracetamol is usually sold as its sodium salt:



in authorised pharmacies.

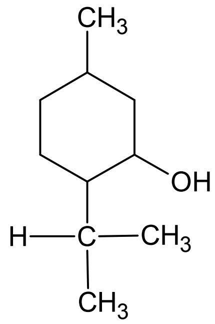
When the sodium salt has dissolved inside the patient's body, the anions and cations are each surrounded by a number of water molecules. This process is known as ion dipole interaction which will improve the solubility of drug inside the bloodstream.

Draw simple diagrams to show how a water molecule can be attached to a sodium cation, and to the anion. Label each diagram to show the type of interaction involved. [2]

(iii) A doctor wishes to prescribe oral medication for one of his patients suffering from acute dental pain.

The patient is advised to take four 250 mg paracetamol tablets in each dosage. Calculate the total mass of paracetamol which remains in the blood circulation system when it is introduced into the body after 4 hours. [2]

(d) Menthol is another molecule that is used medicinally in ointments, cough drops, and nasal inhaler. Menthol has the following structure show below:



Pulegone, **A** and isopulegone, **B** are isomers with the molecular formula $C_{10}H_{16}O$.

Both isomers decolourise bromine water, and give an orange precipitate with 2,4-dinitrophenylhydrazine reagent but none reduces Fehling's solution.

On treatment with H_2, and a platinum catalyst, both isomers are reduced to menthol.

When treated with hot concentrated $KMnO_4$, **A** gives two compounds: C_3H_6O, and **C**,$C_7H_{10}O_2$; **B** gives only a single compound **D**, $C_{10}H_{16}O_4$;

Compound **D** gives a yellow precipitate with alkaline aqueous iodine.

Suggest structures for **A, B, C** and **D**, and explain the observations described above.

[7]

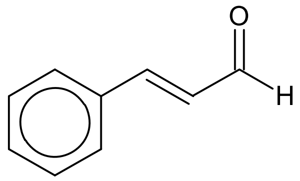
[Total: 20]

2 (a) A white solid is formed when magnesium is burn in air. The solid dissolves partially when water is added, forming a solution which turns red litmus paper blue. When solid phosphorus pentachloride is added, the white solid dissolves.

Explain the observation as fully as you can. [3]

(b) The benzene ring is an important functional group for many natural aromatic compounds. The earliest use of the term '*aromatic*" was by August Wilhelm Hofmann in 1855. The term was used to describe a group of compounds, many of which have aromas.

(i) The compound that gives cinnamon its characteristic smell is cinnamaldehyde.



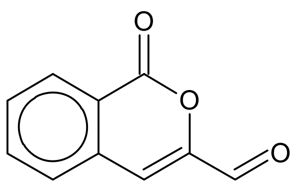
cinnamaldehyde

Draw the organic products when cinnamaldehyde is treated with

(I) Li*Al*H_4 in dry ether

(II) $K_2Cr_2O_7$(aq), H_2SO_4(aq), heat [2]

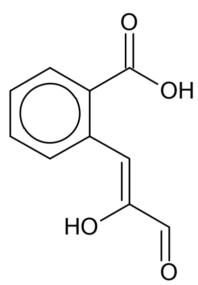
The functional group responsible for the smell of butter and cheese is the lactone functional group. An example of a lactone is artemidinal.



artemidinal

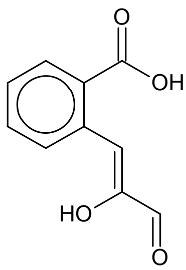
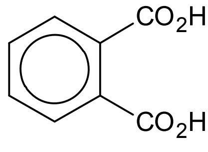
(ii) State the molecular formula of artemidinal. [1]

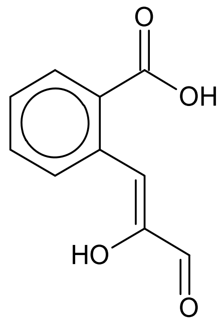
Artemidinal undergoes a reaction to form



(iii) Name the type of reaction that occurs to effect this conversion. [1]

(iv) State the reagents and conditions to effect this conversion. [1]

 can be oxidised to benzene-1,2-dicarboxylic acid .

(v) Write a balanced equation for the conversion of  into benzene-1,2-dicarboxylic acid. [1]

(c) The kinetics of the reaction between sodium thiosulfate(V) and hydrochloric acid was investigated.

$$Na_2S_2O_3 + 2HCl \longrightarrow S + SO_2 + H_2O + 2NaCl$$

An experiment was performed in which 0.200 mol dm^{-3} of sodium thiosulfate, $Na_2S_2O_3$, was reacted with 2.00 $moldm^{-3}$ of hydrochloric acid, HCl. A graph of concentration of $Na_2S_2O_3$ against time was plotted.

The following table shows $[Na_2S_2O_3]$ at various times

Time / s	$[Na_2S_2O_3]$ / $moldm^{-3}$
0	0.200
80	0.167
183	0.135
315	0.103
490	0.071
760	0.039

(i) Plot these data on suitable axes and, showing all your working and drawing clearly any construction lines on your graph, deduce the order of reaction with respect to $Na_2S_2O_3$. [3]

In order to determine the order of reaction with respect to hydrochloric acid, two more experiments are carried out as shown in the table.

Experiment	**Volume of $Na_2S_2O_3$ / cm^3**	**Volume of HC*l* added / cm^3**	**Volume of deionised water / cm^3**	**Relative rate**
1	20	30	10	1
2	20	20	20	1

In both **experiment 1** and **2**, deionised water was added to thiosulfate solution first and hydrochloric acid was added last before timing was started. The time taken for a fixed amount of sulfur to be produced is measured and the relative rate of the reaction is recorded.

(ii) Explain why different volume of deionised water is used in both experiments? [1]

(iii) With relevant workings, determine the order of reaction with respect to hydrochloric acid. [1]

(iv) In **experiment 3**, 20 cm^3 of thiosulfate solution was added to 30 cm^3 of hydrochloric acid first and 10cm^3 of deionised water was added last before timing was started.

He realised that the time taken to produce the same amount of sulfur is shorter than **experiment 1.**

Give a reason when the time taken for **experiment 3** is shorter than **experiment 1**? [1]

(v) Draw the dot and cross diagram for the **ionic compound** $Na_2S_2O_3$ given that in the $S_2O_3^{2-}$ anion,

- it is tetrahedral around the central S atom
- there is no dative bond in the $S_2O_3^{2-}$ anion.
- the negative charge resides on the more electronegative atom.

[2]

(d) The oxides of sulfur namely sulfur (IV) oxide, SO_2 and sulfur (VI) trioxide, SO_3 have different boiling points.

Oxides of sulfur	**Boiling point (ºC)**
SO_2	-10
SO_3	45

In terms of structure and bonding, account for the difference in the boiling points between the two compounds. [3]

[total: 20]

3 Magnesium ions, chloride ions and other ions that are found inside a lake from the weathering of soils and rocks in the watershed, the atmosphere, and dissolved gases such as carbon dioxide is the source of "mineral water". The table below shows the composition of ions found inside a typical lake that is a source of mineral water.

Ion	Concentration / mol dm^{-3}
Ca^{2+}	2.00×10^{-4} mol dm^{-3}
Mg^{2+}	2.00×10^{-4} mol dm^{-3}
Cl^{-}	2.00×10^{-4} mol dm^{-3}
HCO_3^{-}	6.00×10^{-4} mol dm^{-3}

(a) From the data in the table shown above, suggest the relative amounts of the following four ionic compounds, $CaCl_2$:$MgCl_2$: $Ca(HCO_3)_2$: $Mg(HCO_3)_2$, in the mineral water respectively. [1]

(b) Various reactions take place in this ecosystem:

Reaction 1 involves the decomposition of aqueous hydrogen carbonate into the lake as shown:

$2HCO_3^-(aq) \rightleftharpoons CO_2(g) + H_2O(l) + CO_3^{2-}(aq)$ **Reaction 1**

Reaction 2 involves the dissolution of calcium carbonate from the rock into its aqueous ions that were released into the lake as shown:

$CaCO_3(s) \rightleftharpoons Ca^{2+}(aq) + CO_3^{2-}(aq)$ **Reaction 2**

Reaction 3 involves the dissolution of calcium hydrogen carbonate from the rock into its aqueous ions that were released in the lake as shown:

$Ca(HCO_3)_2\ (s) \longrightarrow Ca^{2+}(aq) + 2HCO_3^-(aq)$ **Reaction 3**

By using the appropriate reactions above, answer **(b)(i), (ii)** and **(iii).**

(i) When a sample of the mineral water was partially evaporated, a white solid was formed and the amount of gaseous carbon dioxide increased. Suggest whether the white solid is calcium hydrogen carbonate or calcium carbonate. [1]

(ii) Hence explain how this process leads to the formation of the white solid. [3]

(iii) When rainwater containing dissolved carbon dioxide gas had percolated through the rocks, the concentration of calcium ions in mineral water increased. Explain why. [2]

(c) A sample of rainwater collected from the lake contains carbonic acid, $H_2CO_3(aq)$.

A conical flask containing 25.0 cm^3 of H_2CO_3 obtained from the lake is titrated against NaOH(aq) with three drops of phenolphthalein indicator. The end point is reached when 20.00 cm^3 of NaOH is added.

He proceeded with two more titrations as described below in **(c)(i)** and **(c)(ii)**.

(i) In the second titration, the student rinsed a new conical flask with deionised water but forget to dry it with towel paper.

Predict how will the end point compared to that of the first titration? Explain your answer. [2]

(ii) In the third titration, a student added twenty drops of phenolphthalein in the hope to see a more distinct end point colour change.

Predict how will the end point compared to that of the first titration? Explain your answer. [2]

(d) Carbon dioxide exists in equilibrium with the water in our bloodstream and an equilibrium consisting of H_2CO_3 and HCO_3^- is set up.

This pair of compounds forms a natural buffer solution in our bodies.

(i) Define what is meant by buffer solution. [1]

(ii) When we exercise, lactic acid is produced in our muscles.

Write one equation to represent how the buffer system in our body works when we exercise. [1]

(e) Halogenoalkanes are an important part in the history of humans. They are present in many forms such as antibiotics, refrigerants and polymers.

When one mole of 1-bromo-4-chlorobutane is heated with one mole of aqueous sodium hydroxide, 4-chlorobutan-1-ol is produced but not 4-bromobutan-1-ol.

Explain your answer. [2]

(f) Substitution of alkanes with halogens can be performed to obtain halogenoalkanes in the laboratory.

(i) Alkanes are used in increasing quantities as refrigerant instead of chlorofluorocarbons as they do not contribute to ozone depletion.

Suggest one potential hazard of using alkanes instead of chlorofluorocarbons. [1]

(ii) Alkanes have carbon atoms which undergo sp^3 hybridisation. Draw a sp^3 hybridised carbon atom. [1]

(iii) In terms of electron donating ability, a sp^3 hybridised carbon atom is more electron donating than a sp^2 hybridised carbon atom which is more electron donating than a sp hybridised carbon atom.

By using the above information, explain why $CH_2{=}CHCO_2H$ is a stronger acid than $CH_3CH_2CO_2H$ [3]

[total:20]

End of paper

PIONEER JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
HIGHER 1

CANDIDATE NAME							
CT GROUP	1	6				INDEX NUMBER	

CHEMISTRY **8872/02**

12 September 2017

2 hours

Additional Materials: Data Booklet
Writing Paper
Graph Paper

READ THESE INSTRUCTIONS FIRST

Write your name, CT group and index number in the spaces provided.
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.
The use of an approved scientific calculator is expected where appropriate.

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

Section B
Answer **two** questions on separate writing papers. If there is no answer to the question, a *blank sheet* of paper must still be submitted.
You are advised to show all working in calculations.
You may use a calculator.
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 B**	
Total	/ 30	Total	/ 40
Paper 2 Section A			
1	/ 10	4	/ 6
2	/ 10	5	/ 7
3	/ 7	Total	/ 40
Penalty	s.f. / units	**GRADE**	

This document consists of **19** printed pages

Section A (40 marks)

Answer **all** questions. Write your answers in the spaces provided.

1 **(a)** Burning sodium in air produces a mixture of sodium oxide, Na_2O, and sodium peroxide, Na_2O_2. The amount of sodium oxide in the mixture can be determined by the following method.

- The mixture is dissolved in water

$$Na_2O_2 + 2H_2O \rightarrow 2NaOH + H_2O_2 \qquad \textbf{reaction 1}$$

- The solution is acidified and an excess of potassium iodide solution is added, iodine is liberated by the following reaction.

$$2KI + H_2O_2 + 2H^+ \rightarrow 2H_2O + 2K^+ + I_2 \qquad \textbf{reaction 2}$$

- The iodine is titrated with standard sodium thiosulfate solution

$$2Na_2S_2O_3 + I_2 \rightarrow Na_2S_4O_6 + 2NaI \qquad \textbf{reaction 3}$$

(i) When a sample of the mixed oxides, of mass 1.00 g was treated in this way, it was found that 33.40 cm^3 of 0.200 $mol dm^{-3}$ $Na_2S_2O_3$ was required to react with all the iodine released.

Calculate the amount of Na_2O in the oxide mixture. [4]

Amt of $S_2O_3^{2-}$ = (33.40/1000)(0.200) = 6.68×10^{-3} mol

Amt of I_2 liberated from reaction 2= ½ (6.68×10^{-3}) = 3.34×10^{-3} mol [1]
= amt of H_2O_2 formed from reaction 1 = Amt of Na_2O_2 reacted in reaction 1 [1]

Mass of Na_2O_2 = 3.34×10^{-3} x (2(23.0 + 2(16.0) = 0.2605 g
Mass of Na_2O = 1.00 – 0.2605 = 0.7395 g [1]

n(Na_2O) = 0.7395 / [2(23.0) + 16.0] = 0.01192 mol [1]

(ii) In terms of oxidation state, deduce all the changes in oxidation number that occurs for **reaction 3**, stating which element is involved in each change. [2]

The oxidation state of S changes from +2 in $S_2O_3^{2-}$ to +2.5 in $S_4O_6^{2-}$ [1]

The oxidation state of I changes from 0 in I_2^- to -1 in NaI [1]

(b) Sodium oxide and aluminium oxide are white solids.

A student is tasked to add sodium oxide to water followed by a few drops of universal indicator.

(i) Describe what will be observed when a few drops of universal indicator is added to the resultant solution prepared by adding sodium oxide to water. Write a balanced equation for this reaction.

Sodium hydroxide solution will give a blue/ violet / indigo colour with the universal indicator. [1]

Equation: $Na_2O + H_2O \rightarrow 2NaOH$ [1]

[2]

Another student is tasked to add aluminium oxide to hydrochloric acid and aqueous sodium hydroxide separately.

(ii) Write balanced equations to show the reaction between aluminium oxide with hydrochloric acid and aqueous sodium hydroxide

Equation for the reaction between aluminium oxide and hydrochloric acid.

$Al_2O_3 + 6HCl \longrightarrow 2AlCl_3 + 3H_2O$ [1]

[1]

Equation for the reaction between aluminium oxide and aqueous sodium hydroxide. [1]

$Al_2O_3 + 2NaOH + 3H_2O \longrightarrow 2Na[Al(OH)_4]$ [1]

[total:10]

[Turn Over

2 (a) Chromium, potassium and sodium are common elements that are found in many compounds commonly used in the school laboratory.

(i) Give the full electronic configuration of chromium atom:

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$ [1]

[1]

(ii) The first ionisation energy of potassium is lower than that of sodium. Explain why.

Atomic radius increases down the group due to increasing number of quantum shells [1], attraction decreases down the group. [1] [2]

(b) An aqueous sodium chromate (VI) contains yellow CrO_4^{2-} ions. An aqueous potassium dichromate (VI) contains orange $Cr_2O_7^{2-}$ ions. These chromate (VI) ions exist in equilibrium with dichromate (VI) ions as shown by the expression below:

$$\underset{\text{yellow}}{2\,CrO_4^{2-}\,(aq) + 2H^+} \rightleftharpoons \underset{\text{orange}}{Cr_2O_7^{2-}\,(aq) + H_2O\,(l)}$$

(i) Write an expression for the equilibrium constant K_c, for this reaction.

$K_c = [\ Cr_2O_7^{2-}\ ]\ /\ [\ CrO_4^{2-}\ ]^2\ [\ H^+\ ]^2$ [1] [1]

(ii) A 2.0 dm^3 solution is prepared in which the initial amount of CrO_4^{2-} ions , H^+ ions and $Cr_2O_7^{2-}$ ions are 2.40 mol , 3.00 mol and 0.112 mol respectively. When equilibrium is reached, the pH of the mixture is 0 at 298 K.

Show relevant workings to calculate the amount of H^+ ions at equilibrium.

$[H^+] = 10^{-pH} = 10^{-0} = 1.00$ moldm^{-3}. $n(H^+)$ 1.00 x 2 = 2.00 mol

Amount of H^+ ions at equilibrium = 2.00 mol ……………………………

[1]

(iii) Using your answer in **(b)(ii)**, fill in the blanks with the correct values

	$2CrO_4^{2-}$ (aq)	$+2H^+$ (aq)	$\rightleftharpoons$	$Cr_2O_7^{2-}$(aq)	+ H_2O (*l*)
Initial/ mol	2.40	3.00		0.112	--
Change/ mol	-1.00	-1.00		+0.50	--
Equilibrium/ mol	1.40	2.00		0.612	--

[1]

(iv) Using your K_c expression in **b(i)**, calculate the numerical value of K_c for this equilibrium, stating its units.

K_c = [$Cr_2O_7^{2-}$] / [CrO_4^{2-}]^2 [H^+]^2
= (0.612/2) / (1.40/2)^2 (2.00/2)^2
= 0.6244 ≈ 0.624 [1]

Units: mol^{-3} dm^9 [1]

[2]

(v) Describe and explain the colour changes when solid P_4O_6 was added into the equilibrium mixture containing the CrO_4^{2-}(aq) and $Cr_2O_7^{2-}$ (aq) ions.

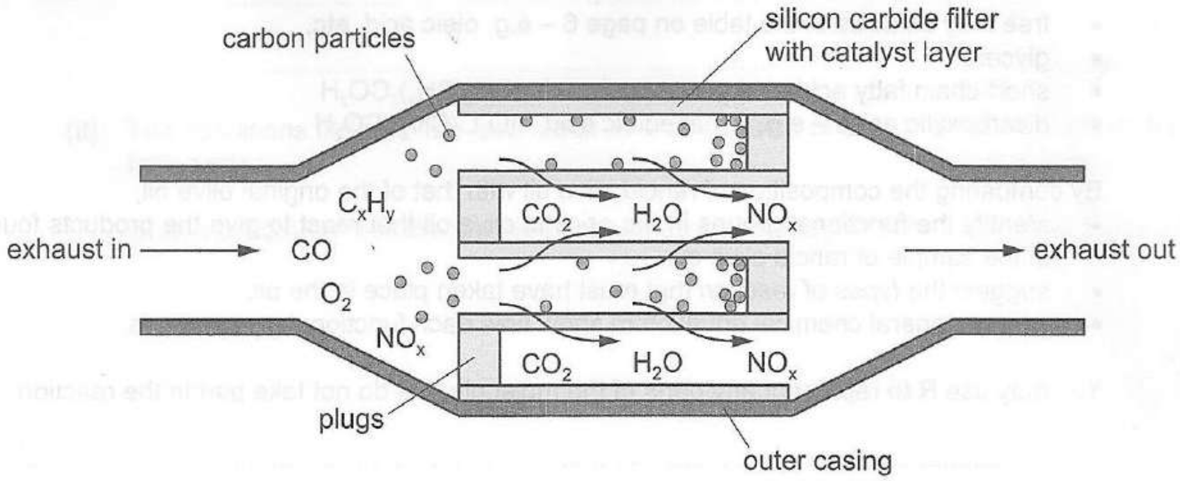
When phosphorus oxide is added, [H^+] increases, position of equilibrium shift to the right to decrease H^+, [1]
hence higher percentage of orange $Cr_2O_7^{2-}$ and lower percentage of yellow CrO_4^{2-} is formed, giving rise to a solution that is more orange and less yellow at the next equilibrium. [1]

[2]

[Total: 10]

3 Nearly all petrol and diesel vehicles have some kind of catalytic converter fitted to the exhaust to reduce the amount of polluting substances emitted into the atmosphere.

For diesel engines the catalytic converter may also include a particle filter to remove solid particles of carbon. The diagram shows one design of diesel particle filter.



(a) The walls of the particle filter are made from silicon carbide, SiC. This is a hard solid that will not melt at the high temperatures of the exhaust.

Suggest how the structure and bonding in silicon carbide makes it resistant to melting, even at high temperatures.

SiC has a <u>giant molecular structure</u> [1] with extensive network of <u>strong covalent bonds</u> [1] to be overcome during melting. Hence even at high temperatures, the energy provided is not sufficient to overcome the bonds .

[2]

(b) CO pollutants react with oxygen and are removed from the exhaust. The reaction is as shown below:

$$CO\ (g) + \frac{1}{2} O_2\ (g) \rightarrow CO_2\ (g)$$

(i) Name the enthalpy change of reaction that is represented by the above reaction.

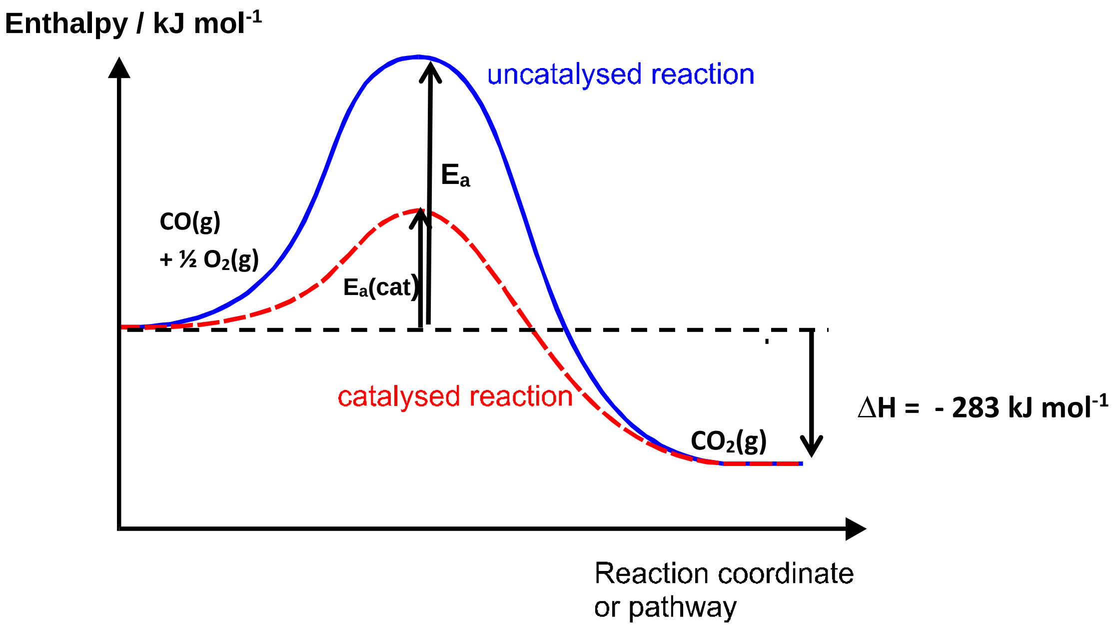
Enthalpy change of combustion of CO. [1] [1]

(ii) The enthalpy change of reaction for this reaction, ΔH is **-283 kJ mol⁻¹**

$$CO\ (g) + ½\ O_2\ (g) \rightarrow CO_2\ (g)$$

The catalyst from the catalytic converter helps to remove the CO pollutants from the exhaust more quickly.

Draw a reaction pathway diagram to represent the reaction. Draw labelled arrows to show ΔH, activation energy, E_a., of the reaction and activation energy of the catalysed reaction, E_a(catalysed) on your diagram.



(any 1 to 2 mistake minus 1 mark, 3 mistakes and more zero mark)

[2]

(iii) Using bond energy data from the *D*ata *B*ooklet, calculate the enthalpy change of the reaction: $CO\ (g) + ½\ O_2\ (g) \rightarrow CO_2\ (g)$

[Use a value of 1070 kJ mol⁻¹ for the bond energy of CO bond in carbon monoxide and a value of 805 kJmol⁻¹ for the bond energy of each C=O bond in CO_2 respectively.]

ΔH = BE(bonds broken) – BE(bonds formed)

= 1070 + ½ (496) – 2(805)

= -292 kJ mol⁻¹ [1] [1]

(iv) The theoretical value given in **b(ii)** is -283 kJmol⁻¹. Comment on the difference between your calculated value in **(b)(iii)** and the theoretical value in **(b)(ii).**

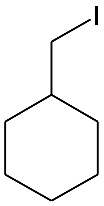
Bond energy used in (b)(iii) are average values and they differ in different chemical and electronic environment the bonds are in. [1] [1]

[total:7]

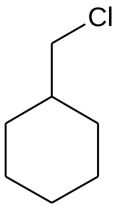
[Turn Over

4 Suggest simple chemical tests to distinguish the following pairs of compounds. You are required to state the observations of each compound.

(a)



and



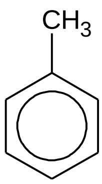
Compound **A** Compound **B**

[3]

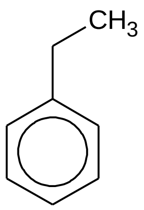
Step 1: NaOH(aq), heat
Step 2: cool
Step 3: acidify with HNO_3(aq)
Step 4: $AgNO_3$(aq) [1]

Compound **A**: yellow precipitate of AgI is formed [1]
Compound **B**: white precipitate of $AgCl$ observed [1]

(b)



and



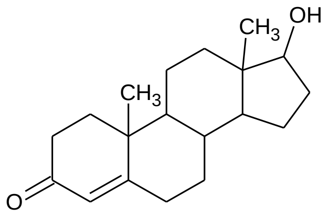
Compound **C** Compound **D**

$KMnO_4$(aq), H_2SO_4(aq), heat [1]

Compound **C**: purple $KMnO_4$ decolourises [1]
Compound **D**: purple $KMnO_4$ decolourises, effervescence observed. Gas forms white precipitate when pass through $Ca(OH)_2$(aq). Gas is CO_2. [1]

[3]
[Total: 6]

5 **(a)** Androstanes are a group of compounds with a tetracyclic hydrocarbon ring structures. An example of an androstane is testosterone.



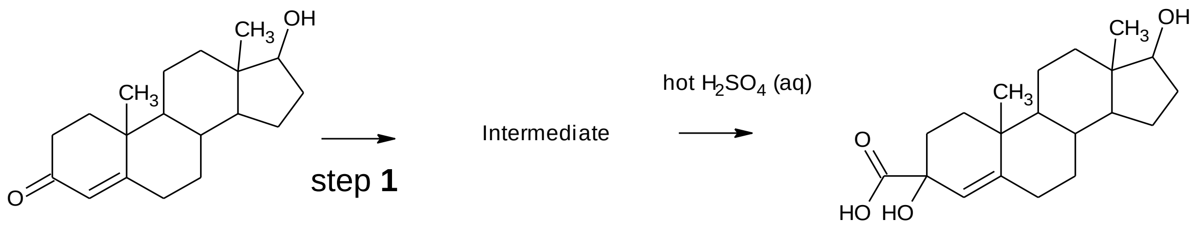
testosterone

(i) Name the functional groups present in testosterone.

Ketone, alkene, 2° alcohol [2 marks for all 3, 1 mark for 2]

[2]

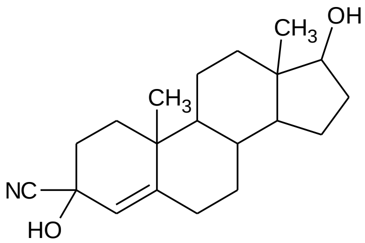
Testosterone can be converted into the compound **A** as shown.



(ii) Give the reagents and conditions for step **1**. [1]

Step **I**: HCN(aq), trace amount of NaCN/NaOH, 10-20 °C [1]

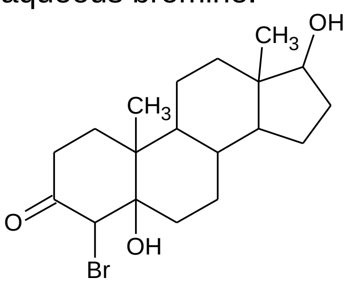
(iii) Draw the structure of the intermediate formed. [1]



[1]

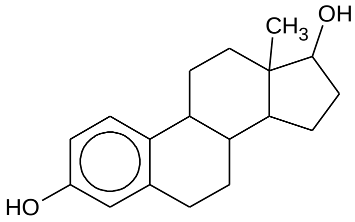
(if there is missing C atoms in the cyclic ring , BOD)

(iv) Draw the structure when testosterone undergoes addition reaction with aqueous bromine. [1]



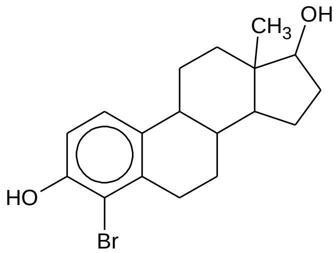
[1]

(b) In the body, the enzyme aromatase can convert testosterone into estrogen.



Estrogen

The following product is obtained when estrogen undergoes substitution with bromine under suitable conditions.



Unlike Testosterone which undergoes addition reaction with aqueous bromine, explain why estrogen undergoes substitution with aqueous bromine instead of addition ?

Addition reaction will cause the destruction of the delocalised pi electron system, thus destroying the aromatic character of benzene. [1]

Hence when benzene reacts, the C-H bonds are broken and not the pi bonds so as to retain its aromaticity which stabilises benzene. [1]

[2]

[Total:7]

[total: 40]

Section B (40 marks)

Answer **two** of the three questions in this section on separate paper.

1 (a) Sodium and silicon are elements in Period 3 of the Periodic Table.

Describe what will you see when both elements are burned separately in chlorine? Give an equation for each reaction. [4]

$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$ [1]

Reacts vigorously in chlorine with an **orange flame** to give a **white solid**, sodium chloride. [1 for both observations]

$Si(s) + 2Cl_2(g) \rightarrow SiCl_4(l)$ [1]

Reacts slowly to form a colourless liquid [1]

(b) Ethanol can be burned in an excess of oxygen as a fuel but in the body ethanol is partially oxidised. Complete combustion of ethanol to give carbon dioxide releases 1367 kJ mol^{-1} whilst the metabolism of ethanol in the human body leads to partial oxidation to give ethanoic acid, CH_3CO_2H, which releases 770 kJ mol^{-1}. Complete oxidation of ethanoic acid,CH_3CO_2H, to give carbon dioxide releases 873 kJmol^{-1}

(i) Write an equation to represent the enthalpy change of combustion of ethanol. [1]

$C_2H_5OH\ (l) + 3O_2\ (g) \rightarrow 2CO_2\ (g) + 3H_2O\ (l)$ [1]

(ii) Calculate the energy released if one mole of ethanol in the body were to be oxidised to ethanoic acid and water only. [1]

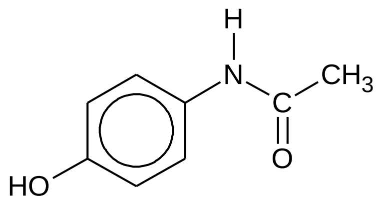
1367 – 873 = 494 kJ mol^{-1} [1]

(iii) Assuming in the body, ethanol is oxidised to a mixture of ethanoic acid and carbon dioxide, use the data to calculate the proportion of ethanol metabolised to form CH_3COOH. [2]

Let 1 mol of C_2H_5OH be partially oxidised, such that x mol is oxidised to CH_3COOH, and 1 – x mol is oxidised to CO_2.

Amt of heat released = 494x + 1367(1-x) ≈ 770 [1]
873x = 597 x = 0.683 [1]

Paracetamol is a suitable analgesic for patients who regularly drink moderate to large amounts of alcohol. It is also used widely to treat fever and pain. Paracetamol is also commonly known as panadol.



paracetamol

Some information on paracetamol is provided in the table below.

Molecular Formula	$C_8H_9NO_2$
Density	1.263 g/cm^3
Melting Point	169 ^oC
Boiling Point	420 ^oC
Bioavailability	75% (oral) 100% (intravenous)
Biological half-life	2 hours

**Bioavailability refers to the percentage of a drug which enters the blood circulation system when introduced into the body and hence able to have an active and effective effect.*
**Biological half-life of a drug is the time taken for the drug to reduce to half its original amount in the body.*

(c) Paracetamol can be produced from the reaction between 4-aminophenol and ethanoic anhydride as shown below.

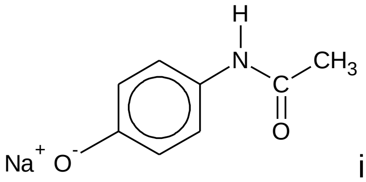
C_6H_7NO	+	$C_4H_6O_3$	$\rightarrow$	$C_8H_9NO_2$	+	$C_2H_4O_2$
4-aminophenol		ethanoic anhydride		paracetamol		
M_r = 109				M_r = 151		

Excess ethanoic anhydride is used in this reaction and it is known that the yield of this reaction is 60%.

(i) Calculate the minimum mass of the 4-aminophenol that are required to produce 10 g of paracetamol. [1]

Mass of 4-aminophenol required = $\frac{10}{151}\times\frac{100}{60}\times 109$ = 12.0 g [1]

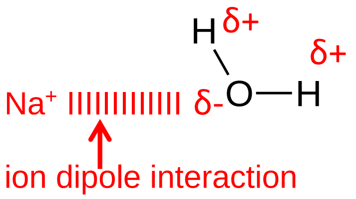
(ii) Paracetamol is usually sold as its sodium salt:



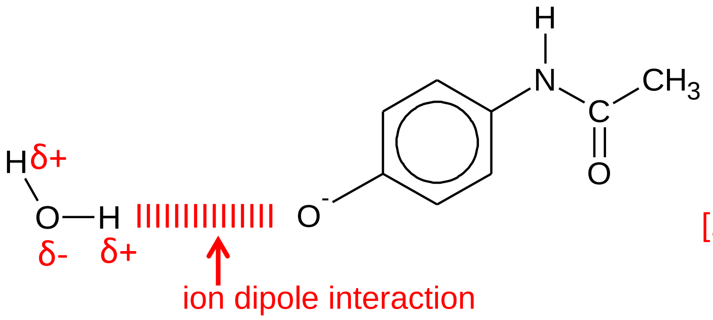
in authorised pharmacies.

When the sodium salt has dissolved inside the patient's body, the anions and cations are each surrounded by a number of water molecules. This process is known as ion dipole interaction which will improve the solubility of drug inside the bloodstream.

Draw simple diagrams to show how a water molecule can be attached to a sodium cation, and to the anion. Label each diagram to show the type of interaction involved. [2]



[1]



[1]

show the correct interaction for cation and anion with water molecules [1] each

(iii) A doctor wishes to prescribe oral medication for one of his patients suffering from acute dental pain.

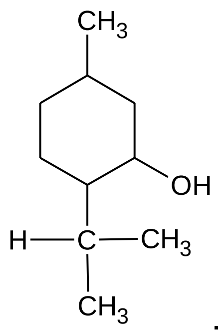
The patient is advised to take four 250 mg paracetamol tablets in each dosage. Calculate the total mass of paracetamol which remains in the blood circulation system when it is introduced into the body after 4hours. [2]

Mass of paracetamol in 4 x 250 mg tablets = 1000 mg
Mass of paracetamol that will be useful and effective
= 75% x 1000 = 750 mg [1]

Since biological half-life of paracetamol is 2 hours,

$$750 \text{ mg} \xrightarrow{2 \text{ hours}} 375 \text{ mg} \xrightarrow{2 \text{ hours}} 187.5 \text{ mg}$$ [1]

(d) Menthol is another molecule that is used medicinally in ointments, cough drops, and nasal inhaler. Menthol has the following structure show below:



Pulegone, **A** and isopulegone, **B** are isomers with the molecular formula $C_{10}H_{16}O$.

Both isomers decolourise bromine water, and give an orange precipitate with 2,4-dinitrophenylhydrazine reagent but none reduces Fehling's solution.

On treatment with H_2, and a platinum catalyst, both isomers are reduced to menthol.

When treated with hot concentrated $KMnO_4$, **A** gives two compounds: C_3H_6O, and **C**,$C_7H_{10}O_2$; **B** gives only a single compound **D**, $C_{10}H_{16}O_4$;

Compound **D** gives a yellow precipitate with alkaline aqueous iodine.

Suggest structures for **A, B, C** and **D**, and explain the observations described above. [7]

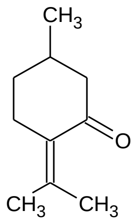
[Total: 20]

- A, B undergoes addition and have alkene functional group.
- A, B undergoes condensation with 2,4-DNPH, and does not undergo oxidation with Felhings solution, therefore ketones are present.
- A, B undergoes oxidation with $KMnO_4$.
- D has CH_3CO- in its structure, it undergoes oxidation with I_2, NaOH(aq). (Yellow ppt is CHI_3)

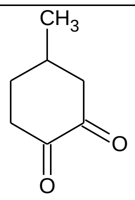
6-7 pt – 3 marks

4-5 pt – 2 marks

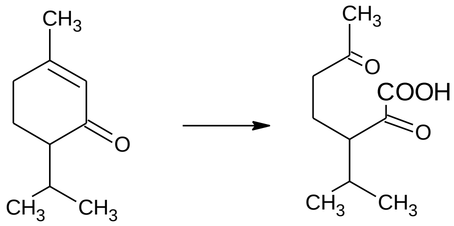
2-3 pt – 1 mark



A

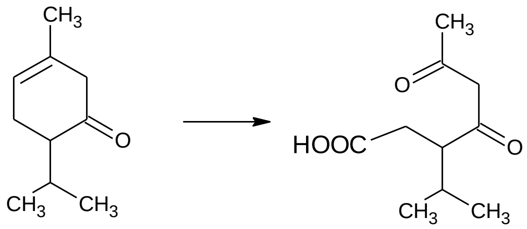


C



B D

OR



[Total: 20]

2 (a) A white solid is formed when magnesium is burn in air. The solid dissolves partially when water is added, forming a solution which turns red litmus paper blue. When solid phosphorus pentachloride is added, the white solid dissolves.

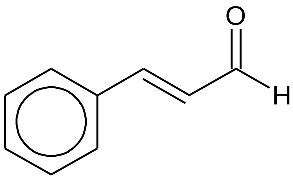
Explain the observation as fully as you can. [3]

Burning Mg in air produces MgO, a white solid. [1]

MgO is dissolves partially in water to form $Mg(OH)_2$, turning the solution basic. [1]
When PCl_5 dissolves in water it forms HCl which neutralises the $Mg(OH)_2$ to form soluble $MgCl_2$ (aq) / causing the solid to dissolve. [1]
Equations also accepted.

(b) The benzene ring is an important functional group for many natural aromatic compounds. The earliest use of the term '*aromatic*" was by August Wilhelm Hofmann in 1855. The term was used to describe a group of compounds, many of which have aromas.

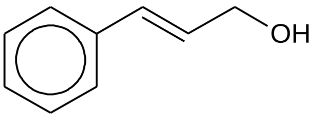
(i) The compound that gives cinnamon its characteristic smell is cinnamaldehyde.



cinnamaldehyde

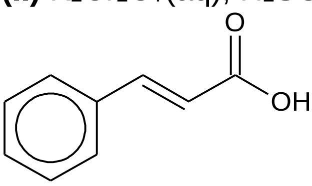
Draw the organic products when cinnamaldehyde is treated with

(I) Li*A*lH_4 in dry ether



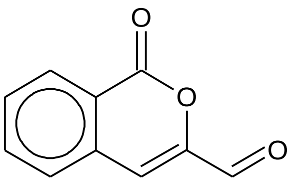
[1]

(II) $K_2Cr_2O_7$(aq), H_2SO_4(aq), heat [2]



[1]

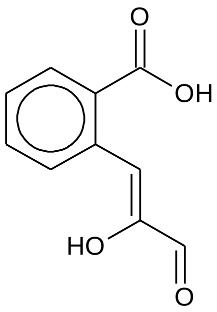
The functional group responsible for the smell of butter and cheese is the lactone functional group. An example of a lactone is artemidinal.



artemidinal

(ii) State the molecular formula of artemidinal. [1]

$C_{10}H_6O_3$ [1]

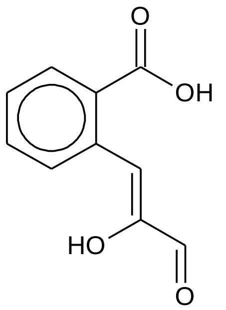
Artemidinal undergoes a reaction to form 

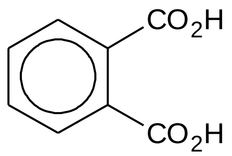
(iii) Name the type of reaction that occurs to effect this conversion. [1]

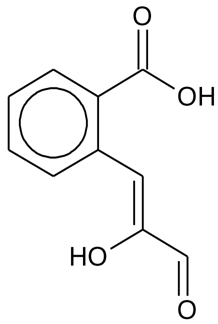
acid hydrolysis [1]

(iv) State the reagents and conditions to effect this conversion. [1]

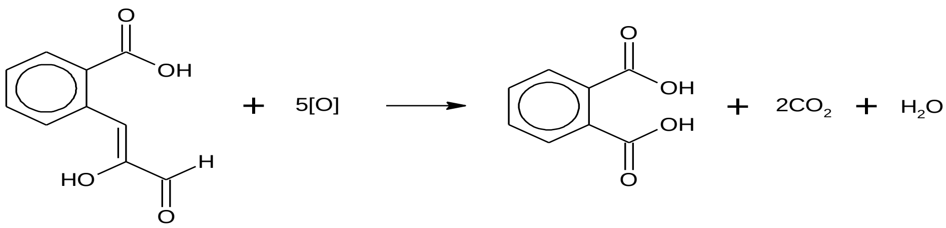
H_2SO_4 (aq), heat [1]


can be oxidised to benzene-1,2-dicarboxylic acid



(v) Write a balanced equation for the conversion of  benzene-1,2-dicarboxylic acid.

[1]



[1]

(c) The kinetics of the reaction between sodium thiosulfate(V) and hydrochloric acid was investigated.

$$Na_2S_2O_3 + 2HCl \longrightarrow S + SO_2 + H_2O + NaCl$$

An experiment was performed in which 0.200 mol dm^{-3} of sodium thiosulfate, $Na_2S_2O_3$, was reacted with 2.00 moldm^{-3} of hydrochloric acid, HC*l*. A graph of concentration of $Na_2S_2O_3$ against time was plotted.

The following table shows [$Na_2S_2O_3$] at various times

Time / s	[$Na_2S_2O_3$] / moldm^{-3}
0	0.200
80	0.167
183	0.135
315	0.103
490	0.071
760	0.039

(i) Plot these data on suitable axes and, showing all your working and drawing clearly any construction lines on your graph, deduce the order of reaction with respect to $Na_2S_2O_3$. [3]

Correct plotting to ½ small square & Correct axes ([$Na_2S_2O_3$] / moldm^{-3} on vertical axis and time/s on the horizontal axis --- (1)

Construction lines to show two constant half lives ≈ 325 s on graph paper (1)

Correct determination of first order for $Na_2S_2O_3$ – (1)

In order to determine the order of reaction with respect to hydrochloric acid, two more experiments are carried out as shown in the table.

Experiment	**Volume of $Na_2S_2O_3$ / cm^3**	**Volume of HC*l* added / cm^3**	**Volume of deionised water / cm^3**	**Relative rate**
1	20	30	10	1
2	20	20	20	1

In both **experiment 1** and **2**, deionised water was added to thiosulfate solution first and hydrochloric acid was added last before timing was started. The time taken for a fixed amount of sulfur to be produced is measured and the relative rate of the reaction is recorded.

(ii) Explain why different volume of deionised water is used in both experiments? [1]
To maintain a constant total volume so that the volume of reagent added is proportional to the concentration in the reaction mixture. [1]

(iii) With relevant workings, determine the order of reaction with respect to hydrochloric acid. [1]

When the volume (hence [$S_2O_3^{2-}$]) is kept constant, and the volume increases by 30/20 = 1.5 times from experiment 2 to 1, the relative rate remains unchanged, hence it is zero order with respect to HCl [1]

OR

Rate = $k[S_2O_3^{2-}]^a[HCl]^b \propto \underline{k(V_{S2O32-})^a\,(V_{HCl})^b}$

$$\frac{(\text{Relative rate})_{\text{experiment 1}}}{(\text{Relative rate})_{\text{experiment 2}}} = \frac{k(V_{S2O32-})^a\,(V_{HCl})^b}{k(V_{S2O32-})^a\,(V_{HCl})^b}$$

$$\frac{1}{1} = \frac{k(20)^a\,(30)^b}{k(20)^a\,(20)^b}$$

Hence b = 0 hence it is zero order wrt HCl [1]

(iv) In **experiment 3**, 20 cm^3 of thiosulfate solution was added to 30 cm^3 of hydrochloric acid first and 10cm^3 of deionised water was added last before timing was started.

He realised that the time taken to produce the same amount of sulfur is shorter than **experiment 1.**

Give a reason when the time taken for **experiment 3** is shorter than **experiment 1**? [1]

Before (timing) deionised water is added, the reaction has already started hence the time recorded for the fixed amount of sulfur to be produced will be shorter.

OR

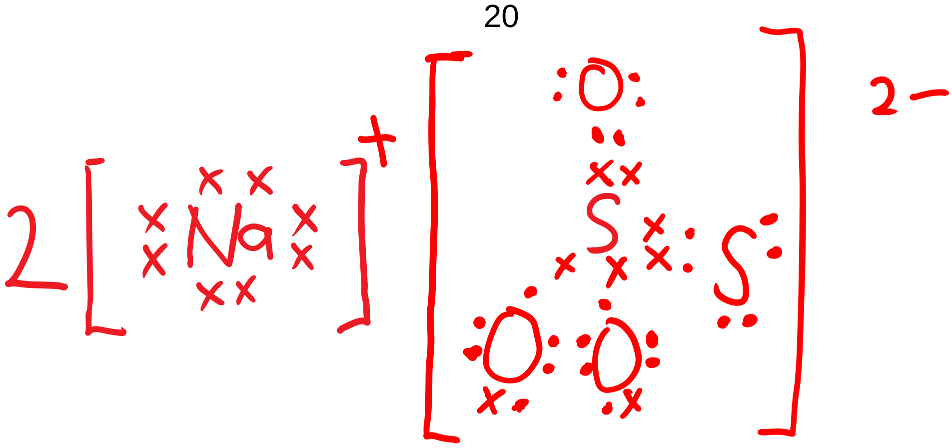
The total volume is 50 cm^3 instead of 60cm^3 hence the reaction started with higher concentration of $S_2O_3^{2-}$ resulting in shorter time required to produce fix amount of sulfur.

(v) Draw the dot and cross diagram for the **ionic compound** $Na_2S_2O_3$ given that in the $S_2O_3^{2-}$ anion,

- it is tetrahedral around the central S atom
- there is no dative bond in the $S_2O_3^{2-}$ anion.
- the negative charge resides on the more electronegative atom.

[2]

[1] for "2" Na^+ with eight valence electrons [1] for correct $S_2O_3^{2-}$



(d) The oxides of sulfur namely sulfur (IV) oxide, SO_2 and sulfur (VI) trioxide, SO_3 have different boiling points.

Oxides of sulfur	Boiling point (ºC)
SO_2	-10
SO_3	45

In terms of structure and bonding, account for the difference in the boiling points between the two compounds. [3]

Both have simple molecular structure. [1]

There are more electrons to be polarised in SO_3 than in SO_2. [1]

Hence, the instantaneous dipole - induced dipole attraction between SO_3 molecules is *stronger* than the permanent dipole – dipole forces between SO_2 molecules, [1] accounting for the higher boiling point of SO_3.

[total: 20]

3 Magnesium ions, chloride ions and other ions that are found inside a lake from the weathering of soils and rocks in the watershed, the atmosphere, and dissolved gases such as carbon dioxide is the source of "mineral water". The table below shows the composition of ions found inside a typical lake that is a source of mineral water.

Ion	Concentration / mol dm^{-3}
Ca^{2+}	2.00×10^{-4} mol dm^{-3}
Mg^{2+}	2.00×10^{-4} mol dm^{-3}
Cl^-	2.00×10^{-4} mol dm^{-3}
HCO_3^-	6.00×10^{-4} mol dm^{-3}

(a) From the data in the table shown above, suggest the relative amounts of the following four ionic compounds, $CaCl_2$:$MgCl_2$: $Ca(HCO_3)_2$: $Mg(HCO_3)_2$, in the mineral water respectively. [1]

Mol ratio of $CaCl_2$: $MgCl_2$: $Ca(HCO_3)_2$: $Mg(HCO_3)_2$ = 1 : 1 : 3 : 3 [1]

(b) Various reactions take place in this ecosystem:

Reaction 1 involves the decomposition of aqueous hydrogen carbonate into the lake as shown:

$2HCO_3^-(aq) \rightleftharpoons CO_2(g) + H_2O(l) + CO_3^{2-}(aq)$ **Reaction 1**

Reaction 2 involves the dissolution of calcium carbonate from the rock into its aqueous ions that were released into the lake as shown

$CaCO_3(s) \rightleftharpoons Ca^{2+}(aq) + CO_3^{2-}(aq)$ **Reaction 2**

Reaction 3 involves the dissolution of calcium hydrogen carbonate from the rock into its aqueous ions that were released in the lake as shown.

$Ca(HCO_3)_2\ (s) \longrightarrow Ca^{2+}(aq) + 2HCO_3^-(aq)$ **Reaction 3**

By using the appropriate reactions above, answer **(b)(i), (ii)** and **(iii).**

(i) When a sample of the mineral water was partially evaporated, a white solid was formed and the amount of gaseous carbon dioxide increased. Suggest whether the white solid is calcium hydrogen carbonate or calcium carbonate. [1]

Calcium carbonate [1]

(ii) Hence explain how this process leads to the formation of the white solid. [3]

When mineral water was evaporated, [HCO_3^-] and [CO_3^{2-}] increased, [1pt] but [HCO_3^-] increase to a greater extent [1pt] since there are more moles

Hence POE in **reaction 1** shift to the right [1pt] and increased [CO_3^{2-}] overall.[1pt]

The increase in [CO_3^{2-}] caused POE in **reaction 2** to shift to the left, [1pt] producing $CaCO_3$ (s)
4-5 pt – 3 marks 3 pt – 2 marks 2 pt – 1 mark

(iii) When rainwater containing dissolved carbon dioxide gas had percolated through the rocks, the concentration of calcium ions in mineral water increased. Explain why. [2]

When rainwater percolates through the rock, the carbon dioxide reacts with some of the dissolved CO_3^{2-} from the partial dissolution of calcium carbonates to form HCO_3^- as present in the mineral water. [1]

The decrease in concentration of CO_3^{2-} causes the equilibrium position of **reaction 2** to shift to the right, [1] enabling more carbonate to dissolve to produce the calcium ions present in the mineral water.

(c) A sample of rainwater collected from the lake contains carbonic acid, H_2CO_3(aq).

A conical flask containing 25.0 cm^3 of H_2CO_3 obtained from the lake is titrated against NaOH(aq) with three drops of phenolphthalein indicator. The end point is reached when 20.0 cm^3 of NaOH is added.

He proceeded with two more titrations as described in **(c)(i)** and **(c)(ii)**

(i) In the second titration, the student rinsed a new conical flask with deionised water but forget to dry it with towel paper.

Predict how will the end point compared to that of the first titration? Explain your answer. [2]

It will be the same [1]. The amount of carbonic acid in the conical flask is the same hence it will require the same amount of sodium hydroxide.

(ii) In the third titration, a student added twenty drops of phenolphthalein in the hope to see a more distinct end point colour change.

Predict how will the end point compared to that of the first titration? Explain your answer. [2]

Since indicator is weak acid [1], hence higher volume of sodium hydroxide is required to reach end point [1]

(d) Carbon dioxide exists in equilibrium with the water in our bloodstream and an equilibrium consisting of H_2CO_3 and HCO_3^- is set up.

This pair of compounds forms a natural buffer solution in our bodies.

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

A solution that resists changes in pH when a small amount of acids or alkalis is added or upon dilution. [1]

(ii) When we exercise, lactic acid is produced in our muscles.

Write one equation to represent how the buffer system works in our body when we exercise. [1]

$HCO_3^- + H^+ \rightarrow H_2CO_3$ [1]

(e) Halogenoalkanes are an important part in the history of humans. They are present in many forms such as antibiotics, refrigerants and polymers.

When one mole of 1-bromo-4-chlorobutane is heated with one mole of aqueous sodium hydroxide, 4-chlorobutan-1-ol is produced but not 4-bromobutan-1-ol.

Explain your answer. [2]

The <u>C-Br bond is weaker than the C-C*l* bond</u> [1] as it is longer due to the larger atomic radius of I. Less energy is required to break the bond to form 4-chlorobutan-1-ol [1]

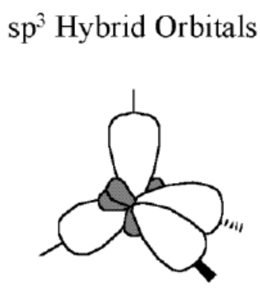
(f) Substitution of alkanes with halogens can be performed to obtain halogenoalkanes in the laboratory.

(i) Alkanes are used in increasing quantities as refrigerant instead of chlorofluorocarbons as they do not contribute to ozone depletion.

Suggest one potential hazard of using alkanes instead of chlorofluorocarbons. [1]

Alkanes are flammable.

(ii) Alkanes have carbon atoms which undergo sp^3 hybridisation. Draw a sp^3 hybridised carbon atom. [1]



[1]

(iii) In terms of electron donating ability, a sp^3 hybridised carbon atom is more electron donating than a sp^2 hybridised carbon atom which is more electron donating than a sp hybridised carbon atom.

By using the above information,explain why $CH_2{=}CHCO_2H$ is a stronger acid than $CH_3CH_2CO_2H$ [3]

The carbon atoms in the $CH_2{=}CHCO_2H$ are sp^2 hybridised.
While the type of hybridisation in C atom of CH_3CH_2COOH is sp^3
[1 mark for both correctly identified hybridisation]

Since sp^2 is less electron donating than sp^3 C [1],

hence the negative charge on oxygen of anion of $CH_2{=}CHCO_2^-$ is less intensified (or $CH_3CH_2CO_2^-$ is more destabilised and less stable than anion of $CH_2{=}CHCO_2^-$) and more stable [1] than $CH_3CH_2CO_2^-$

resulting in higher percentage of H^+ formed for $CH_2{=}CHCO_2H$

[total:20]

End of paper

RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATION II

CANDIDATE NAME	
CLASS	
CENTRE NUMBER	S 3 0 4 4
INDEX NUMBER	0 0

H1 CHEMISTRY 8872/02

Paper 2 Structured and Free Response Questions **13 Sep 2017**

2 hours

Additional Materials: Ruled paper, Graph Paper, Section B Cover Page, Data Booklet

READ THESE INSTRUCTIONS FIRST.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Write your name, class and index number in the spaces at the top of this page. 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** questions on the Question Paper.

Section B
Answer **all** questions on separate ruled paper. Begin each question on a fresh sheet of ruled paper. At the end of the examination, fasten all ruled paper securely, with the cover page for Section B on top.
Hand in the Question Paper and answers to Section B **separately**.
The number of marks is given in brackets [ ] at the end of each question or part question.

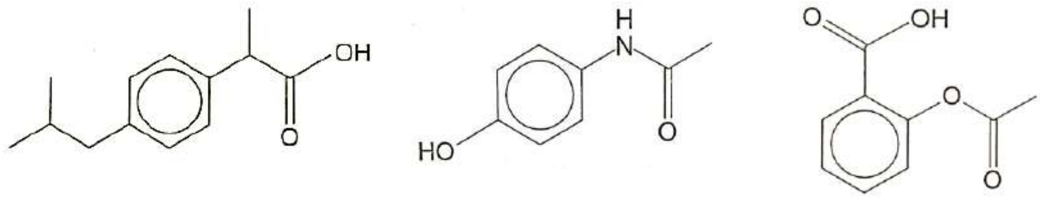
For Examiner's Use							
Paper 2							
Section A	**1**	**2**	**3**	**4**	**Section B**	**5/6/7**	**Total (Paper 2)**
	15	**11**	**7**	**7**		**40**	**80**
Paper 1	**30**				**Total**	**110**	**Grade**

This paper consists of **17** printed pages.

Section A (40 marks)

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

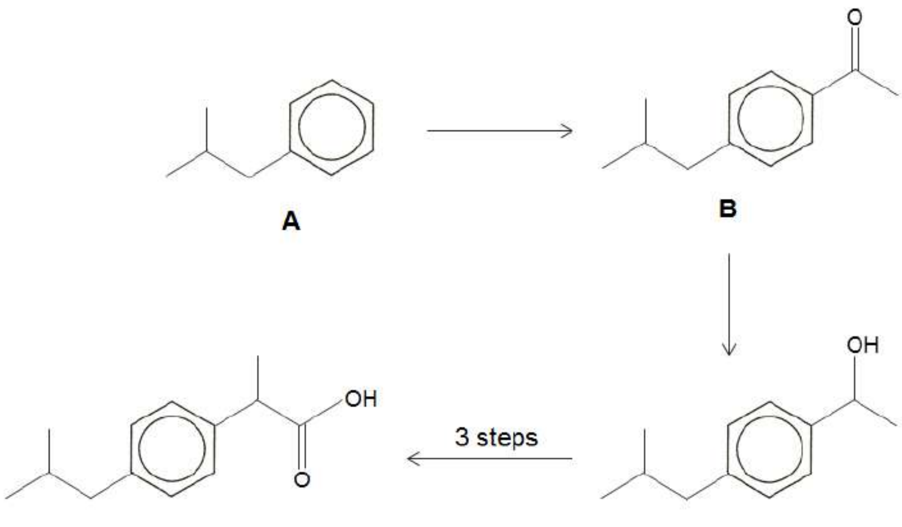
1 Among the many pharmaceutical drugs manufactured worldwide, one of the most important types is the painkillers. The structures of three such painkillers are shown.



ibuprofen	**paracetamol**	**aspirin**
(M_r = 206)	(M_r = 151)	(M_r = 180)

Ibuprofen is used to treat arthritis and relieve pain, fever and swelling. It is available over-the-counter in 200 and 400 mg tablets. The recommended dosage varies with body mass and indication, but 1.20 g is considered the maximum daily adult dosage. Long term use of ibuprofen can lead to stomach ulcers.

Ibuprofen can be synthesised via the following process:



(a) A man bought some ibuprofen tablets of dosage 200 mg over the counter and consumed one pill 4 times a day. Explain if this level of consumption safe for the man.

………………………………………………………………………………………………

……………………………………………………………………………………………… **[1]**

(b) State the type of reaction that converts Compound **A** to **B**.

……………………………………………………………………………………………… **[1]**

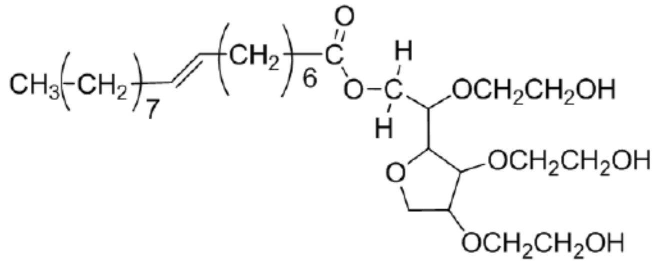
(c) In the laboratory, Compound **C** can be converted to ibuprofen using a 3-step synthesis route.

Suggest reagents and conditions for each step, and draw the structures of all intermediates.

[5]

(d) Young children often find it difficult to swallow tablets. Thus, ibuprofen is supplied as an "infant formula" emulsion.

Given that ibuprofen and water are immiscible, an emulsifier such as polysorbate 80 is used to create a homogeneous mixture.



polysorbate 80

Explain why this molecule is able to act as an emulsifier.

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………… **[1]**

(e) A certain pharmaceutical brand claims that the ibuprofen tablets it manufactures are 95.0% pure by mass.

To investigate this claim, 5.00 g of a sample was crushed and dissolved in 250 cm^3 of 0.450 mol dm^{-3} aqueous KOH. 25.0 cm^3 of this solution was withdrawn and titrated against sulfuric acid. The unreacted KOH in this solution required 25.50 cm^3 of 0.180 mol dm^{-3} of sulfuric acid for complete neutralisation.

Showing relevant calculations, deduce if the claim is valid.

[3]

(f) Compare the acidity of ibuprofen and aspirin. Explain your answer.

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…………………………………………………………………………………… **[2]**

(g) Describe a simple chemical test to distinguish between ibuprofen and aspirin.

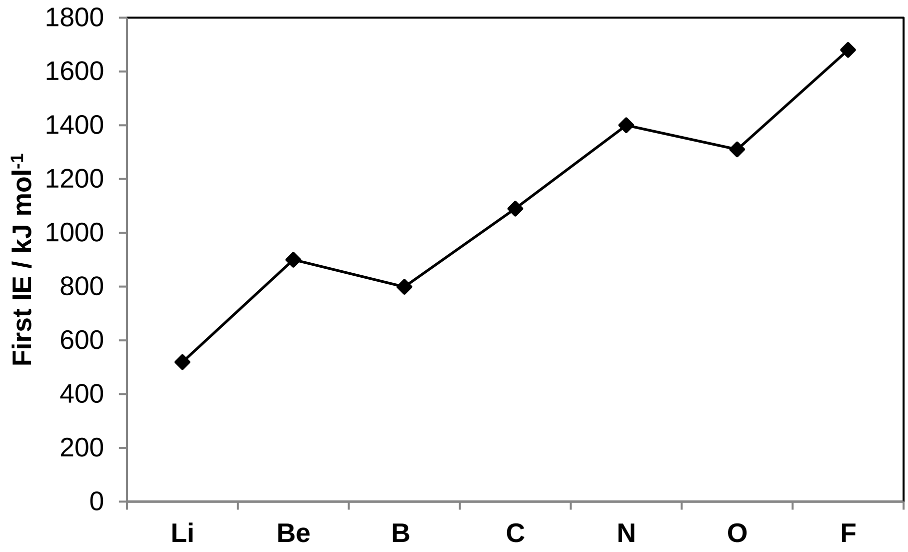
………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………………… **[2]**

[Total: 15]

2 **(a)** The first ionisation energies of the elements lithium to fluorine are shown below.



(i) Using an equation, define the first ionisation energy of boron.

.... **[1]**

(ii) Describe and explain the general trend in first ionisation energies for the elements lithium to fluorine.

....

....

....

....

....

.... **[2]**

(iii) Stating the electronic configurations of oxygen and nitrogen, suggest why the first ionisation energy of oxygen is lower than that of nitrogen.

....

....

....

.... **[2]**

(b) Across Period 3, the nature of elements changes from metallic to non-metallic. The difference in electronegativity between the elements and the oxide decreases correspondingly, giving rise to different types of oxides.

Choose and describe three oxides which are different in terms of structure and bonding. For each type of oxide, write equations for the reactions with water when applicable, and give the approximate pH of resultant solutions.

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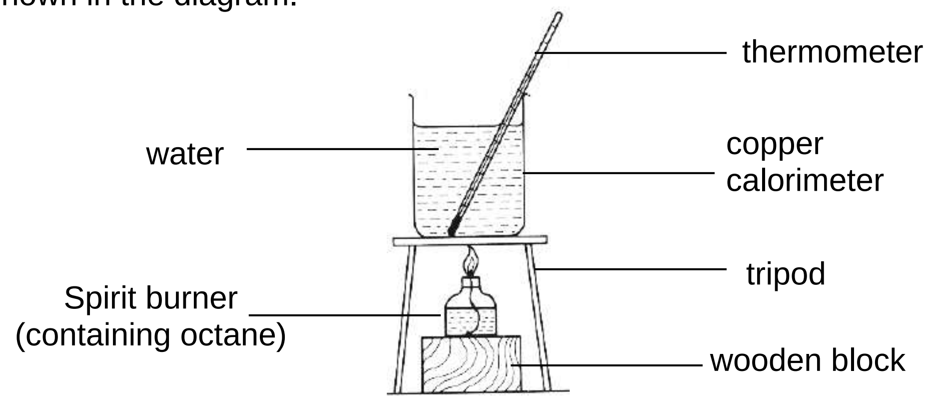
………………………………………………………………………………………… **[6]**

[Total: 11]

3 **(a)** Some important uses of hydrocarbons include fuels, plastics, paints and solvents. In some countries, where crude oil is either scarce or expensive, biofuels such as ethanol are also increasingly being used for fuels instead of hydrocarbons.

(i) James carried out an experiment to determine the enthalpy change of combustion of octane, C_8H_{18}, using the apparatus shown in the diagram.



These are the results that James obtained:

Volume of water = 1000 cm^3

Initial temperature of water = 29.6 °C

Highest temperature of water = 50.0 °C

Initial mass of burner and octane = 59.35 g

Final mass of burner and octane = 53.77 g

Specific heat capacity of water = 4.18 J g^{-1} K^{-1}

Heat capacity of calorimeter = 385 J K^{-1}

Use these results to determine the experimental enthalpy change of combustion of octane.

[3]

(ii) Define the standard enthalpy change of combustion.

…………………………………………………………………………….

…………………………………………………………………………….

……………………………………………………………………………. **[1]**

(b) Liquid hydrazine reacts with oxygen to form nitrogen and steam which could involve the following energy cycle shown below.

$$\begin{tikzcd}
N_2H_4(l) + O_2(g) \arrow[r] \arrow[d] & N_2(g) + 2H_2O(g) \arrow[d] \\
N_2H_4(g) + O_2(g) \arrow[r] & 2N(g) + 4H(g) + 2O(g)
\end{tikzcd}$$

(i) Given that the enthalpy change of vapourisation of hydrazine is +58.0 kJ mol^{-1}, use appropriate bond energies from the *Data Booklet* to calculate the enthalpy change of reaction between liquid hydrazine and oxygen.

[2]

(ii) Suggest a reason to account for the discrepancy between the theoretical enthalpy change of reaction between liquid hydrazine and oxygen and your answer in **(b)(i)**.

…………………………………………………………………………….

…………………………………………………………………………….

……………………………………………………………………………. **[1]**

[Total: 7]

4 Under suitable conditions, SCl_2 reacts with water to produce a yellow precipitate of sulfur and an acidic solution **G**. Solution **G** contains a mixture of SO_2(aq) and another compound.

(a) State the oxidation number of S in SCl_2 .

.... **[1]**

(b) Construct an equation for the reaction between SCl_2 and water.

.... **[1]**

(c) In the Contact Process, one important step is the conversion of SO_2 to SO_3 as shown below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

2.00 L flask was filled with 0.0400 mol SO_2 and 0.0200 mol O_2. At equilibrium, at 900 K, the flask contained 0.0296 mol of SO_3. Determine the value of K_c.

[3]

(d) State and explain how the position of equilibrium and equilibrium constant, K_c, will change when the volume of the flask is doubled.

....

....

....

.... **[2]**

[Total: 7]

Section B (40 marks)

Answer **two** questions from this section on separate answer paper.

5 **(a)** Carbon also forms compounds with other Group 16 elements like sulfur and selenium. The properties of some of these compounds, along with CO_2, are given in Table 5.1.

Table 5.1

Compound	Structure	Dipole moment	Boiling point / °C
CO_2	O=C=O	0	sublimes
CS_2	S=C=S	0	46
COS	S=C=O	0.71	–50
COSe	Se=C=O	0.73	–22

(i) Explain, in terms of structure and bonding, the difference in the boiling point of CS_2 and COS. **[2]**

(ii) Explain why

- CO_2 has no overall dipole moment.
- COSe has a greater dipole moment than COS. **[2]**

(b) Aside from the common oxides, carbon forms a series of reactive oxocarbons. One such compound is tricarbon monoxide, C_3O, a reactive molecule found in space.

(i) Suggest a structure of tricarbon monoxide. Indicate clearly any lone pairs present. **[1]**

Tricarbon monoxide is isoelectronic to cyanogen, $(CN)_2$. The molecule of cyanogen contains a C–C single bond.

(ii) Draw the dot-and-cross diagram of cyanogen. In your diagram, you should distinguish the electrons originating from the two carbon atoms and those from the two nitrogen atoms. **[1]**

(iii) Suggest the shapes of tricarbon monoxide and cyanogen. **[1]**

(c) Another oxycarbon is pentacarbon dioxide, C_5O_2. It can be obtained by heating compound **X**, $C_6H_6O_3$, at a high temperature.

X also gives an orange precipitate with 2,4-DNPH but does not give a silver mirror with Tollens' reagent. **X** reacts with hydrogen in the presence of platinium catalyst under suitable conditions to for **Y**, $C_6H_{12}O_3$. When reacted with limited bromine under ultraviolet light, **X** produced **only one** monobromo compound.

Y reacts with ethanolic sodium hydroxide to form **Z**, C_6H_6.

Suggest the structures of compounds **X**, **Y** and **Z**. Explain your reasoning. **[8]**

(d) **(i)** Define the term *Bronsted acid.* **[1]**

(ii) The concentration of a monobasic acid, HY is 0.01 mol dm^{-3}, while the pH of the solution is 3.5.

Calculate the concentration of H^+ in this solution. State, with reasoning, if HY is a strong or weak acid. **[2]**

(e) Values for the ionic product of water, K_w, at two different temperatures are given in Table 5.2.

Table 5.2

Temperature / ^{o}C	K_w / mol^2 dm^{-6}
25	1.00×10^{-14}
50	5.48×10^{-14}

Using Le Chatelier's Principle, explain whether the ionisation of water is an endothermic or exothermic process. **[2]**

[Total: 20]

6 In the late 1940s, Willard Libby developed the radiocarbon dating method for determining the age of an object containing organic material by using the properties of radiocarbon (^{14}C), a radioactive isotope of carbon. The principle of carbon dating is as such:

During its life, a plant or animal is exchanging carbon with its surroundings, so the carbon it contains will have the same proportion of ^{14}C as the atmosphere. Once it dies, it ceases to acquire ^{14}C, but the ^{14}C within its biological material at that time will continue to decay, and so the ratio of ^{14}C to ^{12}C in its remains will gradually decrease.

Because ^{14}C decays with first order kinetics, the proportion of radiocarbon can be used to determine how long it has been since a given sample stopped exchanging carbon – the older the sample, the less ^{14}C will be left.

(a) A sample of carbon dioxide gas (that contained both $^{12}CO_2$ and $^{14}CO_2$) was analysed to determine the proportion of $^{14}CO_2$ found within. Analysis results showed that there is one $^{14}CO_2$ molecule for every 10^{12} CO_2 molecules.

(i) Calculate the number of $^{14}CO_2$ molecules in a 10.0 dm^3 carbon dioxide gas sample, measured under s.t.p. **[2]**

(ii) Calculate the mass of $^{14}CO_2$ in the 10.0 dm^3 sample. **[1]**

(iii) Hence, explain why it would be difficult to determine the proportion of $^{14}CO_2$ by means of mass measurement. **[1]**

(b) To more accurately determine the proportion of ^{14}C in a sample of graphite, the graphite is vaporised and ionised to C^+(g) ions. These ions were then passed through two electric plates.

Given that H^+ is deflected with an angle of 8.4°, what is the angle of deflection for $^{14}C^+$ ions under the same experimental set-up? **[1]**

(c) The half-life of ^{14}C is 5730 years. Determine the time that has elapsed for a piece of wood from a dead tree to contain 30.0% of its original ^{14}C. **[2]**

(d) Benzene is obtained from the fractional distillation of crude oil. It can be converted to a series of different useful chemicals such as phenylamine. The formation of phenylamine involves the direct reaction of nitrobenzene and hydrogen gas in the presence of a heterogeneous catalyst.

A series of experiments were carried out at a specific temperature to study the kinetics of this reaction, and the results are shown in Table 6.1.

Table 6.1

Experiment	[nitrobenzene] / mol dm^{-3}	[H_2] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.010	0.010	4.50×10^{-5}
2	0.015	0.010	6.74×10^{-5}
3	0.020	0.020	1.80×10^{-4}
4	0.030	x	4.05×10^{-4}

(i) Define the term *catalyst*. **[1]**

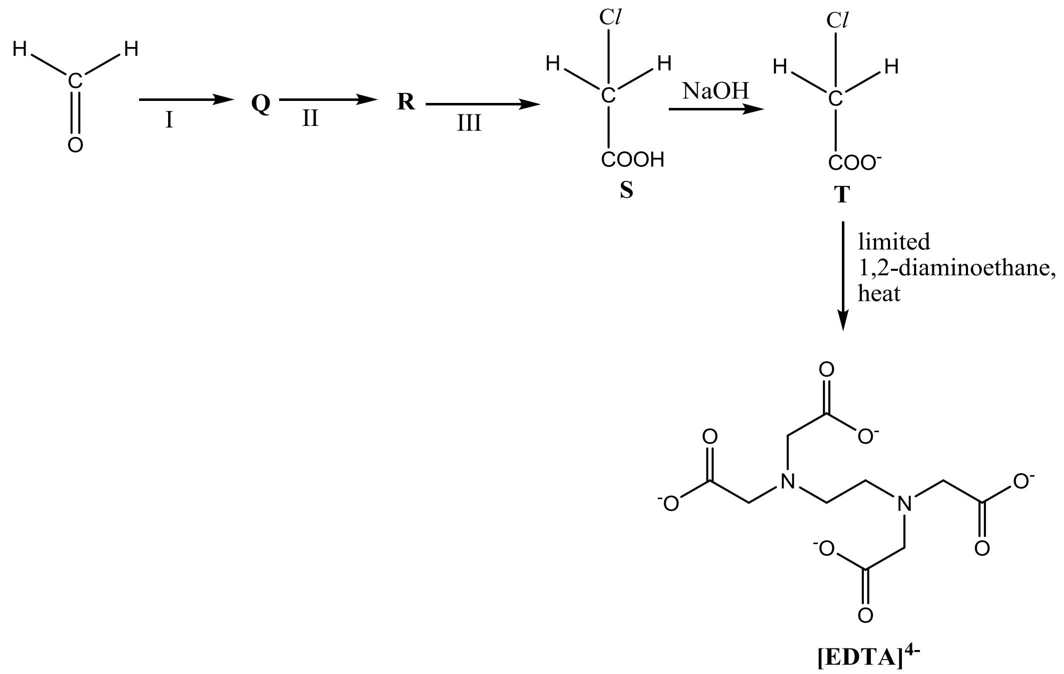
(ii) Determine the order of reaction with respect to nitrobenzene and hydrogen. **[2]**

(iii) Calculate the rate constant, stating its units. **[2]**

(iv) Hence, determine the value of x. **[1]**

(e) Ethylenediamine tetraacetate, $[EDTA]^{4-}$, is a ligand that acts as a chelating agent. It is widely used to remove transition metal ions such as those of chromium from aqueous solutions.

A possible reaction scheme used to synthesise $[EDTA]^{4-}$ from methanal is given below.



(i) Suggest the reagents and conditions in steps I, II and III. **[3]**

(ii) Draw the displayed formulae of intermediates **Q** and **R**. **[2]**

(iii) State the type of reaction when **T** is converted to $[EDTA]^{4-}$.
Give a reason why a limited amount of 1,2-diaminoethane is used. **[2]**

[Total: 20]

7 **(a)** 2-chlorobutane undergoes a substitution reaction with hot aqueous sodium hydroxide. Two separate experiments with different concentrations of 2-chlorobutane were carried out to investigate the kinetics of the reaction.

The obtained results are presented in Table 7.1.

Table 7.1

	Experiment 1 [2-chlorobutane] = 0.05 mol dm^{-3}	**Experiment 2** [2-chlorobutane] = 0.10 mol dm^{-3}
Time / min	[NaOH] / mol dm^{-3}	[NaOH] / mol dm^{-3}
0	0.0050	0.0050
15	0.0045	0.0040
30	0.0040	0.0032
45	0.0036	0.0026
60	0.0032	0.0021
75	0.0029	0.0017
90	0.0026	0.0014

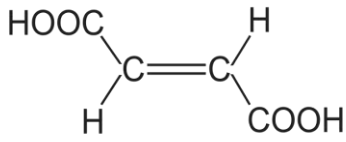
(i) On the same axes, plot graphs of [2-chlorobutane] against time for both Experiments 1 and 2. Label each curve clearly. **[2]**

(ii) Use your graphs to determine the order of reaction with respect to 2-chlorobutane and NaOH. Justify your answer in each case. **[4]**

(iii) Hence, write a rate equation for the reaction. **[1]**

(iv) With the aid of a Maxwell-Boltzmann distribution curve, explain how an increase in temperature affects the rate of reaction in Experiment 2. **[3]**

(b) Fumaric acid is a dibasic acid. When fumaric acid and its potassium salt are added to foods, they act as an acidity regulator and flavouring agent.



fumaric acid

(i) Identify the type of isomerism fumaric acid exhibits, and explain how it arises. **[2]**

(ii) When 25 cm^3 of fumaric acid was titrated against 0.15 mol dm^{-3} potassium hydroxide, the volume of potassium hydroxide required for complete neutralisation was 27 cm^3. The pH at this end point was approximately 8.2.

Calculate the concentration of fumaric acid used in the titration. **[2]**

(iii) Suggest an indicator that is suitable for the titration of fumaric acid with potassium hydroxide. **[2]**

(c) The buffer system of lactic acid, $CH_3CH(OH)COOH$, and sodium lactate, $CH_3CH(OH)COO^-Na^+$, can also be used as acidity regulators in food.

The following equilibrium is established in the buffer system:

$$CH_3CH(OH)COOH(aq) \rightleftharpoons CH_3CH(OH)COO^-(aq) + H^+(aq)$$

The numerical value of the equilibrium constant, K_a, is 1.38×10^{-4}.

(i) Write the K_a expression for the equilibrium shown above. **[1]**

(ii) The pH of a buffer solution is deduced using the formula:

$$pH = -\lg K_a + \lg \frac{[salt]}{[acid]}$$

Given that the equilibrium concentrations of lactic acid and sodium lactate are 0.35 mol dm^{-3} and 0.20 mol dm^{-3} respectively, calculate the pH of this buffer solution. **[1]**

(iii) Write two equations to show how this buffer solution controls pH when a small amount of acid or base is added. **[2]**

[Total: 20]

END OF PAPER

RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATION II

CANDIDATE NAME	**MARK SCHEME**
CLASS	
CENTRE NUMBER	S 3 0 4 4
INDEX NUMBER	0 0

H1 CHEMISTRY 8872/02

Paper 2 Structured and Free Response Questions **13 Sep 2017**

2 hours

Additional Materials: Ruled paper, Graph Paper, Section B Cover Page, Data Booklet

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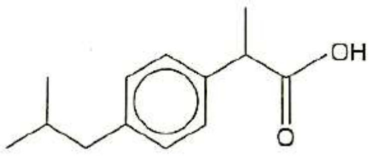
Paper 2							
Section A	**1**	**2**	**3**	**4**	**Section B**	**5/6/7**	**Total (Paper 2)**
	15	11	7	7		40	80
Paper 1	30				**Total**	110	**Grade**

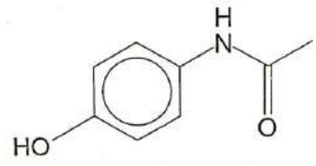
This paper consists of **17** printed pages.

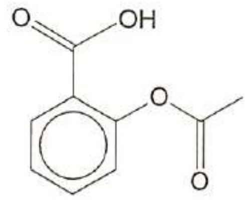
Section A (40 marks)

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

1 Among the many pharmaceutical drugs manufactured worldwide, one of the most important types is the painkillers. The structures of three such painkillers are shown.



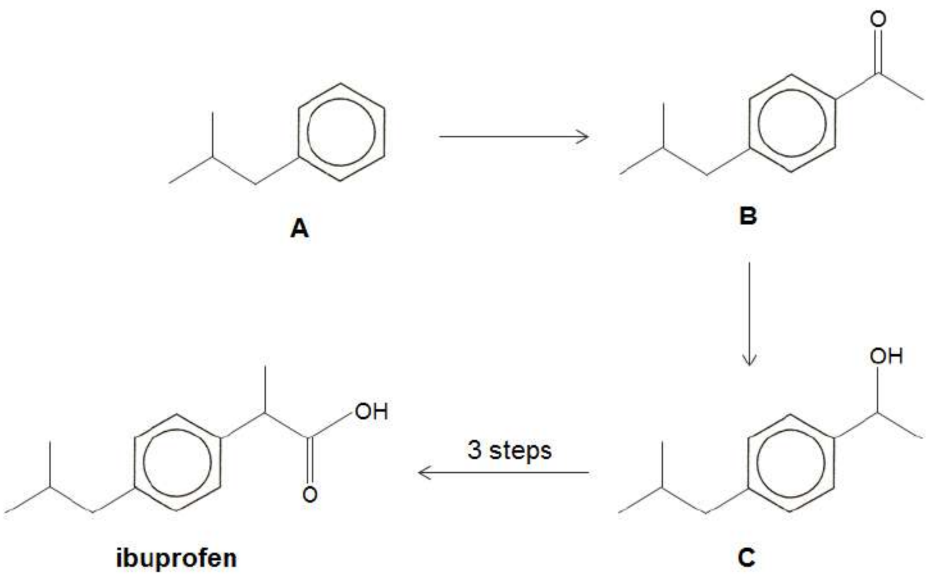




ibuprofen	**paracetamol**	**aspirin**
(M_r = 206)	(M_r = 151)	(M_r = 180)

Ibuprofen is used to treat arthritis and relieve pain, fever and swelling. It is available over-the-counter in 200 and 400 mg tablets. The recommended dosage varies with body mass and indication, but 1.20 g is considered the maximum daily adult dosage. Long term use of ibuprofen can lead to stomach ulcers.

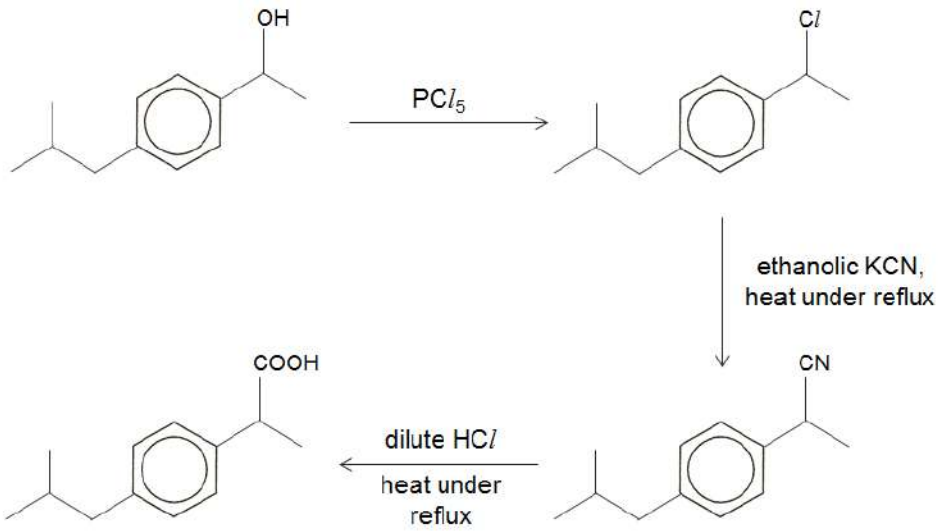
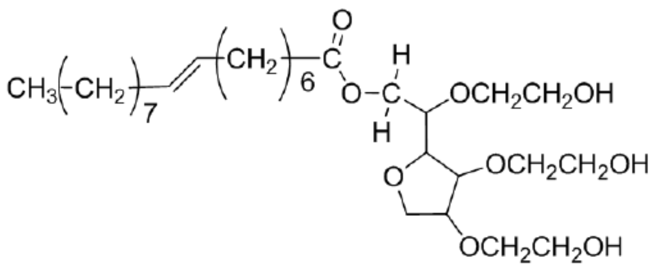
Ibuprofen can be synthesised via the following process:

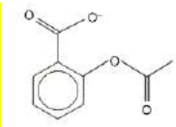
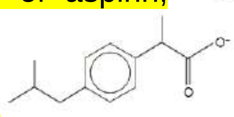


(a) A man bought some ibuprofen tablets of dosage 200 mg over the counter and consumed one pill 4 times a day. Explain if this level of consumption safe for the man.

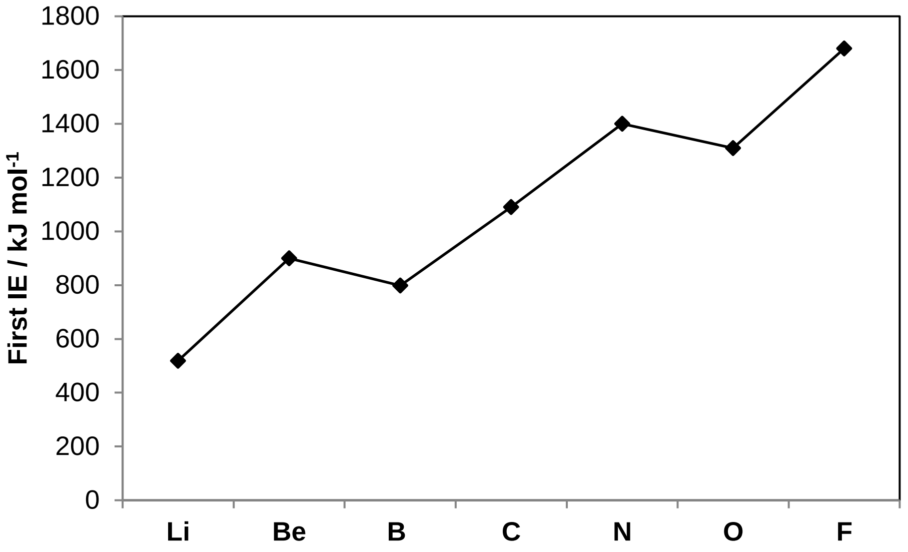
Since 4 x 200 = 800 mg is lower than the maximum dosage of 1200 mg, the level of consumption is safe for the man. **[1]**

(b) State the type of reaction that converts Compound **A** to **B**.

		(Electrophilic) substitution	**[1]**
	(c)	In the laboratory, Compound **C** can be converted to ibuprofen using a 3-step synthesis route. Suggest reagents and conditions for each step, and draw the structures of all intermediates.	
			**[5]**
	(d)	Young children often find it difficult to swallow tablets. Thus, ibuprofen is supplied as an "infant formula" emulsion. Given that ibuprofen and water are immiscible, an emulsifier such as polysorbate 80 is used to create a homogeneous mixture.  **polysorbate 80** Explain why this molecule is able to act as an emulsifier.	
		The <u>-OH polar groups</u> allow the molecule to be soluble in water, while the <u>non-polar hydrocarbon groups</u> allow the molecule to be soluble in oil / non-polar liquids. **Accept hydrogen bonding and id-id interactions, in addition to identification of groups.**	**[1]**
	(e)	A certain pharmaceutical brand claims that the ibuprofen tablets it manufactures are 95.0% pure by mass.	

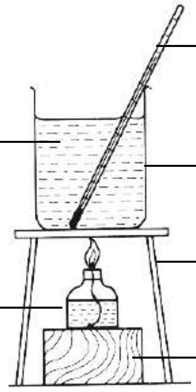
		To investigate this claim, 5.00 g of a sample was crushed and dissolved in 250 cm^3 of 0.450 mol dm^{-3} aqueous KOH. 25.0 cm^3 of this solution was withdrawn and titrated against sulfuric acid. The unreacted KOH in this solution required 25.50 cm^3 of 0.180 mol dm^{-3} of sulfuric acid for complete neutralisation. Showing relevant calculations, deduce if the claim is valid.	
		Amount of $H_2SO_4 = \frac{25.50}{1000} \times 0.180$ $= 0.00459$ mol Amount of unreacted KOH = 0.00459 x 2 = 0.00918 mol Amount of unreacted KOH (in 250 cm^3) = 0.0918 mol Amount of KOH reacted with ibuprofen sample = $\frac{250}{1000} \times 0.450 - 0.0918$ = 0.0207 mol Since ibuprofen $\equiv$ KOH, Amount of ibuprofen = 0.0207 mol Mass of ibuprofen = 0.0207 x [13(12.0) + 18(1.0) + 2(16.0)] = 4.26 g Percentage purity = $\frac{4.26}{5.00} \times 100\%$ = 85.2% Hence, the claim is invalid.	[3]
	(f)	Compare the acidity of ibuprofen and aspirin. Explain your answer.	
		Aspirin is a stronger acid than ibuprofen. The anion of aspirin, , is more stable than the anion of ibuprofen, , as the negative charge is delocalised over the COO^- group and into the benzene ring.	[2]

	(g)	Describe a simple chemical test to distinguish between ibuprofen and aspirin.	
		Test: Heat with acidified $KMnO_4$(aq) Observations: Purple $KMnO_4$ turns colourless for ibuprofen. $KMnO_4$ remains purple for paracetamol and aspirin.	**[2]**
			[Total: 15]

2	**(a)**	The first ionisation energies of the elements lithium to fluorine are shown below. 		
		(i)	Using an equation, define the first ionisation energy of boron.	
			$B(g) \rightarrow B^+(g) + e^-$	**[1]**
		(ii)	Describe and explain the general trend in first ionisation energies for the elements lithium to fluorine.	
			There is a general increase in the first ionisation energies for elements lithium to fluorine. Across a period, nuclear charge increases while shielding effect remains approximately constant. Effective nuclear charge increases and valence electrons are increasingly attracted to the nucleus. Thus, more energy is required to remove the valence electrons.	**[2]**
		(iii)	Stating the electronic configurations of oxygen and nitrogen, suggest why the first ionisation energy of oxygen is lower than that of nitrogen.	
			O: $1s^22s^22p^4$ N: $1s^22s^22p^3$	**[2]**

		Due to coulombic repulsion between the paired 2p electrons in oxygen, less energy is required to remove the 2p electron.	
	(b)	Across Period 3, the nature of elements changes from metallic to non-metallic. The difference in electronegativity between the elements and the oxide decreases correspondingly, giving rise to different types of oxides. Choose and describe three oxides which are different in terms of structure and bonding. For each type of oxide, write equations for the reactions with water when applicable, and give the approximate pH of resultant solutions.	
		Na_2O/MgO/Al_2O_3 has giant ionic lattice structure with strong electrostatic forces of attraction between its oppositely-charged ions. $Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$ pH = 12 $MgO(s) + H_2O(l) \rightleftharpoons Mg(OH)_2(aq)$ pH = 8 Al_2O_3 is insoluble in water and hence gives a resultant solution of pH 7. SiO_2 has giant covalent structure with strong covalent bonds between the Si and O atoms. SiO_2 is insoluble in water and hence gives a resultant solution of pH 7. P_4O_6/P_4O_{10}/SO_2/SO_3 has simple covalent structure with weak van der Waals forces between molecules. $P_4O_6(s) + 6H_2O(l) \rightarrow 4H_3PO_3(aq)$ pH =2 $P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$ pH = 2 $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$ pH = 2 $SO_3(l) + H_2O(l) \rightarrow H_2SO_4(aq)$ pH = 2	**[6]**
			[Total: 11]

3	**(a)**	Some important uses of hydrocarbons include fuels, plastics, paints and solvents. In some countries, where crude oil is either scarce or expensive, biofuels such as ethanol are also increasingly being used for fuels instead of hydrocarbons.	

		(i)	James carried out an experiment to determine the enthalpy change of combustion of octane, C_8H_{18}, using the apparatus shown in the diagram.  These are the results that James obtained: Volume of water = 1000 cm^3 Initial temperature of water = 29.6 °C Highest temperature of water = 50.0 °C Initial mass of burner and octane = 59.35 g Final mass of burner and octane = 53.77 g Specific heat capacity of water = 4.18 J g^{-1} K^{-1} Heat capacity of calorimeter = 385 J K^{-1} Use these results to determine the experimental enthalpy change of combustion of octane.	
			Heat evolved = 1000 × 4.18 × 20.4 + 385 × 20.4 = 93100 J Amount of octane reacted = $\frac{59.35-53.77}{8\times12.0+18\times1.0}$ = 4.89 × 10^{-2} mol Enthalpy change of combustion of octane = $-\frac{93100}{4.89\times10^{-2}}$ = −1900 kJ mol^{-1}	**[3]**
		(ii)	Define the standard enthalpy change of combustion.	
			Standard enthalpy change of combustion is the <u>energy evolved</u> when <u>one mole</u> of the substance is <u>burnt in excess oxygen</u> under <u>standard conditions</u>.	**[1]**

	(b)	Liquid hydrazine reacts with oxygen to form nitrogen and steam which could involve the following energy cycle shown below.		

$$\begin{tikzcd} N_2H_4(l) + O_2(g) \arrow[r] \arrow[d] & N_2(g) + 2H_2O(g) \arrow[d] \\ N_2H_4(g) + O_2(g) \arrow[r] & 2N(g) + 4H(g) + 2O(g) \end{tikzcd}$$

		(i)	Given that the enthalpy change of vapourisation of hydrazine is +58.0 kJ mol^{-1}, use appropriate bond energies from the *Data Booklet* to calculate the enthalpy change of reaction between liquid hydrazine and oxygen.	
			$\Delta H_r = \Delta H_{vap}(N_2H_4) + [BE(N–N) + 4BE(N–H) + BE(O=O)]$ $– [BE(N\equiv N) + 4BE(O–H)]$ $= +58 + [(+160) + 4(+390) + (+496)] – [(+944) + 4(+460)]$ $= –510$ kJ mol^{-1}	**[2]**
		(ii)	Suggest a reason to account for the discrepancy between the theoretical enthalpy change of reaction between liquid hydrazine and oxygen and your answer in **(b)(i)**.	
			The bond energy values obtained from the *Data Booklet* are <u>average values</u> and would not be representative of the specified reaction.	**[1]**
				[Total: 7]

4	Under suitable conditions, SCl_2 reacts with water to produce a yellow precipitate of sulfur and an acidic solution **G**. Solution **G** contains a mixture of SO_2(aq) and another compound.		
	(a)	State the oxidation number of S in SCl_2 .	
		+2	**[1]**
	(b)	Construct an equation for the reaction between SCl_2 and water.	

		$2SCl_2 + 2H_2O \rightarrow S + SO_2 + 4HCl$	[1]
	(c)	In the Contact Process, one important step is the conversion of SO_2 to SO_3 as shown below. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ 2.00 L flask was filled with 0.0400 mol SO_2 and 0.0200 mol O_2. At equilibrium, at 900 K, the flask contained 0.0296 mol of SO_3. Determine the value of K_c.	

	$2SO_2$	+	O_2	$\rightleftharpoons$	$2SO_3$
I / mol	0.0400		0.0200		0
C / mol	−0.0296		–0.0148		+0.0296
E / mol	0.0104		0.00520		0.0296

K_c (where V = 2)

$= \frac{[^{0.0296}/_{V}]^2}{[^{0.0104}/_{V}]^2[^{0.0052}/_{V}]}$

= 3116

= 3120 $mol^{-1}\,dm^3$ [3]

(d) State and explain how the position of equilibrium and equilibrium constant, K_c, will change when the volume of the flask is doubled.

When the volume of flask is doubled, concentration of all gases will be halved. Since there are more concentration terms on the left hand side of the equation, equilibrium position will shift left.

There will be no change to K_c as temperature remains unchanged. [2]

[Total: 7]

Section B (40 marks)

Answer **two** questions from this section on separate answer paper.

5 **(a)** Carbon also forms compounds with other Group 16 elements like sulfur and selenium. The properties of some of these compounds, along with CO_2, are given in Table 5.1.

Table 5.1

Compound	Structure	Dipole moment	Boiling point / °C
CO_2	O=C=O	0	sublimes
CS_2	S=C=S	0	46
COS	S=C=O	0.71	–50
COSe	Se=C=O	0.73	–22

(i) Explain, in terms of structure and bonding, the difference in the boiling point of CS_2 and COS. **[2]**

Both CS_2 and COS have simple covalent structures. CS_2 has a larger number of electrons (or larger electron cloud) than COS. More energy is required to overcome the stronger instantaneous dipole-induced dipole interactions between CS_2 molecules than the weaker permanent dipole-induced dipole interactions between COS molecules. Hence, CS_2 has a higher boiling point.

(ii) Explain why

- CO_2 has no overall dipole moment.
- COSe has a greater dipole moment than COS. **[2]**

CO_2 is linear and hence the dipoles cancel out.

C=S bond is more polar than C=O. There is smaller difference between the dipole moment of C=O and C=S than that between C=O and C=Se.

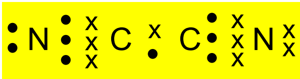
(b) Aside from the common oxides, carbon forms a series of reactive oxocarbons. One such compound is tricarbon monoxide, C_3O, a reactive molecule found in space.

(i) Suggest a structure of tricarbon monoxide. Indicate clearly any lone pairs present. **[1]**

:C═C═C═Ö:

Tricarbon monoxide is isoelectronic to cyanogen, $(CN)_2$. The molecule of cyanogen contains a C–C single bond.

(ii) Draw the dot-and-cross diagram of cyanogen. In your diagram, you should distinguish the electrons originating from the two carbon atoms and those from the two nitrogen atoms. **[1]**



(iii) Suggest the shapes of tricarbon monoxide and cyanogen. **[1]**

They are both <u>linear</u>.

(c) Another oxycarbon is pentacarbon dioxide, C_5O_2. It can be obtained by heating compound **X**, $C_6H_6O_3$, at a high temperature.

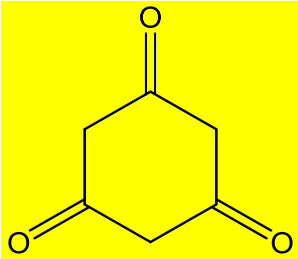
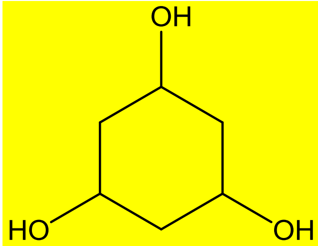
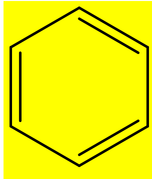
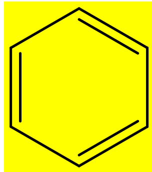
X also gives an orange precipitate with 2,4-DNPH but does not give a silver mirror with Tollens' reagent. **X** reacts with hydrogen in the presence of platinium catalyst under suitable conditions to for **Y**, $C_6H_{12}O_3$. When reacted with limited bromine under ultraviolet light, **X** produced **only one** monobromo compound.

Y reacts with ethanolic sodium hydroxide to form **Z**, C_6H_6.

Suggest the structures of compounds **X**, **Y** and **Z**. Explain your reasoning. **[8]**

Information/Reaction	**Deduction**
X/Y has <u>C:H ratio of 1:1</u>	**X/Y** might contain a <u>benzene ring</u>.
X undergoes <u>condensation</u> with 2,4-DNPH but does not undergo <u>oxidation</u> with Tollens' reagent.	**X** is a <u>ketone</u>.
X undergoes reduction with H_2 **[✓]**	**Y** has 3 OH group**.** **Y** is a 2^0 alcohol**.**
X undergoes <u>free-radical substitution</u> with Br_2 to give only one monobromo compound.	**X** is <u>highly symmetrical</u>.
Y undergoes <u>elimination</u> with NaOH(alc) to form **Z**.	**Z** has 3 C=C bond.

Structures:

		 or 
X	**Y**	**Z**

(d) (i) Define the term *Bronsted acid.* **[1]**

A Bronsted acid is a proton donor.

(ii) The concentration of a monobasic acid, HY is 0.01 mol dm^{-3}, while the pH of the solution is 3.5.

Calculate the concentration of H^+ in this solution. State, with reasoning, if HY is a strong or weak acid. **[2]**

pH = 3.5

$[H^+] = 10^{-3.5} = 3.16 \times 10^{-4}$ mol dm^{-3}

Given that the concentration of HY is 0.01 mol dm^{-3} which is much larger than the concentration of H^+, it is a weak acid as it ionises partially.

(e) Values for the ionic product of water, K_w, at two different temperatures are given in Table 5.2.

Table 5.2

Temperature / ^oC	K_w / $mol^2\ dm^{-6}$
25	1.00×10^{-14}
50	5.48×10^{-14}

Using Le Chatelier's Principle, explain whether the ionisation of water is an endothermic or exothermic process. **[2]**

When temperature increases, the value of K_w increases. This implies that equilibrium position of $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$ lies more to the right to remove some of the added heat. Hence, the ionisation of water is an endothermic process.

		[Total: 20]

6	In the late 1940s, Willard Libby developed the radiocarbon dating method for determining the age of an object containing organic material by using the properties of radiocarbon (^{14}C), a radioactive isotope of carbon. The principle of carbon dating is as such: During its life, a plant or animal is exchanging carbon with its surroundings, so the carbon it contains will have the same proportion of ^{14}C as the atmosphere. Once it dies, it ceases to acquire ^{14}C, but the ^{14}C within its biological material at that time will continue to decay, and so the ratio of ^{14}C to ^{12}C in its remains will gradually decrease. Because ^{14}C decays with first order kinetics, the proportion of radiocarbon can be used to determine how long it has been since a given sample stopped exchanging carbon – the older the sample, the less ^{14}C will be left.			
	(a)	A sample of carbon dioxide gas (that contained both $^{12}CO_2$ and $^{14}CO_2$) was analysed to determine the proportion of $^{14}CO_2$ found within. Analysis results showed that there is one $^{14}CO_2$ molecule for every 10^{12} CO_2 molecules.		
		(i)	Calculate the number of $^{14}CO_2$ molecules in a 10.0 dm^3 carbon dioxide gas sample, measured under s.t.p.	**[2]**
			Number of moles of $CO_2 = \frac{10}{22.7}$ $= 0.441$ mol Number of $^{14}CO_2$ molecules $= 0.441 \times \frac{6.02\times10^{23}}{10^{12}}$ $= 2.65 \times 10^{11}$ molecules	
		(ii)	Calculate the mass of $^{14}CO_2$ in the 10.0 dm^3 sample.	**[1]**
			Mass of $^{14}CO_2 = \frac{2.65\times10^{11}}{6.02\times10^{23}} \times (14.0 + 16.0 \times 2)$ $= 2.03 \times 10^{-11}$ g	
		(iii)	Hence, explain why it would be difficult to determine the proportion of $^{14}CO_2$ by means of mass measurement.	**[1]**
			The amount/mass of $^{14}CO_2$ is too small to be accurately measured.	
	(b)	To more accurately determine the proportion of ^{14}C in a sample of graphite, the graphite is vaporised and ionised to C^+(g) ions. These ions were then passed through two electric plates. Given that H^+ is deflected with an angle of 8.4°, what is the angle of deflection for $^{14}C^+$ ions under the same experimental set-up?		**[1]**

Angle of deflection of $^{14}C^{+}$ = $\left(\frac{1}{14}\right)(8.4)$

= 0.60°

(c) The half-life of ^{14}C is 5730 years. Determine the time that has elapsed for a piece of wood from a dead tree to contain 30.0% of its original ^{14}C. **[2]**

Let the number of half-life be n.

$$\frac{30.0}{100} = \left(\frac{1}{2}\right)^n$$

$$n = \frac{lg\left(\frac{30.0}{100}\right)}{lg\left(\frac{1}{2}\right)}$$

$n = 1.74$

Time taken = 5730 × 1.74 = 9970 years

(d) Benzene is obtained from the fractional distillation of crude oil. It can be converted to a series of different useful chemicals such as phenylamine. The formation of phenylamine involves the direct reaction of nitrobenzene and hydrogen gas in the presence of a heterogeneous catalyst.

A series of experiments were carried out at a specific temperature to study the kinetics of this reaction, and the results are shown in Table 6.1.

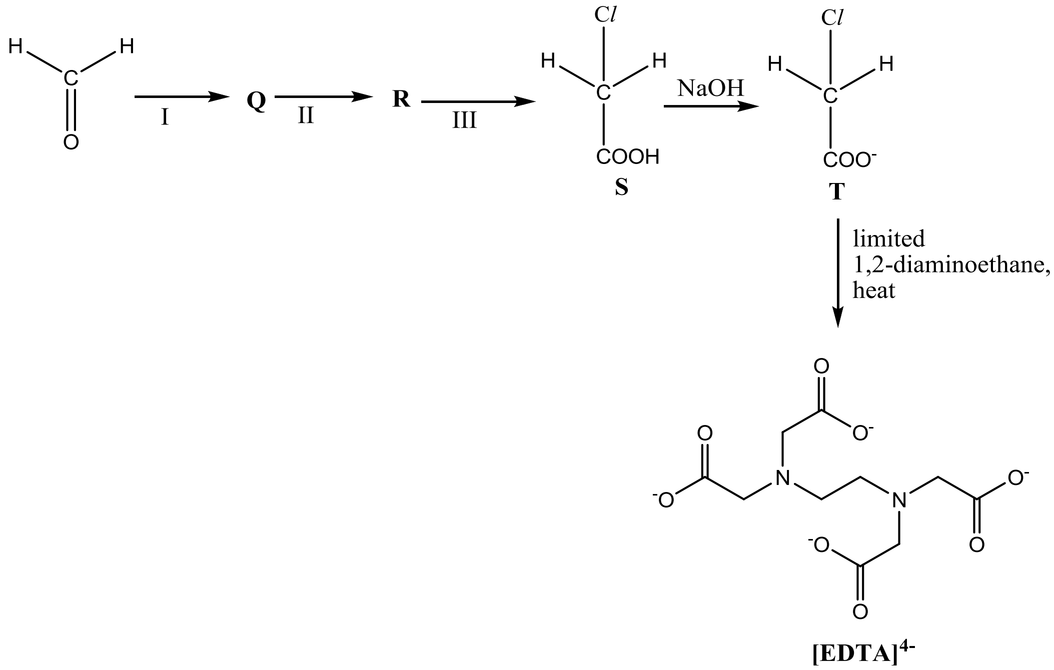
Table 6.1

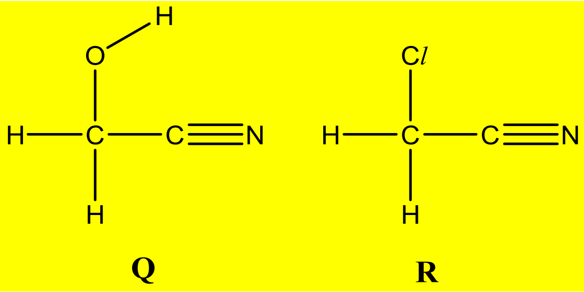
Experiment	[nitrobenzene] / mol dm^{-3}	[H_2] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.010	0.010	4.50×10^{-5}
2	0.015	0.010	6.74×10^{-5}
3	0.020	0.020	1.80×10^{-4}
4	0.030	x	4.05×10^{-4}

(i) Define the term *catalyst*. **[1]**

A catalyst is a substance that increases the rate of reaction by providing an alternative reaction pathway of lowered activation energy, and is regenerated at the end of the reaction.

(ii) Determine the order of reaction with respect to nitrobenzene and hydrogen. **[2]**

			Comparing Experiment 1 and 2, when [nitrobenzene] is increased to 1.5 times, rate is increased to 1.5 times. Hence, the reaction is first order with respect to nitrobenzene. Let the rate equation be Rate = k[nitrobenzene]$[H_2]^a$ Comparing Experiment 2 and 3: $\frac{6.74\times10^{-5}}{1.80\times10^{-4}} = \frac{k(0.015)(0.01)^a}{k(0.02)(0.02)^a}$ $\left(\frac{6.74\times10^{-5}}{1.80\times10^{-4}}\right)\left(\frac{0.02}{0.015}\right) = \left(\frac{0.01}{0.02}\right)^a$ $a = 1$	
		(iii)	Calculate the rate constant, stating its units.	**[2]**
			Using Experiment 1, $4.50 \times 10^{-5} = k(0.01)(0.01)$ k = 0.450 mol^{-1} dm^3 s^{-1}	
		(iv)	Hence, determine the value of x.	**[1]**
			$4.05 \times 10^{-4} = (0.45)(0.03)x$ $x = 0.0300$ (mol dm^{-3})	
	(e)	Ethylenediamine tetraacetate, $[EDTA]^{4-}$, is a ligand that acts as a chelating agent. It is widely used to remove transition metal ions such as those of chromium from aqueous solutions. A possible reaction scheme used to synthesise $[EDTA]^{4-}$ from methanal is given below. 		

		(i)	Suggest the reagents and conditions in steps I, II and III.	[3]
			Step I: HCN with small amount of NaCN Step II: PCl_5/PCl_3/$SOCl_2$ Step III: H_2SO_4(aq), heat under reflux	
		(ii)	Draw the displayed formulae of intermediates **Q** and **R**.	[2]
				
		(iii)	State the type of reaction when **T** is converted to $[EDTA]^{4-}$. Give a reason why a limited amount of 1,2-diaminoethane is used.	[2]
			(Nucleophilic) substitution To enable multiple substitution on the amine group.	
			[Total: 20]	

7	**(a)**	2-chlorobutane undergoes a substitution reaction with hot aqueous sodium hydroxide. Two separate experiments with different concentrations of 2-chlorobutane were carried out to investigate the kinetics of the reaction. The obtained results are presented in Table 7.1.	

Table 7.1

	Experiment 1 [2-chlorobutane] = 0.05 mol dm^{-3}	**Experiment 2** [2-chlorobutane] = 0.10 mol dm^{-3}
Time / min	[NaOH] / mol dm^{-3}	[NaOH] / mol dm^{-3}
0	0.0050	0.0050
15	0.0045	0.0040
30	0.0040	0.0032
45	0.0036	0.0026
60	0.0032	0.0021
75	0.0029	0.0017
90	0.0026	0.0014

(i) On the same axes, plot graphs of [2-chlorobutane] against time for both Experiments 1 and 2. Label each curve clearly. **[2]**

See graph

(ii) Use your graphs to determine the order of reaction with respect to 2-chlorobutane and NaOH. Justify your answer in each case. **[4]**

Using graph of Experiment 2, $t_{1/2}$ is constant at 48 min.

Hence, order of reaction with respect to NaOH is 1.

For Experiment 1, initial rate = −gradient

= 3.64×10^{-5} mol dm^{-3} min^{-1}

For Experiment 2, initial rate = −gradient

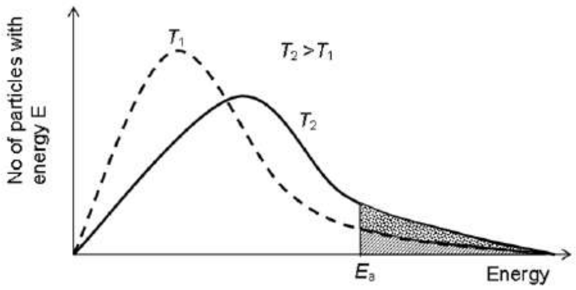
= 6.67×10^{-5} mol dm^{-3} min^{-1}

When [2-chlorobutane] is doubled, rate is doubled. Hence, order of reaction with respect to 2-chlorobutane is 1.

(iii) Hence, write a rate equation for the reaction. **[1]**

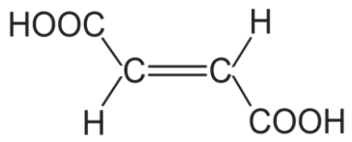
Rate = k[2-chlorobutane][NaOH]

(iv) With the aid of a Maxwell-Boltzmann distribution curve, explain how an increase in temperature affects the rate of reaction in Experiment 2. **[3]**



When temperature increases, the average kinetic energy of the reactant particles increases. More reactant particles possess energy greater than or equal to the activation energy. As a result, the frequency of effective collisions increases and the rate of reaction increases.

(b) Fumaric acid is a dibasic acid. When fumaric acid and its potassium salt are added to foods, they act as an acidity regulator and flavouring agent.



fumaric acid

(i) Identify the type of isomerism fumaric acid exhibits, and explain how it arises. **[2]**

Geometrical isomerism, because the presence of π bond in C=C prevents free rotation about the double bond.

(ii) When 25 cm^3 of fumaric acid was titrated against 0.15 mol dm^{-3} potassium hydroxide, the volume of potassium hydroxide required for complete neutralisation was 27 cm^3. The pH at this end point was approximately 8.2.

Calculate the concentration of fumaric acid used in the titration. **[2]**

Amount of KOH = $\frac{27}{1000} \times 0.15$

= 0.00405 mol

Amount of fumaric acid = $\frac{0.00405}{2}$

= 0.00203 mol

Concentration of fumaric acid = $\frac{0.00203}{0.025}$

= 0.0812 mol dm^{-3}

		(iii)	Suggest an indicator that is suitable for the titration of fumaric acid with potassium hydroxide.	**[2]**
			Phenolphthalein, because its working pH range (8-10) lies within the sharp pH change near the equivalence point of the titration.	
	(c)	The buffer system of lactic acid, $CH_3CH(OH)COOH$, and sodium lactate, $CH_3CH(OH)COO^-Na^+$, can also be used as acidity regulators in food. The following equilibrium is established in the buffer system: $$CH_3CH(OH)COOH(aq) \rightleftharpoons CH_3CH(OH)COO^-(aq) + H^+(aq)$$ The numerical value of the equilibrium constant, K_a, is 1.38×10^{-4}.		
		(i)	Write the K_a expression for the equilibrium shown above.	**[1]**
			$K_a = \frac{[CH_3CH(OH)COO^-]\,[H^+]}{[CH_3CH(OH)COOH]}$	
		(ii)	The pH of a buffer solution is deduced using the formula: $$pH = -\lg K_a + \lg \frac{[salt]}{[acid]}$$ Given that the equilibrium concentrations of lactic acid and sodium lactate are 0.35 mol dm^{-3} and 0.20 mol dm^{-3} respectively, calculate the pH of this buffer solution.	**[1]**
			$pH = -\lg(1.38 \times 10^{-4}) + \lg\left(\frac{0.20}{0.35}\right)$ $= 3.62$	
		(iii)	Write two equations to show how this buffer solution controls pH when a small amount of acid or base is added.	**[2]**
			$CH_3CH(OH)COO^- + H^+ \rightarrow CH_3CH(OH)COOH$ $CH_3CH(OH)COOH + OH^- \rightarrow CH_3CH(OH)COO^- + H_2O$	
				[Total: 20]

END OF PAPER

SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 1

Candidate Name

Class

CHEMISTRY **8872/01**

JC2 Preliminary Examination 22 Sept 2017 (AM)

Paper 1 Multiple Choice 50 min

Additional Materials: Data Booklet
Optical Mark Sheet (OMS)

READ THESE INSTRUCTIONS FIRST

On the separate multiple choice OMS given, write your name, subject title and class in the spaces provided.
Shade correctly your FIN/NRIC number.

There are **30** questions in 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 using a **soft pencil** on the separate OMS.

You are advised to fill in the OMS as you go along; no additional time will be given for the transfer of answers once the examination has ended.

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.

This document consists of **11** 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 In a titration, a 30.0 cm^3 sample of 0.05 mol dm^{-3} of the phosphoric acid, H_3PO_4, was found to require 15.00 cm^3 of 11.22 g dm^{-3} solution of potassium hydroxide to reach the endpoint. Which of the following is the salt formed from the reaction?

A KH_2PO_4

B K_2HPO_4

C K_3PO_4

D KPO_3

2 Which species are oxidised and reduced in the following reaction?

$$IO_3^- + 2I^- + 6H^+ + 6Cl^- \rightarrow 3ICl_2^- + 3H_2O$$

	species oxidised	species reduced
A	IO_3^-	I^-
B	I^-, IO_3^-	Cl^-
C	I^-	IO_3^-
D	H^+, Cl^-	IO_3^-

3 How many unpaired electrons are present in S and S^{2-} respectively?

	S	S^{2-}
A	1	0
B	1	2
C	2	0
D	2	2

4 Which statement about $(CH_3)_3NAlH_3$ is correct?

A It exist as a dimer.

B It contains hydrogen bonding.

C The A*l* atom is electron deficient.

D The bonds around the A*l* atom are in a tetrahedral arrangement.

5 In which substance must covalent bonds break on melting?

A Phosphorus(V) chloride

B Beryllium chloride

C Silicon carbide

D Iron(II) hydroxide

6 Which of the following elements has an oxide with a giant structure and a chloride which is readily hydrolysed?

A Silicon

B Sodium

C Carbon

D Phosphorus

7 Archaeologists used $_{14}C$, a radioactive isotope, in carbon dating. An artefact is analysed and its $_{14}C$ content is measured to be 20% of the typical initial amount of $_{14}C$ in trees. Given that the radioactive decay of $_{14}C$ has a half–life of 5500 years, what is the approximate age of this artefact?

A 1.10×10^4 years

B 1.28×10^4 years

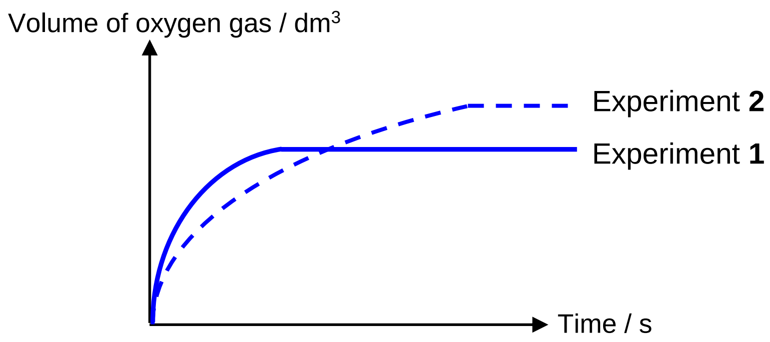
C 1.38×10^4 years

D 1.65×10^4 years

8 Experiments were carried out to investigate the rates of decomposition of 100 cm^3 of 1.0 mol dm^{-3} hydrogen peroxide, catalysed by manganese (IV) oxide.

$$H_2O_2\,(aq) \longrightarrow H_2O\,(l) + ½\,O_2\,(g)$$

The volume of oxygen gas collected using a gas syringe was monitored. The results are shown in the diagram below.



Which of the following alteration to the experimental conditions in Experiment **1** would produce the curve observed in Experiment **2**?

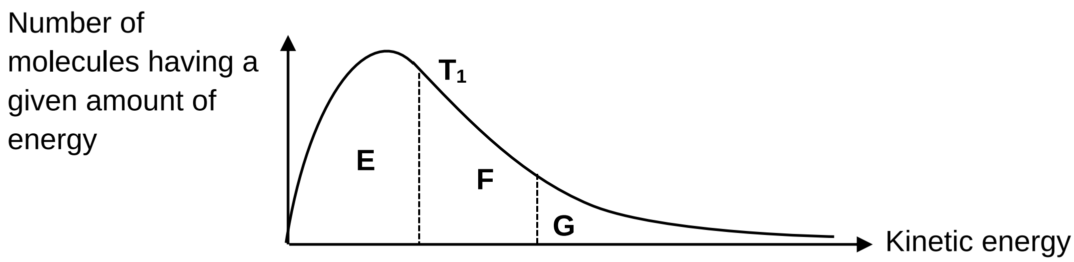
A Lowering the temperature.

B Decreasing the amount of MnO_2 used.

C Diluting the hydrogen peroxide solution with water.

D Adding 100 cm^3 of 0.1 mol dm^{-3} hydrogen peroxide.

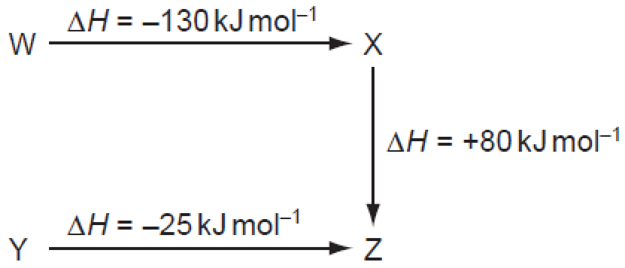
9 The Maxwell Boltzman distribution curve shows the number of molecules having a given amount of kinetic energy at constant temperature, $\mathbf{T_1}$.



How would the size of the areas labelled **E**, **F** and **G** change if a lower temperature, $\mathbf{T_2}$ was used?

	E	**F**	**G**
A	Increase	Increase	Decrease
B	Increase	Decrease	Decrease
C	Decrease	Increase	Increase
D	Decrease	Decrease	Increase

10 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

11 Consider the following equilibrium system:

$$2AlCl_3(g) \rightleftharpoons Al_2Cl_6(g)$$

Which of the following statements will cause the position of the equilibrium to shift to the left?

A Increasing the temperature.

B Pumping $AlCl_3$ gas into the vessel.

C Decreasing the volume of the vessel.

D Adding a solid catalyst into the vessel.

12 Cyanidin (Cy) is a water-soluble plant pigment which can be found in blackberries. Blackberry juice is usually preserved by the addition of a small amount of SO_2(g) and the following equilibrium is set up:

$$CyH^+(aq) + SO_2(aq) + H_2O(l) \rightleftharpoons CySO_3H_2(aq) + H^+(aq)$$

What are the units for K_c?

A mol dm^{-3}

B mol dm^{-3} s^{-1}

C mol^{-1} dm^{3}

D no units

13 A solution of an acid **H** has the same pH as a solution of acid **J.** Equal dilution increases the pH of acid **H** more than that of acid **J**. Which of the following pairs of acids would show this behaviour?

	H	**J**
A	H_3PO_4	HCl
B	HCl	CH_3CO_2H
C	HCl	H_2SO_4
D	CH_3CO_2H	H_2SO_4

14 What is the total number of isomers possible for the molecular formula of $C_2H_2Br_2$?

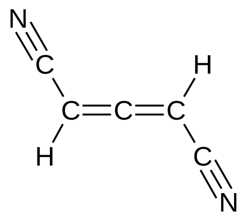
A 1

B 2

C 3

D 4

15 Which statement is **incorrect** for the compound shown below?



A There are 6 π bonds.

B There are 8 σ bonds.

C There are two different bond angles.

D There are three sp^2 hybridised carbons.

16 Samples of $C_6H_5CHCH_2$ and Br_2 were mixed under different conditions. Which pair of conditions and products are correctly paired together?

	Conditions	Product
A	Br_2 (aq)	$C_6H_4BrCH(OH)CH_2Br$
B	Br_2 (g), uv light	$C_6H_4BrCHCH_2$
C	Br_2 (g)	$C_6H_4BrCH(Br)CH_2Br$
D	Br_2 (g), Fe (s)	$C_6H_4BrCH(Br)CH_2Br$

17 Which of these statements is true for the reaction of 2,3,4−trimethylpenta−2,3,4−triol with concentrated sulfuric acid at 443 K.

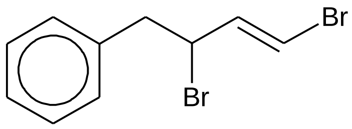
A Oxidation reaction taken place.

B Carbon dioxide gas is a by-product.

C There are a total of 8 possible geometrical isomers.

D Organic product with three carbon-carbon double bonds is formed.

18 Which of the following reagents and conditions will not yield any reaction with the compound shown below.



A Cold aqueous hydrogen cyanide with trace amounts of sodium hydroxide.

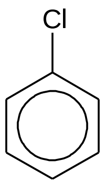
B Hot potassium dichromate in aqueous potassium hydroxide.

C Cold potassium manganate(VII) in aqueous sulfuric acid.

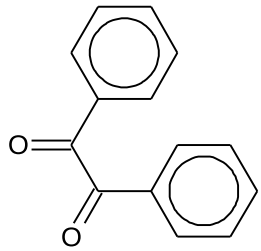
D Aqueous sodium hydroxide and heat.

19 Which of the following compounds would be the most inert towards a nucleophilic attack?

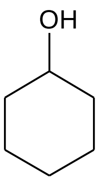
A



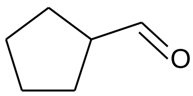
C



B



D



20 Penta−1,3−diene was heated with acidified potassium manganate(VII) to form compound **L** and **M**.

Compound **L** was then added to lithium aluminium hydride in dry ether to form compound **N**. Compound **N** was then bubbled with hydrogen bromide gas to form compound **O**.

Which of these statements can be correctly deduced from the information above?

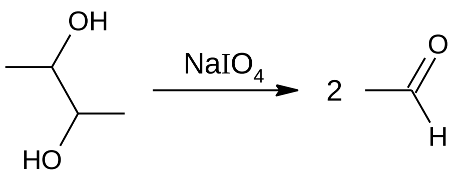
A Compound **O** cannot undergo further nucleophilic substitution with ethanolic potassium cyanide.

B 1 mol of compound **N** forms 1 mol of hydrogen gas when reacted with sodium metal.

C Compound **L** is a gas which forms white precipitate with calcium hydroxide.

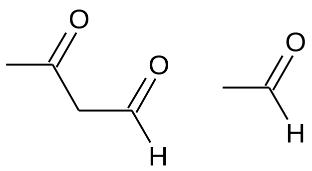
D Compound **M** is a non-polar acidic gas.

21 Buta-2,3-diol can be oxidized by $NaIO_4$ as shown below,

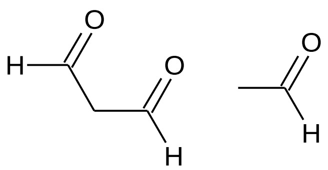


Deduce the products when $CH_3CH{=}C(CH_3){-}CH_2{-}CH{=}CH(CH_3)$ is first treated with cold alkaline aqueous $KMnO_4$ followed by $NaIO_4$.

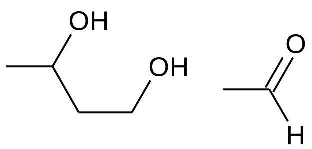
A



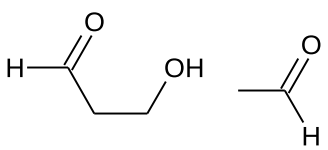
B



C



D



22 Which reagent could be used to distinguish between pentan-2-ol and pentan-2-one?

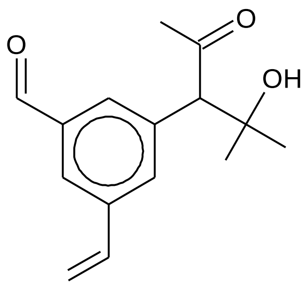
A Acidified potassium manganate(VII)

B Alkaline aqueous iodine

C Sodium carbonate

D Aqueous bromine

23 Which of the following chemical tests will yield a **positive** observation with the compound shown below?



A Fehling's solution

B Hot ethanolic silver nitrate

C Sodium carbonate

D Alkaline aqueous iodine

24 Which compound can undergo a reaction when treated with hot ethanolic potassium hydroxide?

A CH_2Br_2

B CBr_3CBr_3

C $(CH_3)_2CCBr_2$

D $CH_3CBr_2CH_3$

25 Which of these would have the lowest pH value in solution?

A $CH_2(Cl)CH_2CO_2H$

B $CH_2CH(Cl)CO_2H$

C $CH_3CO_2CH_2CH_3$

D $CH_3CH_2NH_2$

For **questions 26 – 30**, one or more of the numbered statements **1** to **3** may be correct. Decide whether each of the statements is or is not correct. The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

No other combination of statements is to be used as correct response.

26 Which of the following contain hydrogen bonding?

1 NH_4Cl (s)

2 NH_3(*l*)

3 $CH_3CH_2CH_2OH$ (*l*)

27 Which reaction represents standard enthalpy change at 298 K?

1 HBr (aq) + NaOH (aq) → NaBr (aq) + H_2O (*l*)

2 P_4 (s) → 4P (g)

3 H_2 (g) + Br_2 (g) → 2HBr (g)

28 At 50 °C, pure water is found to have a pH value of 6.6. Which of the following statements are true?

1 Concentration of hydrogen ion in water is higher at 50 °C compared to at 25°C.

2 The K_w value is smaller at 50 °C compared to at 25°C.

3 Water is acidic at 50 °C.

29 Which of these compounds are planar?

1 Ethene

2 Benzene

3 Propanone

30 Glucose is a simple molecular solid.

$HOCH_2CH(OH)CH(OH)CH(OH)CH(OH)CHO$

Which of the following statements are correct?

1 The hydrogen atom in the hydroxyl groups can form hydrogen bonds with water.

2 The hydrogen atom in the aldehyde group form hydrogen bonds with ethanol.

3 All the oxygen atoms in glucose can form hydrogen bonds with propanone.

END OF PAPER

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SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 1

Candidate Name

Class

CHEMISTRY 8872/01

JC2 Preliminary Examination
Paper 1 Multiple Choice

22 Sept 2017 (AM)
50 min

Additional Materials: Data Booklet
Optical Mark Sheet (OMS)

READ THESE INSTRUCTIONS FIRST

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This document consists of __ printed pages.

Section A

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

1 In a titration, a 30.0 cm^3 sample of 0.05 mol dm^{-3} of the phosphoric acid, H_3PO_4, was found to require 15.00 cm^3 of 11.22 g dm^{-3} solution of potassium hydroxide to reach the endpoint. Which of the following is the salt formed from the reaction?

A	KH_2PO_4
B	K_2HPO_4
C	K_3PO_4
D	KPO_3

Answer: B

$nH_3PO_4 = \frac{30}{100} \times 0.05 = 0.0015 mol$

$nKOH = \frac{11.22}{56.1} \times \frac{15}{1000} = 0.003 mol$

$0.0015\ H_3PO_4 \equiv 0.003\ KOH$

$H_3PO_4 \equiv 2\ KOH$

$\therefore$ K_2HPO_4 is formed.

2 Which species are oxidised and reduced in the following reaction?

$$IO_3^- + 2I^- + 6H^+ + 6Cl^- \rightarrow 3ICl_2^- + 3H_2O$$

	species oxidised	species reduced
A	IO_3^-	I^-
B	I^-, IO_3^-	Cl^-
C	I^-	IO_3^-
D	H^+, Cl^-	IO_3^-

Answer: C

$$\underset{+5}{IO_3^-} + 2\underset{-1}{I^-} + 6\underset{+1}{H^+} + 6\underset{-1}{Cl^-} \rightarrow 3\underset{+1\ -1}{ICl_2^-} + 3\underset{+1}{H_2O}$$

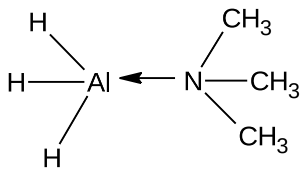
3	How many unpaired electrons are present in S and S^{2-} respectively?		
		S	S^{2-}
	A	1	0
	B	1	2
	C	2	0
	D	2	2

Answer: C

${}_{16}S$: $1s^2 2s^2 2p^6 3s^2 3p^4$ (2 unpaired electron)
${}_{16}S^{2-}$: $1s^2 2s^2 2p^6 3s^2 3p^6$ (0 unpaired electrons)

4	Which statement about $(CH_3)_3NAlH_3$ is correct?	
	A	It exist as a dimer.
	B	It contains hydrogen bonding.
	C	The A*l* atom is electron deficient.
	D	The bonds around the A*l* atom are tetrahedrally arranged.

Answer: D



A*l* has energetically accessible orbitals to accept the lone pair of electrons form N. There are four bond pairs about A*l*. The shape about A*l* is tetrahedral.

5	In which substance must covalent bonds break on melting?	
	A	Phosphorus(V) chloride
	B	Beryllium chloride
	C	Silicon carbide
	D	Iron(II) hydroxide

Answer: C

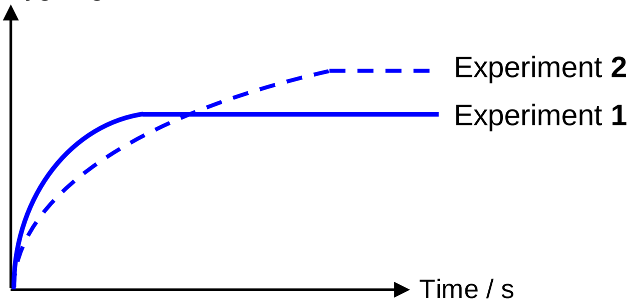
A and B are simple molecular compounds. C has a giant molecular structure and thus

	covalent bonds are broken during boiling. D has a giant ionic lattice structure.			
6	Which of the following elements has an oxide with a giant structure and a chloride which is readily hydrolysed?			
	A	Silicon		
	B	Sodium		
	C	Carbon		
	D	Phosphorus		
	Answer: A SiO_2 is a giant molecular compound. $SiCl_4$ is readily hydrolysed in water to form HCl. $SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl\ (aq)$			
7	Archaeologists used $_{14}C$, a radioactive isotope, in carbon dating. An artefact is analysed and its $_{14}C$ content is measured to be 20% of the typical initial amount of $_{14}C$ in trees. Given that the radioactive decay of $_{14}C$ has a half–life of 5500 years, what is the approximate age of this artefact?			
	A	1.10×10^4 years	**C**	1.38×10^4 years
	B	1.28×10^4 years	**D**	1.65×10^4 years
	Answer: B $\frac{C}{C_o} = \left(\frac{1}{2}\right)^n$ $\frac{20}{100} = \left(\frac{1}{2}\right)^n$ n = 2.32 $t_{1/2} = 2.32 \times 5500 = 1.28 \times 10^4$ years			

8	Experiments were carried out to investigate the rates of decomposition of 100 cm^3 of 1.0 mol dm^{-3} hydrogen peroxide, catalysed by manganese (IV) oxide.

$$H_2O_2\ (aq) \longrightarrow H_2O\ (l) + \tfrac{1}{2}\ O_2\ (g)$$

The volume of oxygen gas collected using a gas syringe was monitored. The results are shown in the diagram below.



Which of the following alteration to the experimental conditions in Experiment **1** would produce the curve observed in Experiment **2**?

A	Lowering the temperature.
B	Decreasing the amount of MnO_2 used.
C	Diluting the hydrogen peroxide solution with water.
D	Adding 100 cm^3 of 0.1 mol dm^{-3} hydrogen peroxide.

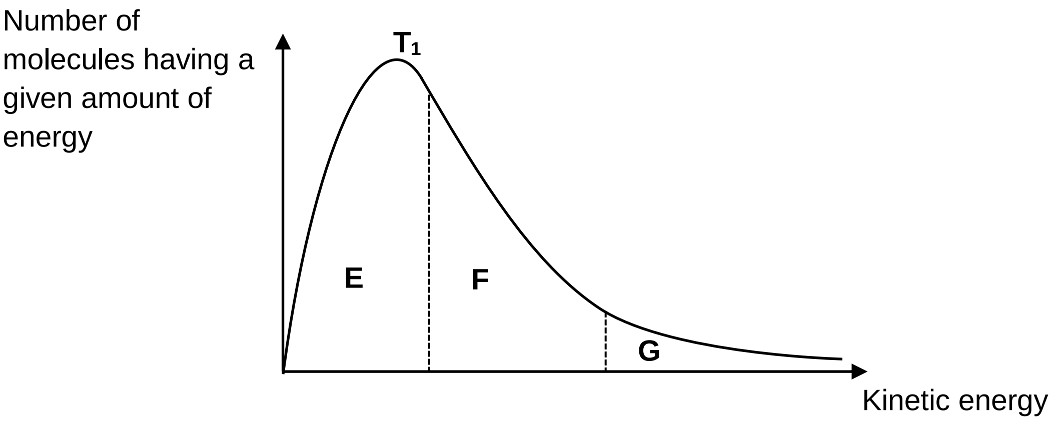
Answer: D

Lowering the temperature and decreasing the amount of MnO_2 will slow down the rate of reaction (less steep curve) but will not change the volume of oxygen produced.

Diluting hydrogen peroxide solution with water will slow down the rate of reaction (less steep curve) and decrease the volume of oxygen produced.

Adding some 0.1 mol dm^{-3} hydrogen peroxide will lower the concentration of hydrogen peroxide which leads to slower rate of reaction (less steep curve). As there are moles of hydrogen peroxide in the vessel, it will lead to more oxygen gas being produced.

9 The Maxwell Boltzman distribution curve shows the number of molecules having a given amount of kinetic energy at constant temperature, $\mathbf{T_1}$.



How would the size of the areas labelled **E**, **F** and **G** change if a lower temperature, $\mathbf{T_2}$ was used?

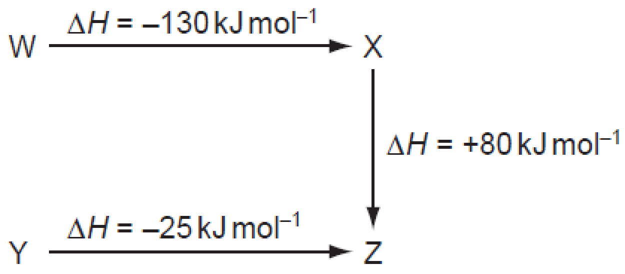
	E	F	G
A	Increase	Increase	Decrease
B	Increase	Decrease	Decrease
C	Decrease	Increase	Increase
D	Decrease	Decrease	Increase

Answer: B

At a lower temperature T_2, the graph will shift to the left hand side and the peak of the graph will be higher than the original. Since there is no change to the number of molecules, the area under both graphs (T_1 and T_2) should be the same.

At a lower temperature, the number of molecules of lower kinetics energy will increase thus the area of E will increase. Also, there will be less molecules of higher kinetics energy thus area F and G will decrease.

10 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

Answer: B

W → Y : ΔH = -130 +80 – (-25) = - 25 kJ mol^{-1}

Y → X : ΔH = -25 -80 = -105 kJ mol^{-1}

Z → W: -80 + 130 = + 50 kJ mol^{-1}

11 Consider the following equilibrium system:

$$2AlCl_3(g) \rightleftharpoons Al_2Cl_6(g)$$

Which of the following statements will cause the position of the equilibrium to shift to the left?

A	Increasing the temperature
B	Pumping $AlCl_3$ gas into the vessel
C	Decreasing the volume of the vessel
D	Adding a solid catalyst into the vessel

Answer: A

This reaction involves bond formation between 2 monomers of $AlCl_3$ to form the dimer

	Al_2Cl_6 hence forward reaction is exothermic. By Le Chatelier's Principle, increasing the temperature will shift position of equilibrium to the left to favour endothermic reaction to absorb the excess heat. Adding $AlCl_3$ gas into the vessel will shift position of equilibrium to the right to use up the excess $AlCl_3$ gas. Decreasing the volume of the vessel will increase the partial pressure of both gases. By LCP, the position of equilibrium will shift to the right to produce lesser moles of gas. Adding a catalyst has no effect on the position of equilibrium. It will just lower the E_a and speed up both forward and backward reaction equally.
12	Cyanidin (Cy) is a water-soluble plant pigment which can be found in blackberries. Blackberry juice is usually preserved by the addition of a small amount of $SO_2(g)$ and the following equilibrium is set up: $$CyH^+(aq) + SO_2(aq) + H_2O(l) \rightleftharpoons CySO_3H_2(aq) + H^+(aq)$$ What are the units for K_c?

A	mol dm^{-3}	**C**	mol^{-1} dm^3
B	mol dm^{-3} s^{-1}	**D**	no units

Answer: D

$$K_c = \frac{[CySO_3H_2][H^+]}{[CyH^+][SO_2]} \quad \text{no units}$$

13 A solution of an acid **H** has the same pH as a solution of acid **J.** Equal dilution increases the pH of acid **H** more than that of acid **J**. Which of the following pairs of acids would show this behaviour?

	H	J
A	H_3PO_4	HCl
B	HCl	CH_3CO_2H
C	HCl	H_2SO_4
D	CH_3CO_2H	H_2SO_4

Answer: B

H is a strong acid and **J** is a weak acid.

Strong acid: pH = – lg [strong acid]

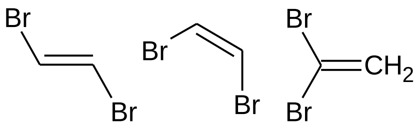
Weak acid: pH = – lg √(Ka ×[Weak acid])

As shown from the equations, the pH of the strong acid will increase more than that of the weak acid when both are diluted to the same extent.

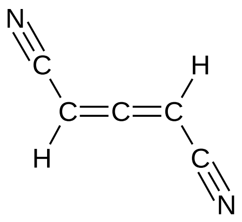
14 What is the total number of isomers possible for the molecular formula of $C_2H_2Br_2$?

A	1	**C**	3
B	2	**D**	4

Answer: C



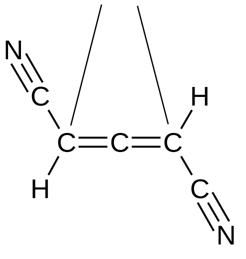
15 Which statement is **incorrect** for the compound shown below?



A	There are 6 π bonds.
B	There are 8 σ bonds.
C	There are two different bond angles.
D	There are three sp^2 hybridised carbons.

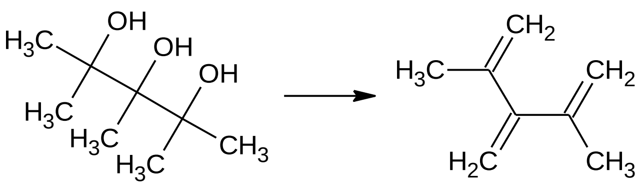
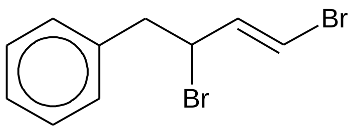
Answer: D

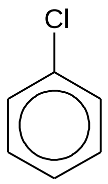
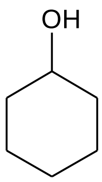
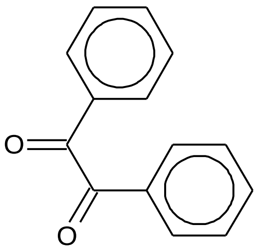
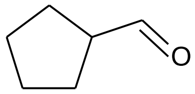
sp^2 hybridised

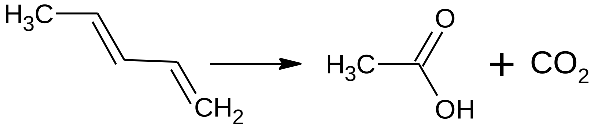
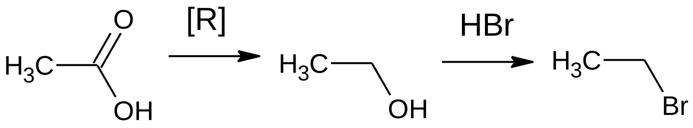
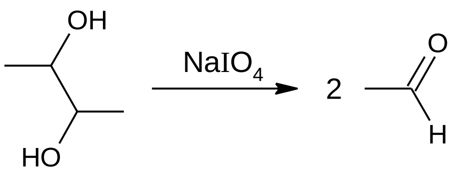
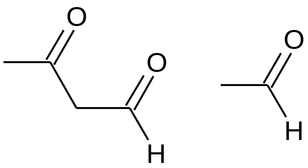
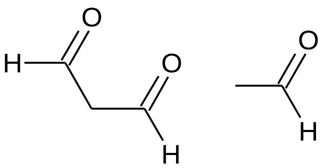
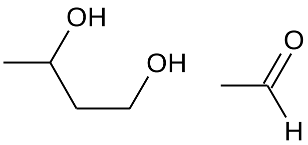


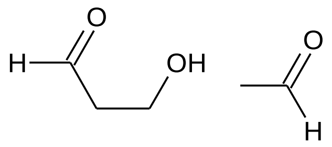
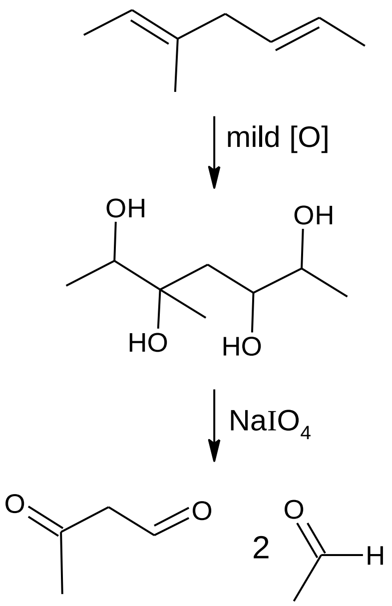
16 Samples of $C_6H_5CHCH_2$ and Br_2 were mixed under different conditions. Which pair of conditions and products are correctly paired together?

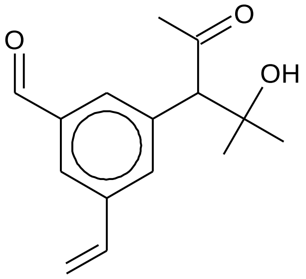
	Conditions	Product

	A	Br_2 (aq)	$C_6H_4BrCH(OH)CH_2Br$	
	B	Br_2 (g), uv light	$C_6H_4BrCHCH_2$	
	C	Br_2 (g)	$C_6H_4BrCH(Br)CH_2Br$	
	D	Br_2 (g), Fe (s)	$C_6H_4BrCH(Br)CH_2Br$	
	Answer: D Both electrophilic substitution and electrophilic addition took place when exposed to Br_2 (g), Fe (s).			
17	Which of these statements is true for the reaction of 2,3,4−trimethylpenta−2,3,4−triol with concentrated sulfuric acid at 443 K.			
	A	Oxidation reaction taken place.		
	B	Carbon dioxide gas is a by-product.		
	C	There are a total of 8 possible geometrical isomers.		
	D	Organic product with three carbon-carbon double bonds is formed.		
	Answer: D  .			
18	Which of the following reagents and conditions will not yield any reaction with the compound shown below. 			
	A	Cold aqueous hydrogen cyanide with trace amounts of sodium hydroxide.		
	B	Hot potassium dichromate in aqueous potassium hydroxide.		
	C	Cold potassium manganate(VII) in aqueous sulfuric acid.		
	D	Aqueous sodium hydroxide and heat.		
	Answer: A			

	Cold aqueous hydrogen cyanide with trace amounts of sodium hydroxide is the reagent and conditions for nucleophilic addition of carbonyls	
19	Which of the following compounds would be the most inert towards a nucleophilic attack?	
	A	
	B	
	C	
	D	
	Answer: A C−C*l* bond in chlorobenzene is very strong and cannot be broken easily.	
20	Penta−1,3−diene was heated with acidified potassium manganate(VII) to form compound **L** and **M**. Compound **L** was then added to lithium aluminium hydride in dry ether to form compound **N**. Compound **N** was then bubbled with hydrogen bromide gas to form compound **O**. Which of these statements can be correctly deduced from the information above?	
	A	Compound **O** cannot undergo further nucleophilic substitution with ethanolic potassium cyanide.
	B	1 mol of compound **N** forms 1 mol of hydrogen gas when reacted with sodium metal.

	C	Compound **L** is a gas which forms white precipitate with calcium hydroxide.
	D	Compound **M** is a non-polar acidic gas.
	Answer: D  L M  N O Compound M is carbon dioxide which is a non-polar acidic gas.	
21	Buta-2,3-diol can be oxidized by $NaIO_4$ as shown below,  What would be the final organic products obtained when compound **P** is first treated with cold alkaline aqueous $KMnO_4$ followed by $NaIO_4$? Compound **P** is $CH_3CH{=}C(CH_3){-}CH_2{-}CH{=}CH(CH_3)$	
	A	
	B	
	C	

	D	
	Answer: A 	
22	Which reagent could be used to distinguish between pentan-2-ol and pentan-2-one?	
	A	Acidified potassium manganate(VII)
	B	Alkaline aqueous iodine
	C	Sodium carbonate
	D	Aqueous bromine
	Answer: A A: Pentan-2-ol, a 2° alcohol can be oxidised by acidified potassium maganate(VII) to form a ketone. Purple solution decolourise B: Both react with aq I_2. C: Both do not react with Na_2CO_3. D: Both do not react with aqueous bromine.	
23	Which of the following chemical tests will yield a **positive** observation with the compound shown below?	

		
	A	Fehling's solution
	B	Hot ethanolic silver nitrate
	C	Sodium carbonate
	D	Alkaline aqueous iodine
	Answer: D Brown iodine solution will decolourise due to the alkene functional group and methyl ketone present in the side chains.	
24	Which compound can undergo a reaction when treated with hot ethanolic potassium hydroxide?	
	A	CH_2Br_2
	B	CBr_3CBr_3
	C	$(CH_3)_2CCBr_2$
	D	$CH_3CBr_2CH_3$
	Answer: D Only compound D has a bromine atom on a carbon with an adjacent carbon atom that has a H atom for it to undergo elimination.	
25	Which of these would have the lowest pH value in solution?	
	A	$CH_2(Cl)CH_2CO_2H$
	B	$CH_2CH(Cl)CO_2H$
	C	$CH_3CO_2CH_2CH_3$
	D	$CH_3CH_2NH_2$
	Answer: B The electron withdrawing chlorine atom is nearer to COO^- and the negative charge is more dispersed, hence stabilising the anion.	

For **questions 26 – 30**, one or more of the numbered statements **1** to **3** may be correct. Decide whether each of the statements is or is not correct. The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, 2 and 3 are correct	1 and 2 only are correct	2 and 3 only are correct	1 only is correct

No other combination of statements is to be used as correct response.

26	Which of the following contain hydrogen bonding?	
	1	NH_4Cl (s)
	2	NH_3(*l*)
	3	$CH_3CH_2CH_2OH$ (*l*)
	Answer: C (2 & 3 are correct only) 1: Ionic salt. No hydrogen bonding 2 and 3: Both NH_3 and $CH_3CH_2CH_2OH$: Both can form intermolecular hydrogen bonding as they have lone pairs on N and O, with H attached to N and O respectively.	
27	Which reaction represents standard enthalpy change at 298 K?	
	1	HBr (aq) + NaOH (aq) → NaBr (aq) + H_2O (*l*)
	2	P_4 (s) → 4P (g)
	3	H_2 (g) + Br_2 (g) → 2HBr (g)
	Answer: B (1 & 2 are correct only) Bromine is a liquid and not a gas at 298 k.	
28	At 50 °C, pure water is found to have a pH value of 6.6. Which of the following statements are true?	
	1	Concentration of hydrogen ion in water is higher at 50 °C compared to at 25°C.
	2	The K_w value is smaller at 50 °C compared to at 25°C
	3	Water is acidic at 50 °C
	Answer: D (only 1 is correct)	

	1: Since pH = – lg [H^+], [H^+] is higher at pH 6.6 at 50 °C compared to pH 7 at 25°C. 2: Kw is temperature dependent and is larger at higher temperatures, as H_2O dissociation is endothermic 3: [OH^-] = [H^+], water is still neutral at 50 °C.	
29	Which of these compounds are planar?	
	1	Ethene
	2	Benzene
	3	Propanone
	Answer: **B (1 & 2 only)** Propanone is not planar due to the two CH_3 groups being tetrahedral in shape	
30	Glucose is a simple molecular solid. $HOCH_2CH(OH)CH(OH)CH(OH)CH(OH)CHO$ Which of the following statements are correct?	
	1	The hydrogen atom in the hydroxyl groups can form hydrogen bonds with water.
	2	The hydrogen atom in the aldehyde group form hydrogen bonds with ethanol.
	3	All the oxygen atoms in glucose can form hydrogen bonds with propanone.
	Answer: D 1 Hydrogen is directly bonded to oxygen in the hydroxyl group, hence it can form hydrogen bonds with water. 2: Hydrogen in aldehyde is not bonded to oxygen, hence no hydrogen bonds can be formed 3: There are no hydrogen atoms bonded directly to oxygen in propanone, hence no hydrogen bonds can be formed.	

END OF PAPER

P1 SOLUTIONS

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

SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 1

Candidate Name

Class

CHEMISTRY **8872/02**
JC2 Preliminary Examination **13th Sep 2017 (AM)**
Paper 2 **2 hours**

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark or blue pen.
You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** the questions

Section B
Answer **two** questions on a separate answer paper.

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 of part question.

FOR EXAMINER'S USE		
P1 (MCQ)		30
P2	Section A	
	1	15
	2	15
	3	10
	Section B	
		20
		20
Total		110

This document consists of **15** printed pages and **1** blank page.

For Examiner's Use

Section A

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

1 **(a)** An excess of water was added to 3.9 g of unknown phosphorus chloride, PCl_x, and the resulting solution was made up to 250 cm^3 in a standard flask. 25.0 cm^3 of this solution was titrated with 0.40 $mol dm^{-3}$ NaOH and required 37.40 cm^3 for neutralisation.

(i) Write equations, for the reactions of PCl_5 and PCl_3 with water. [1]

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(ii) Calculate the total amount, in moles, of H^+ ions present in the 250 cm^3 standard flask. [2]

(iii) Hence, calculate the numerical value of x. [2]

(iv) Draw out the Lewis structure of H_3PO_4. State the bond angles and shape about any central atoms. [3]

(v) Explain why PCl_5 exist but not NCl_5. [1]

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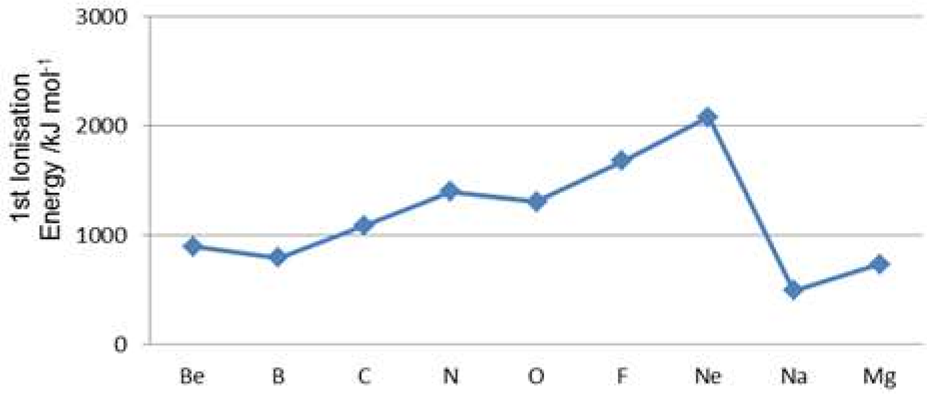
For Examiner's Use

(b) The graph below shows the first ionisation energy of the elements beryllium to magnesium.



(i) Define the term *first ionisation energy*. [1]

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(ii) Account for the increasing ionisation energy from beryllium to neon. [2]

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(iii) Explain why the first ionisation energy decreases from beryllium to boron and nitrogen to oxygen. [2]

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For Examiner's Use

(iv) Explain why the first ionisation energy decreases sharply from neon to sodium. [1]

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[Total: 15]

For Examiner's Use

2 Ethyl propanoate can be hydrolysed according to the following equation.

$$C_2H_5OCOCH_2CH_3 + H_2O \rightarrow C_2H_5OH + CH_3CH_2CO_2H$$

The kinetics of the above hydrolysis may be investigated by measuring the concentration of propanoic acid produced. In this investigation, 0.240 moles of the ester was mixed with a suitable catalyst in 1 dm^3 of water and the mixture was kept at a constant temperature of 35 °C.

10 cm^3 samples were withdrawn periodically at hourly intervals and rapidly cooled by the addition of cold water. The resulting solution was then titrated against a solution of standard sodium hydroxide every hour over a period of four hours. The following results were obtained.

Time / h	Concentration of propanoic acid / mol dm^{-3}
0	0.000
1	0.084
2	0.140
3	0.178
4	0.195

(a) **(i)** Identify the role of the cold water used prior to the titration and explain why it is necessary. [2]

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For Examiner's Use

(ii) By using a suitable graphical method, determine the half-life of the reaction and hence show that the hydrolysis reaction is first order with respect to the ester. [4]

For Examiner's Use

(b) The ester, ethyl propanoate, can also undergo base hydrolysis and the reaction is monitored using the initial rates method. The initial rate of the hydrolysis reaction between the ester and NaOH(aq) was measured in three separate experiments at a constant temperature.

The results are obtained below:

Experiment	Temperature / ^oC	Initial [NaOH] / mol dm^{-3}	Initial [ester] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	T_1	0.020	0.015	2.70 x 10^{-3}
2	T_1	0.030	0.015	4.05 x 10^{-3}
3	T_1	0.060	0.020	$\boldsymbol{r_1}$
4	T_2	0.120	0.020	4.32 x 10^{-2}

(i) Deduce the order of reaction with respect to NaOH. [2]

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(ii) Given that the reaction is first order with respect to the ester, calculate the initial rate of reaction, $\boldsymbol{r_1}$, for Experiment 3. [1]

(iii) Calculate the value of the rate constant in experiment 1 and experiment 4, specifying the correct unit. Hence, deduce whether T_1 or T_2 is higher. [3]

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For Examiner's Use

(iv) Draw the Maxwell-Boltzmann distribution curve, explain how the increase in temperature increases the rate of reaction. [3]

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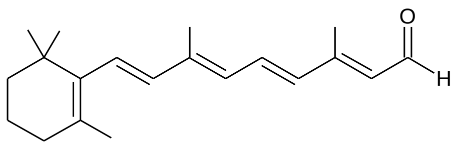
[Total: 15]

For Examiner's Use

3 This question revolves around carbonyl compounds involved in biological applications in living things.

(a) Retinal is one of the many forms of vitamin A, bound to proteins called opsins. It is the chemical basis of vision in animals and humans as well as allowing certain microorganisms to convert light into metabolic energy.



Retinal

(i) State the number of geometrical isomers for retinal. [1]

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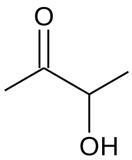
(ii) Draw all the organic products formed when retinal is reacted with cold acidified potassium manganate(VII). [1]

(b) Acetoin is a colorless or pale yellow liquid with a pleasant buttery odour. It is a neutral, four-carbon molecule used as an external energy store by a number of fermentive bacteria.



Acetoin

(i) Suggest a chemical test to **positively** distinguish acetoin from retinal, including relevant chemical equations. [3]

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(ii) Compound **F** is an isomer of acetoin and contains an aldehyde and a tertiary alcohol. **F** was reacted in a sequential procedure as shown below.

Step 1:
It is reacted with aqueous hydrogen cyanide at low temperatures.

Step 2:
Hot acidified potassium dichromate(VI) added to product formed earlier

Step 3:
2,4-dinitrophenylhydrazine added to product formed in step 2 to form compound **G**.

Draw the structures of compounds **F** and **G** and state the types of reactions taken place. [5]

Step 1: ……………………………………...………………………………

Step 2: ……………………………………...………………………………

Step 3: ……………………………………...………………………………

F	**G**

[Total: 10]

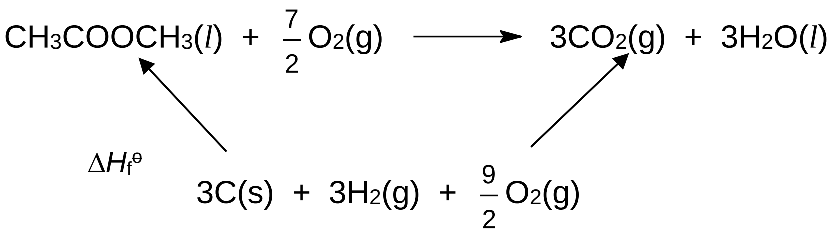
Section B

Answer **two** questions from this section on separate answer paper.

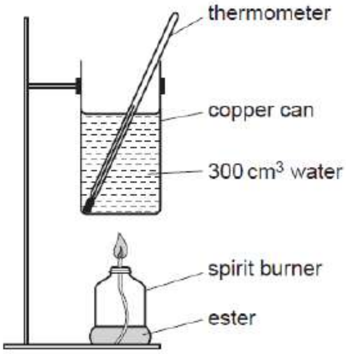
1 **(a)** **(i)** Define standard enthalpy change of formation. [1]

(ii) Use the energy cycle below and the standard enthalpy changes of combustion, $\Delta H_c^{\ominus}$, in the table to calculate the standard enthalpy change of formation, $\Delta H_f^{\ominus}$, of methyl ethanoate, CH_3COOCH_3. [2]

	$\Delta H_c^{\ominus}$ / kJ mol^{-1}
carbon	–393.5
hydrogen	–285.8
methyl ethanoate	–1592.1



(b) A student used the apparatus shown to carry out experiments to determine the standard enthalpy change of combustion of methyl ethanoate, CH_3COOCH_3.



Mass of copper can = 250 g

An initial experiment was carried out using methyl ethanoate. This ester was burnt in a spirit burner underneath a copper can so that the flame from the burner heated 300 cm^3 of water in the can. It was found that 0.980 g of ester was required to raise the temperature of the water in the can by 10.0 ^{o}C

(i) Calculate the heat gain by the water given that the specific heat capacity of water is 4.18 J g^{-1} K^{-1}. Take the density of water to be 1.00 g cm^{-3}. [1]

(ii) Given that the **total** heat energy gain is 13.5 kJ, calculate the specific heat capacity of the copper can used in this experiment. [2]

(iii) Using the $\Delta H_c^\ominus$ of methyl ethanoate given in the table of part **(a)**, calculate the total theoretical heat energy **in kJ** released by the mass of methyl ethanoate burnt in this experiment. [2]

(iv) Calculate the percentage efficiency of heat transfer in this experiment and suggest a reason for this value. [2]

(c) Methane is used to produce synthesis gas (syngas), a mixture that includes carbon monoxide and hydrogen, by reacting with steam on a nickel catalyst in a 2 dm^3 vessel. Syngas is then used to produce liquid hydrocarbons and methanol.

$$CH_4\,(g) + H_2O\,(g) \rightleftharpoons CO\,(g) + 3H_2\,(g) \qquad \Delta H > 0$$

The equilibrium mixture was found to contain 1 mole of methane, 1 mole of steam, 1.5 moles of carbon monoxide and 4.5 moles of hydrogen gas.

(i) State Le Chatelier's Principle. [1]

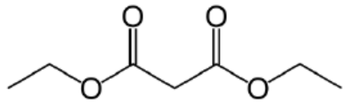
(ii) Write an expression for the equilibrium constant, K_c and determine its value, including units. [2]

(iii) Define the term *endothermic reaction*. [1]

(iv) With reference to the above equilibrium, predict and explain the effect of **separately** increasing pressure and decreasing temperature on the position of equilibrium, yield and K_c. [6]

[Total : 20]

2 Diethyl malonate, also known as DEM exist as a colourless liquid, commonly used in the manufacture of perfumes, artificial flavourings and vitamins. The structure of diethyl malonate is shown below.

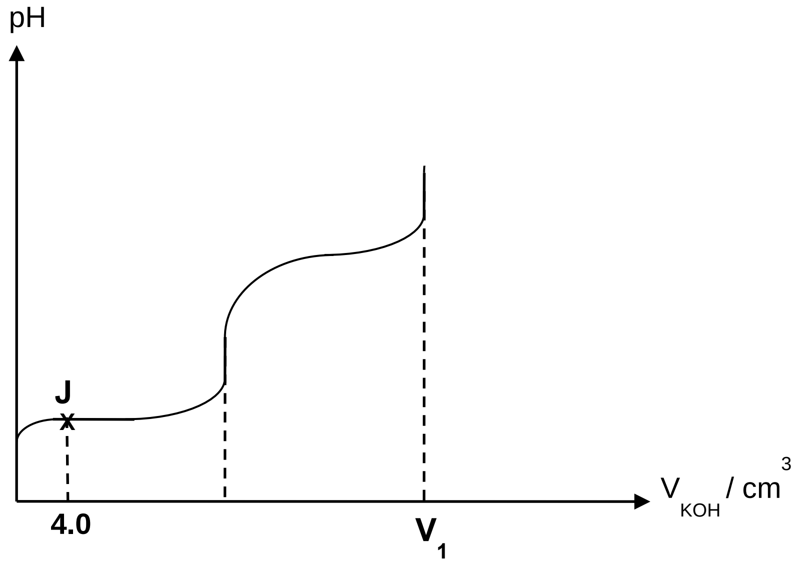


diethyl malonate

(a) (i) Diethyl malonate is synthesised from the esterification of malonic acid and an alcohol. Draw the structure of malonic acid and state the reagents and conditions required for this process. Write a balanced chemical equation for this synthesis. [3]

(ii) State the number of moles of H_2 gas produced per mole of malonic acid with Mg. [1]

(b) 7.0 grams of malonic acid was dissolved in 250 cm^3 of distilled water. The following titration curve was obtained when 25 cm^3 of this solution was titrated against 0.40 mol dm^{-3} potassium hydroxide.



The dissociation of malonic acid (H_2A) can be regarded as follows.

$H_2A \rightleftharpoons HA^- + H^+$ $\quad K_{a1} = 1.479 \times 10^{-3}$

$HA^- \rightleftharpoons A^{2-} + H^+$ $\quad K_{a2} = 2.042 \times 10^{-6}$

(i) Suggest why K_{a2} is much smaller than K_{a1}. [1]

(ii) Write an expression for K_{a1} stating its units. [2]

(iii) Ignoring the effects of K_{a2}, hence, or otherwise, calculate the initial pH of the solution. [2]

(iv) Calculate the volume of KOH, $\mathbf{V_1}$, required to completely neutralise malonic acid in 25 cm^3 of solution. [1]

(v) Explain what it means to be a buffer solution. [1]

(vi) The pH of a buffer solution can be determined by the following equation.

$$pH = -\lg K_a + \lg \frac{[\text{conjugate base}]}{[\text{acid}]}$$

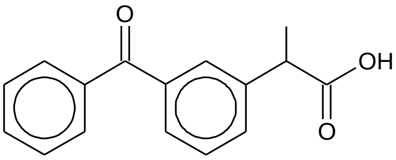
Identify the species present at point **J**. Calculate the amount of malonic acid remaining, and use the above equation to calculate the pH. [3]

(vii) The pH at the second end point is more than 7. Explain this observation with the aid of relevant equations. [2]

(c) Account for the relative acidities of ethanoic acid, ethanol and fluoroethanoic acid. [4]

[Total: 20]

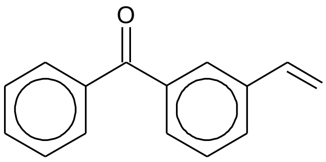
3 Ketoprofen, is one of the propionic acid class of nonsteroidal anti-inflammatory drugs (NSAID) with analgesic and antipyretic effects. It is generally prescribed for arthritis-related inflammatory pains or severe toothaches that result in the inflammation of the gums.



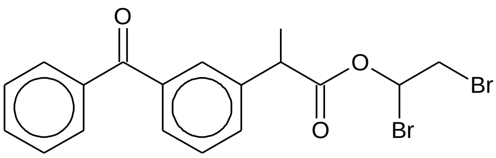
Ketoprofen

(a) Describe the bonding in benzene in terms of orbital overlap, illustrating your answer with a suitable diagram. [3]

(b) Propose a synthetic pathway for the formation of ketoprofen from the structure below. [3]



(c) Ketoprofen is reacted with an alcohol and forms an ester as shown.

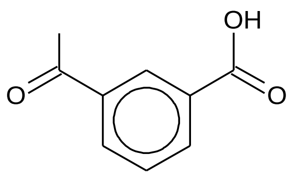


(i) Name the alcohol used in forming the ester. [1]

(ii) The alcohol was heated in the presence of aluminum oxide. Draw the structures of the two isomeric products formed and name them accordingly. [2]

(iii) Predict the relative boiling points of the products formed, giving reasons for your answer. [1]

(d) Compound **K**, a sweet smelling liquid, is an isomer of ketoprofen. Upon heating **K** with dilute sulfuric acid, compound **L** and benzoic acid are produced. Compound **L** is an alcohol which also produces a silver mirror with Tollens' reagent and a blue solution with Fehling's solution. It also reacts with hot acidified potassium dichromate(VI) to form compound **M** as shown below.



Compound **M**

Compound **L** reacts with hot acidified potassium manganate(VII) to form carbon dioxide and compound **N** which will subsequently react with liquid bromine and anhydrous aluminium bromide solid to form compound **O**.
Deduce, with reasoning, the structures for compounds **K**, **L**, **N** and **O.** [10]

[Total: 20]

END OF PAPER

SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 1

Candidate Name

Class

CHEMISTRY **8872/02**
JC2 Preliminary Examination **14th Sep 2017 (AM)**
Paper 2 **2 hours**

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark or blue pen.
You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** the questions

Section B
Answer **two** questions on a separate answer paper.

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 of part question.

FOR EXAMINER'S USE		
P1 (MCQ)		/ 30
P2	Section A	
	1	/ 15
	2	/ 15
	3	/ 10
	Section B	
		/ 20
		/ 20
Total		/ 110

This document consists of **15** printed pages and **1** blank page.

Section A

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

1 **(a)** An excess of water was added to 3.9 g of unknown phosphorus chloride, PCl_x, and the resulting solution was made up to 250 cm^3 in a standard flask. 25.0 cm^3 of this solution was titrated with 0.40 $mol dm^{-3}$ NaOH and required 37.40 cm^3 for neutralisation.

(i) Write equations, for the reactions of PCl_5 and PCl_3 with water. [1]

$PCl_5 + 4H_2O \rightarrow 5HCl + H_3PO_4$
$PCl_3 + 3H_2O \rightarrow 3HCl + H_3PO_3$ **[1] for both equations**

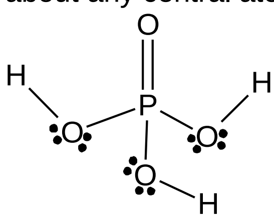
(ii) Calculate the total amount, in moles, of H^+ ions present in the 250 cm^3 standard flask. [2]
$n(H^+)$ in 25.0 cm^3 = n(NaOH) = 0.40 x 37.40/1000 = 0.01496 mol **[1]**
$n(H^+)$ in 250 cm^3 = 0.01496 x 250/25 = 0.1496 mol **[1]**

(iii) Hence, calculate the numerical value of x. [2]
Assuming it is PCl_5:

8 x $n(PCl_5) = n(H^+)$ **[1]**
$n(PCl_5)$ $^{0.1496}/_{8}$ = = 1.87 x 10^{-2} mol
$n(PCl_5)$ = $^{3.9}/_{208.2}$ = 1.87 x 10^{-2} mol
x = **5** **[1]**
Identify of phosphorus chloride = PCl_5

The amounts would not match if you assumed it to be PCl_3

(iv) Draw out the Lewis structure of H_3PO_4. State the bond angles and shape about any central atoms. [3]

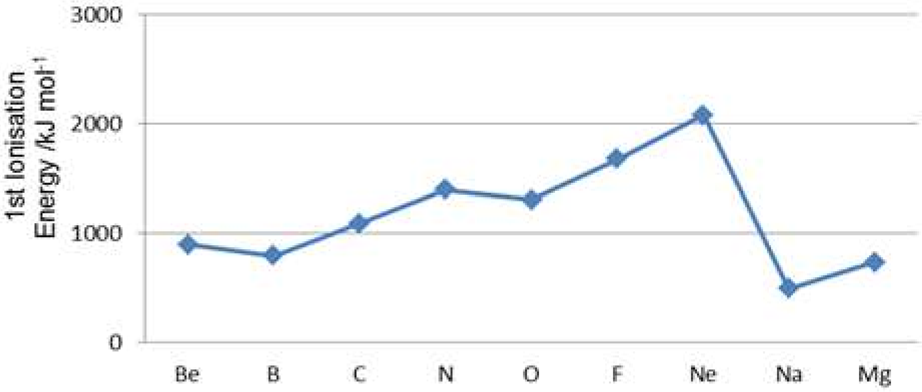


[1] show all bond angles and lp.
P: tetrahedral, 109.5º**[1]**
O: Bent, 104.5º**[1]**

(v) Explain why PCl_5 exist but not NCl_5. [1]

PCl_5 belongs to **period 3** and is able to **expand octet configuration** **[1]** due to energetically accessible 3d orbitals.

(b) The graph below shows the first ionisation energy of the elements beryllium to magnesium.



(i) Define the term *first ionisation energy*. [1]

First ionisation energy is the **energy required to remove one mole of electrons from one mole of gaseous atoms to form one mole of singly positively-charged gaseous ions.** **[1]**

(ii) Account for the increasing ionisation energy from beryllium to neon. [2]

Across the period,
Nuclear charge increases.
Shielding effect is similar **[1]** since successive elements in the period have an additional electron in the same valence shell.
Effective nuclear charge increases. **More energy is required to overcome the stronger electrostatic forces of attraction between the nucleus and the valence electron** to be removed. **[1]**

(iii) Explain why the first ionisation energy decreases from beryllium to boron and nitrogen to oxygen. [2]

Be : $1s^2\ 2s^2$ B : $1s^2\ 2s^2\ 2p^1$
The **2p electron** to be removed from B is at a **higher energy level** compared to the **2s electron** to be removed from Be. **Less energy** is required to overcome the **weaker electrostatic forces of attraction between the nucleus and the valence 2p electron in B**. **[1]**

N**:** $1s^2\ 2s^2\ 2p^3$ O: $1s^2\ 2s^2\ 2p^4$
There is **interelectronic repulsion between the pair of electrons in the doubly-filled 2*p* orbital of O**.
Less energy is required to overcome the **weaker electrostatic forces of attraction between the nucleus and the paired valence 2*p* electron in O compared to the unpaired valence 2*p* electron in N.** **[1]**

(iv) Explain why the first ionisation energy decreases sharply from neon to sodium. [1]

Sodium (Na) is in period 3 while neon (Ne) is in period 2.
Na: $1s^2\ 2s^2\ 2p^6\ 3s^1$ Ne: $1s^2\ 2s^2\ 2p^6$
The number of filled **principal quantum shells increases**. The **valence electrons in Na** are **further** from the nucleus. **Less energy** is required to overcome the **weaker electrostatic forces of attraction between the nucleus and the valence electron** to be removed. **[1]**

[Total: 15]

2 Ethyl propanoate can be hydrolysed according to the following equation.

$$C_2H_5OCOCH_2CH_3 + H_2O \rightarrow C_2H_5OH + CH_3CH_2CO_2H$$

The kinetics of the above hydrolysis may be investigated by measuring the concentration of propanoic acid produced. In this investigation, 0.240 moles of the ester was mixed with a suitable catalyst in 1 dm^3 of water and the mixture was kept at a constant temperature of 35 °C.

10 cm^3 samples were withdrawn periodically at hourly intervals and rapidly cooled by the addition of cold water. The resulting solution was then titrated against a solution of standard sodium hydroxide every hour over a period of four hours. The following results were obtained.

Time / h	Concentration of propanoic acid / mol dm^{-3}
0	0.000
1	0.084
2	0.140
3	0.178
4	0.195

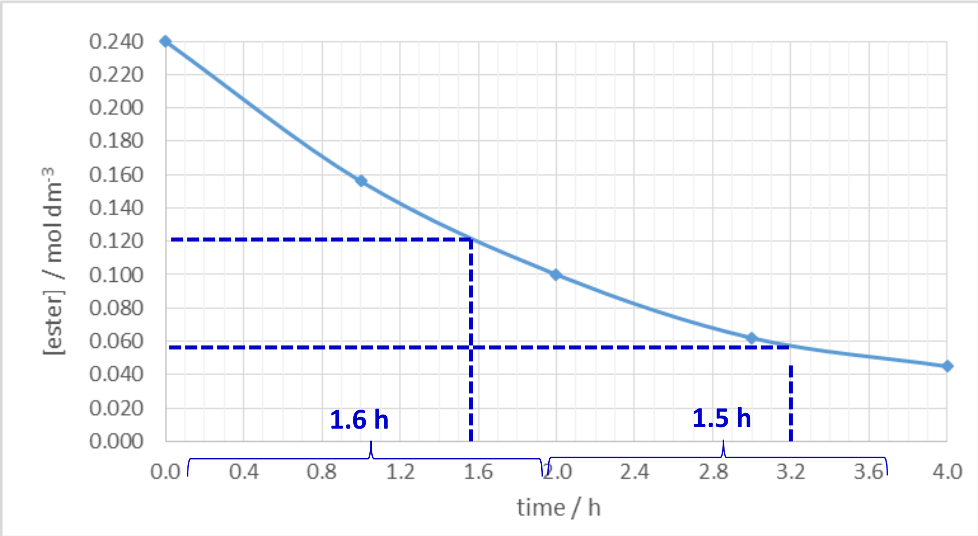
(a) **(i)** Identify the role of the cold water used prior to the titration and explain why it is necessary. [2]

The cold water is a **quenching agent** **[1]**.
It is necessary to **slow down the reaction significantly** (by lowering concentration and temperature of the reaction) so that the reaction is **considered to have stopped at that instant**. **[1]**

(ii) By using a suitable graphical method, determine the half-life of the reaction and hence show that the hydrolysis reaction is first order with respect to the ester. [4]

Time / h	Concentration of propanoic acid / mol dm^{-3}	**Concentration of ester / mol dm^{-3}**
0	0.000	**0.240**
1	0.084	**0.156**
2	0.140	**0.100**
3	0.178	**0.062**
4	0.195	**0.045**

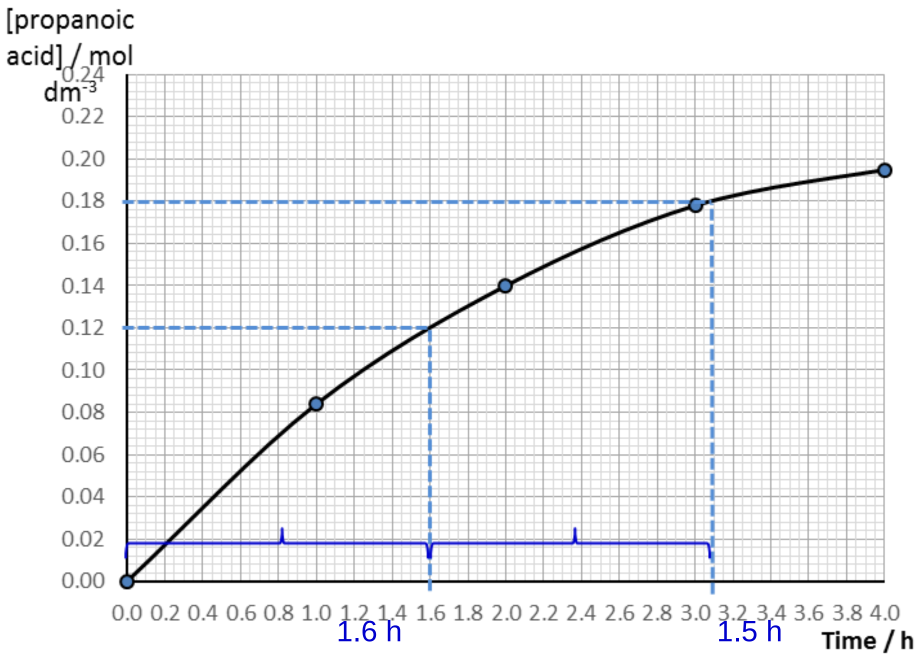
[Reactant]-time graph
Correct labelled axis and plotted points: 1m; Show at least 2 $t_{1/2}$: 1m; Smooth curve: 1m



The **half life is constant** **[1]** hence it is first order with respect to the ester. **Accept : 1.45 h < $t_{1/2}$ < 1.75 h**

OR

[Product]-time graph



Assuming the reaction goes into completion, the 0.24 mol dm^{-3} of the ester would form 0.24 mol dm^{-3} of propanoic acid.
The first half-life of a product-time graph would be the time taken to form half the total amount of propanic acid (0.12 mol dm^{-3}) and the time subsequently taken to form 3/4 of the total amount of propanoic acid (0.18 mol dm^{-3}).

(b) The ester, ethyl propanoate, can also undergo base hydrolysis and the reaction is monitored using the initial rates method. The initial rate of the hydrolysis reaction between the ester and NaOH(aq) was measured in three separate experiments at a constant temperature.

The results are obtained below:

Experiment	Temperature / °C	Initial [NaOH] / mol dm^{-3}	Initial [ester] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	T_1	0.020	0.015	2.70 x 10^{-3}
2	T_1	0.030	0.015	4.05 x 10^{-3}
3	T_1	0.060	0.020	$\boldsymbol{r_1}$
4	T_2	0.120	0.020	4.32 x 10^{-2}

(i) Deduce the order of reaction with respect to NaOH. [2]

Comparing expt 1 and 2, when **[OH$^-$]** increased **1.5 times** while keeping **[ester] constant**, **initial rate increased 1.5 times**. **[1]**

Hence, **order of reaction wrt [OH$^-$]** is **1**. **[1]**

(ii) Given that the reaction is first order with respect to the ester, calculate the initial rate of reaction, $\boldsymbol{r_1}$, for Experiment 3. [1]

rate = k [NaOH] [ester]

Comparing expts 2 and 3,

$$\frac{r_1}{4.05\times10^{-3}} = \frac{k(0.06)(0.02)}{k(0.03)(0.015)}$$

r_1 = **0.0108** mol dm^{-3} s^{-1} **[1] allow ecf**

(iii) Calculate the value of the rate constant in experiment 1 and experiment 4, specifying the correct unit. Hence, deduce whether T_1 or T_2 is higher. [3]

For experiment 1: 2.70 x 10^{-3}= k (0.020) (0.015)

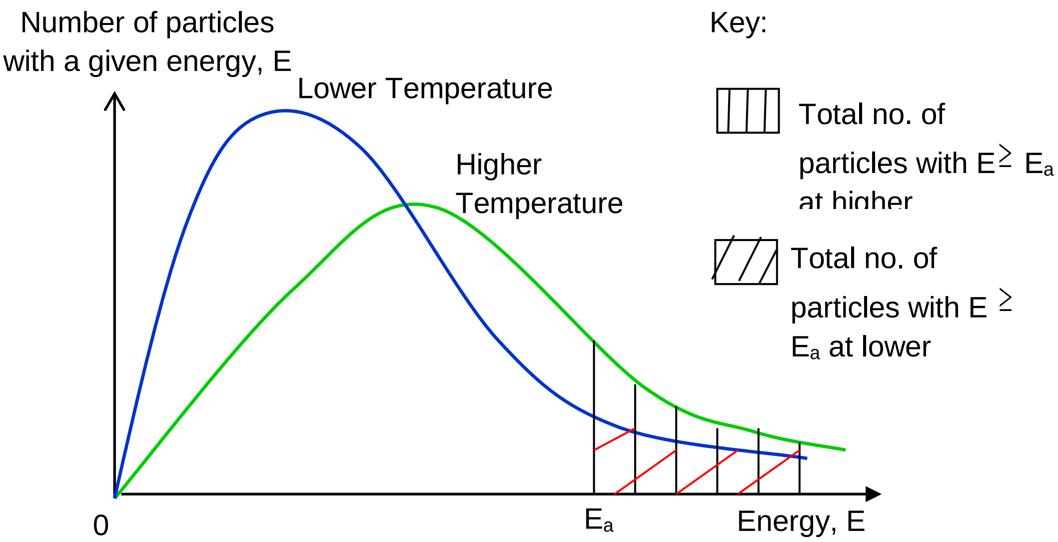
k = 9 mol^{-1}dm^{3} s^{-1} **[1] allow ecf**

For experiment 2: 4.32 x 10^{-2}= k (0.120) (0.020)

k = 18 mol^{-1}dm^{3} s^{-1} **[1] allow ecf**

T_2 is higher **[1]** as the rate constant for Experiment **4** is **larger** than that of Experiment **1**. **Increasing the temperature increases the value of the rate constant.**

(iv) Draw the Maxwell-Boltzmann distribution curve, explain how the increase in temperature increases the rate of reaction. [3]
Marking point: [Any 2 mistakes minus 1m]



-Correctly labelled axis & orgin
-Correctly labelled curve & E_a
-Correct legend & shading

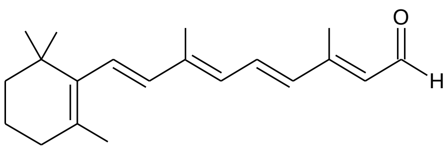
When temperature of the reaction increases,

- **average kinetic energy** of the reactant particles **increases**
- **more reactant particles with energy ≥ E_a** **[1]**
- **more effective collisions**
- Since **rate of reaction** is proportional to the **frequency of effective collisions**, **rate** of reaction **increases** **[1]**

[Total: 15]

3 This question revolves around carbonyl compounds involved in biological applications in living things.

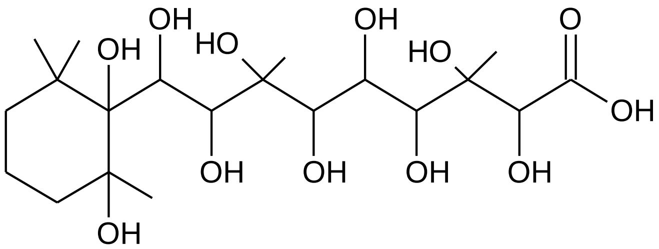
(a) Retinal is one of the many forms of vitamin A, bound to proteins called opsins. It is the chemical basis of vision in animals and humans as well as allowing certain microorganisms to convert light into metabolic energy.



Retinal

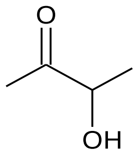
(i) State the number of geometrical isomers for retinal. [1]
2^4 = **16 isomers** **[1]**

(ii) Draw all the organic products formed when retinal is reacted with cold acidified potassium manganate(VII). [1]



[1]

(b) Acetoin is a colorless or pale yellow liquid with a pleasant buttery odour. It is a neutral, four-carbon molecule used as an external energy store by a number of fermentive bacteria.



Acetoin

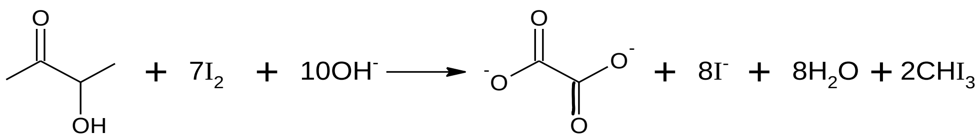
(i) Suggest a chemical test to **positively** distinguish acetoin from retinal, including relevant chemical equations. [3]

Test:

Add **aqueous iodine and sodium hydroxide to both samples and heat**. **[1]**

Observation:

Acetoin would **decolourise the brown iodine solution** and **yellow precipitate** of tri-iodomethane would be formed, but retinal **no decolourisation and no yellow ppt**. **[1]**



[1]

(ii) Compound **F** is an isomer of acetoin and contains an aldehyde and a tertiary alcohol. **F** was reacted in a sequential procedure as shown below.

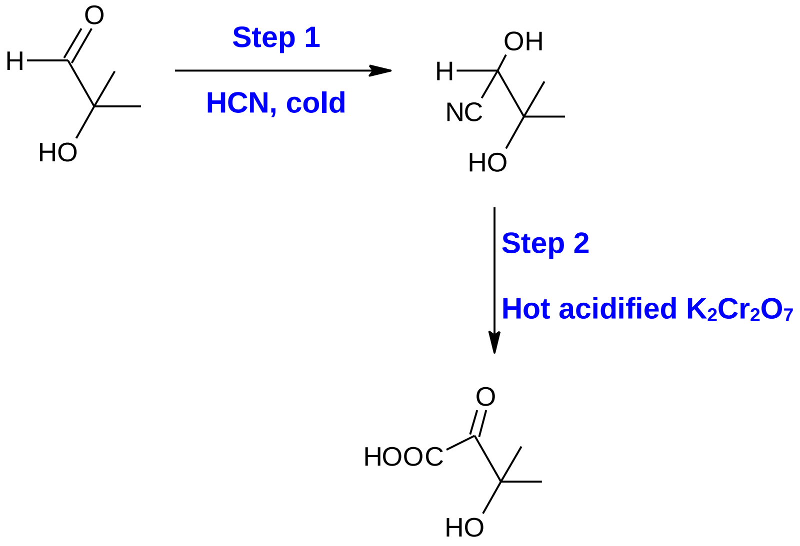
Step 1:
It is reacted with aqueous hydrogen cyanide at low temperatures.

Step 2:
Hot acidified potassium dichromate(VI) added to product formed earlier

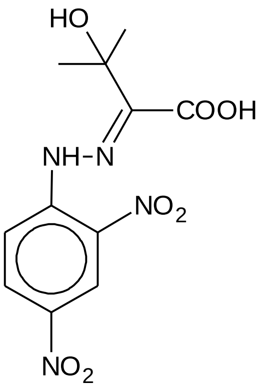
Step 3:
2,4-dinitrophenylhydrazine added to product formed in step 2 to form compound **G**.

Draw the structures of compounds **F** and **G** and state the types of reactions taken place. [5]

F [1]



G:



[1]

Step 1: **Nucleophilic Addition**
Step 2: **Oxidation and acidic hydrolysis**
Step 3: **Condensation** **[1 each]**

[Total: 10]

Section B

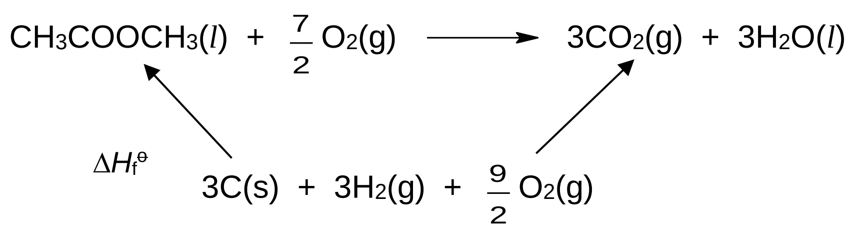
Answer **two** questions from this section on separate answer paper.

1 (a) (i) Define standard enthalpy change of formation. [1]

Standard enthalpy change of formation ($\Delta H_f^\ominus$) of a substance is the **energy change** when ***one mole*** of the **substance** is formed from its **elements** under **standard conditions**. **[1]**

(ii) Use the energy cycle below and the standard enthalpy changes of combustion, $\Delta H_c^\ominus$, in the table to calculate the standard enthalpy change of formation, $\Delta H_f^\ominus$, of methyl ethanoate, CH_3COOCH_3. [2]

	$\Delta H_c^\ominus$ / kJ mol^{-1}
carbon	–393.5
hydrogen	–285.8
methyl ethanoate	–1592.1



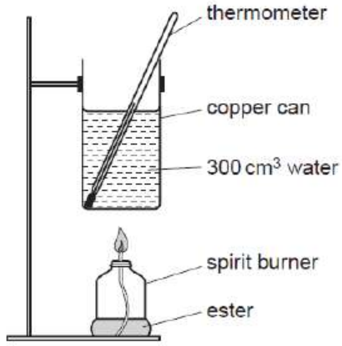
By Hess's law,

$\Delta H_f^\ominus(CH_3COOCH_3) = \mathbf{3}\Delta H_f^\ominus(CO_2) + \mathbf{3}\Delta H_f^\ominus(H_2O) - \Delta H_c^\ominus(CH_3COOCH_3)$

$= 3(-393.5) + 3(-285.8) - (-1592.1)$ **[M1]**

$= -445.8 \approx$ **-446 kJ mol^{-1}** **[1]**

(b) A student used the apparatus shown to carry out experiments to determine the standard enthalpy change of combustion of methyl ethanoate, CH_3COOCH_3.



Mass of copper can = 250 g

An initial experiment was carried out using methyl ethanoate. This ester was burnt in a spirit burner underneath a copper can so that the flame from the burner heated 300 cm^3 of water in the can. It was found that 0.980 g of ester was required to raise the temperature of the water in the can by 10.0 °C.

(i) Calculate the heat gain by the water given that the specific heat capacity of water is 4.18 J g^{-1} K^{-1}. Take the density of water to be 1.00 g cm^{-3}. [1]

Heat energy gained by water = (300)(4.18)(10)
= **12540 J** **[1]**

(ii) Given that the **total** heat energy gain is 13.5 kJ, calculate the specific heat capacity of the copper can used in this experiment. [2]

Heat energy gained by copper can = 13500- 12540
= **960 J** **[1]**

Specific heat capacity of copper can= $\frac{960}{(250)(10)}$ = **0.384 J g^{-1} K^{-1}** **[1]**

(iii) Using the $\Delta H_c^\ominus$ of methyl ethanoate given in the table of part **(a)**, calculate the total theoretical heat energy **in kJ** released by the mass of methyl ethanoate burnt in this experiment. [2]

n(methyl ethanoate) = $\frac{0.98}{74.0}$ = **0.01324 mol** **[1]**

Heat energy released = 0.01324 x 1592.1 = **21.1 kJ** **[1]**

(iv) Calculate the percentage efficiency of heat transfer in this experiment and suggest a reason for this value. [2]

Percentage efficiency of heat transfer = $\frac{13500}{21100}$ x 100 % = **64.0 %** **[1]**

Heat loss to surroundings/ Room temperature was not constant. **[1]**

(c) Methane is used to produce synthesis gas (syngas), a mixture that includes carbon monoxide and hydrogen, by reacting with steam on a nickel catalyst in a 2 dm^3 vessel. Syngas is then used to produce liquid hydrocarbons and methanol.

$$CH_4\,(g) + H_2O\,(g) \rightleftharpoons CO\,(g) + 3H_2\,(g) \qquad \Delta H > 0$$

The equilibrium mixture was found to contain 1 mole of methane, 1 mole of steam, 1.5 moles of carbon monoxide and 4.5 moles of hydrogen gas.

(i) State Le Chatelier's Principle. [1]

Le Chatelier's Principle states that when a system in equilibrium is disturbed, the **system will react to counteract the change imposed** so as to **re-establish the equilibrium**. **[1]**

(ii) Write an expression for the equilibrium constant, K_c and determine its value, including units. [2]

$$K_c = \frac{[CO][H_2]^3}{[CH_4][H_2O]} = \frac{\left(\frac{1.5}{2}\right)\left(\frac{4.5}{2}\right)^3}{\frac{1}{2}\left(\frac{1}{2}\right)}$$ = **34.2** **[1]** **mol² dm⁻⁶** **[1]**

(iii) Define the term *endothermic reaction*. [1]

Endothermic means that ***heat/energy*** **is** **absorbed/** **[1]** from the surrounding / **required** to take place.

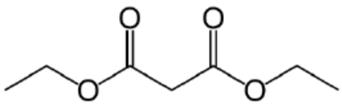
(iv) With reference to the above equilibrium, predict and explain the effect of **separately** increasing pressure and decreasing temperature on the position of equilibrium, yield and K_c. [6]

On increasing the pressure, by Le Chatelier's Principle, the **position of equilibrium will shift to the left to reduce the total number of moles of gas.** **[1]** **Yield decreases**. **[1]** **K_c remained unchanged** as it is **temperature dependent**. **[1]**

On decreasing the temperature, by Le Chatelier's Principle, the **position of equilibrium will shift to the left towards the exothermic reaction to release heat.** **[1]** **Yield decreased.** **[1]** **K_c decreased.** **[1]**

[Total : 20]

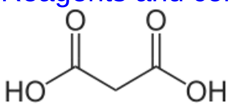
2 Diethyl malonate, also known as DEM exist as a colourless liquid, commonly used in the manufacture of perfumes, artificial flavourings and vitamins. The structure of diethyl malonate is shown below.



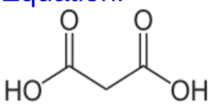
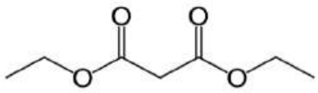
diethyl malonate

(a) **(i)** Diethyl malonate is synthesised from the esterification of malonic acid and an alcohol. Draw the structure of malonic acid and state the reagents and conditions required for this process. Write a balanced chemical equation for this synthesis. [3]

Reagents and conditions: **conc H_2SO_4, heat**. **[1]**

 **[1]**

Equation:

 $+ 2\ CH_3CH_2OH \rightleftharpoons$  $+ 2\ H_2O$ **[1]**

(ii) State the number of moles of H_2 gas produced per mole of malonic acid with Mg. [1]

1 **[1]**

(b) 7.0 grams of malonic acid was dissolved in 250 cm^3 of distilled water. The following titration curve was obtained when 25 cm^3 of this solution was titrated against 0.40 mol dm^{-3} potassium hydroxide.

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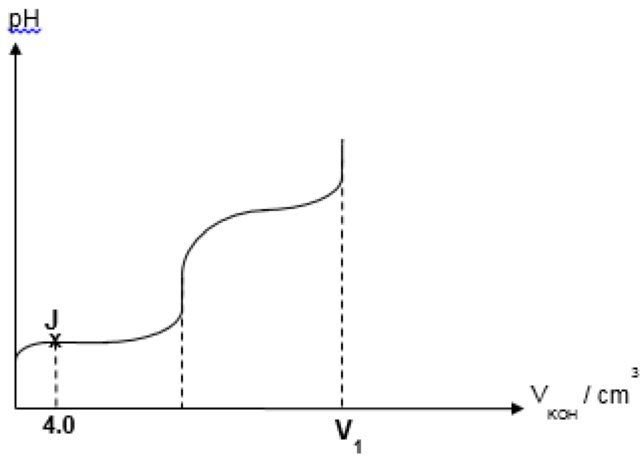


The dissociation of malonic acid (H_2A) can be regarded as follows.

$H_2A \rightleftharpoons HA^- + H^+$ $\quad K_{a1} = 1.479 \times 10^{-3}$
$HA^- \rightleftharpoons A^{2-} + H^+$ $\quad K_{a2} = 2.042 \times 10^{-6}$

(i) Suggest why K_{a2} is much smaller than K_{a1}. [1]

It is **more difficult to remove** a second positively charged **proton** from a **negatively charged anion** in the second dissociation as compared to the first dissociation from a **neutral molecule**. **[1]**

OR

The **'second' acidic proton** in the COOH group is **held more tightly** by the monoanion via **intramolecular hydrogen bonding**, resulting in a /**very stable monoanion**. This stabilisation effect also explains why the second K_a of these 2 acids is significantly smaller as the second acid proton will not be dissociated easily.

(ii) Write an expression for K_{a1} stating its units. [2]

$$K_{a1} = \frac{[HA^-][H^+]}{[H_2A]}$$ **[1]**

$mol dm^{-3}$ **[1]**

(iii) Ignoring the effects of K_{a2}, hence, or otherwise, calculate the initial pH of the solution. [2]

n_{H_2A} in 250 $cm^3 = \frac{7.0}{104} = 0.06731$ mol

$[H_2A] = \frac{0.06731}{\frac{250}{1000}} =$ **0.2692 $moldm^{-3}$** **[1]**

$[H^+] = \sqrt{K_a \times [H2A]} = \sqrt{1.479 \times 10^{-3} \times 0.2692} = 0.01996$ mol dm^{-3}

pH = – lg $[H^+]$ = **1.70** **[A1]**

(iv) Calculate the volume of KOH, V_1, required to completely neutralise malonic acid in 25 cm^3 of solution. [1]

$n_{\text{malonic acid}}$ in 25 $cm^3 = \frac{0.06731}{10} = 0.006731$ mol

V_{KOH} required for **complete neutralisation, V_1**

$= \frac{0.006731}{0.40} \times 2 = 0.033653\ dm^3$ = **33.7 cm^3** **[1] with ecf**

(v) Explain what it means to be a buffer solution. [1]

It is the **buffer** which is able to **resist pH change/maintain a fairly constant pH** when a **small amount** of acid or base is added to. **[1]**

(vi) The pH of a buffer solution can be determined by the following equation.

$$pH = -\lg K_a + \lg \frac{[\text{conjugate base}]}{[\text{acid}]}$$

Identify the species present at point **J**. Calculate the amount of malonic acid remaining, and use the above equation to calculate the pH. [3]

Species present: **H_2A and HA^-** **[1] ignore H_2O**
n_{NaOH} = 4.0/1000 x 0.4 = 1.60 x 10^{-3}
nH_2A = (0.006731 – 1.60 x 10^{-3}) = **0.005131 mol** **[1]**

nHA^- = (1.60 x 10^{-3})

$pH = -\lg 1.479 \times 10^{-3} + \lg \frac{\frac{[0.00160]}{V}}{\frac{[0.005131]}{V}}$ = **2.32** **[1] ecf**

(vii) The pH at the second end point is more than 7. Explain this observation with the aid of relevant equations. [2]

Only A^{2-} and water is present at the second end-point.
$A^{2-} + H_2O \rightleftharpoons HA^- + OH^-$ **[1]**
A^{2-} undergoes **salt hydrolysis to produce OH^-** **[1]** ions. Hence pH > 7.

(c) Account for the relative acidities of ethanoic acid, ethanol and fluoroethanoic acid. [4]

Acid strength: **ethanol < ethanoic acid < fluoroethanoic acid [1]**

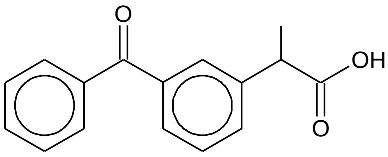
The **electron-donating R group** on ethanol **intensifies the negative charge on the carboxylate anion** hence **destabilising the ethoxide anion relative to the acid.** Hence, ethanol is the weakest acid. **[1]**

The carboxylate anion ($RCOO^-$) is **resonance stabilised** by the **delocalisation of the negative charge over the C atom and both oxygen atoms** in **ethanoic and fluoroethanoic** anion, hence stabilising the carboxylate anion relative to acid. Hence, both carboxylic acids are stronger acids then ethanol. **[1]**

The electron-withdrawing fluoro group **disperses the negative charge** on the fluoroethanoic anion hence **stabilises the carboxylate anion relative to the acid. Fluoroethanoic acid is a stronger acid then ethanoic acid.** **[1]**

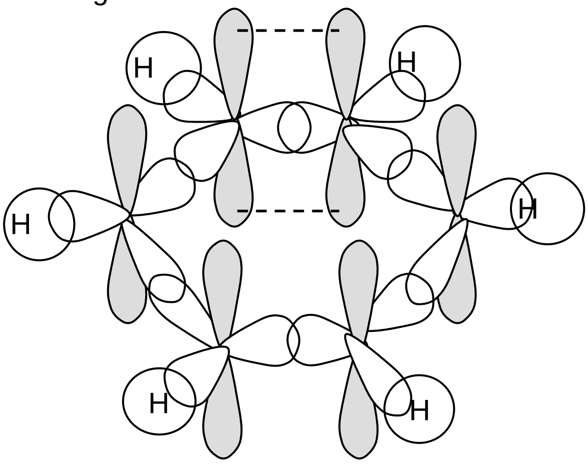
[Total: 20]

3 Ketoprofen, is one of the propionic acid class of nonsteroidal anti-inflammatory drugs (NSAID) with analgesic and antipyretic effects. It is generally prescribed for arthritis-related inflammatory pains or severe toothaches that result in the inflammation of the gums.



Ketoprofen

(a) Describe the bonding in benzene in terms of orbital overlap, illustrating your answer with a suitable diagram. [3]

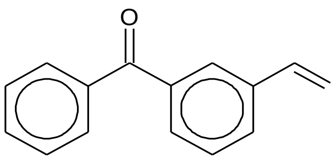


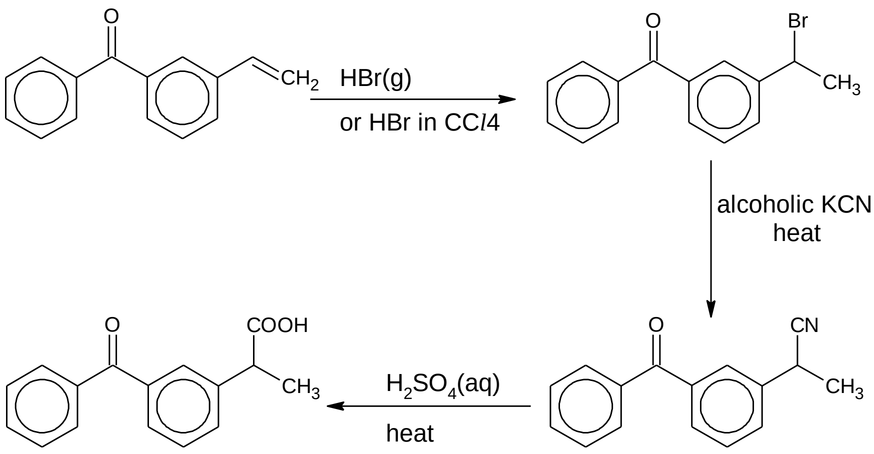
[1] for correct diagram

The carbon atoms in benzene are **<u>sp^2 hybridised</u>** forms **<u>3 σ bonds with 2 adjacent C and 1 H via head on overlap.</u>** making the molecule **<u>planar</u>** in shape**.** **[1]**

The **<u>p-orbitals</u>** overlaps with its **<u>adjacent p-orbitals</u>** via **<u>side on overlap</u>**, forming **<u>π bonds.</u>** **[1]**

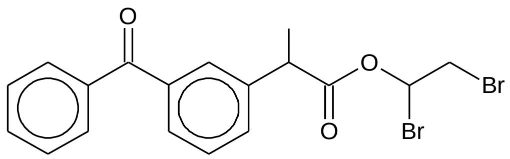
(b) Propose a synthetic pathway for the formation of ketoprofen from the structure below. [3]





[1] for logical sequence of steps
[1] for all reagents and conditions correct
[1] for all correct intermediates drawn

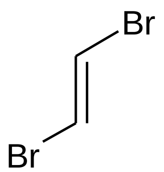
(c) Ketoprofen is reacted with an alcohol and forms an ester as shown.



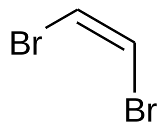
(i) Name the alcohol used in forming the ester. [1]

1,2−dibromoethanol **[1]**

(ii) The alcohol was heated in the presence of aluminum oxide. Draw the structures of the two isomeric products formed and name them accordingly. [2]



trans−1,2−dibromoethene



cis−1,2−dibromoethene

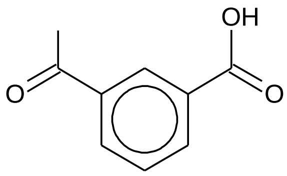
[1] for each correct structure + name

(iii) Predict the relative boiling points of the products formed, giving reasons for your answer. [1]

Both are simple molecular structures, but **cis−1,2−dibromoethene is polar with stronger intermolecular permanent dipole permanent dipole interactions which requires more energy to overcome than the weaker intermolecular instantaneous dipole induced dipole interactions in the non polar trans−1,2−dibromoethene**.

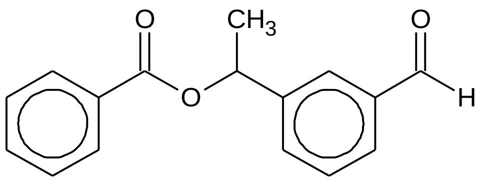
Hence trans−1,2−dibromoethene has a **lower boiling point** than cis−1,2−dibromoethene. **[1]**

(d) Compound **K**, a sweet smelling liquid, is an isomer of ketoprofen. Upon heating **K** with dilute sulfuric acid, compound **L** and benzoic acid are produced. Compound **L** is an alcohol which also produces a silver mirror with Tollens' reagent and a blue solution with Fehling's solution. It also reacts with hot acidified potassium dichromate(VI) to form compound **M** as shown below.

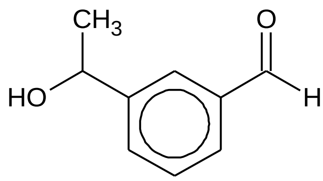


Compound **M**

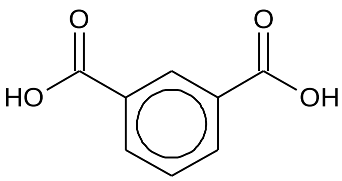
Compound **L** reacts with hot acidified potassium manganate(VII) to form carbon dioxide and compound **N** which will subsequently react with liquid bromine and anhydrous aluminium bromide solid to form compound **O**.
Deduce, with reasoning, the structures for compounds **K**, **L**, **N** and **O.** [10]



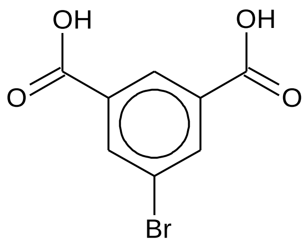
K



L



N



O

[1] each for each structure

Compound **K** undergoes **acidic hydrolysis** to form **L** and benzoic acid
⇒ **K** is an **ester** **[1]**

Compound **L** is **oxidised** by Tollens' reagent but not Fehling's solution
⇒ **L** contains **aromatic aldehyde** **[1]**

Compound **L** reacted with $K_2Cr_2O_7$ to form **M**
⇒ **aldehyde oxidised** to **carboxylic acid** **[1]**
⇒ **secondary alcohol oxidised** to **ketone** **[1]**

Compound **L** reacted with $KMnO_4$ to form **N**
⇒ **aldehyde oxidised** to **carboxylic acid** **[1]**
⇒ **sidechain oxidised** to **carboxylic acid** **[1]**

Compound **N** undergoes **electrophilic substitution** with Br_2 to form **O**
⇒ **O** is a **bromoarene** **[1]**

Statements max 6 out of 7 marks

[Total: 20]

END OF PAPER

Name:		Class:	

ST ANDREW'S JUNIOR COLLEGE

JC2 Preliminary Examinations

Chemistry	**8872/1**
Higher 1	**18 Sep 2017**
Paper 1	**1300 – 1350**

Candidates answer on separate paper.

Additional Materials: Writing paper, Data Booklet, OAS

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
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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 **12** pages including a blank page.

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Section A

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

1 How many carbon atoms are present in 4.0 g of ethanoic acid? [L = Avogradro constant]

A L/12

B L/15

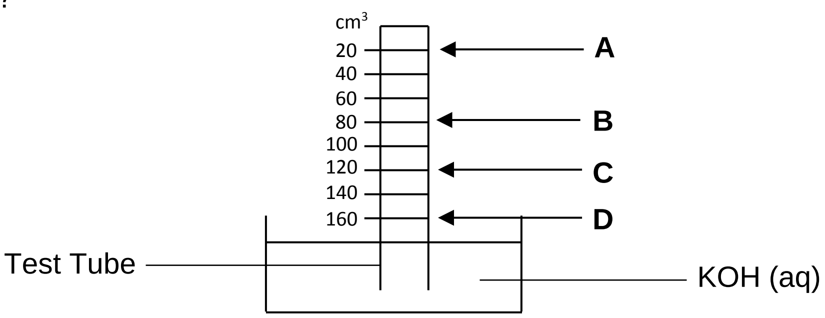
C 2L/15

D 2/15L

2 A test tube is filled with 20 cm^3 of propane and 160 cm^3 of oxygen at room temperature. The open end of the test tube is placed in a beaker of KOH (aq) as shown. The gas mixture was sparked according to the following reaction.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

What will be the final level of liquid in the test tube after it has cooled back to room temperature?



3 A sample containing ammonium sulfate (M_r = 132) was warmed with 100 cm^3 of 0.500 mol dm^{-3} sodium hydroxide. When the evolution of ammonia ceased, the excess sodium hydroxide solution was neutralised with 25.00 cm^3 of 0.500 mol dm^{-3} hydrochloric acid. What was the mass of ammonium sulfate in the sample?

A 2.48 g

B 4.95 g

C 6.60 g

D 13.20 g

4 Which of the following ions has two more electrons in the third quantum shell than in the second quantum shell?

A Ca^{2+}

B K^{+}

C Ti^{+}

D V^{2+}

5 Which of the following ions would be deflected in an electric field to the same extent as CO^{+} under the same conditions?

A OF^{-}

B Ca^{2+}

C OH^{-}

D BeF^{+}

6 Which of the following sets of compounds consists of a simple molecular structure, giant ionic structure and giant molecular structure?

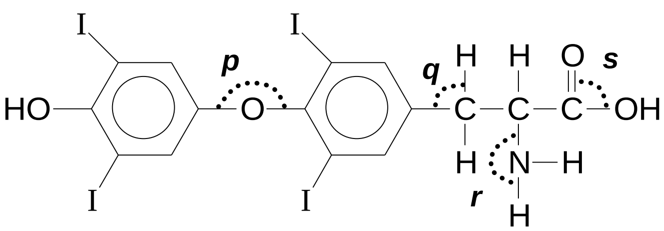
A SiO_2, HBr, $BeCl_2$

B $SiCl_4$, AlF_3, $C_{(graphite)}$

C SrO, ICl_3, $SnCl_2$

D $C_6H_5CO_2H$, P_4O_{10}, SiO_2

7 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***, ***r*** and ***s***?

	p	***q***	***r***	***s***
A	180°	90°	180°	90°
B	105°	90°	107°	180°
C	180°	90°	120°	180°
D	105°	109.5°	107°	120°

8 Which of the following reactions can the bond energy of the Si–C*l* bond be determined by using the standard enthalpy change of the reaction?

A $SiCl_4\ (l) \rightarrow SiCl_4\ (g)$

B $SiCl_4\ (g) \rightarrow Si\ (g) + 4Cl\ (g)$

C $SiCl_4\ (g) \rightarrow SiCl_2\ (g) + Cl_2\ (g)$

D $2Cl_2\ (g) + Si\ (s) \rightarrow SiCl_4\ (g)$

9 Which of the following shows the sequence of the magnitude of lattice energies of the following compounds in ascending order?

I NaC*l*

II RbC*l*

III MgS

IV BaS

A I, II, III, IV

B II, I, IV, III

C III, IV, I, II

D IV, III, II, I

10 The table below shows the standard enthalpy change of neutralisation, ΔH, for the various acids and bases listed.

Acid	**Base**	**ΔH / kJ mol^{-1}**
hydrobromic acid	sodium hydroxide	–57.0
P	sodium hydroxide	less exothermic than –57.0
hydrofluoric acid	potassium hydroxide	less exothermic than –57.0
Q	potassium hydroxide	–57.0

What could be **P** and **Q**?

	P	**Q**
A	hydrochloric acid	nitric acid
B	ethanoic acid	hydrofluoric acid
C	hydrogen cyanide	ethanoic acid
D	ethanoic acid	hydrobromic acid

11 A chemical plant illegally dumped two radioactive isotopes **P** and **Q** in a landfill. The amount of **P** is 4 times the amount of **Q**. The radioactive decay of isotopes follows first-order kinetics. The half-life of **P** is 2 days whereas that of **Q** is 8 days. By the time the authorities found out about this illegal dumping and analysed a sample of the waste, the ratio of **P** to **Q** was found to be **1**:**2**. How long was the waste in the landfill before the authorities arrived?

A 8 days

B 16 days

C 32 days

D 64 days

12 The table below gives data for the reaction between **A** and **B** at a constant temperature.

Experiment	**[A] / mol dm^{-3}**	**[B] / mol dm^{-3}**	**Initial rate / mol dm^{-3} s^{-1}**
1	0.3	0.2	4.0 x 10^{-4}
2	0.6	0.2	4.0 x 10^{-4}
3	0.6	0.8	6.4 x 10^{-3}

Which of the following correctly represents the units of the rate constant, *k,* in the rate equation?

A mol^{-1} dm^{3} s^{-1}

B mol dm^{-3} s^{-1}

C mol s^{-1}

D s^{-1}

13 At 298 K, 0.20 mol dm^{-3} of propanone reacts with 0.30 mol dm^{-3} of methanol to form 0.04 mol dm^{-3} of acetal as shown below.

$$CH_3COCH_3\ (l)\ +\ 2CH_3OH\ (l) \xrightleftharpoons{H^+} \underset{\text{acetal}}{CH_3C(OCH_3)_2CH_3\ (l)}\ +\ H_2O\ (l)$$

What is the equilibrium constant of the reaction at 298 K?

A 0.0385

B 0.0455

C 0.148

D 0.207

14 Fe^{3+} and SCN^{-} react in a closed system to give the complex, $[Fe(SCN)]^{2+}$, which is blood-red in colour.

$Fe^{3+}\ (aq) + SCN^{-}\ (aq) \rightleftharpoons [Fe(SCN)]^{2+}\ (aq)$ $\Delta H < 0$

Which one of the following changes will result in the solution turning pale red?

A Increase the concentration of SCN^{-}

B Decrease the pressure of the system

C Decrease the temperature of the system

D Add a small amount of dilute NaOH to the resulting mixture

15 A mixture was made by adding 10 cm^3 of a solution of pH 1 to 30 cm^3 of another solution of pH 5. What is the final pH of the mixture?

A 1.6

B 2.5

C 3.0

D 4.0

16 Which of the following is a general trend from left to right of the elements in the third period of the Periodic Table?

A The radii of the atoms increase.

B The melting points of the chlorides decrease.

C The electrical conductivity of the elements decrease.

D The first ionisation energies of the elements increase.

17 Which element has a chloride with a simple molecular structure that is readily hydrolysed in water?

A sodium

B magnesium

C aluminium

D silicon

18 Which property decreases from Na_2O to P_4O_{10} for the oxides of period 3 elements?

A melting point

B covalent character

C solubility in aqueous alkali

D pH when mixed with water

19 Linoleic acid is an essential fatty acid with the structural formula.

$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7CO_2H$

Which of the following statements about linoleic acid is correct?

A It undergoes electrophilic substitution with liquid bromine.

B It undergoes oxidation with acidified potassium dichromate(VI) solution.

C 1 mole of linoleic acid requires 48 dm^3 of hydrogen for hydrogenation at room temperature.

D 1 mole of linoleic acid reacts with 1 mole of sodium carbonate to form 24 dm^3 of carbon dioxide at room temperature.

20 Which property of benzene is reflected as a consequence of the delocalised electrons in its molecule?

A Benzene is a planar molecule.

B Benzene is a good conductor of electricity.

C Substitution in benzene takes place at a carbon atom.

D Addition reactions of benzene take place more easily than substitution.

21 The volatile liquid, fluothane, $CF_3CHBrCl$, is a widely used anaesthetic.

Which statement about fluothane is **incorrect**?

A It has a simple molecular structure.

B It may cause depletion of ozone layer.

C It may undergo substitution with chlorine.

D It can form hydrogen bonds between its molecules.

22 A compound **V** gives yellow precipitate with alkaline aqueous iodine. One mole of **V** liberates one mole of hydrogen when it reacts with excess sodium.

What could be the formula of **V**?

A $CH_3CH(OH)CHO$

B $CH_3CH(OH)CO_2H$

C $HOCH_2CH_2CO_2H$

D $HOCH_2CH(CH_3)CH_2OH$

23 A compound, **W**, has the following properties.

- It reacts with hydrogen in the presence of nickel catalyst.
- It reacts with phosphorus pentachloride to give off HC*l* fumes.
- It reacts with sodium hydroxide to form an ionic compound.
- It reacts with ethanol.

What formula could represent **W**?

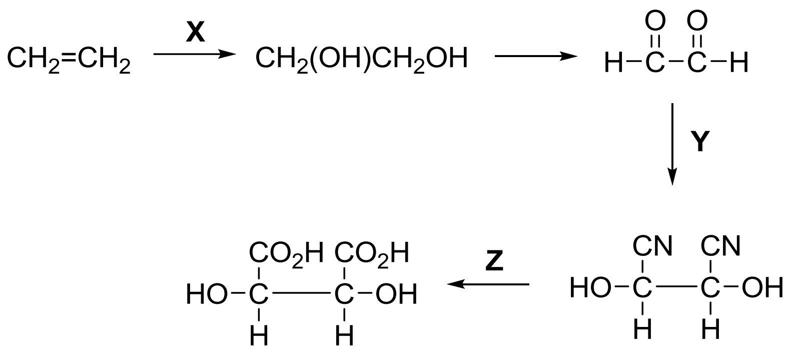
A CH_3CHO

B CH_3COCH_3

C $CH_2{=}CHCO_2H$

D $CH_2{=}CHCH_2OH$

24 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?

	X	Y	Z
A	cold concentrated H_2SO_4, followed by boiling H_2O	cold HCN, NaOH(aq)	hot $K_2Cr_2O_7$, H_2SO_4(aq)
B	cold $KMnO_4$, H_2SO_4(aq)	cold HCN, NaOH(aq)	HC*l*(aq), heat
C	cold concentrated H_2SO_4, followed by boiling H_2O	ethanolic KCN, heat	hot $K_2Cr_2O_7$, H_2SO_4(aq)
D	cold $KMnO_4$, NaOH(aq)	ethanolic KCN, heat	HC*l*(aq), heat

25 Which of the following shows the descending order of acid strength?

A CH_3CO_2H > CH_2ClCO_2H > CH_3CH_2OH

B CH_3CH_2OH > CH_2ClCO_2H > CH_3CO_2H

C CH_2ClCO_2H > CH_2FCO_2H > CH_3CH_2OH

D CH_2ClCO_2H > CH_2BrCO_2H > CH_3CO_2H

Section B

For each of the following questions, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 Materials are insulators when the outer shells of electrons of all the constituent particles are completely filled and there is a considerable energy gap before the next unoccupied shell.

Which compounds have completely filled shells and might therefore act as insulators?

1 MgO

2 SiO_2

3 SiC (diamond structure)

27 Calcium reacts with water to form calcium hydroxide and hydrogen.

$Ca(s) + 2H_2O\,(l) \rightarrow Ca(OH)_2\,(s) + H_2\,(g)$

The standard enthalpy change for this reaction can be determined experimentally.

What further information are needed to calculate the standard enthalpy change of formation of calcium hydroxide, $\Delta H_f^{\ominus}$?

1 $\Delta H_f^{\ominus}$ for $H_2O(l)$

2 $\Delta H_f^{\ominus}$ for $H_2(g)$

3 First and second ionisation energies for Ca

28 Which of the following pairs would form an acidic buffer when mixed together?

1 CH_3CO_2H and NaC*l*

2 HCN and KCN

3 $C_6H_5CO_2H$ and $(C_6H_5CO_2)_2Ca$

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

29 A halogenoalkane has the formula of $C_3H_5Cl_3$.

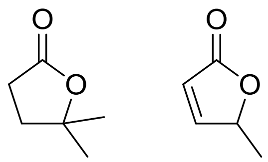
Which of the isomers have the correct IUPAC name?

1 1,1,1-trichloropropane

2 1,2,2-trichloropropane

3 2,2,3-trichloropropane

30 Below are the structures of compounds **X** and **Y**.



X **Y**

Which sets of reagents and conditions can be used to distinguish between them?

1 aqueous bromine

2 acidified $K_2Cr_2O_7$, heat

3 alkaline aqueous iodine, heat

--- End of Paper ---

Name:		Class:	

ST ANDREW'S JUNIOR COLLEGE

JC2 Preliminary Examinations

Chemistry **8872/1**

Higher 1 **18 Sep 2017**

Paper 1 **1300 − 1350**

Candidates answer on separate paper.

Additional Materials: Writing paper, Data Booklet, OAS

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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 **12** printed pages including this page.

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Section A

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

1 How many carbon atoms are present in 4.0 g of ethanoic acid? [L = Avogradro constant]

A L/12

B L/15

C 2L/15

D 2/15L

Mr of ethanoic acid (CH_3COOH) = (12.0 x 2) + (1.0 x 4) + (16.0 x 2) = 60.0

Amount of ethanoic acid = 4.0 / 60.0

Amount of carbon present = 2 x 4 / 60 = 2 /15

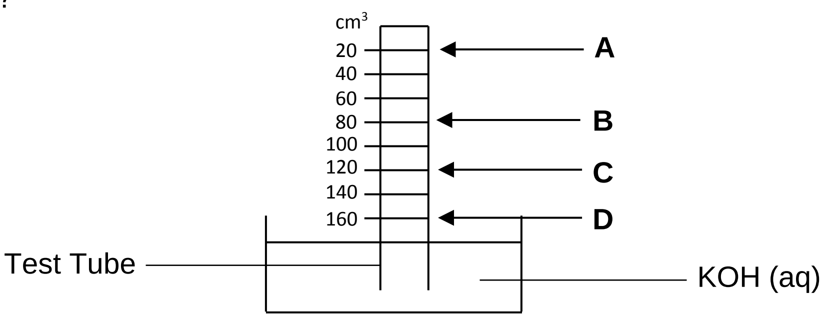
No. of C atoms = (2 / 15) x L = 2L / 15

Ans: (C)

2 A test tube is filled with 20 cm^3 of propane and 160 cm^3 of oxygen at room temperature. The open end of the test tube is placed in a beaker of KOH (aq) as shown. The gas mixture was sparked according to the following reaction.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

What will be the final level of liquid in the test tube after it has cooled back to room temperature?



Volume of O_2 used = 100 cm^3

Volume of CO_2 formed = 60 cm^3

Volume of O_2 remained = 160 - 100 = 60 cm^3

Final volume of gas = vol of CO_2 + vol of O_2 remained = 60 + 60 = 120cm^3

Ans: (C)

3 A sample containing ammonium sulfate (M_r = 132) was warmed with 100 cm^3 of 0.500 mol dm^{-3} sodium hydroxide. When the evolution of ammonia ceased, the excess sodium hydroxide solution was neutralised with 25.00 cm^3 of 0.500 mol dm^{-3} hydrochloric acid. What was the mass of ammonium sulfate in the sample?

A 2.48 g

B 4.95 g

C 6.60 g

D 13.20 g

$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$

Volume of NaOH reacts with $(NH_4)_2SO_4$ = 100 - 25 = 75.00 cm^3

Amount of $(NH_4)_2SO_4$ present = ½ (75 / 1000 x 0.500) = 0.01875 mol

Mass of $(NH_4)_2SO_4$= 0.01875 x 132.1 =2.475 = 2.48 g

Ans: (A)

4 Which of the following ions has two more electrons in the third quantum shell than in the second quantum shell?

A Ca^{2+}

B K^+

C Ti^+

D V^{2+}

$_{22}Ti$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$

Ti^+ : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^1$

Third quantum shell has 10 electrons, second quantum shell has 8 electrons.

Ans: (C)

5 Which of the following ions would be deflected in an electric field to the same extent as CO^+ under the same conditions?

A OF^-

B Ca^{2+}

C OH^-

D BeF^+

Angle of deflection α charge/mass

CO^+ = 1/ (12+16) = 1 / 28

BeF^+ = 1 / (9+19) = 1 / 28

Ans: (D)

6 Which of the following sets of compounds consists of a simple molecular structure, giant ionic structure and giant molecular structure?

A SiO_2, HBr, $BeCl_2$

B $SiCl_4$, AlF_3, $C_{(graphite)}$

C SrO, ICl_3, $SnCl_2$

D $C_6H_5CO_2H$, P_4O_{10}, SiO_2

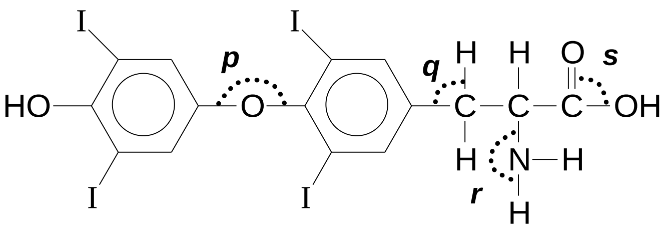
HBr, $BeCl_2$, ICl_3, $SiCl_4$, $C_6H_5CO_2H$, P_4O_{10} – simple molecular

SiO_2, $C_{(graphite)}$ – giant molecular

SrO, AlF_3, $SnCl_2$ – giant ionic

Ans: (B)

7 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***, ***r*** and ***s***?

	p	***q***	***r***	***s***
A	180°	90°	180°	90°
B	105°	90°	107°	180°
C	180°	90°	120°	180°
D	105°	109.5°	107°	120°

p – oxygen has 2 b.p, 2 *l*.p, bond angle = 105°

q – carbon has 4 b.p, no *l*.p, bond angle = 109.5°

r – nitrogen has 3 b.p, 1 *l*.p, bond angle = 107°

s – carbon has 3 b.p, no *l*.p, bond angle = 120°

Ans: (D)

8 Which of the following reactions can the bond energy of the Si–C*l* bond be determined by using the standard enthalpy change of the reaction?

A $SiCl_4 (l) \rightarrow SiCl_4 (g)$

B $SiCl_4 (g) \rightarrow Si (g) + 4Cl (g)$

C $SiCl_4 (g) \rightarrow SiCl_2 (g) + Cl_2 (g)$

D $2Cl_2 (g) + Si (s) \rightarrow SiCl_4 (g)$

ΔH for B = 4 x BE(Si-C*l*)

Ans: (B)

9 Which of the following shows the sequence of the magnitude of lattice energies of the following compounds in ascending order?

I NaC*l*

II RbC*l*

III MgS

IV BaS

A I, II, III, IV

B II, I, IV, III

C III, IV, I, II

D IV, III, II, I

$|\text{Lattice Energy}| \propto \left|\frac{q^+q^-}{r_+ + r_-}\right|$

MgS, BaS has a bigger q^+q^- than NaC*l* and RbC*l*.

Rb^+ has a bigger ionic radius than Na^+, hence RbC*l* has the smallest magnitude of L.E.

Mg^{2+} has a smaller ionic radius than Ba^{2+}, hence MgS has the largest magnitude of L.E.

Ans: (B)

10 The table below shows the standard enthalpy change of neutralisation, Δ*H*, for the various acids and bases listed.

Acid	Base	Δ*H* / kJ mol^{-1}
hydrobromic acid	sodium hydroxide	–57.0
P	sodium hydroxide	less exothermic than –57.0
hydrofluoric acid	potassium hydroxide	less exothermic than –57.0
Q	potassium hydroxide	–57.0

What could be **P** and **Q**?

	P	Q
A	hydrochloric acid	nitric acid
B	ethanoic acid	hydrofluoric acid
C	hydrogen cyanide	ethanoic acid
D	ethanoic acid	hydrobromic acid

Hydrobromic acid is a strong acid since it reacts with NaOH gives an enthalpy change of –57.0 kJ mol^{-1}. Hydrofluoric acid is a weak acid since it reacts with NaOH that gives an enthalpy change that is less exothermic than –57.0 kJ mol^{-1}. P must be a weak acid, ethanoic acid and Q must be a strong acid, hydrobromic acid.

Ans: (D)

11 A chemical plant illegally dumped two radioactive isotopes **P** and **Q** in a landfill. The amount of **P** is 4 times the amount of **Q**. The radioactive decay of isotopes follows first-order kinetics. The half-life of **P** is 2 days whereas that of **Q** is 8 days. By the time the authorities found out about this illegal dumping and analysed a sample of the waste, the ratio of **P** to **Q** was found to be **1**:**2**. How long was the waste in the landfill before the authorities arrived?

A 8 days

B 16 days

C 32 days

D 64 days

4P → 2P → 1P → 1/2 P → 1/4 P

= 4 half-lives = 4 x 2 = 8 days

Q → 1/2 Q = 1 half-lives = 1 x 8 = 8 days

Ratio of P : Q = 1/4: 1/2 = 1: 2

Ans : (A)

12 The table below gives data for the reaction between **A** and **B** at a constant temperature.

Experiment	**[A] / mol dm^{-3}**	**[B] / mol dm^{-3}**	**Initial rate / mol dm^{-3} s^{-1}**
1	0.3	0.2	4.0×10^{-4}
2	0.6	0.2	4.0×10^{-4}
3	0.6	0.8	6.4×10^{-3}

Which of the following correctly represents the units of the rate constant, *k,* in the rate equation?

A mol^{-1} dm^{3} s^{-1}

B mol dm^{-3} s^{-1}

C mol s^{-1}

D s^{-1}

Comparing between experiment 1 and 2, when [B] is constant, [A] x 2, rate is the same, therefore it is zero order with respect to [A].

Comparing between experiment 2 and 3, when [A] constant, [B] x 4, rate increases 16 times, therefore it is second order with respect to [B].

Rate = k $[B]^2$

mol dm^{-3} s^{-1}= k(mol dm^{-3})^2

k= mol^{-1} dm^{3} s^{-1}

Ans: (A)

13 At 298 K, 0.20 mol dm^{-3} of propanone reacts with 0.30 mol dm^{-3} of methanol to form 0.04 mol dm^{-3} of acetal as shown below.

$$CH_3COCH_3\,(l) + 2CH_3OH\,(l) \underset{}{\overset{H^+}{\rightleftharpoons}} \underset{\text{acetal}}{CH_3C(OCH_3)_2CH_3\,(l)} + H_2O\,(l)$$

What is the equilibrium constant of the reaction at 298 K?

A 0.0385

B 0.0455

C 0.148

D 0.207

	CH_3COCH_3 (*l*)	CH_3OH (*l*)	$CH_3C(OCH_3)_2CH_3$ (*l*)	H_2O (*l*)
Initial conc	0.20	0.30	0	0
Change in conc	0.20 – 0.04	0.30 – 2(0.04)	+0.04	+0.04
Equilibrium conc	0.16	0.22	0.04	0.04

$K_c = [CH_3C(OCH_3)_2CH_3]\,[H_2O]\,/\,[CH_3COCH_3]\,[CH_3OH]^2$

$= (0.04)^2 / [0.16 \times (0.22)^2]$

$= 0.207$ mol^{-1}dm^{3}

Ans: (D)

14 Fe^{3+} and SCN^- react in a closed system to give the complex, $[Fe(SCN)]^{2+}$, which is blood-red in colour.

$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons [Fe(SCN)]^{2+}(aq)$ $\Delta H < 0$

Which one of the following changes will result in the solution turning pale red?

A Increase the concentration of SCN^-

B Decrease the pressure of the system

C Decrease the temperature of the system

D Add a small amount of dilute NaOH to the resulting mixture

The NaOH added will react with Fe^{3+} to form $Fe(OH)_3$, causing $[Fe^{3+}]$ to be decreased. By L.C.P, position of equilibrium shift to the left to replenish the $[Fe^{3+}]$, hence the colour becomes less blood-red.

Ans: (D)

15 A mixture was made by adding 10 cm^3 of a solution of pH 1 to 30 cm^3 of another solution of pH 5. What is the final pH of the mixture?

A 1.6

B 2.5

C 3.0

D 4.0

$[H^+]$ in 10 cm^3 = 10^{-1} = 0.1

$[H^+]$ in 30 cm^3 = 10^{-5} = 0.00001

Total amount of H^+ = (10/1000 x 0.1) + (30/1000 x 0.00001) = 0.0010003 mol

$[H^+]$ = 0.0010003 / (40/1000)

= 0.0250 mol dm^{-3}

pH = $-\log_{10}[H^+] = -\log_{10}(0.0250) = 1.6$

Ans: (A)

16 Which of the following is a general trend from left to right of the elements in the third period of the Periodic Table?

A The radii of the atoms increase.

B The melting points of the chlorides decrease.

C The electrical conductivity of the elements decrease.

D The first ionisation energies of the elements increase.

Across the period, the effective nuclear charge of the element increases, Hence, more energy is required to remove the valence electrons and ionisation energies increases.

Ans: (D)

17 Which element has a chloride with a simple molecular structure that is readily hydrolysed in water?

A sodium

B magnesium

C aluminium

D silicon

$SiCl_4$ has a simple molecular structure and is completely hydrolysed in water.

18 Which property decreases from Na_2O to P_4O_{10} for the oxides of period 3 elements?

A melting point

B covalent character

C solubility in aqueous alkali

D pH when mixed with water

pH of Na_2O in water = 13; pH of MgO in water = 9; pH of Al_2O_3 and SiO_2 = 7, P_4O_{10} = 3

Ans: (D)

19 Linoleic acid is an essential fatty acid with the structural formula.

$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7CO_2H$

Which of the following statements about linoleic acid is correct?

A It undergoes electrophilic substitution with liquid bromine.

B It undergoes oxidation with acidified potassium dichromate(VI) solution.

C 1 mole of linoleic acid requires 48 dm^3 of hydrogen for hydrogenation at room temperature.

D 1 mole of linoleic acid reacts with 1 mole of sodium carbonate to form 24 dm^3 of carbon dioxide at room temperature.

1 mole of linoleic acid reacts with 2 mole of H_2. 1 mole of gas at r.t.p is 24 dm^3. Hence 24 dm^3 of H_2 is needed.

Ans: (C)

20 Which property of benzene is reflected as a consequence of the delocalised electrons in its molecule?

A Benzene is a planar molecule.

B Benzene is a good conductor of electricity.

C Substitution in benzene takes place at a carbon atom.

D Addition reactions of benzene take place more easily than substitution.

Benzene is resonance stabilised by the delocalised electrons present in its molecule. Hence it will undergo substitution instead of addition reaction.

Ans: (C)

21 The volatile liquid, fluothane, $CF_3CHBrCl$, is a widely used anaesthetic.

Which statement about fluothane is **incorrect**?

A It has a simple molecular structure.

B It may cause depletion of ozone layer.

C It may undergo substitution with chlorine.

D It can form hydrogen bonds between its molecules.

The hydrogen is not bonded to F,O and N hence it is not able to form hydrogen bonds between its molecules.

Ans: (D)

22 A compound **V** gives yellow precipitate with alkaline aqueous iodine. One mole of **V** liberates one mole of hydrogen when it reacts with excess sodium.

What could be the formula of **V**?

A $CH_3CH(OH)CHO$

B $CH_3CH(OH)CO_2H$

C $HOCH_2CH_2CO_2H$

D $HOCH_2CH(CH_3)CH_2OH$

$CH_3CH(OH)$- gives yellow ppt with alkaline aqueous iodine. It has –OH and –COOH group which reacts with 2 moles of sodium to form 1 mole of H_2.

Ans: (B)

23 A compound, **W**, has the following properties.

- It reacts with hydrogen in the presence of nickel catalyst.
- It reacts with phosphorus pentachloride to give off HCl fumes.
- It reacts with sodium hydroxide to form an ionic compound.
- It reacts with ethanol.

What formula could represent **W**?

A CH_3CHO

B CH_3COCH_3

C $CH_2{=}CHCO_2H$

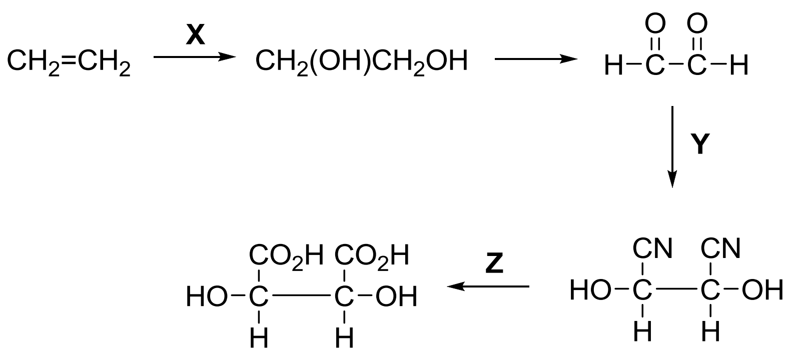
D $CH_2{=}CHCH_2OH$

- Carboxylic acid functional group reacts with NaOH to form $–CO_2^-Na^+$ an ionic compound.
- Carboxylic acid functional group reacts with PCl_5 to form $RCOCl$ and HCl.
- Alkene functional group present to reacts with H_2 in the presence of Ni catalyst.
- Carboxylic acid functional group reacts with alcohol to form ester.

X has both carboxylic acid and alkene functional groups.

Ans: (C)

24 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?

	X	Y	Z
A	cold concentrated H_2SO_4, followed by boiling H_2O	cold HCN, NaOH(aq)	hot $K_2Cr_2O_7$, H_2SO_4(aq)
B	cold $KMnO_4$, H_2SO_4(aq)	cold HCN, NaOH(aq)	HCl(aq), heat
C	cold concentrated H_2SO_4, followed by boiling H_2O	ethanolic KCN, heat	hot $K_2Cr_2O_7$, H_2SO_4(aq)
D	cold $KMnO_4$, NaOH(aq)	ethanolic KCN, heat	HCl(aq), heat

Mild oxidation of **X** with cold $KMnO_4$, H_2SO_4(aq) to form diol.

Addition of carbonyl functional group with cold HCN, NaOH(aq) to form cyanohydrin.

Acidic hydrolysis of nitrile group to form carboxylic acid.

Ans: (B)

25 Which of the following shows the descending order of acid strength?

A	CH_3CO_2H	>	CH_2ClCO_2H	>	CH_3CH_2OH
B	CH_3CH_2OH	>	CH_2ClCO_2H	>	CH_3CO_2H
C	CH_2ClCO_2H	>	CH_2FCO_2H	>	CH_3CH_2OH
D	CH_2ClCO_2H	>	CH_2BrCO_2H	>	CH_3CO_2H

F being more electronegative than C*l* can better disperse the negative charge on the conjugate base, hence stabilising the conjugate base more, therefore CH_2FCO_2H is the most acidic.

C*l* being more electronegative than Br can better disperse the negative charge on the conjugate base, hence stabilising the conjugate base more, therefore CH_2ClCO_2H is more acidic.

CH_3CO_2H is more acidic than CH_3CH_2OH due to the negative charge being able to delocalise over the O-C-O bond in the conjugate base, hence forming a resonance structure.

Acid strength:

CH_2FCO_2H > CH_2ClCO_2H > CH_2BrCO_2H > CH_3CO_2H > CH_3CH_2OH

Section B

For each of the following questions, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 Materials are insulators when the outer shells of electrons of all the constituent particles are completely filled and there is a considerable energy gap before the next unoccupied shell.

Which compounds have completely filled shells and might therefore act as insulators?

1 MgO

2 SiO_2

3 SiC (diamond structure)

MgO has completely filled outer shells as Mg has transferred 2 electrons to oxygen. Ionic compounds in solid states are insulators as there are no free mobile electrons. MgO is sparingly soluble in water, hence no ions are formed.

SiO_2 and SiC are giant molecular structure in a tetrahedral network. Therefore the outer shells are completely filled. They are insulators as there are no free mobile electrons.

Ans: (A)

27 Calcium reacts with water to form calcium hydroxide and hydrogen.

$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(s) + H_2(g)$

The standard enthalpy change for this reaction can be determined experimentally.

What further information are needed to calculate the standard enthalpy change of formation of calcium hydroxide, $\Delta H_f^\ominus$?

1 $\Delta H_f^\ominus$ for $H_2O(l)$

2 $\Delta H_f^\ominus$ for $H_2(g)$

3 First and second ionisation energies for Ca

$$Ca(s) + 2H_2O(l) \xrightarrow{\Delta H_r^{\ominus}} Ca(OH)_2(s) + H_2(g)$$

$\Delta H_r^{\ominus} = \sum n\Delta H_f^{\ominus}(\text{products}) - \sum n\Delta H_f^{\ominus}(\text{reactants})$

$= [\Delta H_f^{\ominus}(Ca(OH)_2) + \Delta H_f^{\ominus}(H_2)] - [\Delta H_f^{\ominus}(Ca) + 2\Delta H_f^{\ominus}(H_2O)]$

$= [\Delta H_f^{\ominus}(Ca(OH)_2) - 2\Delta H_f^{\ominus}(H_2O)$

$\Delta H_f^{\ominus}(Ca(OH)_2) = \Delta H_r^{\ominus} + 2\Delta H_f^{\ominus}(H_2O)$

Ans: (D)

28 Which of the following pairs would form an acidic buffer when mixed together?

1 CH_3CO_2H and NaC*l*

2 HCN and KCN

3 $C_6H_5CO_2H$ and $(C_6H_5CO_2)_2Ca$

An acidic buffer is made up of weak acid and its conjugate base. HCN and $C_6H_5CO_2H$ are both weak acid. KCN and $(C_6H_5CO_2)_2Ca$ are the respective conjugate base.

Ans: (C)

29 A halogenoalkane has the formula of $C_3H_5Cl_3$.

Which of the isomers have the correct IUPAC name?

1 1,1,1-trichloropropane

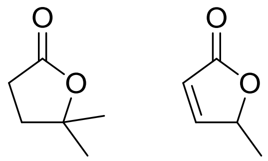
2 1,2,2-trichloropropane

3 2,2,3-trichloropropane

2,2,3- trichloropropane is the same as 1,2,2-trichloropropane. Smaller numbers are preferred on the IUPAC name.

Ans: (B)

30 Below are the structures of compounds **X** and **Y**.



X **Y**

Which sets of reagents and conditions can be used to distinguish between them?

1 aqueous bromine

2 acidified $K_2Cr_2O_7$, heat

3 alkaline aqueous iodine, heat

For **1**, C=C in **Y** will decolourise orange-red Br_2(aq). No decolouisation of Br_2(aq) for **X**.

For **2**, ester group in **X** undergoes acid hydrolysis to form tertiary alcohol which cannot be oxidised by $K_2Cr_2O_7$. There is no change in the colour of solution. However, the acid hydrolysis of **Y** formed secondary alcohol which can be oxidised by $K_2Cr_2O_7$. The colour of solution changes from orange to green.

For **3**, both the ester groups in **X** and **Y** undergo base hydrolysis. However, only **Y** shows a positive iodoform test due to presence of $CH_3CH(OH)$– group after hydrolysis.

Ans: (A)

--- End of Paper ---

Name:		Class:	

ST ANDREW'S JUNIOR COLLEGE

Preliminary Examinations

Chemistry **8872/2**

Higher 1 **11 Sep 2017**

Paper 2 **1300 – 1500**

Candidates answer on separate paper.

Additional Materials: Writing paper, graph paper, 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 **two** questions from this section on separate answer paper.

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	9	1	20
2	14	2	20
3	7	3	20
4	10		
Total	40	**Total**	40
TOTAL (Section A + Section B)			80

This document consists of **17** pages including a blank page.

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Section A

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

1. Apricot kernels containing glycoside amygdalin turns into deadly hydrogen cyanide acid, HCN, when the kernel is crushed. High doses of hydrogen cyanide can cause coma with seizures and cardiac arrest, leading to death in a matter of minutes. A fatal dose for a human can be as low as 1.50 mg kg^{-1} of body weight.

(1 mg = 1.00 x 10^{-3} g)

The forensics department of the local law enforcement agency was trying to determine the cause of death of a 90 kg deceased man who was found at home on the couch with a few empty packets of apricot kernels lying on the ground.

A typical human has 70 cm^3 of blood per kg of body mass. A 10 cm^3 sample of blood was obtained from the body and dissolved to form 25 cm^3 of solution. The amount of HCN can be determined through the amount of Fe^{2+} present in the blood. The Fe^{2+} required 1.70 cm^3 of 0.00100 mol dm^{-3} acidified $Na_2Cr_2O_7$ solution for complete reaction.

(a) Write a balanced redox equation between Fe^{2+} and $Cr_2O_7^{2-}$. **[1]**

……………………………………………………………………………………………

(b) Show by oxidation number that the reaction in **(a)** is a redox reaction. **[2]**

……………………………………………………………………………………………

……………………………………………………………………………………………

(c) Calculate the number of moles of hydrogen cyanide, HCN, in the 25 cm^3 of solution. **[2]**

1 **(d)** Calculate the number of moles of hydrogen cyanide, HCN, in the body of the deceased man. **[1]**

(e) Calculate the concentration of HCN in mg kg^{-1} and hence determine if the cause of death was due to hydrogen cyanide poisoning. **[3]**

[Total: 9]

2. This question is about nitrogen and its compounds.

(a) NO_2 is highly reactive and usually exists in the more stable form of N_2O_4.

(i) Draw a diagram to illustrate the shape of the molecule, N_2O_4, and state the bond angle about the N atom. **[2]**

Bond angle: ……………………………....

(ii) Draw the dot-and-cross diagram of NO_2 and hence suggest a reason why NO_2 is expected to be highly reactive. **[2]**

………………………………………………………………………………..

………………………………………………………………………………..

(iii) Explain why the bond angle for NO_2 is greater than 120°. **[2]**

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

2 **(b)** At room temperature and pressure, NO_2 dimerises to form dinitrogen tetraoxide, N_2O_4, as shown below:

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad\qquad \Delta H < 0$$

(i) Write the expression for the equilibrium constant, K_c, for the above equilibrium, stating its units. **[2]**

Units: ……………………….

(ii) At 298 K and 101 kPa, 1.00 g of NO_2 was placed in the reaction chamber initially. When equilibrium was established, the gaseous mixture was found to occupy a volume of 0.317 dm^3 and showed an average M_r of 77.3. The average M_r of the mixture can be calculated using the following expression, **[2]**

$$\text{Ave } M_r = \frac{[n_{eqm}(NO_2) \times M_r(NO_2)] + [n_{eqm}(N_2O_4) \times M_r(N_2O_4)]}{\text{Total number of moles at equilibrium}}$$

where n_{eqm} = number of moles at equilibrium

Fill in the table below and use the expression given above to solve for the value of y.

	NO_2	N_2O_4
Initial/ mol		
Change/ mol	$-2y$	$+y$
Equilibrium/ mol		y

2 **(b)** **(iii)** Hence, calculate the value of K_c. **[2]**

(iv) Describe how the average M_r will be affected when pressure decreases. **[2]**

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

[Total: 14]

3. Many biological processes only occur within a narrow range of pH values. The pH of different fluids found in the body is given below:

Body Fluid	**pH**
Saliva	6.8
Blood	7.4
Stomach juices	1.0 - 3.0
Intestinal juices	8.5

(a) Calculate the hydroxide ion concentration in intestinal juices. **[2]**

(b) The low pH in the human stomach is due to the existence of hydrochloric acid, which is known to be a *strong Brønsted-Lowry acid*. Explain the terms in italics. **[2]**

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

(c) The body maintains the pH of blood within a narrow range of values. Death could result if the blood pH decreases below 6.8 or increases above 7.8. The need to maintain the pH within a narrow range of values requires the use of a buffer. In blood, the main buffering system is the H_2CO_3 / HCO_3^- buffer.

(i) What do you understand by the term *buffer* solution? **[1]**

……………………………………………………………………………………..

……………………………………………………………………………………..

3 **(c)** **(ii)** Write equations to show how the H_2CO_3/HCO_3^- buffer system regulates the acidity on the addition of a small amount of H^+ and OH^-. **[2]**

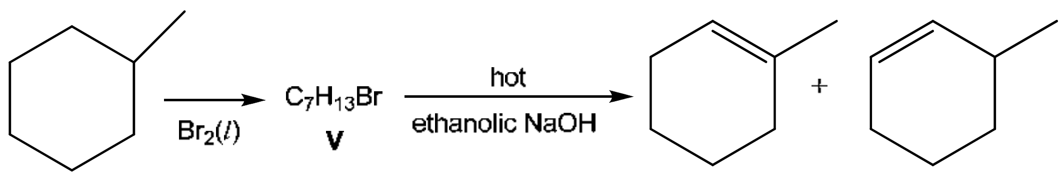
…………………………………………………………………………………..

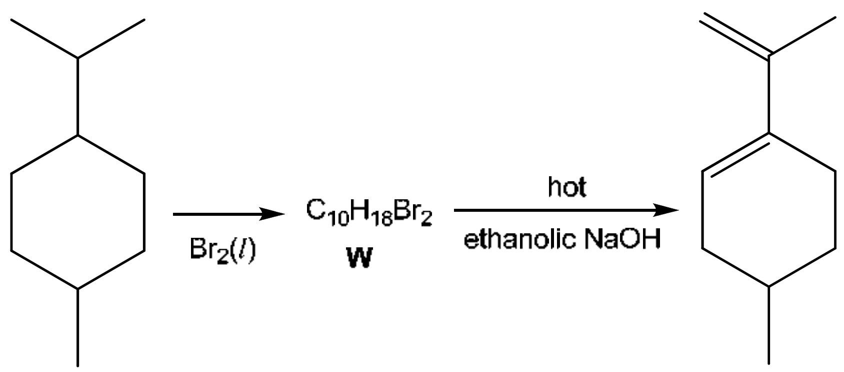
…………………………………………………………………………………..

…………………………………………………………………………………..

[Total: 7]

4. Alkenes are very useful compounds and can be used as fuels and in the manufacture of a wide variety of polymers. The following reactions involve the formation of some alkenes.





only 1 product formed

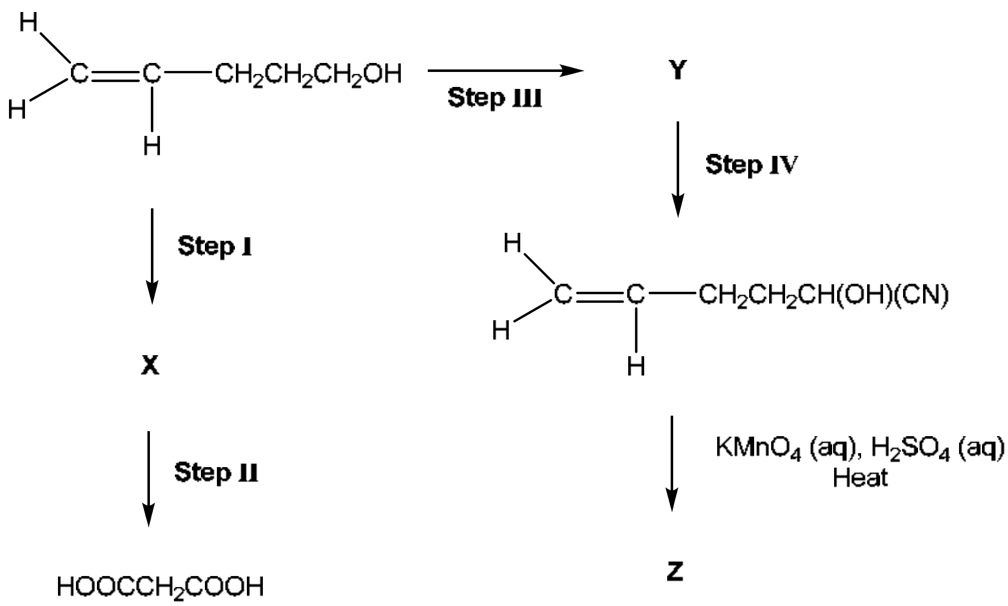
(a) What is the type of reaction for the reaction of the hydrocarbons with $Br_2(l)$ to form **V** and **W?** **[1]**

……………………………………………………………………………………………

4 **(b)** Suggest the skeletal structure of **V** and **W.** **[2]**

Structure **V**	Structure **W**

(c) The flow chart below involves the reaction of pent-4-en-1-ol.



4 (c) (i) Draw the structural formulae of **X**, **Y** and **Z**. **[3]**

Structure **X**	Structure **Y**
Structure **Z**	

(ii) State the reagents and conditions for steps **I – IV** in the spaces provided. **[4]**

	Reagents and Conditions
Step I	
Step II	
Step III	
Step IV	

[Total: 10]

--- END OF SECTION A ---

Section B

Answer 2 out of 3 questions.

1. The Andrussow oxidation is invented by Leonid Andrussow in which methane and ammonia react in the presence of oxygen, over platinum catalyst, to produce hydrogen cyanide.

$$2CH_4(g) + 2NH_3(g) + 3O_2(g) \rightarrow 2HCN(l) + 6H_2O(l)$$

(a) Draw the dot-and-cross diagram for HCN. State the shape and bond angle. **[3]**

(b) **(i)** Calculate the standard enthalpy change of the above reaction using the data below. **[2]**

	$\Delta H_f^\ominus$ / kJ mol^{-1}
CH_4	–74.9
NH_3	–45.9
HCN	+130.5
H_2O	–285.8

(ii) Using data from the *Data Booklet*, calculate another value for the standard enthalpy change of the above reaction. **[3]**

(iii) Explain why the two values differ in **(b)(i)** and **(b)(ii)**. **[1]**

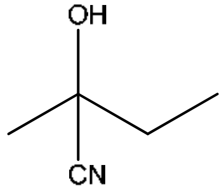
(c) The data below shows the boiling points of HCN and NaCN, and their solubility in water.

	Boiling Point / °C	Solubility in water
HCN	25.6	Miscible
NaCN	1496	Miscible

(i) Explain, in terms of structure and bonding, the difference between the boiling points of HCN and NaCN. **[3]**

(ii) Explain with the aid of a diagram the solubility of NaCN in water. **[3]**

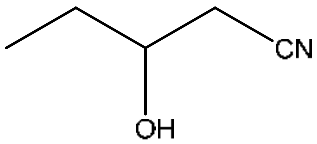
1 **(d)** Hydrogen cyanide is used as a reagent in the formation of cyanohydrin. The structure below shows an example of a cyanohydrin.



(i) Draw the structure of the organic compound that forms the cyanohydrin above. **[1]**

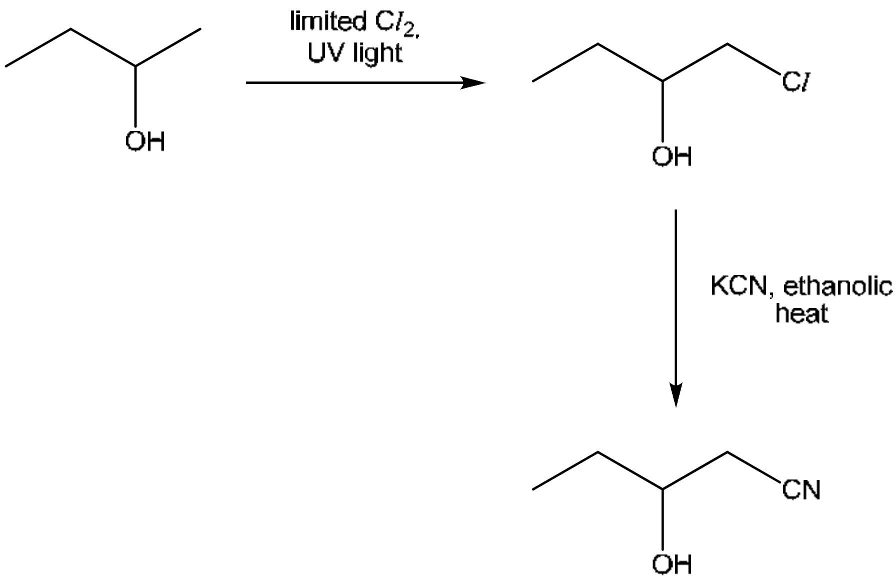
(ii) Suggest why the reaction needs to be performed at a low temperature. **[1]**

(iii) The structure below is an isomer of the cyanohydrin above. **[2]**



Outline a simple chemical test to distinguish between the two compounds.

(iv) A student suggested that the isomer can be synthesised in the following reaction scheme. Suggest why this synthesis is not the best method. **[1]**



[Total: 20]

2. Rocket propellant is a high oxygen containing fuel, whose combustion takes place, in a definite and controlled manner with the evolution of a huge volume of gas. There are four main types of chemical rocket propellants: solid, storable liquid, cryogenic liquid and liquid monopropellant. Solid propellant rocket has a higher propellant density than liquid propellant rocket.

(a) Suggest an advantage of using a solid propellant rocket rather than a liquid propellant rocket. **[1]**

During the 1950s, researchers in the United States developed ammonium perchlorate composite propellant, a type of solid propellant. This mixture is made up of finely ground ammonium perchlorate, fine aluminium powder and polybutadiene acrylonitrile.

(b) Ammonium perchlorate undergoes mild heating according to the equation below.

$$4NH_4ClO_4(s) \rightarrow 4HCl(g) + 2N_2(g) + 5O_2(g) + 6H_2O(l)$$

(i) Calculate the volume of gases formed when 25 g of ammonium perchlorate is heated. (All volumes are measured at room temperature and pressure.) **[2]**

(ii) Suggest why strong heating may lead to an explosion. **[1]**

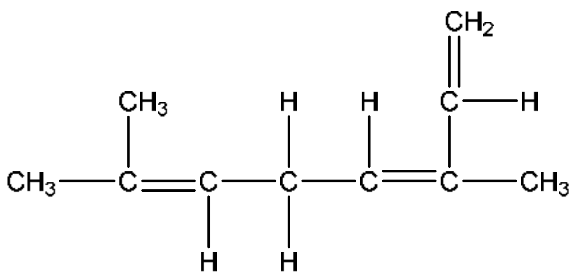
(c) **(i)** Explain why the first ionisation energy of magnesium is higher than that of aluminium. **[2]**

(ii) Explain the difference in electrical conductivity of magnesium, aluminium and silicon. **[2]**

The Soviet utilised syntin, a liquid propellant, for Soyuz U2, is a type of carrier rocket, until 1995. Syntin comprises of synthetic cyclopropane, $C_{10}H_{16}$.

(d) When 0.75 g of cyclopropane undergoes complete combustion, the increase in temperature of 250 cm^3 of water is 18°C and has an efficiency is 85%. Calculate the standard enthalpy change of combustion of cyclopropane. **[3]**

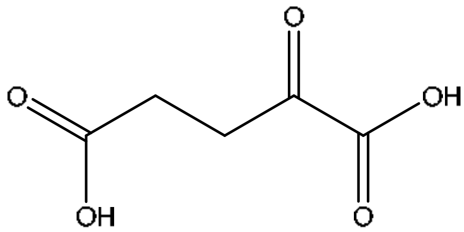
(e) Ocimene is an isomer of syntin with the following structure.



(i) Draw the cis and trans isomers of Ocimene. **[2]**

(ii) Explain why ocimene is able to exhibit cis-trans isomerism. **[2]**

2 **(f)** **W** is another isomer of syntin, with a molecular formula of $C_{10}H_{16}$. When **W** reacts with hot acidified potassium manganate(VII), it forms 2 moles of gas **X**, **Y**, and the product shown below **[5]**



X forms a white precipitate when it reacts with aqueous calcium hydroxide.

Y, C_3H_6O, forms a yellow precipitate when it reacts with aqueous alkaline iodine. **Y** also forms an orange precipitate when it reacts with 2,4–dinitrophenylhydrazine. However, **Y** does not form a sliver mirror when it is warmed with Tollens' Reagent.

Deduce the structures of **W**, **X** and **Y**.

[Total: 20]

3 **(a)** A solution of hydrogen peroxide in aqueous HC*l* slowly oxidises bromide ions according to the equation below.

$$H_2O_2 + 2Br^- + 2H^+ \rightarrow Br_2 + 2H_2O$$

The rate of reaction was followed by measuring the concentration of the remaining hydrogen peroxide after fixed time intervals. Two experiments were carried out, starting with different concentrations of bromide ions. The following results were obtained.

Time / min	Experiment 1 $[Br^-]$ = 1.00 mol dm^{-3}	Experiment 2 $[Br^-]$ = 1.50 mol dm^{-3}
	$[H_2O_2]$/ mol dm^{-3}	$[H_2O_2]$/ mol dm^{-3}
0	0.0100	0.0100
40	0.0078	0.0069
80	0.0061	0.0048
120	0.0048	0.0033
160	0.0037	0.0023
200	0.0028	0.0016

(i) Using the same axes, plot graphs of $[H_2O_2]$ against time for the two experiments. **[2]**

(ii) Use your graphs to determine the order of reaction with respect to $[H_2O_2]$ and to $[Br^-]$, showing your workings clearly. **[4]**

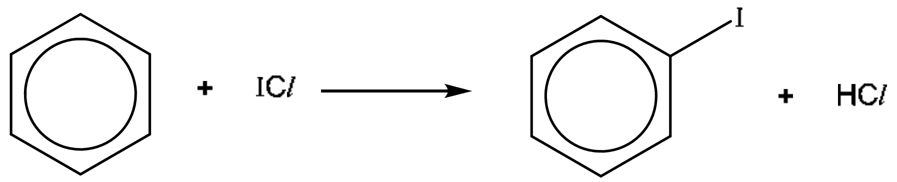
(iii) In another separate experiment, it was found that the order of reaction with respect to [HC*l*] is zero, write the rate equation for the reaction. **[1]**

(iv) Sketch a graph of rate against concentration of H_2O_2. **[1]**

(v) Explain, with an appropriate sketch of the Boltzmann distribution, how an increase in temperature affects the rate of reaction. **[3]**

(b) Explain the difference in ionic radius between Br^- and I^-. **[2]**

3 (c) Aromatic halogenation with iodine monochloride, ICl, produces aryl iodide.



This reaction is typically catalysed by aluminium chloride when it reacts with iodine monochloride to produce the electrophile I^+.

$$ICl + AlCl_3 \longrightarrow [AlCl_4]^- + I^+$$

(i) Draw the structure of $[AlCl_4]^-$ and suggest in terms of bonding how $[AlCl_4]^-$ is formed from $AlCl_3$. **[2]**

(ii) When sodium carbonate is added to a solution of $AlCl_3$, effervescence was seen. Explain the observation with the aid of relevant equations. **[3]**

(iii) Ethanolic silver nitrate is added to iodobenzene and iodopropane in two separate test tubes. Yellow precipitate is seen immediately in one of the test tubes, whereas no precipitate is seen in the other test tube. Explain the observations. **[2]**

[Total: 20]

--- THE END ---

Name:		Class:	

ST ANDREW'S JUNIOR COLLEGE

Preliminary Examinations

Chemistry **8872/2**

Higher 1 **11 Sep 2017**

Paper 2 **1300 – 1500**

Candidates answer on separate paper.

Additional Materials: Writing paper, graph paper, 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 **two** questions from this section on separate answer paper.

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	9	1	20
2	14	2	20
3	7	3	20
4	10		
Total	40	**Total**	40
TOTAL (Section A + Section B)			80

This document consists of **17** pages including a blank page.

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Section A

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

1. Apricot kernels containing glycoside amygdalin turns into deadly hydrogen cyanide acid, HCN, when the kernel is crushed. High doses of hydrogen cyanide can cause coma with seizures and cardiac arrest, leading to death in a matter of minutes. A fatal dose for a human can be as low as 1.50 mg kg^{-1} of body weight.

(1 mg = 1.00 x 10^{-3} g)

The forensics department of the local law enforcement agency was trying to determine the cause of death of a 90 kg deceased man who was found at home on the couch with a few empty packets of apricot kernels lying on the ground.

A typical human has 70 cm^3 of blood per kg of body mass. A 10 cm^3 sample of blood was obtained from the body and dissolved to form 25 cm^3 of solution. The amount of HCN can be determined through the amount of Fe^{2+} present in the blood. The Fe^{2+} required 1.70 cm^3 of 0.00100 mol dm^{-3} acidified $Na_2Cr_2O_7$ solution for complete reaction.

(a) Write a balanced redox equation between Fe^{2+} and $Cr_2O_7^{2-}$. **[1]**

$6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \rightarrow 6Fe^{3+} + 7H_2O + 2\,Cr^{3+}$ [1]

(b) Show by oxidation number that the reaction in **(a)** is a redox reaction. **[2]**

Fe changed from +2 in Fe^{2+} to +3 in Fe^{3+} (oxidation) [1]

Cr changed from +6 in $Cr_2O_7^{2-}$ to +3 in Cr^{3+} (reduction) [1]

(c) Calculate the number of moles of hydrogen cyanide, HCN, in the 25 cm^3 of solution. **[2]**

Amount of $Cr_2O_7^{2-}$ reacted = (1.70/1000) x 0.001 = 1.70 x 10^{-6} mol [1]

Amount of Fe^{2+} in 25 cm^3 of solution

= 6 x 1.70 x 10^{-6}

= 1.02 x 10^{-5} mol

= Amount of HCN [1]

(d) Calculate the number of moles of hydrogen cyanide, HCN, in the body of the deceased man. **[1]**

Amount of HCN in the body = (70/10) x 90 x 1.02 x 10^{-5} = 0.006426 mol [1]

(e) Calculate the concentration of HCN in mg kg^{-1} and hence determine if the cause of death was due to hydrogen cyanide poisoning. **[3]**

Mass of HCN in the body

= 0.006426 x (1.0 + 12.0 + 14.0) = 0.1735 g = 173.5 mg [1]

[HCN] = 173.5 / 90.0 = 1.93 mg kg^{-1} [1]

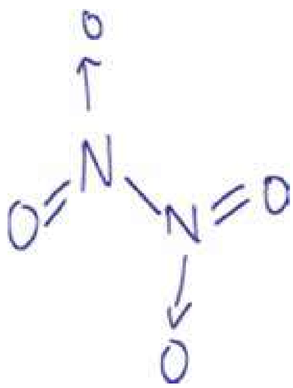
Since 1.93 mg kg^{-1} > 1.50 mg kg^{-1}, therefore the death is due to HCN poisoning. [1]

[Total: 9]

2. This question is about nitrogen and its compounds.

(a) NO_2 is highly reactive and usually exists in the more stable form of N_2O_4.

(i) Draw a diagram to illustrate the shape of the molecule, N_2O_4, and state the bond angle about the N atom. **[2]**



[1]

120° about N [1]

(ii) Draw the dot-and-cross diagram of NO_2 and hence suggest a reason why NO_2 is expected to be highly reactive. **[2]**

[1]

There is an unpaired electron on N / NO_2 is a radical. [1]

(iii) Explain why the bond angle for NO_2 is greater than 120°. **[2]**

NO_2 has a <u>lone electron and two bond pairs</u> [1]. The <u>lone electron-bond pair repulsion is lesser than the bond pair-bond pair repulsion</u> [1] in a trigonal planar shape, hence the angle is larger than 120°.

(b) At room temperature and pressure, NO_2 dimerises to form dinitrogen tetraoxide, N_2O_4, as shown below:

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H < 0$$

(i) Write the expression for the equilibrium constant, K_c, for the above equilibrium, stating its units. **[2]**

$K_c = [N_2O_4] / [NO_2]^2$ [1]

Units: $mol^{-1}\ dm^3$ [1]

(ii) At 298 K and 101 kPa, 1.00 g of NO_2 was placed in the reaction chamber initially. When equilibrium was established, the gaseous mixture was found to occupy a volume of 0.317 dm^3 and showed an average M_r of 77.3. The average M_r of the mixture can be calculated using the following expression, **[2]**

$$\text{Ave } M_r = \frac{[n_{eqm}(NO_2) \times M_r(NO_2)] + [n_{eqm}(N_2O_4) \times M_r(N_2O_4)]}{\text{Total number of moles at equilibrium}}$$

where n_{eqm} = number of moles at equilibrium

Fill in the table below and use the expression given above to solve for the value of y.

	NO_2	N_2O_4
Initial/ mol	1/46	0
Change/ mol	$-2y$	$+y$
Equilibrium/ mol	$1/46 - 2y$	y

[1]

$$\frac{[(1/46 - 2y) \times 46] + [y \times 92]}{(1/46 - y)} = 77.3$$

y = 0.00880 [1]

(iii) Hence, calculate the value of K_c. **[2]**

$n_{eqm}(N_2O_4) = y = 0.00880$ mol

$n_{eqm}(NO_2) = 0.00414$ mol

$[N_2O_4] = 0.00880 / 0.317 = 0.0278\ mol\ dm^{-3}$

$[NO_2] = 0.00414 / 0.317 = 0.0131\ mol\ dm^{-3}$ [1]

$K_c = 0.0278 / (0.0131)^2 = 162\ mol^{-1}\ dm^3$ [1]

(iv) Describe how the average M_r will be affected when pressure decreases. **[2]**

Average M_r will decrease [1]. Equilibrium position shifts to the left to form more gaseous particles [1], hence more NO_2 will be formed, leading to lower average M_r.

[Total: 14]

3. Many biological processes only occur within a narrow range of pH values. The pH of different fluids found in the body is given below:

Body Fluid	**pH**
Saliva	6.8
Blood	7.4
Stomach juices	1.0 - 3.0
Intestinal juices	8.5

(a) Calculate the hydroxide ion concentration in intestinal juices. **[2]**

$[H^+] = 10^{-8.5} = 3.16 \times 10^{-9}$ [1]

$[OH^-] = 10^{-14} / 3.16 \times 10^{-9} = 3.16 \times 10^{-6}$ mol dm^{-3} [1]

(b) The low pH in the human stomach is due to the existence of hydrochloric acid, which is known to be a *strong Brønsted-Lowry acid*. Explain the terms in italics. **[2]**

A strong Brønsted-Lowry acid is a substance that dissociates fully [1] to donate H^+ [1].

(c) The body maintains the pH of blood within a narrow range of values. Death could result if the blood pH decreases below 6.8 or increases above 7.8. The need to maintain the pH within a narrow range of values requires the use of a buffer. In blood, the main buffering system is the H_2CO_3 / HCO_3^- buffer.

(i) What do you understand by the term *buffer* solution? **[1]**

A buffer solution is one that can resist a change in pH (pH changes only very slightly) when a small amount of acid or base is added to it. [1]

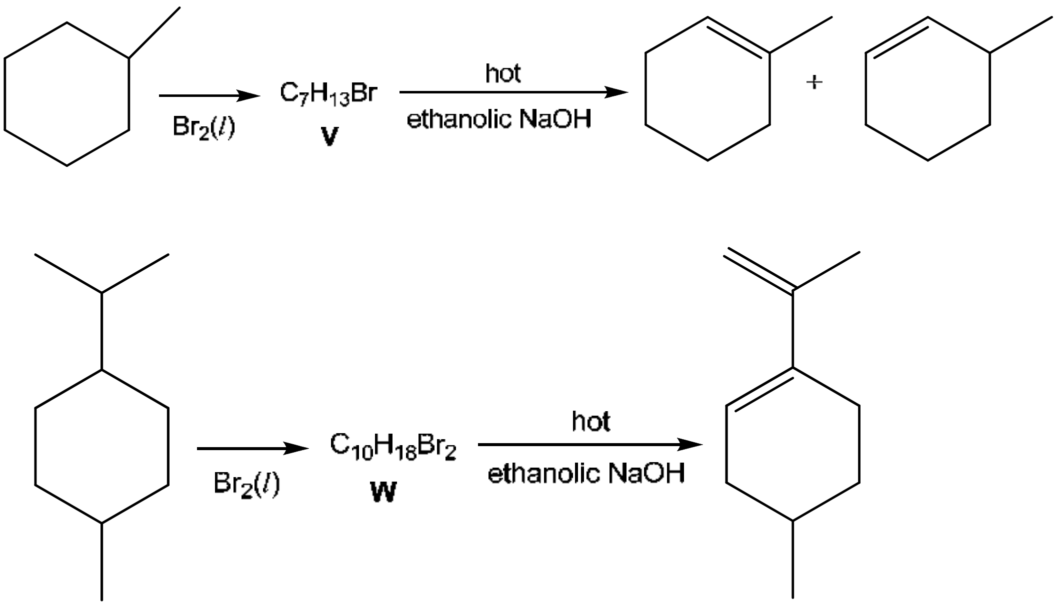
(ii) Write equations to show how the H_2CO_3/HCO_3^- buffer system regulates the acidity on the addition of a small amount of H^+ and OH^-. **[2]**

$H_2CO_3(aq) + OH^-(aq) \rightarrow H_2O(l) + HCO_3^-(aq)$ [1]

$HCO_3^-(aq) + H^+(aq) \rightarrow H_2CO_3(aq)$ [1]

[Total: 7]

4. Alkenes are very useful compounds and can be used as fuels and in the manufacture of a wide variety of polymers. The following reactions involve the formation of some alkenes.

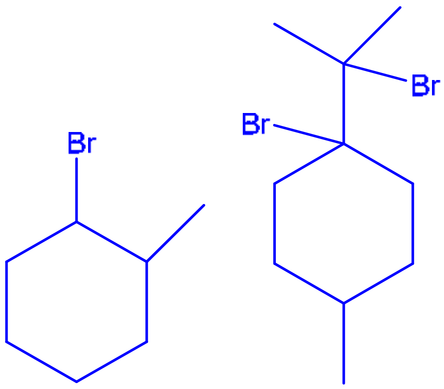


only 1 product formed

(a) What is the type of reaction for the reaction of the hydrocarbons with $Br_2(l)$ to form **V** and **W?** **[1]**

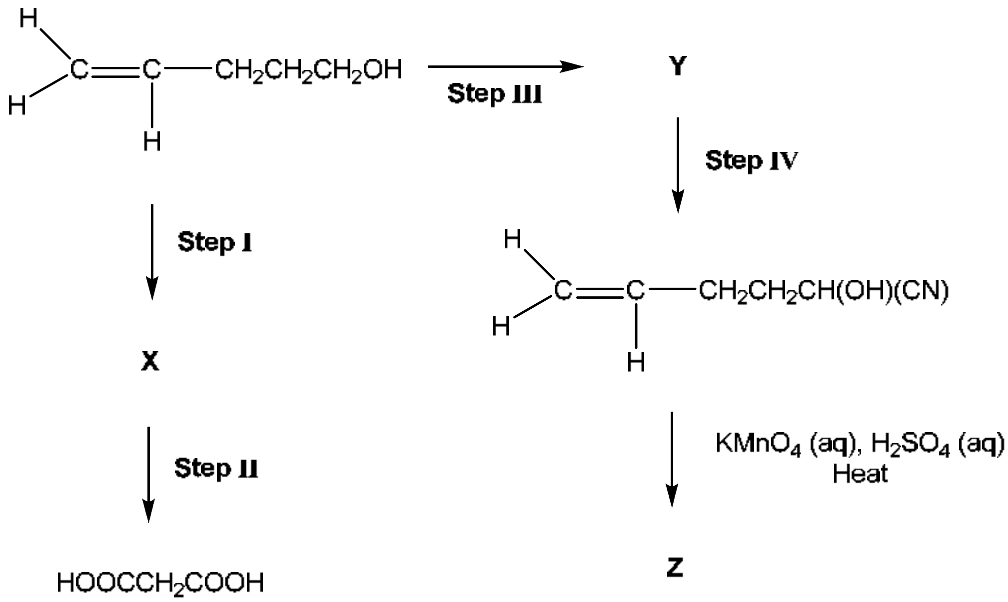
Free Radical <u>Substitution</u> [1]

(b) Suggest the skeletal structure of **V** and **W.** **[2]**

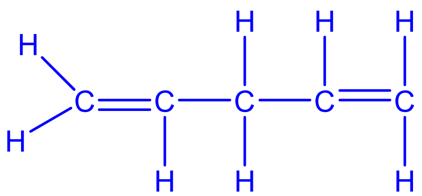


V [1] **W** [1]

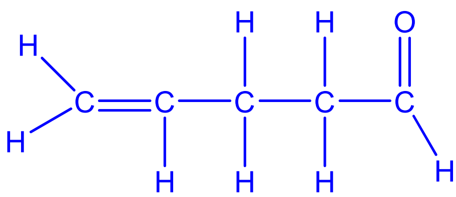
(c) The flow chart below involves the reaction of pent-4-en-1-ol.



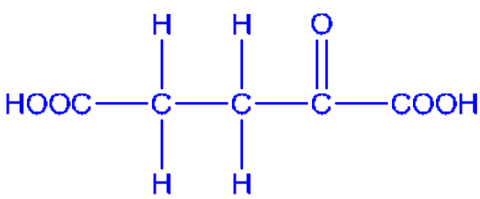
(i) Draw the structural formulae of **X**, **Y** and **Z**. **[3]**



X [1]



Y [1]



Z [1]

(ii) State the reagents and conditions for steps **I – IV** in the spaces provided. **[4]**

	Reagents and Conditions
Step I	Excess conc H_2SO_4, 170°C [1]
Step II	$KMnO_4$ (aq), H_2SO_4 (aq), heat [1]
Step III	$K_2Cr_2O_7$ (aq), H_2SO_4 (aq), heat with distillation [1]
Step IV	HCN, trace NaOH/NaCN, 10 – 20 °C [1]

[Total: 10]

--- END OF SECTION A ---

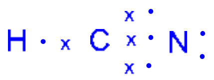
Section B

Answer 2 out of 3 questions.

1. The Andrussow oxidation is invented by Leonid Andrussow in which methane and ammonia react in the presence of oxygen, over platinum catalyst, to produce hydrogen cyanide.

$$2CH_4(g) + 2NH_3(g) + 3O_2(g) \rightarrow 2HCN(l) + 6H_2O(l)$$

(a) Draw the dot-and-cross diagram for HCN. State the shape and bond angle. **[3]**



[1]

Linear [1]

180° [1]

(b) **(i)** Calculate the standard enthalpy change of the above reaction using the data below. **[2]**

	$\Delta H_f^\ominus$ / kJ mol^{-1}
CH_4	–74.9
NH_3	–45.9
HCN	+130.5
H_2O	–285.8

$\Delta H_r^\ominus = \sum n\Delta H_f^\ominus(\text{products}) - \sum n\Delta H_f^\ominus(\text{reactants})$

$= [2(+130.5) + 6(–285.8)] – [2(–74.9) + 2(–45.9)]$ [1]

$= –1212.2$ kJ mol^{-1} [1]

(ii) Using data from the *Data Booklet*, calculate another value for the standard enthalpy change of the above reaction. **[3]**

BE of reactants = 8(C-H) + 6(N-H) + 3(O=O)

= 8(410) + 6(390) + 3(496)

= +7108 kJ mol^{-1} [1]

BE of products = 2(C-H) + 2(C≡N) + 12(O-H)

= 2(410) + 2(890) + 12(460)

= +8120 kJ mol^{-1} [1]

$\Delta H_r^\ominus$ = BE (reactants) – BE (products)

= 7108 – 8120

= –1012 kJ mol^{-1} [1]

(iii) Explain why the two values differ in **(b)(i)** and **(b)(ii)**. **[1]**

The enthalpy of reaction calculated using bond energies in the data booklet is for gaseous reactants and products, but in the above calculation, HCN and H_2O is a liquid. [1]

OR

The bond energies values in the data booklet are average values. [1]

(c) The data below shows the boiling points of HCN and NaCN, and their solubility in water.

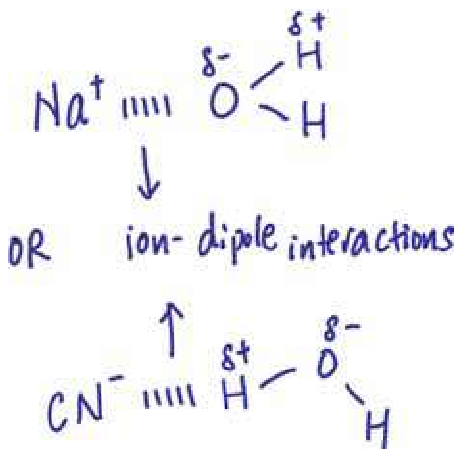
	Boiling Point / °C	Solubility in water
HCN	25.6	Miscible
NaCN	1496	Miscible

(i) Explain, in terms of structure and bonding, the difference between the boiling points of HCN and NaCN. **[3]**

HCN is a polar simple covalent molecule with permanent dipole-permanent dipole interactions [1]. NaCN is a giant ionic lattice structure with electrostatic forces of attraction between Na^+ and CN^- [1]. A greater amount of energy is required the stronger ionic bonds in NaCN. [1]

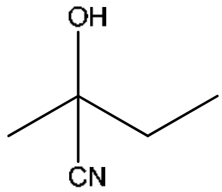
(ii) Explain with the aid of a diagram the solubility of NaCN in water. **[3]**

The energy released from the ion-dipole interactions between NaCN and water is sufficient [1] to overcome the ionic bonds in NaCN and the hydrogen bonds in water [1].

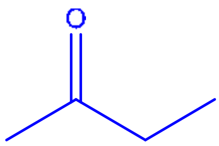


[1]

(d) Hydrogen cyanide is used as a reagent in the formation of cyanohydrin. The structure below shows an example of a cyanohydrin.



(i) Draw the structure of the organic compound that forms the cyanohydrin above. **[1]**

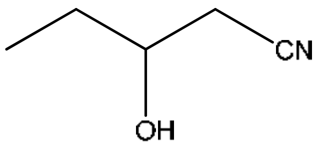


[1]

(ii) Suggest why the reaction needs to be performed at a low temperature. **[1]**

If a high temperature is used, HCN will become a gas which is toxic and it will be difficult to contain the gas. [1]

(iii) The structure below is an isomer of the cyanohydrin above. **[2]**



Outline a simple chemical test to distinguish between the two compounds.

Reagents and conditions: $KMnO_4$ (aq), H_2SO_4 (aq), heat [1]

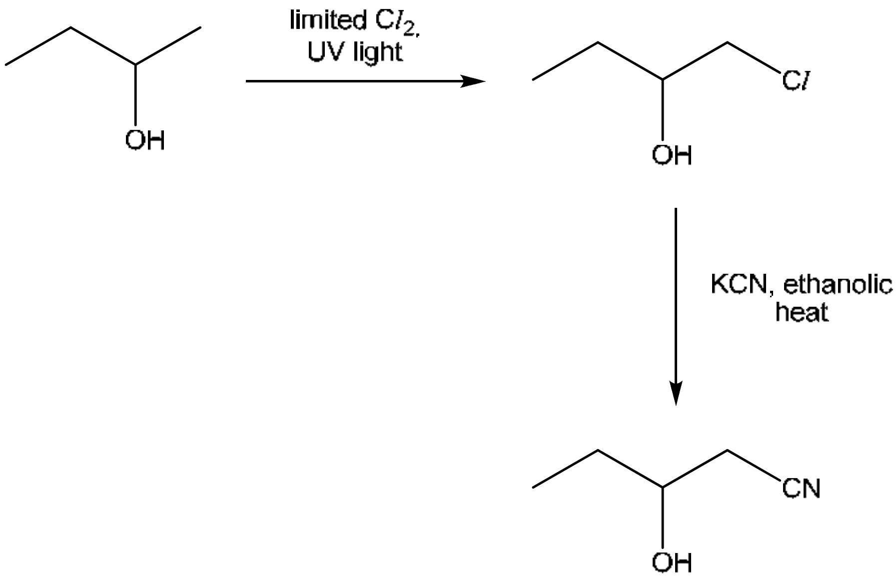
Observation: Purple $KMnO_4$ decolourised for the isomer but purple $KMnO_4$ remains for the cyanohydrin [1]

OR

Reagents and conditions: $K_2Cr_2O_7$ (aq), H_2SO_4 (aq), heat [1]

Observation: Orange $K_2Cr_2O_7$ turned green for the isomer but orange $K_2Cr_2O_7$ remains for the cyanohydrin [1]

(iv) A student suggested that the isomer can be synthesised in the following reaction scheme. Suggest why this synthesis is not the best method. **[1]**



Cl can substitute any of the hydrogen, hence producing a low yield of the product. [1]

[Total: 20]

2. Rocket propellant is a high oxygen containing fuel, whose combustion takes place, in a definite and controlled manner with the evolution of a huge volume of gas. There are four main types of chemical rocket propellants: solid, storable liquid, cryogenic liquid and liquid monopropellant. Solid propellant rocket has a higher propellant density than liquid propellant rocket.

(a) Suggest an advantage of using a solid propellant rocket rather than a liquid propellant rocket. **[1]**

Due to a higher density, the solid propellant rocket has a compact size and thus easier to store. [1]

OR

Solid fuel is able to last longer. [1]

During the 1950s, researchers in the United States developed ammonium perchlorate composite propellant, a type of solid propellant. This mixture is made up of finely ground ammonium perchlorate, fine aluminium powder and polybutadiene acrylonitrile.

(b) Ammonium perchlorate undergoes mild heating according to the equation below.

$$4NH_4ClO_4(s) \rightarrow 4HCl(g) + 2N_2(g) + 5O_2(g) + 6H_2O(l)$$

(i) Calculate the volume of gases formed when 25 g of ammonium perchlorate is heated. (All volumes are measured at room temperature and pressure.) **[2]**

Amount of ammonium perchlorate

= 25 / [14 + 4 + 35.5 + 4(16)] = 0.2127 mol

Amount of gases formed = 0.2127 x 11/4 = 0.5849 mol [1]

Volume of gases formed = 0.5849 x 24 = 14.0 dm^3 [1]

(ii) Suggest why strong heating may lead to an explosion. **[1]**

A large volume of gases are produced. [1]

(c) **(i)** Explain why the first ionisation energy of magnesium is higher than that of aluminium. **[2]**

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

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

The first electron of A*l* is removed from the 3p orbital is further from the nucleus and also experiences additional screening effect by the two 3s electrons [1]. These factors outweigh the effect of increase in nuclear charge from Mg to A*l*, resulting in a weaker attraction by the nucleus and hence less energy required to remove an electron from 3p than the 3s orbital [1].

Alternative:

The first electron of Mg is removed from the 3s orbital which is closer to the nucleus [1], resulting in a stronger attraction by the nucleus and hence more energy required to remove an electron from the 3s orbital [1].

(ii) Explain the difference in electrical conductivity of magnesium, aluminium and silicon. **[2]**

Aluminium has 3 delocalised valence electrons whereas magnesium has only 2, thus aluminium is a better electrical conductor than magnesium [1]. Silicon is a metalloid thus it is not a good electrical conductor [1].

The Soviet utilised syntin, a liquid propellant, for Soyuz U2, is a type of carrier rocket, until 1995. Syntin comprises of synthetic cyclopropane, $C_{10}H_{16}$.

(d) When 0.75 g of cyclopropane undergoes complete combustion, the increase in temperature of 250 cm^3 of water is 18°C and has an efficiency is 85%. Calculate the standard enthalpy change of combustion of synthetic cyclopropane. **[3]**

Heat absorbed by water = $mc\Delta T$ = 250 x 4.18 x 18 = 18810 J [1]

Heat released by combustion of synthetic cyclopropane

= 100 / 85 x 18810 = 22129 J [1]

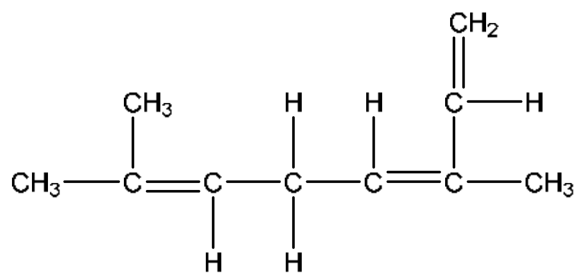
Amount of synthetic cyclopropane = 0.75 / [(10 x 12) + 16] = 0.005514

Standard enthalpy change of combustion of synthetic cyclopropane

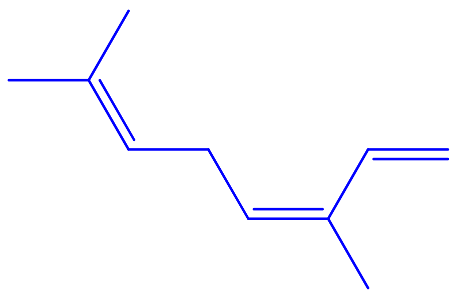
= – 22129 / 0.005514

= – 4013 kJ mol^{-1} [1]

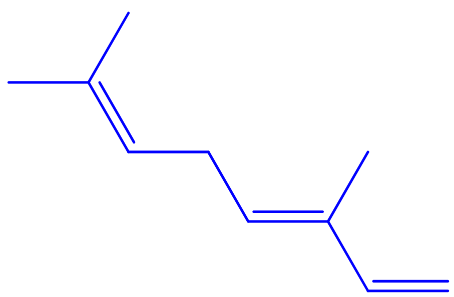
(e) Ocimene is an isomer of syntin with the following structure.



(i) Draw the cis and trans isomers of Ocimene. **[2]**



Cis [1]



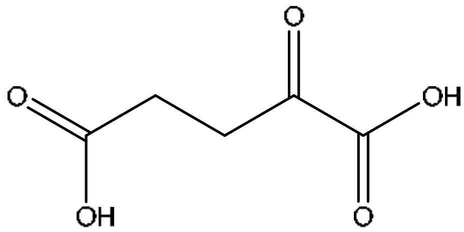
Trans [1]

(ii) Explain why ocimene is able to exhibit cis-trans isomerism. **[2]**

There is restriction of rotation due to the presence of C=C. [1]

There are no two identical atoms or groups of atoms that are bonded to the same carbon on the C=C. [1]

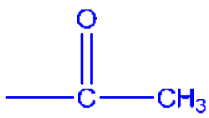
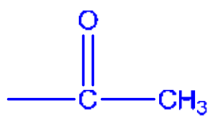
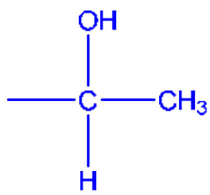
(f) **W** is another isomer of syntin, with a molecular formula of $C_{10}H_{16}$. When **W** reacts with hot acidified potassium manganate(VII), it forms 2 moles of gas **X**, **Y**, and the product shown below **[5]**



X forms a white precipitate when it reacts with aqueous calcium hydroxide.

Y, C_3H_6O, forms a yellow precipitate when it reacts with aqueous alkaline iodine. **Y** also forms an orange precipitate when it reacts with 2,4–dinitrophenylhydrazine. However, **Y** does not form a sliver mirror when it is warmed with Tollens' Reagent.

Deduce the structures of **W**, **X** and **Y**.

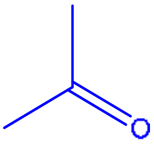
Observations	**Deductions**
X forms a white precipitate when it reacts with aqueous calcium hydroxide.	**X** undergoes acid-base reaction and it is CO_2. [1]
W reacts with hot acidified potassium manganate(VII), it forms 2 moles of gas **X**	**W** undergoes oxidation. Presence of 2 terminal C=C in **W** since **X** is CO_2. [1]
Y, C_3H_6O, forms a yellow precipitate when it reacts with aqueous alkaline iodine.	**Y** undergoes oxidation and contains . [1] (Do not accept if student gave both  and )
Y also forms an orange precipitate when it react with 2,4–dinitrophenylhydrazine.	**Y** undergoes condensation and is a carbonyl compound. [1]

Y does not form a sliver mirror when it is warmed with Tollens' Reagent.	**Y** does not undergo oxidation and is a ketone. [1]

Deductions total [5], max [2]

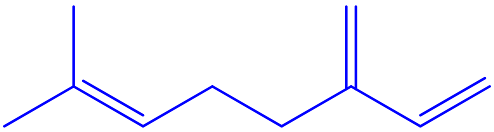
X: CO_2 [1]

Y:



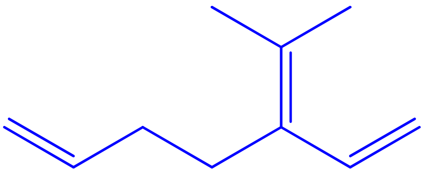
[1]

W:



[1]

OR



[Total: 20]

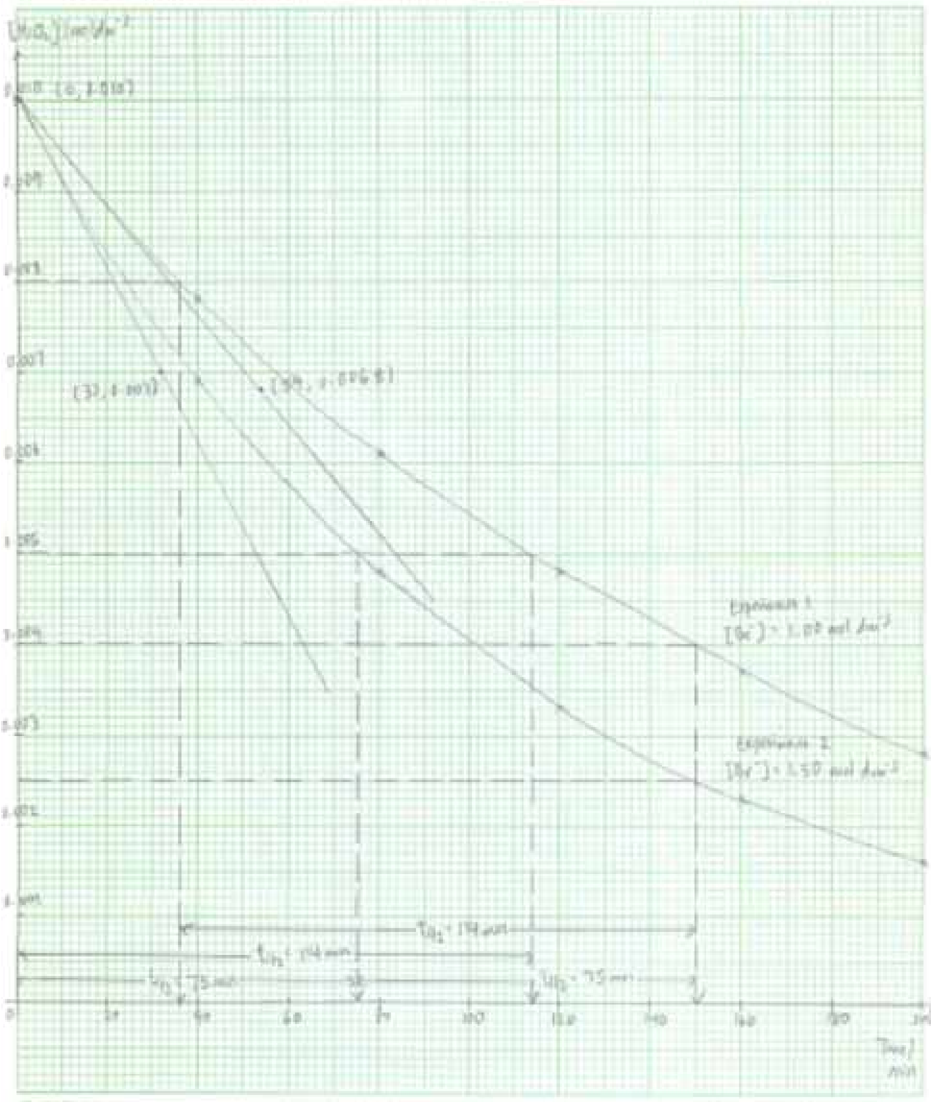
3 **(a)** A solution of hydrogen peroxide in aqueous HC*l* slowly oxidises bromide ions according to the equation below.

$$H_2O_2 + 2Br^- + 2H^+ \rightarrow Br_2 + 2H_2O$$

The rate of reaction was followed by measuring the concentration of the remaining hydrogen peroxide after fixed time intervals. Two experiments were carried out, starting with different concentrations of bromide ions. The following results were obtained.

Time / min	Experiment 1 $[Br^-]$ = 1.00 mol dm^{-3}	Experiment 2 $[Br^-]$ = 1.50 mol dm^{-3}
	$[H_2O_2]$/ mol dm^{-3}	$[H_2O_2]$/ mol dm^{-3}
0	0.0100	0.0100
40	0.0078	0.0069
80	0.0061	0.0048
120	0.0048	0.0033
160	0.0037	0.0023
200	0.0028	0.0016

(i) Using the same axes, plot graphs of [H_2O_2] against time for the two experiments. **[2]**



Each graph [1] x 2

Graph must have the following:

- correct axis with units
- labelling of experiment 1 and 2
- graph plotted accurately
- uses proper scale
- occupy ½ of the graph paper

Minus 1 mark if any of the above is missing.

(ii) Use your graphs to determine the order of reaction with respect to [H_2O_2] and to [Br^-], showing your workings clearly. **[4]**

Two sets of half-life clearly drawn on the graph for experiment 1 or 2.

Experiment 1:

$t_{1/2}$ = 114 min [1]

OR

Experiment 2:

$t_{1/2}$ = 75 min

Since the two half-lives are constant, the order of reaction with respect to $[H_2O_2]$ is one. [1]

Draw tangent at t = 0.

Initial rate for experiment 1

= $|0.010 - 0.0068 / 0 - 54|$ = 5.926×10^{-5} mol dm^{-3} min^{-1}

Initial rate for experiment 2

= $|0.010 - 0.007 / 0 - 32|$ = 9.375×10^{-5} mol dm^{-3} min^{-1}

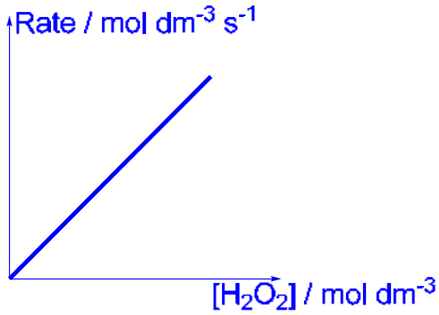
Calculation of 2 initial rates [1]

When $[Br^-]$ increases 1.5 times, the rate increases approximately 1.5 times. Hence the order of reaction with respect to $[Br^-]$ is one. [1]

(iii) In another separate experiment, it was found that the order of reaction with respect to [HC*l*] is zero, write the rate equation for the reaction. **[1]**

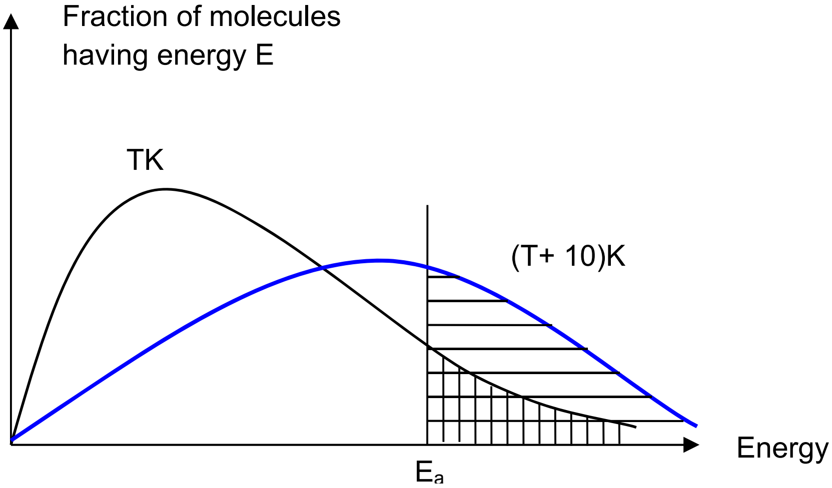
Rate = $k[H_2O_2][Br^-]$ [1]

(iv) Sketch a graph of rate against concentration of H_2O_2. **[1]**



[1]

(v) Explain, with an appropriate sketch of the Boltzmann distribution, how an increase in temperature affects the rate of reaction. **[3]**



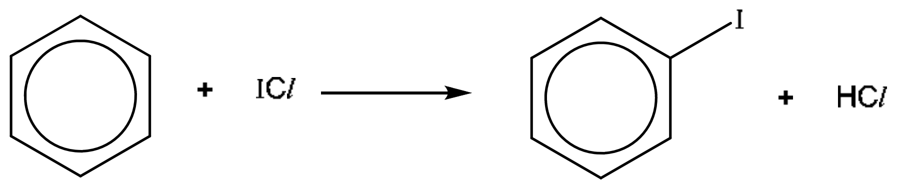
[1]

When temperature is increased, the molecules gain kinetic energy and move about faster. The number of molecules having energy greater than or equal to the activation energy increases. [1] Frequency of effective collisions increases. Reaction rate thus increases. [1]

(b) Explain the difference in ionic radius between Br^- and I^-. **[2]**

I^- has more number of principal quantum shells than Br^-, thus the distance of the valence electrons is further away from its nucleus. [1] The valence electrons are less strongly attracted to the nucleus. Therefore the ionic radius of I^- is bigger than Br^-. [1]

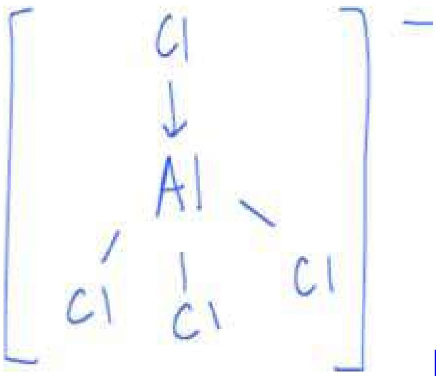
(c) Aromatic halogenation with iodine monochloride, ICl, produces aryl iodide.



This reaction is typically catalysed by aluminium chloride when it reacts with iodine monochloride to produce the electrophile I^+.

$$ICl + AlCl_3 \longrightarrow [AlCl_4]^- + I^+$$

(i) Draw the structure of $[AlCl_4]^-$ and suggest in terms of bonding how $[AlCl_4]^-$ is formed from $AlCl_3$. **[2]**



[1]

Lewis structure (with correct shape) or dot-and-cross diagram is accepted.

The empty orbital of A*l* in A*l*C*l*$_3$ accepts a lone pair of electrons from C*l*$^-$, forming a dative bond [1].

(ii) When sodium carbonate is added to a solution of A*l*C*l*$_3$, effervescence was seen. Explain the observation with the aid of relevant equations. **[3]**

$[Al(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons [Al(H_2O)_5OH]^{2+}(aq) + H_3O^+(aq)$ [1]

$2H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O(l)$ [1]

Al^{3+} hydrolyses in water to form H^+ which reacts with carbonate ions to give carbon dioxide gas. [1]

(iii) Ethanolic silver nitrate is added to iodobenzene and iodopropane in two separate test tubes. Yellow precipitate is seen immediately in one of the test tubes, whereas no precipitate is seen in the other test tube. Explain the observations. **[2]**

The yellow precipitate is AgI in the test tube containing iodopropane. [1]

No precipitate is seen in the test tube with iodobenzene as the lone pair of electrons on I is delocalised into the benzene ring, resulting in a partial double bond character in the C–I bond [1]. Hence the C–I bond is very strong to be broken to form AgI.

[Total: 20]

--- THE END ---

TEMASEK JUNIOR COLLEGE

CHEMISTRY 8872/01

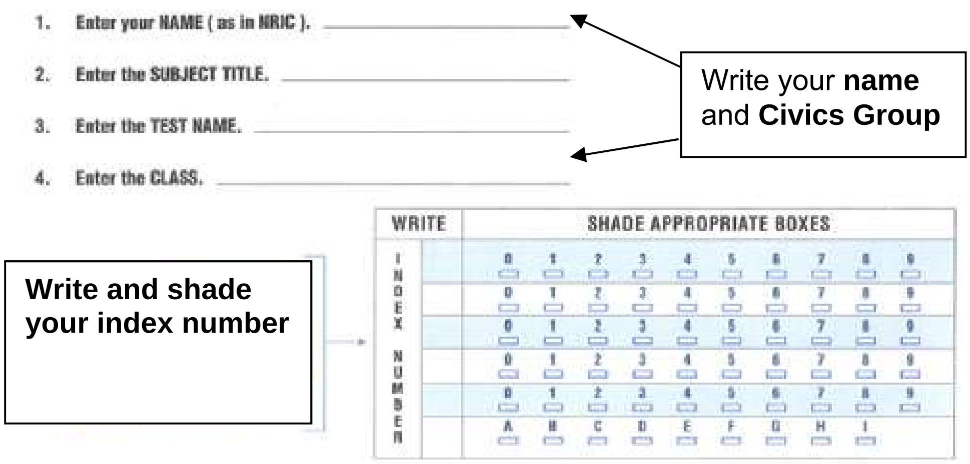
Paper 1 Multiple Choice

15^{th} September 2017
50 minutes

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.

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

Part 1

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

1 The reaction between aluminium powder and anhydrous barium nitrate is used as the propellant in some fireworks. Nitrogen gas is one of the products formed.

Which volume of nitrogen, measured under room conditions, is produced when 1 g of anhydrous barium nitrate reacts with an excess of aluminium?

A 86.9 cm^3 **B** 91.8 cm^3 **C** 174 cm^3 **D** 184 cm^3

2 Which statements about relative molecular mass are correct?

A It is the mass of one mole of the molecule.

B It is the ratio of the average mass of a molecule to the mass of a ^{12}C atom.

C It is the sum of the relative atomic masses of all the atoms within the molecule.

D It is the mass of one mole of molecules on a scale where one atom of ^{12}C has a mass of 12 units.

3 The first stage in the manufacturing of nitric acid is the oxidation of ammonia by oxygen.

$$\mathbf{w}NH_3(g) + \mathbf{x}O_2(g) \rightarrow \mathbf{y}NO(g) + \mathbf{z}H_2O(g)$$

Which values of **w**, **x**, **y** and **z** are needed to balance the equation?

	w	x	y	z
A	4	5	4	6
B	4	6	4	5
C	5	6	5	4
D	6	5	6	4

4 When beams of charged particles are pass through an electric field, they are deflected.

A stream of gaseous protons was passed between two oppositely charged plates and it deflected at an angle of 20.0º.

Under identical conditions, what angles and direction will He^{2+} be deflected?

	Angle of deflection	Deflected towards
A	5	Positive plate
B	10	Negative plate
C	20	Positive plate
D	40	Negative plate

5 In the reaction shown, M represents a Group 2 element.

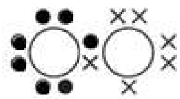
$$MO_2 \rightarrow MO + \frac{1}{2} O_2$$

Which statement about this reaction is correct?

A It is a redox reaction.

B The anion in MO_2 contains 8 electrons.

C The lattice energy of MO_2 is greater in magnitude than the lattice energy of MO.

D The dot and cross diagram of the anion is  .

6 Which of the following species do not have all atoms that lie on the same plane?

A CH_2CH_2 **B** I_3^- **C** XeF_4 **D** $BeCl_4^{2-}$

7 In which pair of compounds does the first compound have higher boiling point than the second compound?

A HI, HF

B MgO, NaC*l*

C CH_4, SiH_4

D *trans*-$C_2H_2Cl_2$, *cis*-$C_2H_2Cl_2$

8 A slow stream of water from a tap can be deflected by an electrostatically charged plastic rod because water is a polar molecule.

Why is a water molecule polar?

A Water is able to dissociate into ions.

B The oxygen atom has 2 lone pairs of electrons

C Molecules are bonded together by hydrogen bonds.

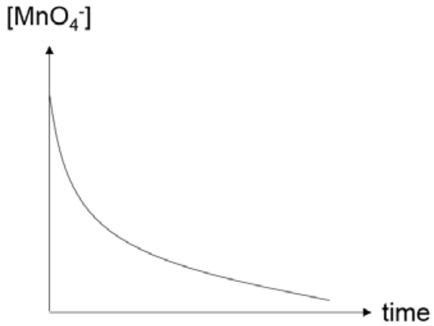
D The oxygen and hydrogen atoms have different electronegativities.

9 An autocatalytic reaction is one whereby the products catalyses the reaction. One such reaction is the reaction between ethanedioate and manganate(VII) anions.

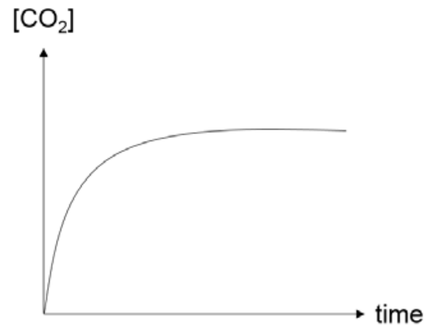
$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

Which of the following graphs would be obtained for an autocatalytic reaction?

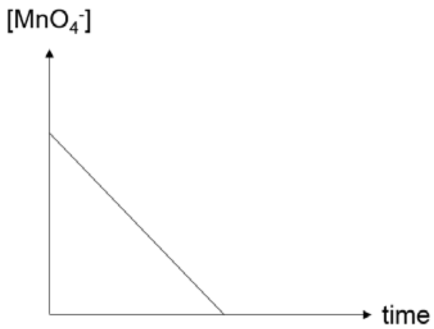
A



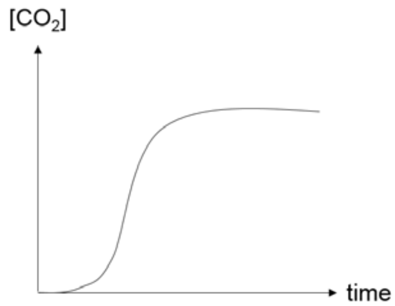
B



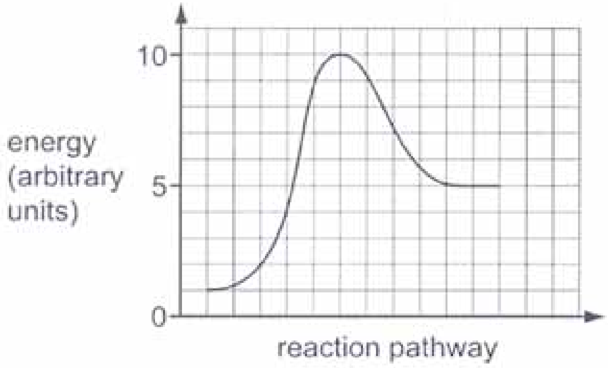
C



D

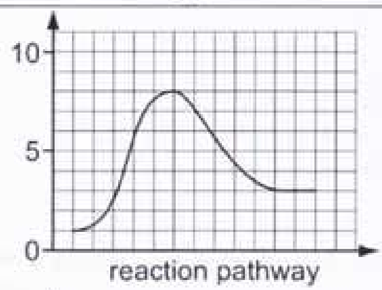
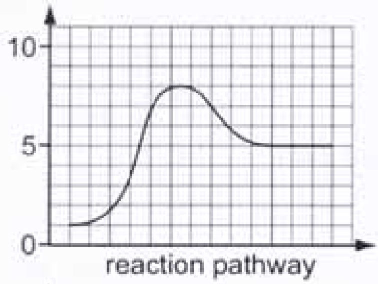
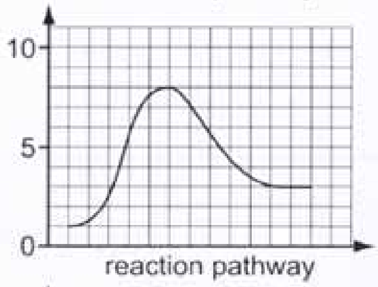
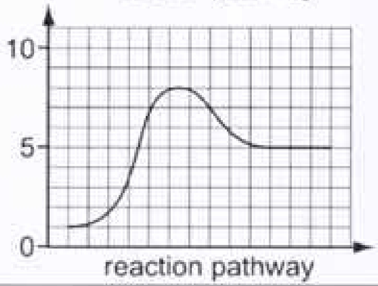


10 The diagram shows the reaction pathway diagram for an uncatalysed reaction.



The reaction is then catalysed.

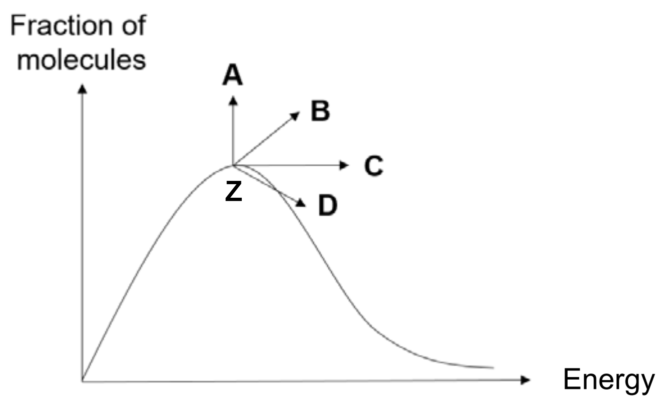
What are the changes in the rate constant and the reaction pathway diagram?

	rate constant	energy profile
A	decrease	
B	decrease	
C	increase	
D	increase	

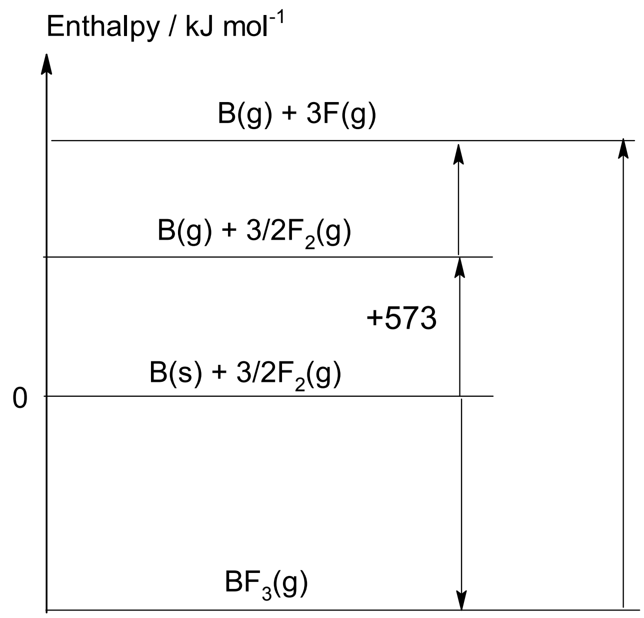
11 The following Maxwell-Boltzmann distribution curve shows the reaction when excess sodium carbonate reacts with 1 mol dm^{-3} hydrochloric acid at room temperature.

Point **Z** on the curve shows the most probable energy attained by the reactant molecules.

In which direction will point **Z** move when the same experiment is repeated with 2 mol dm^{-3} hydrochloric acid at 50 ^{o}C?



12 Reaction of boron hydride with fluorine is a vigorous process and is used as rocket propellant. The reaction yields gaseous boron fluoride, BF_3, as one of the products. An energy level diagram involving BF_3 is shown below.



Given that the standard enthalpy change of formation of boron fluoride = -1137 kJ mol^{-1}

Use the above information and appropriate data from the Data Booklet, calculate the bond energy of B-F bond.

A 623 **B** 649 **C** 1869 **D** 1947

13 When 0.47 g of pentene was completely burnt in air, the heat produced raised the temperature of 200 g of water by 26.4 °C.

What is the enthalpy change of the reaction?

A - 22 kJ mol^{-1}

B - 3290 kJ mol^{-1}

C - 3296 kJ mol^{-1}

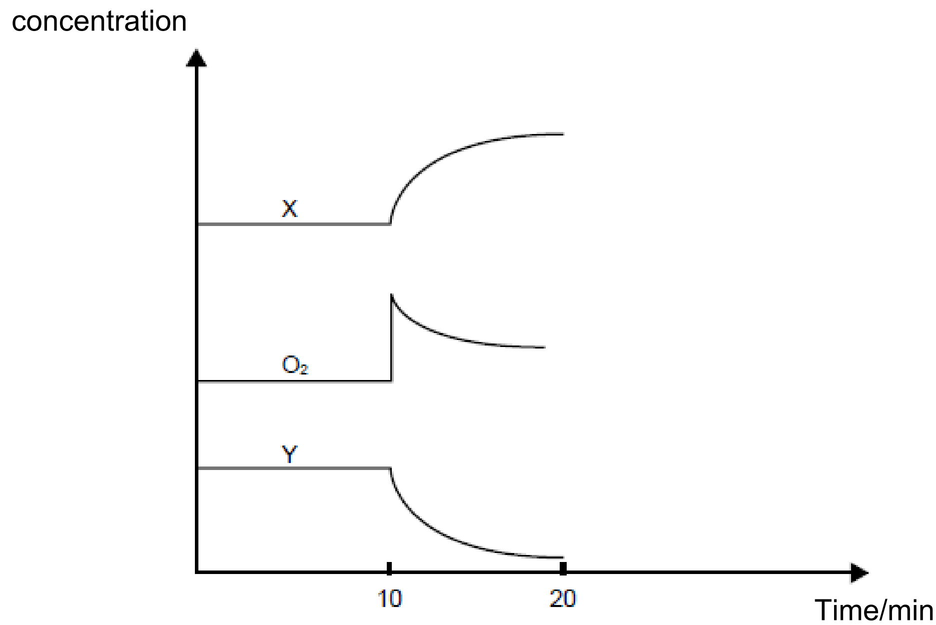
D - 3380kJ mol^{-1}

14 Sulfur dioxide can be converted to sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -192 \text{ kJ mol}^{-1}$$

A container was filled with an equilibrium mixture of sulfur dioxide, sulfur trioxide and oxygen in the presence of a catalyst. The container was initially at 450°C.

Concentrations during an experiment are shown on the diagram below.



Which of the following correctly shows the change at the 10 minute point and the identities of **X** and **Y**?

	X	Y	Change at the 10 min point
A	SO_2	SO_3	Temperature increases
B	SO_3	SO_2	Temperature increases
C	SO_3	SO_2	Oxygen was added
D	SO_2	SO_3	Oxygen was added

15 Which of the following could act as buffer solutions?

A sodium hydrogen carbonate + sodium carbonate

B nitric acid + sodium nitrate

C sodium hydroxide + sodium chloride

D ethanoic acid + methylethanoate

16 Element **Y** is in Period 13 of the Periodic Table. The following four statements were made about the properties of element **Y** or its compounds.

Three statements are correct descriptions and one is false.

Which statement does **not** fit with the other three?

A Element **Y** is a solid at room temperature.

B Element **Y** forms only one chloride when reacted with chlorine.

C The oxide of **Y** reacts with water to give an acidic solution.

D Adding NaOH(aq) to the solution resulting from the reaction of the chloride with water produces a white precipitate which is insoluble in excess of NaOH(aq).

17 For the elements in the third period of the Periodic Table, which property increases consistently from sodium to chlorine?

A electronegativity

B electrical conductivity

C melting point

D first ionisation energy

18 The equations for the complete combustion of the first four members of the alcohol homologous series are shown below.

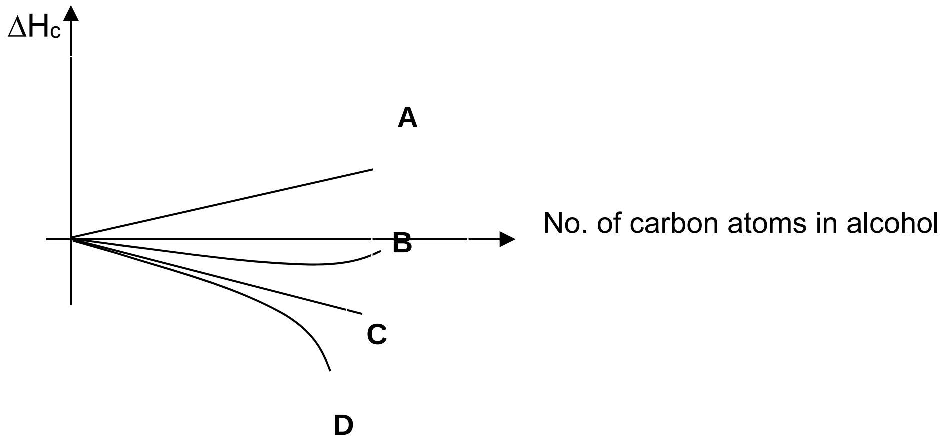
Methanol: $CH_3OH(l) + 1\frac{1}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

Ethanol: $CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

Propan-1-ol: $CH_3CH_2CH_2OH(l) + 4\frac{1}{2}O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

Butan-1-ol : $CH_3CH_2CH_2CH_2OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$

Which line on the graph shows the relationship between the number of carbon atoms in the alcohol and enthalpy change of combustion of the alcohol?

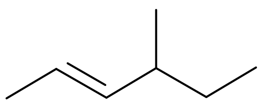


19 Use of the *Data Booklet* is relevant to this question.

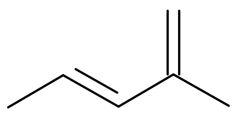
Which compound has a M_r of 84 and will react with HBr to give a product with an M_r of 164.9?

A

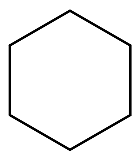
B



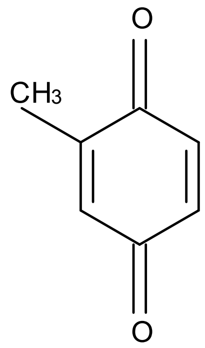
C



D

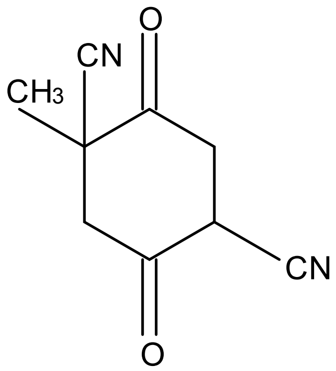


20 The unsaturated diketone shown is excreted by the bombardier beetle.

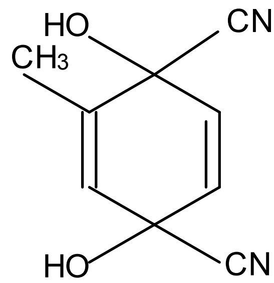


What is the compound formed when this compound reacts with hydrogen cyanide at 10-20°C?

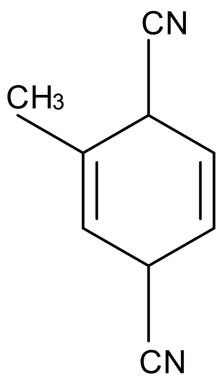
A



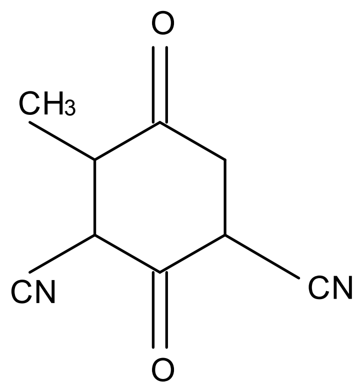
B



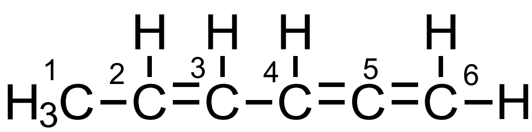
C



D



21



Which bond is present in the compound above?

A a σ bond formed by sp^3 - sp^3 overlap between C3 and C4

B a σ bond formed by sp^2 - sp overlap between C4 and C5

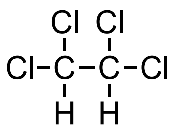
C a σ bond formed by sp^2 - sp^2 overlap between C5 and C6

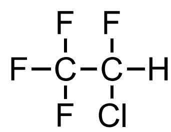
D a π bond formed by sp^2 – sp^2 overlap between C2 and C3

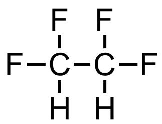
22 How many different alkenes are formed when 2-bromo-3-methylbutane reacts with ethanolic potassium hydroxide?

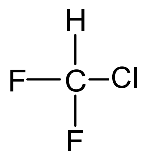
A 2 **B** 3 **C** 4 **D** 5

23 Which of the following will not damage the ozone layer through a radical chain reaction?

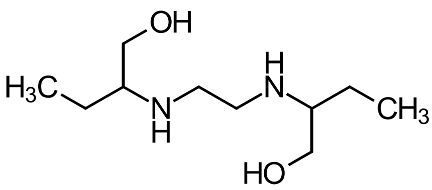
A 

B 

C 

D 

24 Ethambutol (EMB) is commonly used as first line drugs in tuberculosis treating regimes.

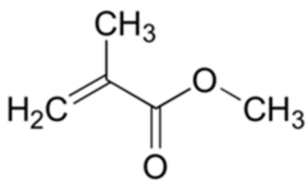


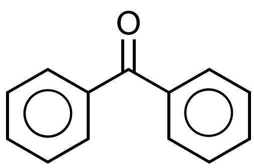
EMB

How many moles of hydrogen gas will be produced when one mole of EMB reacts with sodium?

A 1.0 **B** 2.0 **C** 3.0 **D** 4.0

25 Methyl methacrylate and benzophenone are common ingredients found in nail polishes.





Methyl methacrylate

Which of the following reagents cannot be used to distinguish between these two compounds?

A Acidified $K_2Cr_2O_7$ **B** 2,4-dinitrophenylhydrazine

C Tollens' Reagent **D** Bromine water

SECTION B

For each of the questions in this section, one or more of the 3 numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct. (You may find it helpful to put a tick against the statements which you consider to be correct.)

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1,**2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 The Claus process recovers sulfur from the gaseous hydrogen sulfide found in raw natural gas and from the crude oil refinery by-product gases.

reaction I $2H_2S(g) + 3O_2(g) \rightarrow 2H_2O(l) + 2SO_2(g)$

reaction II $2H_2S(g) + SO_2(g) \rightarrow 2H_2O(l) + 3S(s)$

Which statement about the Claus process is correct?

1 H_2S is oxidised in the reaction.

2 SO_2 is a reducing agent.

3 Reaction II is a disproportionation reaction.

27 Which of the following have a solid lattice structure?

1 Ice

2 Iodine

3 Graphite

28 The following represents the electronic configuration of both a Group 2 cation and a Group 17 anion.

$$1s^22s^22p^63s^23p^63d^{10}4s^24p^6$$

The radius of the anion is approximately twice that of the cation.

Which reasons explain the difference in size?

1 The cation has more protons than the anion.

2 There is more electron shielding in the anion than in the cation.

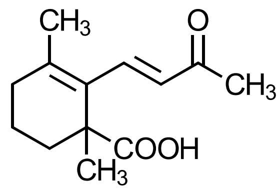
3 The anion is more electronegative than the cation.

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1,**2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

29 Compound **Y** is a derivative of β-ionone, which is an important contributor of the aroma of roses.

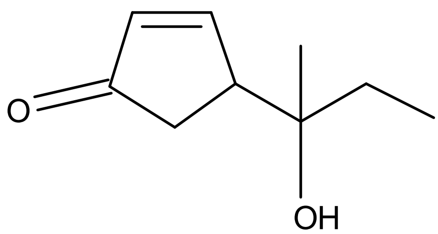


Compound **Y**

What is the correct number of H atoms incorporated per molecule of Compound **Y** when Compound **Y** is reacted with each of the following reducing agents?

	Reducing agent	Number of hydrogen atoms incorporated per molecule of **Y**
1	$NaBH_4$ in ethanol	2
2	H_2 / Ni	6
3	LiA/H_4 in dry ether	8

30 Compound **Z** has the following structure:



Compound **Z**

Which of the following statements about compound **Z** is ***incorrect***?

1 It will give orange crystals with Brady's reagent.

2 It is able to exhibit *cis trans* isomerism.

3 It turns acidified potassium dichromate orange to green.

A: 8 B: 8
C: 7 D: 7

2017 JC2 Prelim H1 CHEMISTRY MCQ Worked Solution

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

1 Answer: B

Since $Ba(NO_3)_2 \equiv N_2$, M_r of $Ba(NO_3)_2$ = 261.3
No. of moles of N_2 = No. of moles of $Ba(NO_3)_2 = \frac{1}{261.3} =$ 3.83×10^{-3} mol
Volume of $N_2 = 3.83 \times 10^{-3} \times 24000 = 91.8\ cm^3$

2 Answer: C

Definition – Relative molecular mass is the average mass of one molecule of an element or compound on a scale on which one atom of the ^{12}C isotope of carbon has a mass of 12 units.

A is incorrect. Relative molecular mass is a ratio.
B is incorrect. It should be the ratio of the average mass of a molecule to <u>1/12</u> the mass of a ^{12}C atom.
C is correct.
D is incorrect. It is the mass of <u>one mole</u> of molecules on a scale where <u>one mole</u> of ^{12}C atoms has a mass of 12 units.

3 Answer: A

$NH_3 + H_2O \rightarrow NO + 5H^+ + 5e$ x4
$4e + 4H^+ + O_2 \rightarrow 2H_2O$ x5
$4NH_3 + 4H_2O + 5O_2 \rightarrow 4NO + 10H_2O$
$4NH_3 + + 5O_2 \rightarrow 4NO + 6H_2O$

4 Answer: B

Positively charged particles deflected towards negative electrode

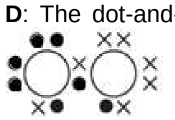
Angle of deflection α $\frac{Charge}{Mass}$

$$\frac{20}{Angle\ of\ deflection\ of\ He^{2+}} = \frac{\frac{+1}{1}}{\frac{+2}{4}}$$

Angle of deflection He^{2+} = +10

5 Answer: A

A. Disproportionation (self-redox) reaction.
Oxidation state of O changes from -1 in MO_2 to -2 in MO and 0 in O_2,
B. O_2^{2-} contains 8+8+2 = 18e
C. lattice energy ∞ ($q_+q_-/r^+ + r^-$) In this case, only r^- is different. Since peroxide ion, O_2^{2-} is bigger than oxide ion, O^{2-} the lattice energy of MO_2 is smaller than MO.
D: The dot-and-cross diagram of the anion should be



6 Answer: D

A: Ethene is a planar molecule which has all atoms on the plane

B: Tri-iodide has 3 lone pairs and 2 bond pairs, hence the ion is linear and all atoms lie on the same plane

C: XeF_4 has 4 bond pairs and 2 lone pairs, hence shape is square planar and all atoms lie on the same plane

D: $BeCl_4^{2-}$ has a total of 4 bond pairs (2 covalent bonds and 2 dative bonds) around Be atom. The shape is tetrahedral.

7 Answer: B

A: HF has hydrogen bonding between its molecules and hence require a larger energy to overcome compared to pd-pd between HI molecules.

B: MgO has a higher boiling point. MgO has a higher lattice energy than NaC*l* due to larger charge and smaller ionic radii of Mg^{2+} and O^{2-} ion compared to Na^+ and Cl^-.

C: SiH_4 has a higher boiling point as its M_r is larger than CCl_4 and thus the id-id interactions are stronger and more extensive than CH_4.

D: *trans*-$C_2H_2Cl_2$ has a lower boiling point as it has no net dipole moment so the molecule is non-polar and only has id-id interactions between the molecules. *cis*-$C_2H_2Cl_2$ has pd-pd interaction between the molecules and more energy is needed to overcome the stronger pd-pd interactions.

8 Answer D

Dipoles are present due to the difference in electronegativity between oxygen and hydrogen atoms. There are is a net dipole hence water is polar.

9 Answer: D

A & C: Wrong as the concentration of manganate would decrease slowly at the start of the reaction before decreasing more quickly as more Mn^{2+} catalyst is generated.

B: Wrong as the volume of CO_2 cannot be increasing rapidly at the start of the reaction due to slow rate of reaction.

10 Answer D

Rate constant is affected by temperature and catalyst.

Rate = k[reactant]

Catalyst increases the rate when concentration is constant hence catalyst increases rate constant.

Energy profile will show NO CHANGE in the ΔH however will lower the E_a of the graph.

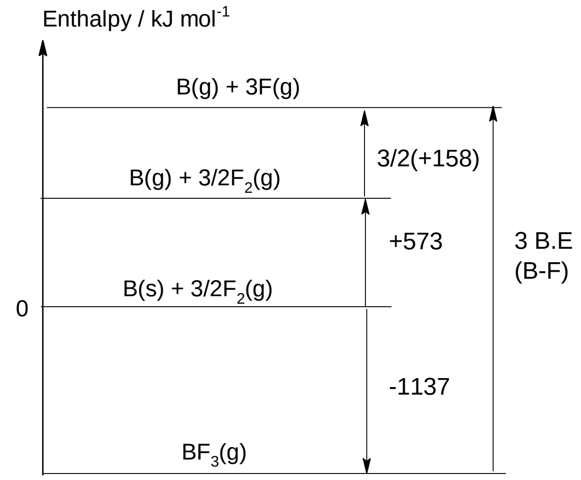
11 Answer: D

When temperature increases, Z will drop below the original point.

When concentration increases, the number of molecules with higher energy increases. The total number of molecules will also increase. Thus, the fraction of molecules remained unchanged.

As the y-axis is the fraction of molecules, shape of the graph is independent of concentration changes.

12 Answer: B



By Hess' Law,

$-1137 + 3\text{ B.E (B-F)} = +573 + 3/2\ (+158)$
$\text{B.E (B-F)} = +649\ \text{kJ mol}^{-1}$

13 Answer B

Heat released when pentene is burnt
= 200 x 4.18 x 26.4
= 22070 J

M_r of pentene = 5(12) + 10(10) = 70

No. of moles of pentene = 0.47/70 = 0.00671 mol

Enthalpy change of combustion = 22070/00671
= -3290 kJ mol^{-1}

Possible errors
A: did not divide by number of moles
C: Added mass of hydrocarbon in mass
D: M_r of pentene is 72

14 Answer: C

When the change was introduced, only the concentration of oxygen increased. This implies that oxygen was added. By Le Chatelier's Principle, the position of equilibrium will shift to the right resulting in an increase in concentration of SO_3 and decrease in concentration of SO_2.

If temperature was increased, there will not be any change in concentration of oxygen.

15 Answer A

A buffer must contain the weak acid and its conjugate base (or weak base and its conjugate acid)
A:Weak Acid (HCO_3^-) + Conjugate base (CO_3^{2-}) → Buffer
B: Strong Acid + Salt → Not a Buffer
C: Strong base + Salt → Not a Buffer
D: Weak Acid + Ester → Not a Buffer

16 Answer C

Option **A** implies **Y** can be Na, Mg, A*l*, Si, P or S.
Option **B** implies **Y** can be Na, Mg, A*l* or Si.
Option **C** implies **Y** can be P or S.
Option **D** implies **Y** must be Mg.

17 Answer A

B: electrical conductivity increase across the metals befor dropping to zero for the non metals.
C: melting point increase from sodium to silicon before dropping.
D: 1st IE generally increase across the period.

18 Answer: C

Enthalpy change of combustion is exothermic thus values are negative. The homologous series defer by a CH_2 hence enthalpy change varies linearly.
Reference table of values for alcohols.

name	alcohol	ΔHcomb
methanol	CH_3OH	–726
ethanol	CH_3CH_2OH	–1367
propan–1–ol	$CH_3(CH_2)_2OH$	–2021
butan–1–ol	$CH_3(CH_2)_3OH$	–2676
pentan–1–ol	$CH_3(CH_2)_4OH$	–3329
hexan–1–ol	$CH_3(CH_2)_5OH$	–3984
heptan–1–ol	$CH_3(CH_2)_6OH$	–4638
octan–1–ol	$CH_3(CH_2)_7OH$	–5294

19 Answer A

B has an M_r of 98.
C will react with 2 HBr to give a compound with M_r = 243.8.
D does not react with HBr.

20 Answer: B

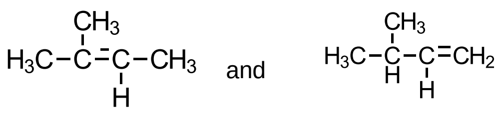
Nucleophilic addition reaction of the C=O.

21 Answer; B

A: a σ bond formed by $sp^2 – sp^2$ overlap between C3 and C4
C: a σ bond formed by $sp – sp^2$ overlap between C5 and C6
D: a π bond formed by p – p overlap between C2 and C3

22 Answer: A

Elimination of HBr results in 2 alkenes,



23 Answer C

In presence of u.v light, the C-C*l* bond cleaves homolytically to produce Cl radical which can damage the ozone layer through a chain reaction. C-H and C-F bonds are stronger and will not break under u.v. light.

24 Answer A

2 –OH groups in 1 mol of EMB react with Na to give 1 mol of H_2 gas.

2 R-OH + 2Na → 2 RO^-Na^+ + H_2

25 Answer C

A: Orange dichromate turns green for methyl methacrylate as ester bond cleave and the primary alcohol part of the ester gets oxidised. Orange dichromate remains orange for benzophenone.

B: orange ppt formed for benzophenone and no orange ppt formed for methyl methacrylate.

C: Tollen's reagent is negative for both compounds as both compounds do not have an aldehyde functional group.

D: reddish-brown bromine water decolourise for methyl methacrylate due to C=C. Reddish brown bromine remain for benzophenone.

26 Answer: D (1 only)

1 is correct as H_2S (oxidation state of sulfur is -2) is oxidized to S (oxidation state 0).
2 is incorrect as SO_2 is an oxidizing agent and oxidises H_2S in reaction.
3 is incorrect as reaction II is a comproportionation reaction.

27 Answer A (1, 2, 3)

All three have solid lattice structure.

28 Answer D (1 only)

Option **1** – cation has more protons mean nuclear charge larger hence the ion is smaller in size.
Option **2** – the shielding is the same since both have the same number of quantum shells
Option **3** – does not explain the size of ions.

29 Answer: B (1 and 2 only)

Compound **Y** has 2 C=C, 1 COOH and 1 ketone functional group. Every functional group in Compound **Y** that gets reduced would have 2 H-atoms incorporated per molecule of Compound **Y**.

	Reducing agent	No. of hydrogen atoms incorporated per molecule of Compound **Y**	Functional group reduced
1	$NaBH_4$ in ethanol	2	1 ketone group
2	H_2 / Ni	6	2C=C + 1 ketone
3	LiA/H_4 in dry ether	<u>**4**</u>	1 ketone and 1 –COOH group

30 Answer C (2 and 3)

1 is correct. Ketone will form orange crystals with Brady's reagent (2,4 DNPH).

2 is wrong. C=C in a ring cannot exhibit cis-trans isomerism.

3 is wrong. Compound Z contains tertiary alcohol which cannot be oxidised hence it does not turn potassium dichromate orange to green.

PRELIMINARY EXAMINATIONS

HIGHER 1

TEMASEK JUNIOR COLLEGE

CANDIDATE NAME										
CIVICS GROUP			/							
CENTER NUMBER	S					INDEX NUMBER				

CHEMISTRY **8872/02**

Paper 2 **11 September 2017**

2 hours

Candidates answer section **A** on the Question Paper.

Additional Materials: Answer Paper
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** questions.

Section B
Answer **two** questions on separate answer paper.

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	/ 15
A2	/ 13
A3	/ 12
Section B	/ 40
Paper 1	/ 30
Total	

This document consists of **17** printed pages.

Section A

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

1 This question is on the elements in period 3 of the Periodic Table.

(a) Describe what you see when phosphorus and sulfur are separately burned in air or oxygen. [2]

(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. Write balanced equations where appropriate. [3]

(c) 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 on the cooler parts of the tube. At low temperatures, the vapour has the empirical formula $AlCl_3$ and a M_r of 267.

(i) Suggest the molecular formula of the vapour, and draw a dot-and-cross diagram to describe its bonding. [2]

(ii) When a large amount of water is added to the yellow-white solid, a clear, weakly acidic solution results.

Write equations to explain the observation. [2]

Chlorine also reacts with phosphorus under suitable condition to give phosphorus pentachloride.

(iii) When phosphorus pentachioride is added to water, the resulting solution has a pH of 1. Explain with the aid of an equation. [2]

(d) Silver chloride is an important photosensitive inorganic material widely used in photographic applications. It is industrially produced by mixing solutions of silver nitrate and sodium chloride.

$$Ag^+(aq) + Cl^-(aq) \rightleftharpoons AgCl(s) \qquad \Delta H^\ominus = -65.7 \text{ kJ mol}^{-1}$$

(i) Use the data in the table to calculate *x*, the standard enthalpy change of formation of Ag^+(aq).

Species	$\Delta H_f^\ominus$
Ag^+(aq)	*x*
Cl^-(aq)	-167
$AgCl$(s)	-127

[2]

(ii) Suggest whether a lower or higher temperature should be used to increase the yield of silver chloride. Explain your answer.

[2]

[Total: 15]

2 **(a)** In 1887, a Swedish scientist Svante Arrhenius postulated that acids and bases dissociate in water to form hydrogen ions, H^+, and hydroxide ions, OH^-, respectively.

(i) Suggest a limitation of the Arrhenius concept of acids and bases.

[1]

A theory proposed by Danish chemist J.N. Brønsted and British chemist T.M. Lowry overcame the shortcomings of the Arrhenius theory.

(ii) Using the Brønsted–Lowry model, explain the roles of nitric acid in the two reactions below.

$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$ *Reaction 1*

$HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$ *Reaction 2*

[2]

(b) Propanoic acid inhibits the growth of mold and some bacteria. Most propanoic acid produced is consumed as a preservative for both animal feed and food for human consumption.

The K_a values of propanol, propanoic acid and malonic acid are given below.

Compound	Formula	K_{a1}	K_{a2}
Propanol	$CH_3CH_2CH_2OH$	7.94×10^{-17}	—
Propanoic acid	$CH_3CH_2CO_2H$	1.35×10^{-5}	—
Malonic acid	$HO_2CCH_2CO_2H$	1.41×10^{-3}	2.00×10^{-6}

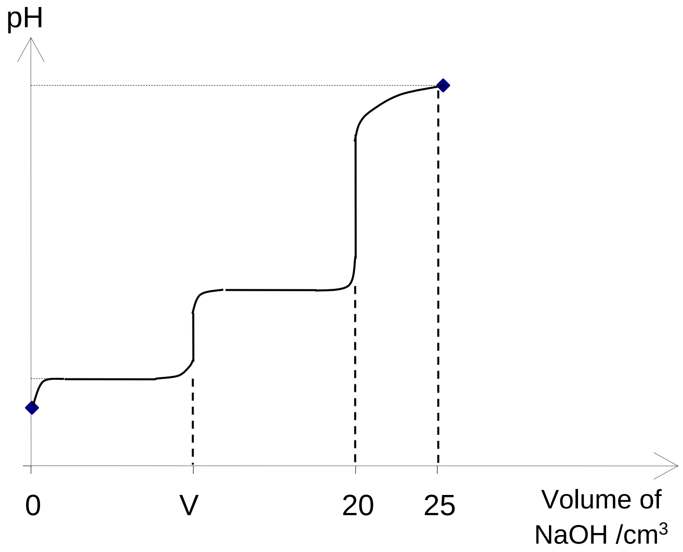
Suggest reason(s) why

(i) K_a of propanoic acid is higher than that of propanol. [2]

(ii) K_{a1} of malonic acid is higher than K_a of propanoic acid. [1]

(iii) K_{a1} of malonic acid is higher than K_{a2} of malonic acid. [1]

(c) 25 cm^3 of 0.10 mol dm^{-3} of NaOH is gradually added to 10 cm^3 of 0.10 mol dm^{-3} malonic acid.

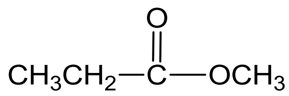


(i) State the value for V. [1]

V = ________________

(ii) Calculate the pH of the mixture when 25 cm^3 of NaOH has been added. [2]

(d) Compound **A** can be directly synthesised from propanoic acid.

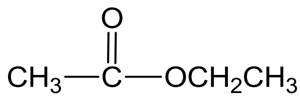


Compound **A**

(i) Suggest reagents and conditions to form compound **A** from propanoic acid. [1]

____

Compound **B** is an isomer of compound **A**.



Compound **B**

(ii) Suggest methods by which compounds **A** and **B** could be distinguished from each other by chemical tests. [2]

____

____

____

____

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[Total: 13]

3 **(a)** Glucose is a reducing sugar and can be identified using Benedict's reagent or Fehling's solution as shown by the following equation.

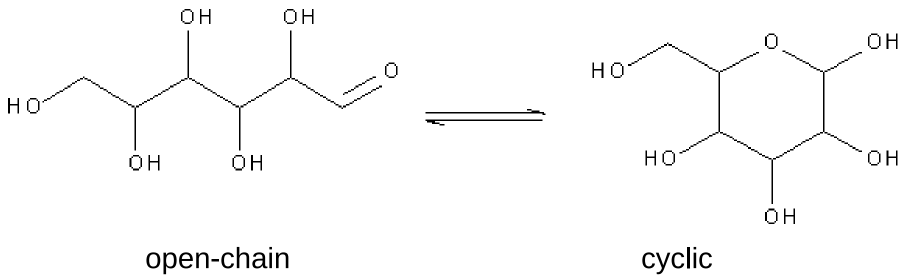
$$C_6H_{12}O_6 + 2Cu^{2+}(aq) \rightarrow Cu_2O(s) + \text{products}$$

A 5.00 g sample of food was treated with an excess copper(II) ions and 0.286 g of copper(I) oxide precipitated was collected.

Calculate the percentage of glucose in the food sample assuming that all the sugar present in the food is in the form of glucose.

[2]

(b) Most of the energy our bodies need comes from carbohydrates and fat. Starch is broken down into glucose,$C_6H_{12}O_6$. Glucose exist mainly in cyclic forms with a small percentage in open chains.



Glucose is transported to the cells to react with oxygen via a series of steps to form carbon dioxide, water and energy.

(i) Write a balanced equation for the reaction of glucose with oxygen.

[1]

(ii) Using data from the *Data Booklet*, calculate the amount of energy released per mole of glucose using the **cyclic** structure.

[2]

(iii) The literature value for the amount of energy released per mole of glucose is – 2800 kJ.

Apart from bond energies being average values, suggest another reason for the difference between this value and that calculated in **(b)(ii)**.

[1]

Like carbohydrates, fats are metabolised into carbon dioxide and water and when subjected to combustion in a bomb calorimeter. The reaction of tristearin, $C_{57}H_{110}O_6$, a typical fat is as follows:

$$C_{57}H_{110}O_6 + \frac{163}{2} O_2 \rightarrow 57\ CO_2 + 55\ H_2O \quad \Delta H^\ominus = -37760 \text{ kJ mol}^{-1}$$

The fuel value is the energy when one gram of the material undergoes combustion. The table below shows the fuel value of carbohydrates and protein and the food label of a cup noodle:

	Fuel value / kJ g^{-1}
Carbohydrate	17
Fat (Tristearin)	To be calculated
Protein	17

Nutrition Facts
Serving Size 1 container (70g)

Amount Per Serving	
Calories 310	Calories from Fat 100
	% Daily Value*
Total Fat 12g	**18%**
Saturated Fat	**25%**
Trans Fat	
Cholesterol 0mg	**0%**
Sodium 1010mg	**42%**
Total Carbohydrate 44g	**15%**
Dietary Fiber 4g	**16%**
Sugars 4g	
Protein 8g	

(iv) Determine the fuel value of tristearin. (M_r of tristearin = 890)

Hence deduce if tristearin or carbohydrate is a better source of energy. [2]

____

____

(v) During reading or watching television, the average adult uses about 7 kJ min^{-1}.

By considering only the total fat, carbohydrate and protein content, calculate the duration in minutes of such activity that can be sustained by one serving of cup noodle. [1]

(c) In the body, glucose is also converted to energy via alcoholic fermentation. This process has been used in making beer and the side products such as esters contribute greatly to the taste and aroma of the beer.

Ethyl acetate can be formed as follows

$$CH_3CO_2H + CH_3CH_2OH \rightleftharpoons CH_3CO_2CH_2CH_3 + H_2O$$

1.51 mol of CH_3CO_2H and 1.66 mol of CH_3CH_2OH was allowed to reach equilibrium in a 100 cm^3 solution. 10 cm^3 of the equilibrium mixture was extracted and large amounts of cold water was added to quench the reaction. The mixture was then titrated with 22.40 cm^3 of 2 mol dm^{-3} NaOH.

Calculate the K_c for the formation of ethyl acetate.

[3]

[Total: 12]

Section B

Answer **two** questions from this section on separate answer paper.

4 **(a)** **(i)** Define the term *empirical formula*. [1]

(ii) Hydrocarbon **P** with M_r = 70 contains 85.7% by mass of carbon.
Determine the empirical formula and hence the molecular formula of **P**. [2]

(iii) Hydrocarbon **P** exhibits stereoisomerism. Draw and label the stereoisomers of **P**. [2]

(b) Organic compound **Q,** with molecular formula $C_6H_8O_4$, can be found in most leather products and is used as a mould inhibitor.

Q decolourises aqueous bromine. On heating one mole of **Q** with dilute acid, two organic products **R**, $C_4H_4O_4$, and methanol are obtained. Vigorous effervescence was observed when **R** reacted completely with sodium carbonate in equimolar proportions.

Use all of the above information to determine the functional groups present in **Q** and **R**. For each functional group you identify, explain how you came to your decision. Hence determine the identity of **Q** and **R**. [6]

(c) Many chemical reactions such as the Contact Process between sulfur dioxide and oxygen occur very slowly at room conditions. One way to speed up the rate of reaction is to use a catalyst.

(i) Explain what is meant by *rate of reaction*. [1]

(ii) Explain with the aid of a Boltzmann distribution curve, how a catalyst speeds up the rate of the reaction. [3]

(d) A kinetics study was conducted on the reaction of $S_2O_8^{2-}$ and I^- to determine the rate equation. Varying volumes of $S_2O_8^{2-}$ and I^- were added to a mixture containing sodium thiosulfate and starch indicator, followed by topping up with suitable volume of water.

As the reaction of $S_2O_8^{2-}$ and I^- proceeds, the iodine produced will be consumed by the $Na_2S_2O_3$. When all $Na_2S_2O_3$ has reacted, the remaining iodine will react with the starch indicator, forming a blue-black complex. The rate of reaction is determined by the time taken for the blue-black colouration to appear.

Experiment	Volume of KI / cm^3	Volume of $Na_2S_2O_8$ / cm^3	Volume of $Na_2S_2O_3$ / cm^3	Volume of water / cm^3	Time for blue-black colour / s
1	10	20	10	10	50
2	5	20	10	15	100
3	30	10	10	0	33
4	20	40	20	20	x

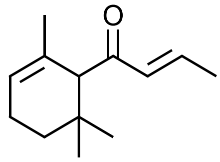
(i) Determine the order of reaction with respect to iodide and peroxodisulfate. [2]

(ii) Hence, construct a rate equation for the above reaction, and determine the units of the rate constant. [2]

(iii) Deduce the time taken, x, for the blue-black colouration to appear for experiment 4. [1]

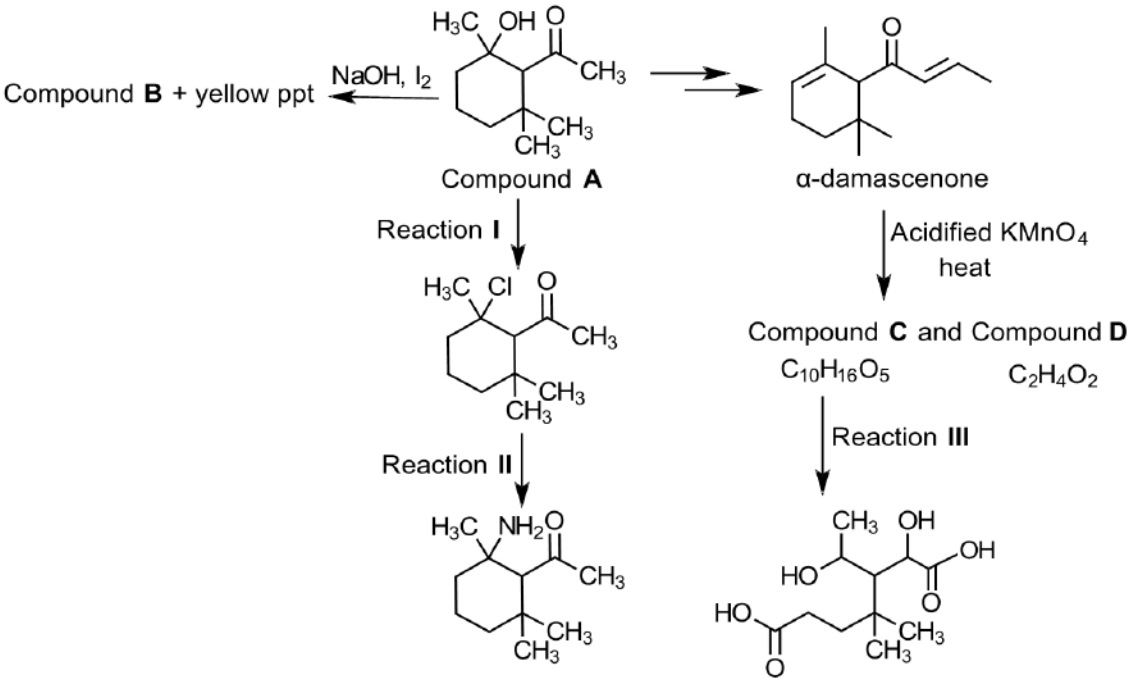
[Total: 20]

5 In the synthesis of damascenones, which are active ingredients in the characteristic smell of Bulgarian rose oil, it was found that compound **B** is a possible pre-cursor.



α-damascenone

Compound **A** and α-damascenone can undergo a series of chemical reactions as shown in the flow chart below:



(a) **(i)** State the reagents and conditions for Reaction **I**, **II** and **III**. [3]

(ii) Draw the structural formulae of Compound **B**, **C** and **D**. [3]

(b) Methanol reacts with acidified potassium dichromate(VI) to form methanoic acid.

Relevant half-equation for this equation is given below:

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

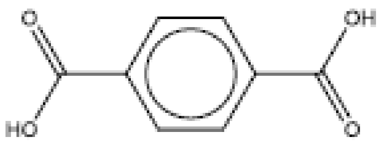
(i) Explain, in terms of the change in oxidation number**,** the role of potassium dichromate(VI) in the reaction with methanol. [2]

(ii) Write the half-equation for the oxidation reaction of methanol to methanoic acid. Hence using the half-equation given above, construct an ionic equation for the reaction between $Cr_2O_7^{2-}$ and CH_3OH in acid solution. [2]

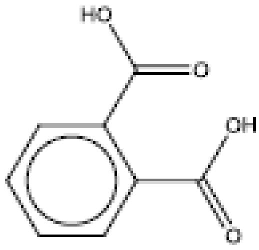
(c) (i) Define second ionisation energy of aluminium. [1]

(ii) Explain why the second ionisation energy of aluminium is greater than that of silicon. [1]

(d) Terephthalic acid (TPA) and phthalic acid (PA) both have the molecular formula $C_6H_4(COOH)_2$. While TPA is used principally to make clothing and plastic bottles, PA has limited commercial application. The structures of TPA and PA are shown below.



TPA



PA

(i) TPA and PA melts at 300 °C and 207 °C, respectively.
With reference to intermolecular interactions, explain why TPA has a higher melting point than PA. [2]

(ii) TPA can be reduced to a diol for the synthesis of a renewable polymer.
Draw the structure of this diol. Illustrate with a diagram, the interaction of this diol with water. [3]

(iii) Hence, explain why the diol in (d)(ii) is soluble in water. [1]

(e) In selecting a suitable material for the manufacture of bulletproof armour, it is necessary to ensure that the material does not shatter upon high impact force from a bullet.

With reference to the structures of gold and fluorite, CaF_2, explain why gold is more suitable for the lining of bulletproof armour. [2]

[Total: 20]

6 High octane fuels that are free from lead additives often contain aromatic hydrocarbons such as benzene, which can be obtained from hexane by the process of "reforming".

$$C_6H_{14} \longrightarrow C_6H_6 + 4H_2$$

(a) **(i)** Suggest reasons for the following statements

- Alkane is generally unreactive.
- Benzene undergoes substitution reaction rather than addition reaction. [3]

(ii) State the reagents and conditions required for the formation of benzoic acid from benzene. [2]

(b) Chlorine-37 is an isotope of chlorine.
Benzene can react with the electrophile $^{37}Cl^{+}$ to form dichlorobenzene

(i) Define the term *isotope*. [1]

(ii) Write the electronic configuration for $^{37}Cl^{+}$. [1]

(iii) State the number, charge and location of the sub-atomic particles in $^{37}Cl^{+}$. [3]

(iv) Draw the non-polar isomer of dichlorobenzene. [1]

(c) Hexane and benzene undergoes combustion to form carbon dioxide.

(i) For each of the three compounds, hexane, benzene and carbon dioxide, state the [3]

- hybridisation
- shape and
- bond angle about carbon.

(ii) Describe the bonding that occurs in hexane and carbon dioxide in terms of the overlap of the orbitals. Draw diagrams to illustrate your answer. [3]

(d) In the stratosphere, chloroflurocarbons (CFC) such as CCl_3F can form radicals such as $\bullet CCl_2F$, which deplete the ozone layer.

(i) Explain what is meant by the term *radical.* [1]

(ii) Draw the dot-and-cross diagram of the $\bullet CCl_2F$ free radical. [1]

(iii) Hydrofluorocarbons (HFC) such as CH_2FCF_3, does not deplete the ozone layer compared to CFCs. Suggest why this is so. [1]

[Total: 20]

TEMASEK JUNIOR COLLEGE

PRELIMINARY EXAMINATIONS

HIGHER 1

CANDIDATE NAME	
CIVICS GROUP	/
CENTER NUMBER	S
INDEX NUMBER	

CHEMISTRY **8872/02**

Paper 2 **11 September 2017**

2 hours

Candidates answer section **A** on the Question Paper.

Additional Materials: Answer Paper

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** questions.

Section B
Answer **two** questions on separate answer paper.

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	/ 15
A2	/ 13
A3	/ 12
Section B	/ 40
Paper 1	/ 30
Total	

This document consists of **18** printed pages.

Section A

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

1 This question is on the elements in period 3 of the Periodic Table.

(a) Describe what you see when phosphorus and sulfur are separately burned in air or oxygen.

[2]

- **For phosphorus, it burns with a white flame on heating in air or oxygen to form white phosphorus(V) oxide, P_4O_{10}.**

($P_4(s)$ + $5O_2(g) \rightarrow P_4O_{10}(s)$)

- **For sulfur, it burns slowly with a blue flame on heating in air or oxygen to form colourless sulfur dioxide, SO_2.**

($S(s)$ + $O_2(g)$ $\rightarrow$ $SO_2(g)$)

[Equations not necessary]

Note : need to describe clearly what is observed.

(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. Write balanced equations where appropriate.

[3]

- **Step 1**

Add NaOH(aq) to the solid. If the solid dissolves, it is Al_2O_3, otherwise it is either MgO or SiO_2

$Al_2O_3 + 2NaOH + H_2O \rightarrow 2Na[Al(OH)_4]$

If solid does not dissolve in NaOH,

- **Step 2**

Add HCl(aq) to the solid. If the solid dissolves, it is MgO otherwise it is SiO_2.

$MgO + 2HCl \rightarrow MgCl_2 + H_2O$

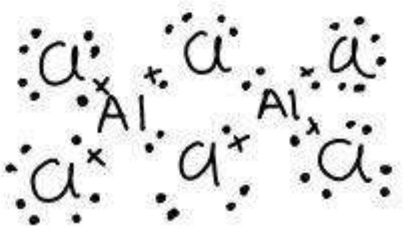
2 equations : 1m

Note : MgO is basic, Al_2O_3 is amphoteric. SiO_2 is acidic but can only react with conc. NaOH.

(c) 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 a M_r of 267.

(i) Suggest the molecular formula of the vapour, and draw a dot-and-cross diagram to describe its bonding.

•Al_2Cl_6

• 

[2]

Note : Do not draw arrows to show dative bonds for dot-cross diagram. Non-bonding valence electrons must be shown for all atoms.

(ii) When a large amount of water is added to the yellow-white solid, a clear, weakly acidic solution results.

Write equations to explain the observation.

- $AlCl_3 + 6H_2O \rightarrow [Al(H_2O)_6]^{3+} + 3Cl^-$ [2]
- $[Al(H_2O)_6]^{3+} \rightarrow [Al(H_2O)_5(OH)]^{2+} + H^+$

Chlorine also reacts with phosphorus under suitable condition to give phosphorus pentachloride.

(iii) When phosphorus pentachioride is added to water, the resulting solution has a pH of 1. Explain with the aid of an equation. [2]

- **It undergoes hydrolysis with water because it has energetically accessible 3d orbitals.**
- $2PCl_5 + 8H_2O \rightarrow 2H_3PO_4 + 10HCl$

Silver chloride is an important photosensitive inorganic material widely used in photographic applications. It is industrially produced by mixing solutions of silver nitrate and sodium chloride.

$$Ag^+(aq) + Cl^-(aq) \rightleftharpoons AgCl(s) \qquad \Delta H^\ominus = -65.7 \text{ kJ mol}^{-1}$$

(d) **(i)** Use the data in the table to calculate *x*, the standard enthalpy change of formation of $Ag^+(aq)$.

Species	$\Delta H_f^\ominus$
$Ag^+(aq)$	*x*
$Cl^-(aq)$	-167
$AgCl(s)$	-127

[2]

$\Delta H_r^\ominus = \Sigma\, n\Delta H_f^\ominus(\text{products}) - \Sigma\, n\Delta H_f^\ominus(\text{reactants})$
• $-65.7 = -127 - (x + (-167))$
x = • + 106 kJ mol^{-1}

Note : Must indicate sign for endothermic enthalpy change.

(ii) Suggest whether a lower or higher temperature should be used to increase the yield of silver chloride. Explain your answer. [2]

• A lower temperature should be used.
• By Le Chatelier's Principle, the system will favour the forward exothermic reaction when temperature is lowered. Hence, the position of equilibrium shifts to the right increasing the yield of silver chloride.

Note : [AgCl(s)] is always a constant but yield increases when position of equilibrium shifts right.

[Total: 15]

2 (a) In 1887, a Swedish scientist Svante Arrhenius postulated that acids and bases dissociate in water to form hydrogen ions, H^+, and hydroxide ions, OH^-, respectively.

(i) Suggest a limitation of the Arrhenius concept of acids and bases. [1]

Accept any of the answers below
- **It applies only to aqueous solutions.**
- **It does not adequately explain why such compounds as ammonia are bases.**
- **The hydrogen ion, H^+, exists as hydronium ion, H_3O^+, in water.**

A theory proposed by Danish chemist J.N. Brønsted and British chemist T.M. Lowry overcame the shortcomings of the Arrhenius theory.

(ii) Using the Brønsted–Lowry model, explain the roles of nitric acid in the two reactions below. [2]

$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$ *Reaction 1*
$HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$ *Reaction 2*

- **In reaction 1, HNO_3 is acting as an acid as it donated a proton, H^+, to OH^-.**
- **In reaction 2, HNO_3 is acting as a base as it accepted a proton, H^+, from H_2SO_4.**

(b) Propanoic acid inhibits the growth of mold and some bacteria. Most propanoic acid produced is consumed as a preservative for both animal feed and food for human consumption.

The K_a values of propanol, propanoic acid and malonic acid are given below.

Compound	Formula	K_{a1}	K_{a2}
Propanol	$CH_3CH_2CH_2OH$	7.94×10^{-17}	—
Propanoic acid	$CH_3CH_2CO_2H$	1.35×10^{-5}	—
Malonic acid	$HO_2CCH_2CO_2H$	1.41×10^{-3}	2.00×10^{-6}

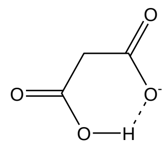
Suggest reason(s) why

(i) K_a of propanoic acid is higher than that of propanol. [2]

- **<u>Delocalisation of negative charge over two oxygen atoms</u> in $CH_3CH_2CO_2^-$ results in a <u>more stable anion</u> while the <u>negative charge is localised</u> on the O atom in $CH_3CH_2CH_2O^-$.**
- **The <u>electron-releasing</u> $–CH_2CH_2CH_3$ group <u>intensifies</u> the <u>negative charge</u> on the O atom, thus <u>destabilising</u> the $CH_3CH_2CH_2O^-$ anion.**

(ii) K_{a1} of malonic acid is higher than K_a of propanoic acid. [1]

- **This is due to the <u>stabilisation of the monoanion by hydrogen bonding</u> with the unionised $–CO_2H$ group in malonic acid.**



or

- **The <u>electron withdrawing -CO_2H group</u> in $HOOC\text{-}CH_2\text{-}CO_2^-$ helps to <u>disperse the negative charge on oxygen</u>, stabilising the anion.**

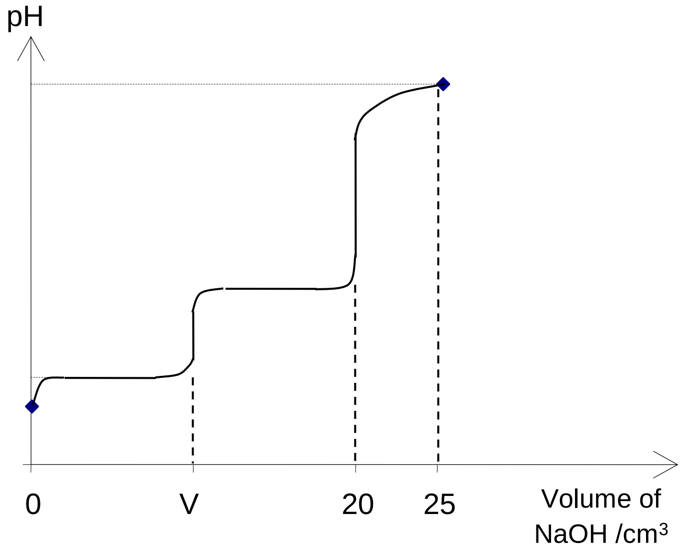
(iii) K_{a1} of malonic acid is higher than K_{a2} of malonic acid. [1]

- **The <u>stabilising hydrogen bonding in the monoanion of malonic acid would be destroyed</u> by the ionisation of the second $–CO_2H$ group.**

or

- **The removal of an <u>H^+ from $HO_2CCH_2CO_2^-$ that already carries a negative charge would be electrostatically unfavourable</u>.**

(c) 25 cm^3 of 0.10 mol dm^{-3} of NaOH is gradually added to 10 cm^3 of 0.10 mol dm^{-3} malonic acid.



(i) State the value for V. [1]

- **V = 10 cm^3**

(ii) Calculate the pH of the mixture when 25 cm^3 of NaOH has been added. [2]

Volume of excess NaOH added = 25 -20 = 5 cm^3

- **No. of moles of excess NaOH = $\frac{5}{1000}$ x 0.10 = 5.00 x 10^{-4} mol**

Total volume of solution = 10 + 25 = 35 cm^3

$[OH^-]$ = $\dfrac{5.00\times10^{-4}}{\frac{35}{1000}}$ = 0.0143 mol dm^{-3}

pOH = -log $[OH^-]$ = 1.85

- **pH = 14 – pOH = 12.2**

(d) Compound **A** can be directly synthesised from propanoic acid.

$$CH_3CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-OCH_3$$

Compound **A**

(i) Suggest reagents and conditions to form compound **A** from propanoic acid. [1]

- **CH_3OH, conc H_2SO_4, heat**

Compound **B** is an isomer of compound **A**.

$$CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-OCH_2CH_3$$

Compound **B**

(ii) Suggest methods by which compounds **A** and **B** could be distinguished from each other by chemical tests. [2]

- **Heat each compound with aqueous sodium hydroxide. Add aqueous alkaline iodine with warming to the reaction products.**
- **Yellow precipitate of CHI_3 is observed for hydrolysed products of compound B but not A.**

or

- **Heat each compound with aqueous sodium hydroxide, followed by heating the reaction products with acidified $KMnO_4$.**
- **CO_2 observed for hydrolysed product (CH_3OH) of compound A but not B.**

[Total: 13]

3 (a) Glucose is a reducing sugar and can be identified using Benedict's reagent or Fehling's solution as shown by the following equation.

$$C_6H_{12}O_6 + 2Cu^{2+}(aq) \rightarrow Cu_2O(s) + \text{products}$$

A 5.00 g sample of food was treated with an excess copper(II) ions and 0.286 g of copper(I) oxide precipitated was collected.

Calculate the percentage of glucose in the food sample assuming that all the sugar present in the food is in the form of glucose.

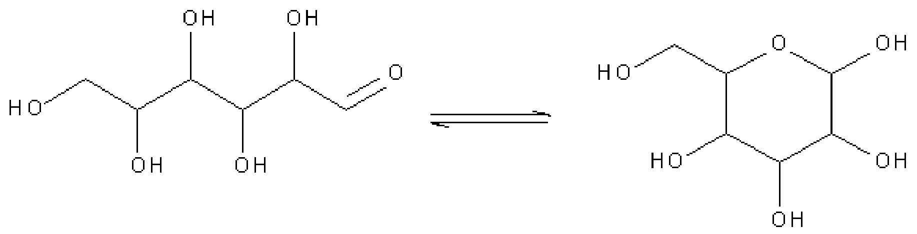
[2]

Number of moles of Cu_2O = 0.286 / ((2 x 63.5) + 16) = 0.286 / 143 = 0.002 mol
● Number of moles of glucose = 0.002 mol

M_r of glucose = 6(12) + 12(1) + 6(16) = 180
Mass of glucose = 180 x 0.002 = 0.360g

● Percentage of glucose = 0.360 / 5 x 100% = 7.20%

(b) Most of the energy our bodies need comes from carbohydrates and fat. Starch is broken down into glucose, $C_6H_{12}O_6$. Glucose exist mainly in cyclic forms with a small percentage in open chains.



open-chain cyclic

Glucose is transported to the cells to react with oxygen via a series of steps to form carbon dioxide, water and energy.

(i) Write a balanced equation for the reaction of glucose with oxygen. [1]

• $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

(ii) Using data from the Data Booklet, calculate the amount of energy released per mole of glucose using the cyclic structure.

[2]

Using the cyclic structure of glucose,

Bond-breaking	**Bond-Forming**
5 x C – C	**12 x C = O**
5 x O – H	**12 x O – H**
7 x C – H	
7 x C – O	
6 x O = O	

• Energy released
= +(5 x 350 + 5 x 460 + 7 x 410 + 7 x 360 + 6 x 496) – (12 x 740 + 12 x 460)
= • - 1980 kJ mol^{-1}

Note: O=O and C-H bonds often missed out.

(iii) The literature value for the amount of energy released per mole of glucose is – 2800 kJ.

Apart from bond energies being average values, suggest another reason for the difference between this value and that calculated in **(b)(ii)**.

[1]

• The ΔH calculated using bond energies applies for the reactants and products in the <u>gaseous phase</u> but the reaction involves solid glucose and <u>liquid H_2O</u> rather than gaseous H_2O.

Like carbohydrates, fats are metabolised into carbon dioxide and water and when subjected to combustion in a bomb calorimeter. The reaction of tristearin, $C_{57}H_{110}O_6$, a typical fat is as follows:

$$C_{57}H_{110}O_6 + \frac{163}{2}\,O_2 \rightarrow 57\,CO_2 + 55\,H_2O \quad \Delta H^{\ominus} = -37760\text{ kJ mol}^{-1}$$

The fuel value is the energy when one gram of the material undergoes combustion. The table below shows the fuel value of carbohydrates and protein and the food label of a cup noodle:

	Fuel Value / kJ g^{-1}
Carbohydrate	17
Fat (Tristearin)	To be calculated
Protein	17

(iv) Determine the fuel value of tristearin. (M_r of tristearin = 890)

No. of moles of tristearin in 1 g = 1/890 = 1.12×10^{-3} mol
• Fuel value of tristearin = $1.12 \times 10^{-3} \times 37760$ = 42.4 kJ/g

Hence deduce if tristearin or carbohydrate is a better source of energy. [2]

• Since <u>more energy</u> is produced per gram, <u>tristearin is a better source</u> of energy than carbohydrate.

(v) During reading or watching television, the average adult uses about 7 kJ/min. By considering only the total fat, carbohydrate and protein content, calculate the duration in minutes of such activity that can be sustained by one serving of cup noodle.

[1]

Total energy provided by cup noodle = 12 x 42.4 + 44 x 17 + 8 x 17 = 1390 kJ
• No. of minutes that can be sustained by energy = 1390/7 = 199 min

(c) In the body, glucose is also converted to energy via alcoholic fermentation. This process has been used in making beer and the side products such as esters contribute greatly to the taste and aroma of the beer.

Ethyl acetate can be formed as follows

$$CH_3CO_2H + CH_3CH_2OH \rightleftharpoons CH_3CO_2CH_2CH_3 + H_2O$$

1.51 mol of CH_3CO_2H and 1.66 mol of CH_3CH_2OH was allowed to reach equilibrium in a 100 cm^3 solution. 10 cm^3 of the equilibrium mixture was extracted and large amounts of cold water was added to quench the reaction. The mixture was then titrated with 22.40 cm^3 of 2 mol dm^{-3} NaOH.

Calculate the K_c for the formation of ethyl acetate.

[3]

NaOH ≡ CH_3CO_2H

No. of moles of CH_3CO_2H in 10 cm^3 = (22.40/1000) x 2 = 0.0448 mol
• No. of moles of CH_3CO_2H in 100 cm^3 = 0.0448 x 10 = 0.448 mol

•	CH_3CO_2H +	CH_3CH_2OH	$\rightleftharpoons$	$CH_3CO_2CH_2CH_3$ +	H_2O
Initial amount/mol	**1.51**	**1.66**		**0**	**0**
Change in amount/mol	**-1.06**	**-1.06**		**+1.06**	**+1.06**
Eqm amount/mol	**0.448**	**0.600**		**1.06**	**1.06**

$$\bullet\ K_c = \frac{[CH3CO2CH2CH3\ ][H2O]}{[CH3CO2H][CH3CH2OH]} = \frac{(\frac{1.06}{0.1})(\frac{1.06}{0.1})}{(\frac{0.448}{0.1})(\frac{0.6}{0.1})} = 4.18$$

[Total: 12]

Section B

Answer **two** questions from this section on separate answer paper.

4 **(a)** **(i)** Define the term *empirical formula*. [1]

Empirical formula is the simplest formula that shows the relative number of atoms of each element in the compound.

(ii) Hydrocarbon **P** with M_r = 70 contains 85.7% by mass of carbon.
Determine the empirical formula and hence the molecular formula of **P**.
[2]

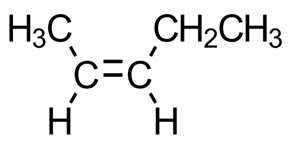
	C	**H**
Mole ratio	**85.7/12**	**14.3/1**
	7.14	**14.3**
Simplest ratio	**1**	**2**

- **Empirical formula : CH_2**

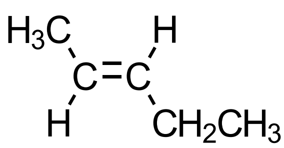
$(CH_2)_n$ = 70
14n = 70
n = 5

- **Molecular formula : C_5H_{10}**

(iii) Hydrocarbon P exhibits stereoisomerism. Draw and label the stereoisomers of P. [2]

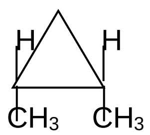


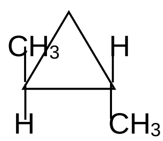
cis



trans

or





(b) Organic compound **Q,** with molecular formula $C_6H_8O_4$, can be found in most leather products and is used as a mould inhibitor.

Q decolourises aqueous bromine. On heating one mole of **Q** with dilute acid, two organic products **R**, $C_4H_4O_4$, and methanol are obtained. Vigorous effervescence was observed when **R** reacted completely with sodium carbonate in equimolar proportions.

Use all of the above information to determine the functional groups present in **Q** and **R**. For each functional group you identify, explain how you came to your decision. Hence determine the identity of **Q** and **R**.

•Q undergoes electrophilic addition reaction with aqueous bromine. Q has C=C.
•Vigorous effervescence observed when R reacts with sodium carbonate
R has carboxylic acid functional group as it liberates CO_2 with carbonate.
• Q reacted with sodium carbonate in equimolar proportions. Q has two carboxylic acid functional groups since 2 moles of $–CO_2H$ will react with 1 mole of sodium carbonate.
•Heating Q with dilute acid gives R, a carboxylic acid and CH_3OH. Q has an ester functional group as it undergoes acid hydrolysis.
•Since Q has 6C and R has 4C and there are only 2 organic products after hydrolysis, 2 moles of CH_3OH must be produced. R is a dicarboxylic acid so Q is a diester.

•R : $HO_2C\text{-}CH{=}CH\text{-}CO_2H$ or $H_2C{=}C(CO_2H)_2$

•Q : $CH_3O\text{-}CO\text{-}CH{=}CH\text{-}CO_2CH_3$ or $H_2C{=}C(CO_2CH_3)_2$

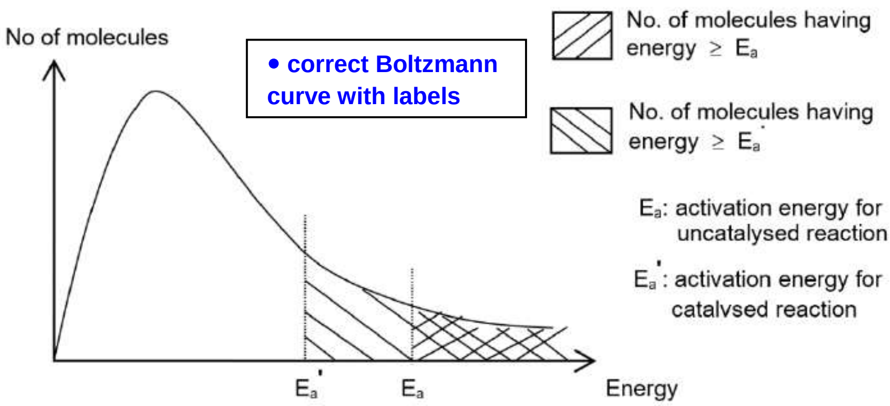
[6]

(c) Many chemical reactions such as the Contact Process between sulfur dioxide and oxygen occur very slowly at room conditions. One way to speed up the rate of reaction is to use a catalyst.

(i) Explain what is meant by *rate of reaction*. [1]

Rate of reaction is defined as the • change in the concentration of reactant or product per unit time.

(ii) Explain with the aid of a Boltzmann distribution curve, how a catalyst speeds up the rate of the reaction. [3]



A catalyst provides • an alternative pathway for the reaction to take place, which has a lower activation energy than the uncatalysed reaction.

• The number of reactant molecules having energy greater than or equal to the lower activation energy, E_a' increases significantly.

Hence the frequency of effective collisions increases and the rate increases.

(d) A kinetics study was conducted on the reaction of $S_2O_8^{2-}$ and I^- to determine the rate equation. Varying volumes of $S_2O_8^{2-}$ and I^- were added to a mixture containing sodium thiosulfate and starch indicator, followed by topping up with suitable volume of water.

As the reaction of $S_2O_8^{2-}$ and I^- proceeds, the iodine produced will be consumed by the $Na_2S_2O_3$. When all $Na_2S_2O_3$ has reacted, the remaining iodine will react with the starch indicator, forming a blue-black complex. The rate of reaction is determined by the time taken for the blue-black colouration to appear.

Experiment	Volume of KI / cm^3	Volume of $Na_2S_2O_8$ / cm^3	Volume of $Na_2S_2O_3$ / cm^3	Volume of water / cm^3	Time for blue-black colour / s	**rate ∝ 1/t**
1	10	20	10	10	50	**0.02**
2	5	20	10	15	100	**0.01**
3	30	10	10	0	33	**0.03**
4	20	40	20	20	*x*	

(i) Determine the order of reaction with respect to iodide and peroxodisulfate. [2]

For expt 1 to 3, total volume is kept constant, so volume of reactant ∝ concentration.

Since thiosulfate is the limiting reagent and volume is constant, relative rate ∝ 1/t, so relative rates for expt 1, 2 and 3 are 0.02, 0.01 and 0.03.

• Comparing expt 1 and 2, when conc of KI decreases by 2 times, rate decreases by 2 times → 1st order with respect to I^-.

• Comparing expt 1 and 3,

$$\frac{Rate_{expt1}}{Rate_{expt3}} = \frac{k[KI][S_2O_8^{2-}]^n}{k[KI][S_2O_8^{2-}]^n}$$

$$\frac{0.02}{0.03} = \frac{k[10][20]^n}{k[30][10]^n}$$

Solving, n = 1

(ii) Hence, construct a rate equation for the above reaction, and determine the units of the rate constant. [2]

• Rate = $k[I^-][S_2O_8^{2-}]$

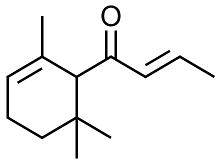
• Units of k is $mol^{-1}\ dm^3\ s^{-1}$

(iii) Deduce the time taken, x, for the blue-black colouration to appear for experiment 4. [1]

Since <u>volume of all reactants double</u> and <u>total volume of mixture doubles</u>, <u>concentration of KI, $Na_2S_2O_8$ and $Na_2S_2O_3$ remain the same</u>. Rate of reaction remains constant, so <u>x = 50 s</u>.

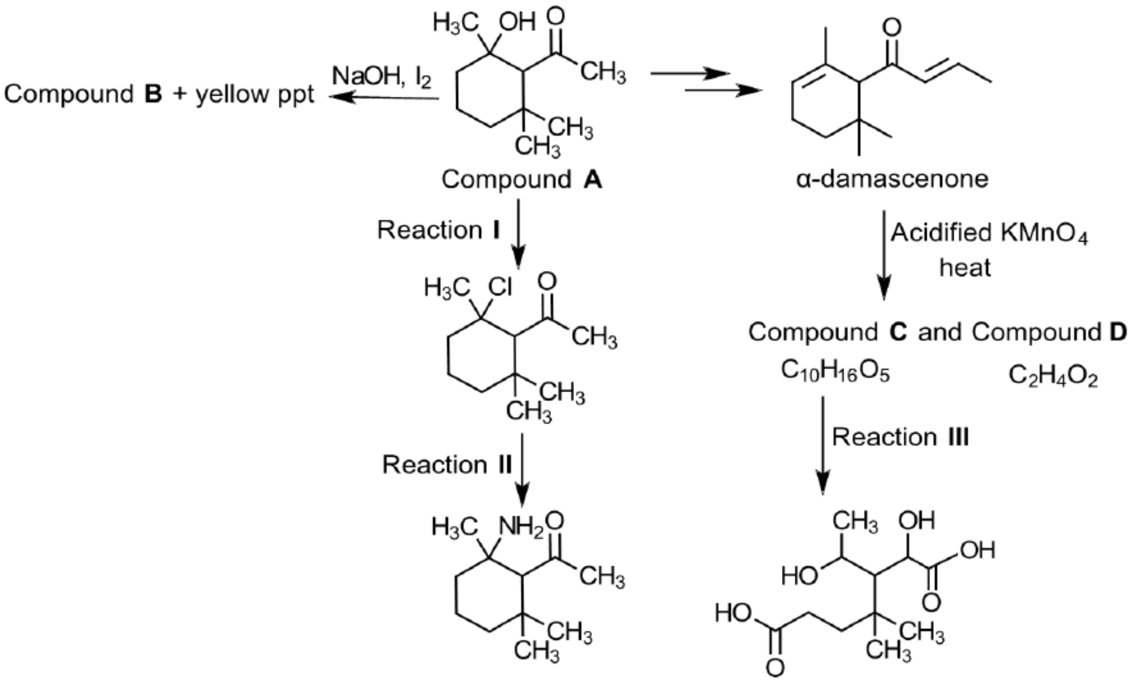
[Total: 20]

5 In the synthesis of damascenones, which are active ingredients in the characteristic smell of Bulgarian rose oil, it was found that compound **B** is a possible pre-cursor.



α-damascenone

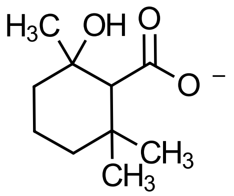
Compound **A** and α-damascenone can undergo a series of chemical reactions as shown in the flow chart below:



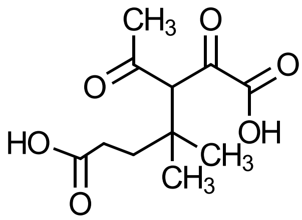
(a) **(i)** State the reagents and conditions for Reaction **I**, **II** and **III**. [3]

- **Reaction I: PCl_5 (s), room temp**
- **Reaction II: Excess concentrated NH_3, heat in a sealed tube**
- **Reaction III: $NaBH_4$, alcohol as solvent, room temp**

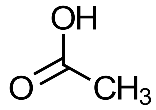
(ii) Draw the structural formulae of Compound **B**, **C** and **D**. [3]



•Compound **B**



•Compound **C**



• Compound **D**

(b) Methanol reacts with acidified potassium dichromate(VI) to form methanoic acid.

Relevant half-equation for this equation is given below:

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

(i) Explain in terms of the change in oxidation number**,** why potassium dichromate(VI) is an oxidising agent in the reaction with methanol. [2]

• $Cr_2O_7^{2-}$ acts as an oxidising agent because it oxidises methanol and the oxidation number of C increases from –2 in CH_3OH to +2 in HCOOH, and •itself is being reduced as oxidation number of Cr decreases from +6 in $Cr_2O_7^{2-}$ to +3 in Cr^{3+}.

(ii) Write the half-equation for the oxidation reaction of methanol to methanoic acid, and using the half-equation given above, construct an ionic equation for the reaction between $Cr_2O_7^{2-}$ and CH_3OH in acid solution. [2]

• Oxidation: $CH_3OH + H_2O \rightarrow HCOOH + 4H^+ + 4e^-$
Overall:
$3CH_3OH + 2Cr_2O_7^{2-} + 28H^+ + 3H_2O \rightarrow 3HCOOH + 4Cr^{3+} + 14H_2O + 12H^+$
• $3CH_3OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3HCOOH + 4Cr^{3+} + 11H_2O$

(c) **(i)** Define second ionisation energy of aluminium. [1]

• 2nd IE of aluminium is the minimum amount of energy to completely remove 1 mole of valence electrons from 1 mole of ground state gaseous Al^+ ions to form 1 mole of gaseous Al^{2+} ions.

(ii) Explain why the second ionisation energy of aluminium is greater than that of silicon. [1]

Al^+: [Ne] $3s^2$

Si^+: [Ne] $3s^2\ 3p^1$

Si has a higher nuclear charge than Al. However, • 2nd IE of Al involves the removal of 3s electron which is more strongly attracted and closer to the

<u>nucleus</u> than the removal of 3p electron for Si. Hence, <u>more energy is needed to remove the 3s electron</u>.

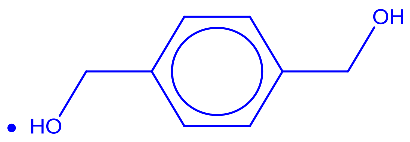
(d) Terephthalic acid (TPA) and phthalic acid (PA) both have the molecular formula $C_6H_4(COOH)_2$. While TPA is used principally to make clothing and plastic bottles, PA has limited commercial application. The structures of TPA and PA are shown below.

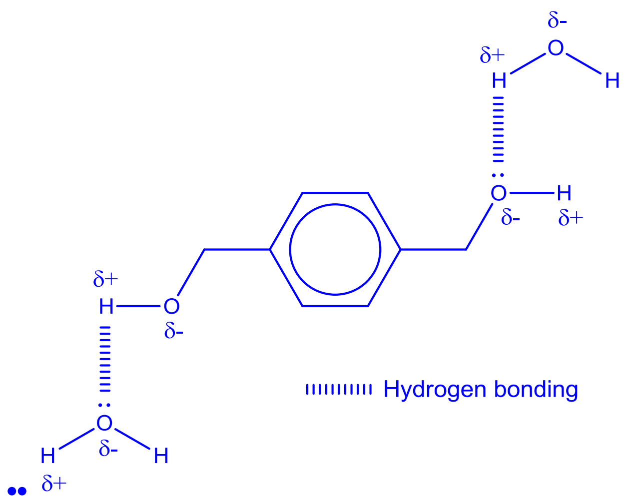
(i) TPA and PA melts at 300 °C and 207 °C, respectively.
With reference to intermolecular interactions, explain why TPA has a higher melting point than PA. [2]

• Due to the <u>close proximity of the 2 -COOH groups</u> in PA, <u>intramolecular hydrogen bonding occurs</u>. This <u>reduces the extent of intermolecular hydrogen bonding</u> between PA molecules.

• In TPA, the <u>2 -COOH groups are further away</u> hence <u>only intermolecular hydrogen bonding</u> occurs. Thus, <u>more heat energy is needed to overcome the more extensive hydrogen bonding.</u>

(ii) TPA can be reduced to a diol for the synthesis of a renewable polymer.
Draw the structure of this diol and illustrate with a diagram, its interaction with water. [3]





(iii) Hence, explain why the diol in **(d)(ii)** is soluble in water. [1]

• Formation of hydrogen bonds between the diol and water releases sufficient energy to overcome the hydrogen bonding between diol molecules and hydrogen bonding between water molecules.

(e) In selecting a suitable material for the manufacture of bulletproof armour, it is necessary to ensure that the material does not shatter upon high impact force from a bullet.
With reference to the structures of gold and fluorite, CaF_2, explain why gold is more suitable for the lining of bulletproof armour. [2]

• When hit with a high impact force, the layers of close-packed gold atoms can slide over one another without breaking the non-directional metallic bonds.

However, for an ionic compound CaF_2, a • high impact force would cause layers of ions to shift and causes ions to same charge to slide next to each other, forcing the layers to come apart and shatter.

[Total: 20]

6 High octane fuels that are free from lead additives often contain aromatic hydrocarbons such as benzene, which can be obtained from hexane by the process of "reforming".

$$C_6H_{14} \longrightarrow C_6H_6 + 4H_2$$

(a) (i) Suggest reasons for the following statements

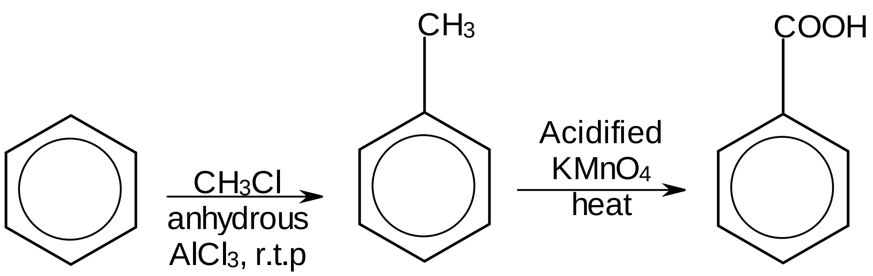
- Alkane is generally unreactive.
- Benzene undergoes substitution reaction rather than addition reaction. [3]

• Alkanes are saturated and contain only C–H and C–C bonds, which are relatively strong and difficult to break.

• In addition, alkane molecules are non-polar due to similar electronegativity of carbon and hydrogen atoms.

• Due to the extra stability of having a π electrons delocalised system, benzene undergoes substitution rather than addition reactions

(ii) State the reagents and conditions required for the formation of benzoic acid from benzene. [2]



• 1m for formation of methylbenzene with correct reagent and condition.
• 1m for formation of benzoic acid with correct reagent and condition.

(b) Chlorine-37 is an isotope of chlorine.
Benzene can react with the electrophile $^{37}Cl^{+}$ to form dichlorobenzene

(i) Define the term *isotope*.

● Atoms of the same element having same number of protons but different number of neutrons [1]

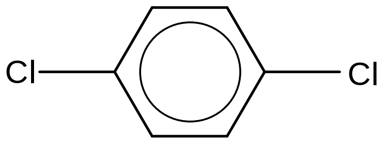
(ii) Write the electronic configuration for $^{37}Cl^{+}$. [1]

● $1s^2 2s^2 2p^6 3s^2 3p^5$

(iii) State the number, charge and location of the sub-atomic particles in $^{37}Cl^{+}$. [3]

● 17 positively charged protons and ● 20 neutrons (no charge) in the nucleus
● 16 negatively charged electrons surrounding the nucleus

(iv) Draw the non-polar isomer of dichlorobenzene. [1]



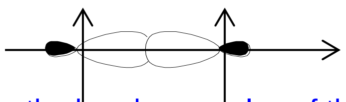
(d) Hexane and benzene undergoes combustion to form carbon dioxide.

(i) For each of the three compounds, hexane, benzene and carbon dioxide, state
- Hybridization state and
- Shape and bond angle about carbon. [3]

	Hexane	Benzene	Carbon dioxide
● Hybridisation	sp^3	sp^2	sp
● Bond angle	109.5°	120°	180°
● Shape	Tetrahedral	Trigonal planar	Linear

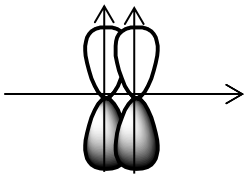
(ii) Describe the bonding that occurs in hexane and carbon dioxide in terms of the overlap of the orbitals. Draw diagrams to illustrate your answer. [3]

● In hexane, the type of covalent bond formed is σ-bond. It is formed by the head-on overlap of sp^3 orbitals to form C-C σ-bond.



[or the head on overlap of the C-H bond represented by overlap of sp^3 orbital with s orbital of H]

● In CO_2, the types of covalent bonds formed are σ-bond and π-bond. A π-bond is formed by the sideways overlap of p orbitals. (This occurs only after a σ-bond is formed)



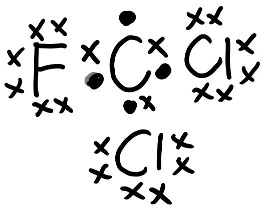
● 1m for diagrams

(e) In the stratosphere, chloroflurocarbons (CFC) such as CCl_3F can form radicals such as $\bullet CCl_2F$, which deplete the ozone layer.

(i) Explain what is meant by the term *radical.* [1]

● A radical is a species that contain an odd number of electrons and has a single unpaired electron in one of its orbital.

(ii) Draw the dot-and-cross diagram of the $\bullet CCl_2F$ free radical. [1]



(iii) Hydrofluorocarbons (HFC) such as CH_2FCF_3, does not deplete the ozone layer compared to CFCs. Suggest why this is so. [1]

● Hydrofluorocarbons are inert. This is because C-F and C-H bonds are very strong and are unlikely to cleave to form free radicals hence they do not deplete the ozone layer.

[Total: 20]

Section A

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.*

What is the number of atoms in 500 cm^3 of oxygen under room conditions?

A 1.25×10^{22} **B** 1.34×10^{22} **C** 2.50×10^{22} **D** 2.68×10^{22}

2 A pure hydrocarbon is used in bottled gas for cooking and heating.

When 10 cm^3 of the hydrocarbon is burned in 70 cm^3 of excess oxygen, the final gaseous mixture contains 30 cm^3 of carbon dioxide and 20 cm^3 of unreacted oxygen. All gaseous volumes were measured under identical conditions.

What is the formula of the hydrocarbon?

A C_2H_6 **B** C_3H_6 **C** C_3H_8 **D** C_4H_{10}

3 Oxygen difluoride, OF_2, will react with sulfur dioxide, SO_2, according to the following equation:

$$OF_2 + SO_2 \rightarrow SO_3 + F_2$$

What is oxidised and what is reduced in this reaction?

	fluorine	oxygen in OF_2	sulfur
A	oxidised	oxidised	reduced
B	oxidised	reduced	oxidised
C	reduced	oxidised	reduced
D	reduced	reduced	oxidised

4 A radioactive isotope of thallium, $^{81}_{201}Tl$, is used to assess damage in heart muscles after a heart attack.

Which one of the following statements about $^{81}_{201}Tl$ is correct?

A $^{82}_{201}Tl$ is an isotope of $^{81}_{201}Tl$.

B This isotope has a nucleon number of 120.

C The number of neutrons in one atom of this isotope is 201.

D The number of electrons in one atom of this isotope is 81.

5 Gallium nitride, GaN, could revolutionise the design of electric light bulbs because only a small length used as a filament gives excellent light at low cost.

GaN is an ionic compound containing the Ga^{3+} ion.

Which one of the following statements about GaN is **not** correct?

A The outer electronic configuration of Ga atom is $4s^2 4p^1$ since Ga is a Group 13 element.

B The electron arrangement of the nitrogen ion in GaN is $1s^2\,2s^2\,2p^3$.

C The electron arrangement of the nitrogen ion in GaN is $1s^2\,2s^2\,2p^6$.

D Ga^{3+} ion deflects less than Al^{3+} ion in an electric field.

6 Sodium borohydride, $NaBH_4$, and boron trifluoride, BF_3, are compounds of boron.

What are the shapes around boron in the borohydride ion and in boron trifluoride?

	borohydride ion	boron trifluoride
A	square pyramidal	trigonal pyramidal
B	square pyramidal	trigonal planar
C	tetrahedral	trigonal pyramidal
D	tetrahedral	trigonal planar

7 Why does aluminium chloride, Al_2Cl_6, sublime at a relatively low temperature of 180 °C?

A The intermolecular forces between Al_2Cl_6 molecules are weak.

B The co-ordinate bonds between A*l* and C*l* atoms are weak.

C The covalent bonds between A*l* and C*l* atoms are weak.

D The ionic bonds between Al^{3+} and Cl^- ions are strong.

8 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.

What is the enthalpy change under standard conditions for the following reaction?

$$3FeO(s) + 2Al(s) \rightarrow 3Fe(s) + Al_2O_3(s)$$

A +878 kJ mol^{-1}

B –878 kJ mol^{-1}

C –1410 kJ mol^{-1}

D –2474 kJ mol^{-1}

9 Some bond energy values are listed below.

bond	bond energy / $kJ\ mol^{-1}$
C–H	410
C–C*l*	340
C*l*–C*l*	244
Br–Br	193

These bond energy values relate to the following four reactions.

P $Br_2 \rightarrow 2Br$

Q $2Cl \rightarrow Cl_2$

R $CH_3 + Cl \rightarrow CH_3Cl$

S $CH_4 \rightarrow CH_3 + H$

What is the order of enthalpy changes of these reactions from most negative to most positive?

A **P → Q → R → S**

B **Q → R → S → P**

C **R → Q → P → S**

D **S → P → Q → R**

10 One mole of phosphorus(V) chloride, PCl_5, is heated to 600 K in a sealed flask of volume 1 dm^3.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

Equilibrium is established and measurements are taken.

The experiment is repeated with one mole of PCl_5 heated to 600 K in a sealed flask of volume 2 dm^3.

How will the measurements vary?

A The equilibrium concentration of $PCl_5(g)$ is lower in the second experiment.

B The equilibrium concentrations of all three gases are the same in both experiments.

C The equilibrium concentrations of $PCl_3(g)$ and $Cl_2(g)$ are higher in the second experiment.

D The value of the equilibrium constant is higher in the second experiment.

11 Nitrogen reacts with hydrogen to produce ammonia.

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

A mixture of 2.00 mol of nitrogen, 6.00 mol of hydrogen, and 2.40 mol of ammonia is allowed to reach equilibrium in a sealed vessel of volume 1 dm^3 under certain conditions. It was found that 2.32 mol of nitrogen were present in the equilibrium mixture.

What is the value of K_c under these conditions?

A $\dfrac{(2.40)^2}{(2.32)(6.00)^3}$

B $\dfrac{(2.08)^2}{(2.32)(6.32)^3}$

C $\dfrac{(1.76)^2}{(2.32)(6.96)^3}$

D $\dfrac{(1.76)^2}{(2.32)(6.32)^3}$

12 A buffer solution is composed of HCO_3^- and CO_3^{2-}.

What is the overall ionic equation that represents the reaction of hydrochloric acid with this buffer?

A $HCl(aq) + HCO_3^-(aq) \rightarrow Cl^-(aq) + H_2CO_3(aq)$

B $H_3O^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + HCO_3^-(aq)$

C $H_3O^+(aq) + HCO_3^-(aq) \rightarrow H_2O(l) + H_2CO_3(aq)$

D $HCl(aq) + CO_3^{2-}(aq) \rightarrow Cl^-(aq) + HCO_3^-(aq)$

13 Magnesium hydroxide dissolves in aqueous ammonium chloride, but not in aqueous sodium chloride.

Which one of the following statements explains this observation?

A The NH_4^+ ion acts as an acid.

B NH_4Cl dissociates less fully than $NaCl$.

C Na^+ and Mg^{2+} ions are isoelectronic (have the same number of electrons).

D The ionic radius of the NH_4^+ ion is similar to that of Mg^{2+}, but not that of Na^+.

14 An experiment was carried out to investigate the initial rate of reaction between ammonium peroxodisulphate, $(NH_4)_2S_2O_8$, an oxidising agent, and potassium iodide, KI.

The initial concentrations of the $(NH_4)_2S_2O_8$ and KI solutions in the mixture together with the time taken for the mixture to darken for the various experimental runs are given below.

initial concentration of $(NH_4)_2S_2O_8$ / mol dm^{-3}	initial concentration of KI / mol dm^{-3}	time taken to darken / s
0.10	0.20	35
0.05	0.20	70
0.10	0.067	105
0.02	0.75	?

What is the expected time taken (in s) to darken when the experiment is repeated using initial concentrations of $(NH_4)_2S_2O_8$ and KI to be 0.02 mol dm^{-3} and 0.75 mol dm^{-3} respectively?

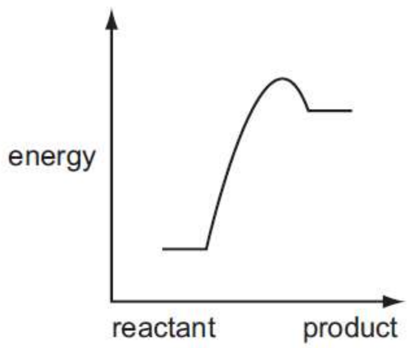
A 40 **B** 47 **C** 60 **D** 72

15 Four reactions of the type shown below are studied at the same temperature:

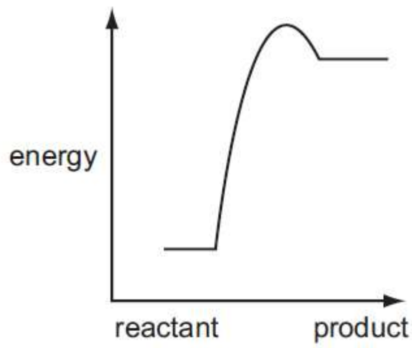
$$X(g) + Y(g) \rightarrow Z(g)$$

Which one of the following is the correct reaction pathway diagram for the reaction that would proceed most rapidly and with good yield?

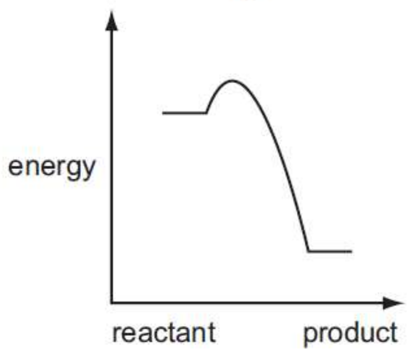
A



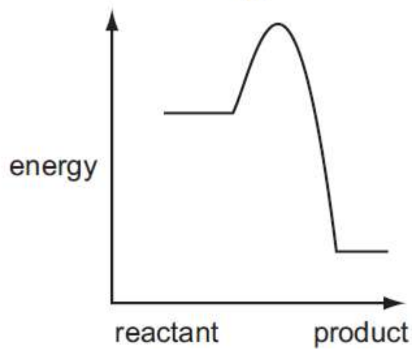
B



C



D



16 Elements **W**, **X**, **Y** and **Z** have proton numbers less than 18. They occupy the following Groups in the Periodic Table.

Element	**W**	**X**	**Y**	**Z**
Group	12	14	15	16

Which two elements could combine to form a compound with giant molecular structure?

A **W** and **X**

B **W** and **Z**

C **X** and **Y**

D **X** and **Z**

17 Element **A** does not react with cold water but reacts vigorously when burnt in chlorine gas to give its chloride. The chloride dissolves in water to give a solution with pH of approximately 3.

What is element **A**?

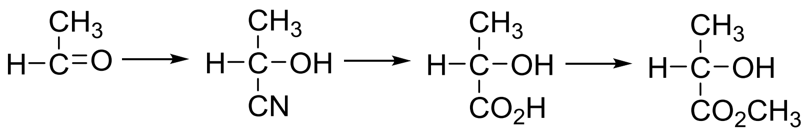
A Mg

B A*l*

C Si

D P

18 A reaction sequence is shown below:



Which one of the following reactions is **not** shown in the reaction sequence?

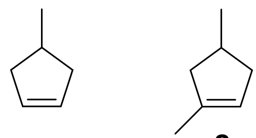
A addition

B condensation

C hydrolysis

D oxidation

19 The diagram shows two different compounds

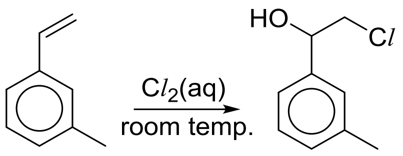


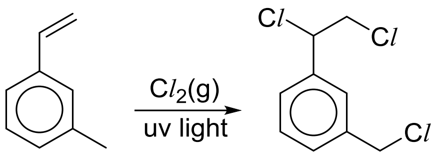
1 **2**

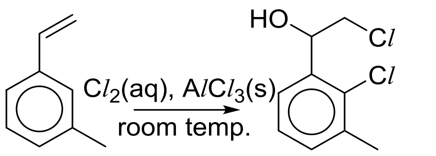
What is the total number of constitutional (structural) isomers, including **compound 2** that could be formed by adding a second methyl group to the ring of **compound 1**?

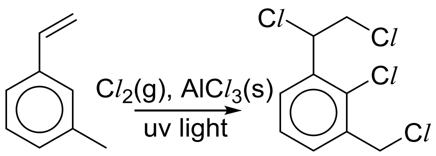
A 2 **B** 3 **C** 4 **D** 5

20 Which one of the following products is **unlikely** to form based on the given reagents and conditions?

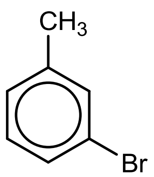
A 

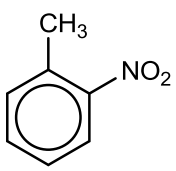
B 

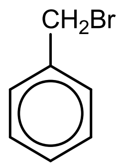
C 

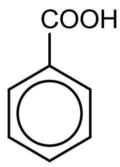
D 

21 Which one of the following compounds **cannot** be made directly from methylbenzene?

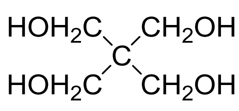
A 

B 

C 

D 

22 The structure of *pentaerythritol* is shown below. It is used in the manufacture of paint.



pentaerythritol

Which one of the following statements best describes a single molecule of *pentaerythritol*?

A It has an empirical formula of CH_3O.

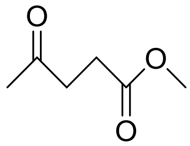
B It has a planar arrangement about the five carbon atoms.

C It reacts with hot excess concentrated sulfuric acid to form alkenes.

D It reacts with carboxylic acid in the presence of hot concentrated sulfuric acid to form esters.

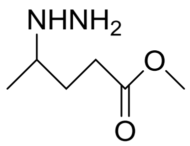
23 Hydrazine, NH_2NH_2, undergoes condensation reaction with carbonyl compounds, similar to 2,4–dinitrophenylhydrazine.

Which one of the following is likely to be the product when compound **Y** reacts with hydrazine?

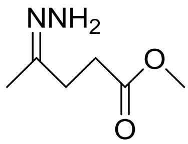


compound **Y**

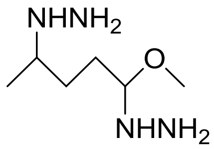
A



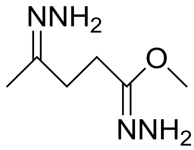
C



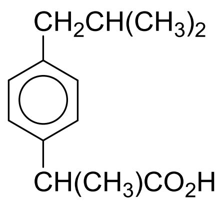
B



D



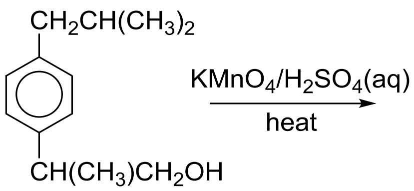
24 *Ibuprofen* is an anti-inflammatory drug.



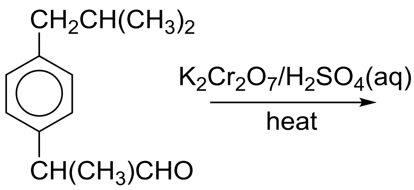
ibuprofen

Which one of the following reactions is **unlikely** to lead to its formation?

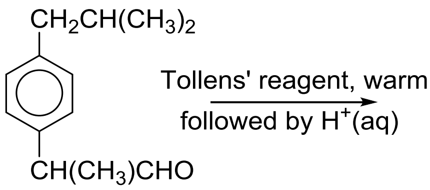
A



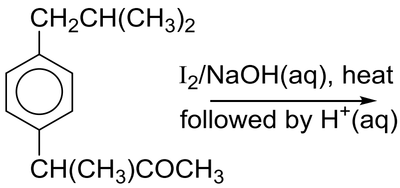
B



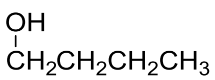
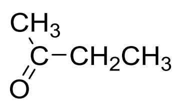
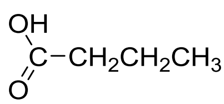
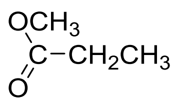
C



D



25 How many of the following compounds can react with hot aqueous sodium hydroxide to form a sodium salt?

A 1 **B** 2 **C** 3 **D** 4

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, 2 and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 In which of the following pairs do **A** have a higher boiling point than **B**?

	A	**B**
1	CH_3CH_2CN	$CH_3CH_2CH_2CH_3$
2	$H_2C{=}CHCH_2OH$	CH_3CH_2CHO
3	$CH_3CH_2CH_2I$	$CH_3CH_2CH_2Cl$

27 Carboxylic acids react with alcohols to form esters in an equilibrium reaction as shown:

$$CH_3COOH(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l) \qquad \Delta H > 0$$

Which of the following will lead to an increase in the yield of the ester?

1 Heating the mixture

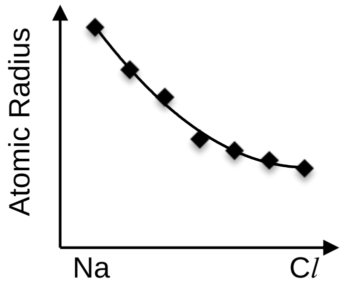
2 Adding water into the mixture

3 Adding excess sodium hydroxide into the mixture

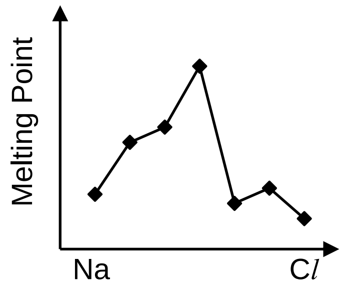
A	B	C	D
1, 2 and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

28 Which of the following graphs show the correct trend of the respective physical properties of elements across the third period (Na to C*l*)?

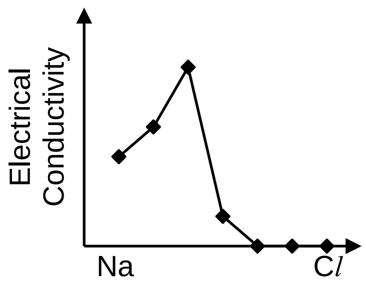
1



2



3



29 Hep–4–enal is present in cow's milk.

$CH_3CH_2CH{=}CHCH_2CH_2CHO$

hep–4–enal

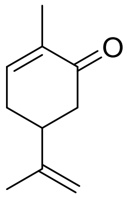
Which of the following options show the correct product for the indicated reducing agent?

1 with H_2/Ni $CH_3CH_2CH_2CH_2CH_2CH_2CHO$

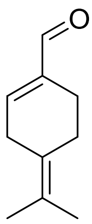
2 with $NaBH_4$ $CH_3CH_2CH{=}CHCH_2CH_2CH_2OH$

3 with $LiAlH_4$ $CH_3CH_2CH{=}CHCH_2CH_2CH_2OH$

30 The structures of two carbonyl derivatives of cyclohexene are shown below.



compound **W**



compound **X**

Which of the following statements about the two molecules are likely to be correct?

1 **W** and **X** cannot exhibit cis–trans isomerism.

2 **W** and **X** can be distinguished using Fehling's solution.

3 **W** and **X** can undergo addition reaction with hot alcoholic NaCN.

VICTORIA JUNIOR COLLEGE

2017 JC2 PRELIM EXAMINATIONS

H1 CHEMISTRY PAPER 1 ANSWERS

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

Section A

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

1 An experiment was conducted to determine the amount of ascorbic acid (vitamin C, $C_6H_8O_6$) in one supplement tablet.

A supplement tablet was dissolved in water and made up to 250 cm^3. 25.0 cm^3 of the solution was pipetted into a conical flask containing 5.0 cm^3 of 0.400 mol dm^{-3} KI and 5.0 cm^3 of 1 mol dm^{-3} HC*l*. A few drops of starch indicator were then added. This resulting solution was titrated against 4.00×10^{-3} mol dm^{-3} KIO_3. 23.90 cm^3 of KIO_3 was required for complete reaction.

When IO_3^- ions are added to an acidic solution containing I^- ions, a redox reaction occurs.

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O \text{ -------- } \mathbf{(1)}$$

The I_2 formed by this reaction then reacts with ascorbic acid to form dehydroascorbic acid ($C_6H_6O_6$).

$$C_6H_8O_6 + I_2 \rightarrow 2I^- + C_6H_6O_6 + 2H^+ \text{ -------- } \mathbf{(2)}$$

Due to reaction **(2)**, the I_2 formed in **(1)** will immediately react away as long as there is any ascorbic acid present. Once all the ascorbic acid has been reacted, the excess I_2 is free to react with the starch indicator, forming the blue-black starch-iodine complex, indicating the end-point of the reaction.

(a) Suggest a reason why the concentration of KI used was much higher than that of KIO_3.

....

....

....

[1]

(b) Explain in terms of the change in oxidation number which species have been reduced in **(1)**. Write a half equation for this reduction.

....

....

....

....

[2]

(c) **(i)** Calculate the amount, in moles, of ascorbic acid present in the original 250 cm^3 solution.

[3]

(ii) Hence, calculate the mass of ascorbic acid in one tablet.

[2]

(d) Ascorbic acid is susceptible to oxidation by atmospheric oxygen over time. A student used a sample of ascorbic acid that was prepared several hours prior to titration.

State, with reasoning, what effect this will have on the volume of KIO_3 required for complete reaction and hence the calculated mass of ascorbic acid.

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.... [2]

[Total: 10]

2 **(a)** The compound whose bonding most resembles pure ionic bonding is a Group 1 fluoride, **M**F.

(i) When the Group 1 cation is passed through an electric field, it is deflected through an angle of +5.0°.

Given that the same electric field deflected $^{92}Sr^{3+}$ through an angle of +22°, calculate the relative atomic mass (A_r) of **M**. Hence suggest a possible identity of the **M**.

[2]

(ii) Explain why the second ionisation energy of **M** is more endothermic than its first ionisation energy.

....

....

.... [1]

(iii) Suggest a reason why the bonding in **M**F resembles pure ionic the most.

....

....

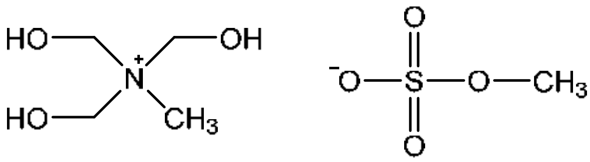
.... [1]

(iv) Draw a dot-cross diagram to show the bonding in **M**F. Show outer electrons only.

[1]

(b) Most ionic compounds are solids at room temperature and pressure. However, researchers have designed ionic compounds whose ionic bonding is so weak that they exist as liquids under these conditions.

An example of an ionic liquid is shown below.



Suggest two features of these ions that account for the compound having a low melting point.

1. ....

2. ....
[2]

(c) Hydrogen bonds are weaker than ionic or covalent bonds, but accounts for many important intermolecular attractions.

State an anomalous property of water that is the result of hydrogen bonding.

....
[1]

(d) Draw and label the hydrogen bond between two water molecules. Indicate the bond angle around the hydrogen atom involved in the hydrogen bond. Include all relevant lone pairs and dipoles.

[2]

[Total: 10]

3 **(a)** Sodium and sulfur are elements in Period 3 in the Periodic Table.

Describe what you would observe when these two elements are separately burned in oxygen. Write equations for the reactions that occur.

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[4]

(b) The oxides, MgO, Al_2O_3 and P_4O_{10}, exist as white powdered solids with high melting points.

(i) Arrange the oxides in decreasing melting points and explain their relative melting points in terms of their structure and bonding.

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…………………………………………………………………………………………………

[4]

(ii) Describe two chemical reactions you could carry out on a sample of white powder to determine the identity of the oxide.

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……………………………………………………………………………………………

[2]

[Total: 10]

4 **(a)** *Cracking* is a process used in the petroleum industry that converts large hydrocarbon molecules into smaller, more useful ones**.**

(i) In one particular reaction, a 16–carbon alkane undergoes cracking to form C_3H_6, C_4H_8 and C_6H_{14} as the **only** products.

Write a balanced equation to represent this reaction.

…………………………………………………………………………………………..
[1]

(ii) The hydrocarbon, C_4H_8, formed from the above reaction is found to display *cis–trans isomerism*.

State the structural requirements for *cis–trans isomerism* to be displayed in an organic molecule.

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…………………………………………………………………………………………..
[2]

(iii) Hence, draw the displayed formulae of the cis–trans isomers of C_4H_8. Label each isomer clearly.

[2]

(b) Another important process in the petroleum industry is *reforming*, which increases the proportion of aromatic, cyclic and branched–chain hydrocarbons in petrol. This enables petrol to burn more smoothly in car engines.

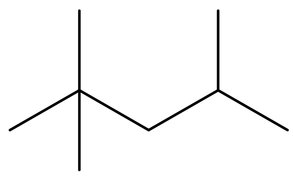
(i) One of the main products formed from the reforming process is methylbenzene, which undergoes two different reactions with bromine, depending on the conditions used.

For each reaction, state the conditions required and write a balanced equation, showing clearly the structure of **any one mono–brominated** organic product formed.

Conditions	**Equation**

[2]

(ii) Another product of the reforming process has the structure below:



State the name of the compound above.

……………………………………………………………………………………………..
[1]

(c) Compound **C** has a symmetrical structure with the molecular formula $C_6H_{12}Br_2$. In the presence of alcoholic NaOH, **C** produces **D**, C_6H_{10}.

When **D** is oxidised by hot acidified $KMnO_4$, three compounds, CO_2, CH_3CO_2H and CH_3COCO_2H, are formed in equimolar amounts.

Deduce the structures of **C** and **D**.

C	**D**

[2]

[Total: 10]

Section B

Answer **two** questions from this section on separate answer papers.

5 **(a)** Nitrogen is an element that is essential to life on earth. In spite of nitrogen's abundance in the atmosphere, the quantity of nitrogen containing compounds that were available for human use was limited. The Haber process for the manufacture of ammonia and the Ostwald process for the conversion of ammonia to nitric acid were developed in the early 20th century.

Ammonia is manufactured from nitrogen and hydrogen by the Haber process as shown in the equation:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H_{rxn} = -45.9 \text{ kJ mol}^{-1}$$

(i) Write an expression for the equilibrium constant, K_c, for the Haber process. [1]

(ii) Calculate the value of K_c given the following equilibrium concentrations at 1000 K. State the units of K_c.

gas	Concentration / mol dm^{-3}
nitrogen	1.36
hydrogen	1.84
ammonia	0.142

[2]

(iii) Explain why the activation energy of the process is high. [1]

(iv) Hence describe and explain the conditions required for the favourable production of ammonia in the Haber process. [3]

(b) A large proportion of the ammonia manufactured is then used to manufacture nitric acid which is another industrially important compound. In Ostwald process, nitric acid is produced industrially from ammonia, air and water using the following sequence of reactions:

Step 1 $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ $\Delta \boldsymbol{H}_{\mathbf{rxn}}$ **(step 1)**

Step 2 $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ $\Delta \boldsymbol{H}_{\mathbf{rxn}}$ **(step 2)**

Step 3 $4NO_2(g) + O_2(g) + 2H_2O(l) \rightarrow 4HNO_3(aq)$ $\Delta \boldsymbol{H}_{\mathbf{rxn}}$ **(step 3)**

Overall reaction $NH_3(g) + 2O_2(g) \rightarrow HNO_3(aq) + 2H_2O(l)$

(i) Using relevant bond energy data from the *Data Booklet* and the following value, calculate the enthalpy change, $\Delta \boldsymbol{H}_{\mathbf{rxn}}$ **(step 1)**, for the reaction between ammonia and oxygen gas.

Bond energy for NO(g) = 607 kJ mol^{-1}

[2]

(ii) Using the following enthalpy changes, calculate the enthalpy changes, $\Delta \boldsymbol{H}_{\mathbf{rxn}}$ **(step 2)** and $\Delta \boldsymbol{H}_{\mathbf{rxn}}$ **(step 3)**.

$\Delta H_f (NO_2)$ = +33.2 kJ mol^{-1}
$\Delta H_f (NO)$ = +90.3 kJ mol^{-1}
$\Delta H_f (HNO_3)$ = –207.4 kJ mol^{-1}
$\Delta H_c (H_2)$ = –285.8 kJ mol^{-1}

[3]

(iii) Hence, or otherwise, calculate the enthalpy change for the **overall reaction**.

[2]

(c) A monobasic acid **HA,** extracted from a fruit has a pH of 3.5.

(i) Calculate the concentration, in mol dm^{-3}, of hydrogen ions in the acid **HA**.

[1]

(ii) 25.0 cm^3 of a sample of the acid **HA** was titrated with 0.25 mol dm^{-3} aqueous NaOH. 21.25 cm^3 of the aqueous NaOH was required to reach equivalence point.

Calculate the concentration, in mol dm^{-3}, of the acid **HA**.

[2]

(iii) Based on your answers to **(c)(i)** and **(c)(ii)** above, what can you deduce about the strength of the acid **HA**? Give a reason for your deduction.

[1]

(iv) Hence predict the volume of carbon dioxide evolved when 25.0 cm^3 of 0.40 mol dm^{-3} of HC*l* and **HA** reacts with excess Na_2CO_3 under standard conditions.

[2]

[Total: 20]

6 **(a)** Potassium reacts with ammonia to give a compound of KNH_2 as shown in the given equation:

$$2K + 2NH_3 \rightarrow 2KNH_2 + H_2$$

The rate of the reaction was investigated by using a freshly cut piece of potassium which was weighed and added to a large excess of ammonia. The experiment was conducted at room temperature and pressure.

The total volume of gas evolved at every minute was recorded and shown below.

Time/ min	0	1	2	3	4	5	6	7	8
Total volume of gas/ cm^3	0	23.0	36.5	46.0	51.0	55	58.0	60	60

(i) Plot the experimental results on graph paper.

[2]

(ii) Hence deduce the order of reaction with respect to potassium.

[1]

(iii) Write a rate equation for the reaction and calculate the rate constant, stating its units.

[2]

(iv) In this experiment, the kinetics appear to be zero order with respect to ammonia. Suggest a reason for this.

[1]

(v) Calculate the mass of potassium used in the experiment.

[2]

(b) Ammonia is an important starting material in the manufacture of fertilisers as well as explosives and plastics. The Haber process is used to form ammonia as shown in the equation below.

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

(i) Draw a Maxwell Boltzmann distribution curve for the reactants at temperature $\mathbf{T_1}$. Label this curve **X**. Mark the position of the activation energy with a line. Label this as $\boldsymbol{E_a}$.

[2]

(ii) On the axes that you have drawn, draw a **second** distribution curve that represents the reaction at a higher temperature $\mathbf{T_2}$. Label this curve **Y**.

Use curves **X** and **Y** to describe and explain the effects of an increase in temperature on the rate of a reaction.

[3]

(iii) Name a catalyst that can be used for the Haber Process.

[1]

(c) **(i)** Draw a dot-and-cross diagram to show the bonding in an ammonia molecule.
[1]

(ii) By using the Valence Shell Electron Pair Repulsion theory, state the shape and bond angle in the ammonia molecule and explain in details how it arises.
[2]

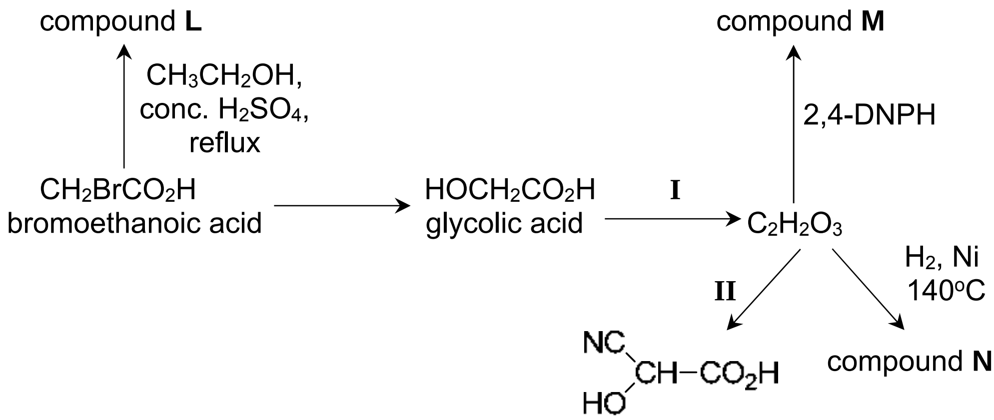
(iii) When ammonia is mixed with aluminium chloride in a 1:1 ratio, a new single compound is formed.

Suggest the type of bond that is formed between ammonia and aluminium chloride, explaining your answer clearly. Draw a ***displayed*** structure of the product formed, indicating the bond angle with respect to nitrogen and aluminium.
[3]

[Total: 20]

7 **(a)** Glycolic acid, $HOCH_2CO_2H$, is a colourless, odourless and hygroscopic crystalline solid which is used in various skin-care products.

The reaction scheme below shows some reactions involving glycolic acid.



(i) State the reagents and conditions for reactions **I** and **II**.

[2]

(ii) Draw the structural formulae for compounds **L**, **M** and **N**.

[3]

(iii) The K_a of bromoethanoic acid is 1.38 x 10^{-3} mol dm^{-3}.

Predict, with reasons, whether the K_a of chloroethanoic acid would be greater or less than that of bromoethanoic acid.

[3]

(b) Bromoethane is used as a solvent, an anaesthetic in medicine and a refrigerant. It is also a useful intermediate for making other organic compounds, such as carboxylic acid.

(i) Bromoethane reacts with aqueous NaOH under heating condition.

How would you expect the rate of this reaction to compare to that of the reaction of iodoethane with aqueous NaOH? Explain your answer.

[3]

(ii) Bromoethane can be used to prepare propanal under laboratory conditions, using propanoic acid as an intermediate.

Suggest a synthesis involving not more than 4 steps for this conversion. Include reagents and conditions for each step, as well as the structures of the intermediate compounds formed.

[5]

(c) Propose appropriate test-tube reactions which would enable you to distinguish between the following compounds. Include expected observations for each compound in your answer.

I. bromoethane and iodoethane

[2]

II. $CH_3CH_2CO_2CH_3$ and $CH_3CH_2CO_2CH_2CH_3$

[2]

[Total : 20]

Victoria Junior College
2017 VJC H1 Chemistry Prelim Exam 8872/2
Suggested Answers

Section A

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

S1 An experiment was conducted to determine the amount of ascorbic acid (vitamin C, $C_6H_8O_6$) in a supplement tablet.

A supplement tablet was dissolved in water and made up to 250 cm^3. 25.0 cm^3 of the solution was pipetted into a conical flask containing 5.0 cm^3 of 0.400 mol dm^{-3} KI and 5.0 cm^3 of 1 mol dm^{-3} HC*l*. A few drops of starch indicator were then added. This resulting solution was titrated against 4.00×10^{-3} mol dm^{-3} KIO_3. 23.90 cm^3 of KIO_3 was required for complete reaction.

When IO_3^- ions are added to an acidic solution containing I^- ions, a redox reaction occurs.

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O \text{ -------- } \mathbf{(1)}$$

The I_2 formed by this reaction then reacts with ascorbic acid to form dehydroascorbic acid ($C_6H_6O_6$).

$$C_6H_8O_6 + I_2 \rightarrow 2I^- + C_6H_6O_6 + 2H^+ \text{ -------- } \mathbf{(2)}$$

Due to reaction **(2)**, the I_2 formed in **(1)** will immediately react away as long as there is any ascorbic acid present. Once all the ascorbic acid has been reacted, the excess I_2 is free to react with the starch indicator, forming the blue-black starch-iodine complex, indicating the end-point of the reaction.

(a) Suggest a reason why the concentration of KI used was much higher than that of KIO_3.

IO_3^- needs to be added <u>in excess</u>, to ensure that there will be <u>sufficient I_2</u> produced to react with $C_6H_8O_6$.

[1]

(b) Explain in terms of the change in oxidation number which species have been reduced in **(1)**. Write a half equation for this reduction.

Oxidation number of I changed from <u>+5</u> in IO_3^- to <u>0</u> in I_2. Hence <u>IO_3^-</u> is reduced.
$IO_3^- + 6H^+ + 5e^- \rightarrow \frac{1}{2} I_2 + 3H_2O$

[2]

(c) **(i)** Calculate the amount, in moles, of ascorbic acid present in the original 250 cm^3 solution.

No. of moles of IO_3^- = $23.90 \times 10^{-3} \times 4.00 \times 10^{-3} = 9.56 \times 10^{-5}$ mol
No. of moles of I_2 = $9.56 \times 10^{-5} \times 3 = 2.87 \times 10^{-4}$ mol
No. of moles of $C_6H_8O_6$ in 25.0 cm^3 = 2.87×10^{-4} mol
No. of moles of $C_6H_8O_6$ in 250 cm^3 = 2.87×10^{-4} mol x 250/25.0
= 2.87×10^{-3} mol

[3]

(ii) Hence, calculate the mass of ascorbic acid in one tablet.

M_r of $C_6H_8O_6$ = 12.0 × 6 + 1.0 × 8 + 16.0 × 6 = 176.0
Mass of $C_6H_8O_6$ in one tablet = 2.87 × 10^{-3} × 176.0 = 0.505 g

[2]

(d) Ascorbic acid is susceptible to oxidation by atmospheric oxygen over time. A student used a sample of ascorbic acid that was prepared several hours prior to titration.

State, with reasoning, what effect this will have on the volume of KIO_3 required for complete reaction and hence the calculated mass of ascorbic acid.

Amount of ascorbic acid in the sample would be lower, less I_2 and hence less KIO_3 would be required for complete reaction. Since mass is proportional to mole, the calculated mass of ascorbic acid would be lower.

[2]

[Total: 10]

2 **(a)** The compound whose bonding most resembles pure ionic bonding is a Group 1 fluoride, **M**F.

(i) When the Group 1 cation is passed through an electric field, it is deflected through an angle of +5.0 °.

Given that the same electric field deflected $^{92}Sr^{3+}$ through an angle of +22 °, calculate the relative atomic mass (A_r) of **M**. Hence suggest a possible identity of the **M**.

deflection angle = k |charge/mass|

For proton,
22 = k |3/92|
k = 675

For unknown Group 1 cation,
5.0 = 675 |1/A_r|
A_r = 135.0
Hence the Group 1 metal is likely to be caesium.

[2]

(ii) Explain why the second ionisation energy of **M** is more endothermic than its first ionisation energy.

The second electron is removed from an inner shell, which is closer and more strongly attracted to the nucleus. More energy is needed to remove the second electron, and second ionisation energy is more endothermic.

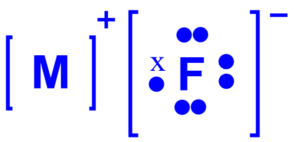
[1]

(iii) Suggest a reason why the bonding in **M**F resembles pure ionic the most.

Largest possible electronegativity difference between the 2 elements.
[OR Lowest polarising power of cation and lowest polarisability of anion.]

[1]

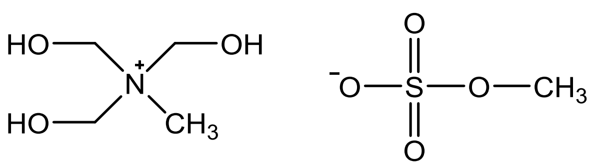
(iv) Draw a dot-cross diagram to show the bonding in **M**F. Show outer electrons only.



[1]

(b) Most ionic compounds are solids at room temperature and pressure. However, researchers have designed ionic compounds whose ionic bonding is so weak that they exist as liquids under these conditions.

An example of an ionic liquid is shown below.



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Suggest two features of these ions that account for the compound having a low melting point.

1. Small cationic and anionic charges
2. Large cationic and anionic radii

[2]

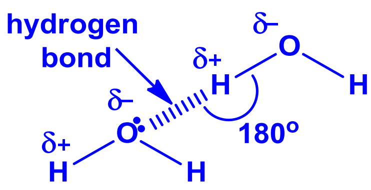
(c) Hydrogen bonds are weaker than ionic or covalent bonds, but accounts for many important intermolecular attractions.

State an anomalous property of water that is the result of hydrogen bonding.

<u>Ice is less dense</u> than liquid water.
[OR <u>H_2O has a higher boiling point</u> than H_2S.]

[1]

(d) Draw and label the hydrogen bond between two water molecules. Indicate the bond angle around the hydrogen atom involved in the hydrogen bond. Include all relevant lone pairs and dipoles.



Correct attractive forces between lone pair of O & δ+H on adjacent molecules
Correct label of hydrogen bond
Correct label of dipoles
Correct bond angle

[2]

[Total: 10]

Q3 (a) Sodium and sulfur are elements in Period 3 in the Periodic Table.

Describe what you would observe when these two elements are separately burned in oxygen. Write equations for the reactions that occur.

Sodium burns vigorously with a bright yellow / orange flame to form a white solid of Na_2O.

$4Na + O_2 \rightarrow 2Na_2O$

Sulfur burns slowly with a pale blue flame to form a colourless gas of SO_2 in limited oxygen and a colourless gas of SO_3 in excess oxygen.

$S + O_2 \rightarrow SO_2$

[OR $2SO_2 + O_2 \rightarrow 2SO_3$]

[4]

(b) The oxides, MgO, Al_2O_3 and P_4O_{10}, exist as white powdered solids with high melting points.

(i) Arrange the oxides in decreasing melting points and explain their relative melting points in terms of their structure and bonding.

Melting points decrease in the order: MgO > Al_2O_3 > P_4O_{10}

Both MgO and Al_2O_3 have giant ionic structure with strong electrostatic attraction between the cations and anions.

As Al^{3+} has a higher charge density and hence higher polarising power than Mg^{2+}, the O^{2-} electron cloud experiences distortion by the highly polarising Al^{3+}. This results in a decrease in ionic character and a lower lattice energy in Al_2O_3 and hence a lower melting point.

P_4O_{10} has a simple molecular structure with weak instantaneous dipole-induced dipole interactions between the molecules. A small amount of energy is needed to break these weak interactions, hence lowest melting point.

[4]

(ii) Describe two chemical reactions you could carry out on a sample of white powder to determine the identity of the oxide.

Add HC*l*(aq) and NaOH(aq)

	MgO	Al_2O_3	P_4O_{10}
Add HC*l*(aq)	Dissolves to form a colourless solution [of $MgCl_2$(aq)].	Dissolves to form a colourless solution [of $AlCl_3$(aq)].	Does not dissolve (negligible dissolution of solid due to solubility of P_4O_{10} in H_2O to give H_3PO_4 is considered).

Add NaOH(aq)	**Does not dissolve (negligible dissolution of solid due to some solubility of MgO in H_2O to form $Mg(OH)_2$ is considered).**	**Dissolves to form a colourless solution [of $NaAl(OH)_4(aq)$].**	**Dissolves to form a colourless solution [of $Na_3PO_4(aq)$].**

React with both NaOH and HC*l*, Al_2O_3 identified
React with both NaOH only, P_4O_{10} identified
React with HC*l* only, MgO identified

[2]

[Total: 10]

4 **(a)** *Cracking* is a process used in the petroleum industry that converts large hydrocarbon molecules into smaller, more useful ones**.**

(i) In one particular reaction, a 16–carbon alkane undergoes cracking to form C_3H_6, C_4H_8 and C_6H_{14} as the **only** products.

Write a balanced equation to represent this reaction.

$C_{16}H_{34} \rightarrow C_6H_{14} + C_4H_8 + 2C_3H_6$

[1]

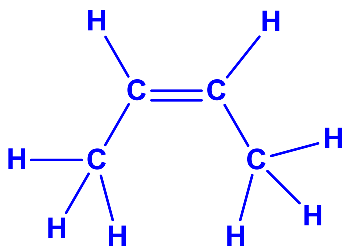
(ii) The hydrocarbon, C_4H_8, formed from the above reaction is found to display *cis–trans isomerism*.

State the structural requirements for *cis–trans isomerism* to be displayed in an organic molecule.

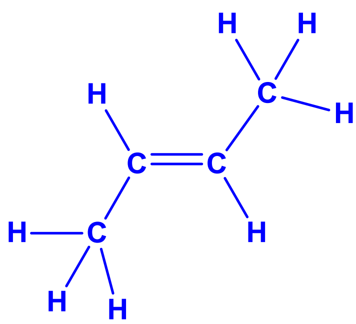
The molecule must have a <u>C=C bond</u> which <u>cannot be rotated</u>.
To <u>each alkene</u> carbon, <u>2 different groups</u> are attached.

[2]

(iii) Hence, draw the displayed formulae of the cis–trans isomers of C_4H_8. Label each isomer clearly.



cis



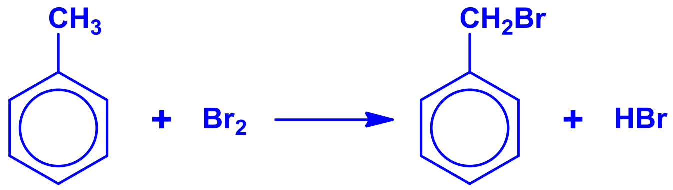
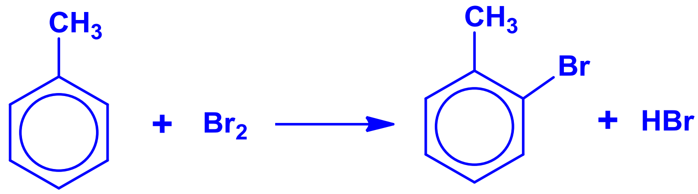
trans

[2]

(b) Another important process in the petroleum industry is *reforming*, which increases the proportion of aromatic, cyclic and branched–chain hydrocarbons in petrol. This enables petrol to burn more smoothly in car engines.

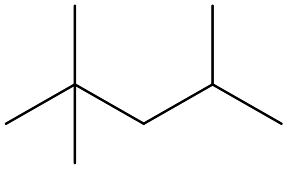
(i) One of the main products formed from the reforming process is methylbenzene, which undergoes two different reactions with bromine, depending on the conditions used.

For each reaction, state the conditions required and write a balanced equation, showing clearly the structure of **any one mono–brominated** organic product formed.

Conditions	Equation
UV light, excess $C_6H_5CH_3$	
Presence of anhydrous $FeBr_3$ catalyst	 [OR show Br at position 4]

[2]

(ii) Another product of the reforming process has the structure below:



State the name of the compound above.

2, 2, 4–trimethylpentane

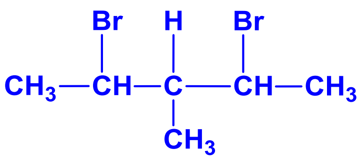
[1]

(c) Compound **C** has a symmetrical structure with the molecular formula $C_6H_{12}Br_2$. In the presence of alcoholic NaOH, **C** produces **D**, C_6H_{10}**.**

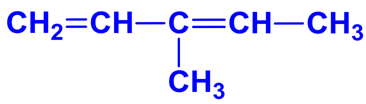
When **D** is oxidised by hot acidified $KMnO_4$, three compounds, CO_2, CH_3CO_2H and CH_3COCO_2H, are formed in equimolar amounts.

Deduce the structures of **C** and **D**.

C



D



[2]

[Total: 10]

Section B

Answer **two** questions from this section on separate answer papers.

5 **(a)** Nitrogen is an element that is essential to life on earth. In spite of nitrogen's abundance in the atmosphere, the quantity of nitrogen containing compounds that were available for human use was limited. The Haber process for the manufacture of ammonia and the Ostwald process for the conversion of ammonia to nitric acid were developed in the early 20th century.

Ammonia is manufactured from nitrogen and hydrogen by the Haber process as shown in the equation:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H_{rxn} = -45.9 \text{ kJ mol}^{-1}$$

(i) Write an expression for the equilibrium constant, K_c, for the Haber process.

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

[1]

(ii) Calculate the value of K_c given the following equilibrium concentrations at 1000 K. State the units of K_c.

gas	concentration/ mol dm^{-3}
nitrogen	1.36
hydrogen	1.84
ammonia	0.142

$$K_c = \frac{(0.142)^2}{(0.136)(1.84)^3}$$
$$= 2.38 \times 10^{-3} \text{ mol}^{-2} \text{ dm}^6$$

[2]

(iii) Explain why the activation energy of the process is high.

The activation energy of the process is high due to the high bond energy of the N≡N bond.

[1]

(iv) Hence describe and explain the conditions required for the favourable production of ammonia in Haber process.

High pressure (200 atm) favors the production of ammonia. By Le Chatelier's Principle, the equilibrium position will shift right to reduce the increase in pressure leading to greater amount of ammonia.

Low temperature favors the production of ammonia. By Le Chatelier's Principle, the equilibrium position will shift right to produce more heat leading to greater amount of ammonia. However low temperature will mean slower rate of reaction. Hence temperature is kept high (450 °C) for faster rate of reaction.

Addition of catalyst (finely divided iron) is used to increase the rate of reaction but not the yield of ammonia.

[3]

(b) A large proportion of the ammonia manufactured is then used to manufacture nitric acid which is another industrially important compound. In Ostwald process, nitric acid is produced industrially from ammonia, air and water using the following sequence of reactions:

Step 1 $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ ΔH_{rxn} **(step 1)**

Step 2 $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ ΔH_{rxn} **(step 2)**

Step 3 $4NO_2(g) + O_2(g) + 2H_2O(l) \rightarrow 4HNO_3(aq)$ ΔH_{rxn} **(step 3)**

Overall reaction $NH_3(g) + 2O_2(g) \rightarrow HNO_3(aq) + 2H_2O(l)$

(i) Using relevant bond energy data from the *Data Booklet* and the following value, calculate the enthalpy change, ΔH_{rxn} **(step 1)**, for the reaction between ammonia and oxygen gas.

Bond energy for NO(g) = 607 kJ mol^{-1}

ΔH_{rxn} (step 1) = Σ(BE of reactants) – Σ(BE of products)
= [12(390) + 5(496)] – [4(607) + 12(460)]
= –788 kJ mol^{-1}

[2]

(ii) Using the following enthalpy changes, calculate the enthalpy change, ΔH_{rxn} **(step 2)** and ΔH_{rxn} **(step 3)**.

$\Delta H_f\,(NO_2)$ = +33.2 kJ mol^{-1}
$\Delta H_f\,(NO)$ = +90.3 kJ mol^{-1}
$\Delta H_f\,(HNO_3)$ = –207.4 kJ mol^{-1}
$\Delta H_c\,(H_2)$ = –285.8 kJ mol^{-1}

ΔH_{rxn} (step 2) = Σ(ΔH_f products) – Σ(ΔH_f reactants)
= (33.2) – 2(90.3)
= –114 kJ mol^{-1}
ΔH_{rxn} (step 3) = Σ(ΔH_f products) – Σ(ΔH_f reactants)
= [4(–207.4)] – [4(+33.2) + 1(0) + 2(–285.8)]
= –391 kJ mol^{-1}

[3]

(iii) Hence, or otherwise, calculate the enthalpy change for the **overall reaction**.

Adding Step 1, Step 2 x 2 and Step 3 gives
$4NH_3(g) + 8O_2(g) \rightarrow 4HNO_3(aq) + 8H_2O(l)$
Dividing by 4 will give:
$NH_3(g) + 2O_2(g) \rightarrow HNO_3(aq) + 2H_2O(l)$
4 x ΔH_{rxn}(overall) = –788 + 2(–114) + (–391)
ΔH_{rxn}(overall) = –352 kJ mol^{-1}

[2]

(c) A monobasic acid **HA,** extracted from a fruit has a pH of 3.5.

(i) Calculate the concentration, in mol dm^{-3}, of hydrogen ions in the acid **HA**.

$[H^+] = 10^{-3.5} = 3.16 \times 10^{-4}$ mol dm^{-3}

[1]

(ii) 25.0 cm^3 of a sample of the acid **HA** was titrated with 0.25 mol dm^{-3} aqueous NaOH. 21.25 cm^3 of the aqueous NaOH was required to reach equivalence point.

Calculate the concentration, in mol dm^{-3}, of the acid **HA**.

No. of mol of NaOH = $\dfrac{21.25}{1000} \times 0.25$ **= 5.312×10^{-3}**
= No. of mol of HA

$$[HA] = \frac{5.312 \times 10^{-3}}{\frac{25}{1000}} = 0.2125 = 0.213 \text{ mol dm}^{-3}$$

[2]

(iii) Based on your answers to **(c)(i)** and **(c)(ii)** above, what can you deduce about the strength of the acid **HA**? Give a reason for your deduction.

HA is a <u>weak acid</u>.
Since <u>[HA] >>[H$^+$]</u>, HA <u>dissociates partially</u> to form H$^+$.

[1]

(iv) Hence predict the volume of carbon dioxide evolved when 25.0 cm^3 of 0.40 mol dm^{-3} of HC*l* and **HA** reacts with excess Na_2CO_3 under standard conditions.

$2H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$
Number of moles of CO_2 = ½ x number of moles of H^+
= ½ x (0.40 x 0.025)
= 5.00×10^{-3}
Volume of CO_2 evolved for HC*l* = 5.00×10^{-3} x 24000
= 120 cm^3
Since volume and conc. used for HA is the same,
Volume of CO_2 evolved for HA = 120 cm^3

Alternative answer
HC*l* + HA + CO_3^{2-} $\rightarrow$ H_2O + CO_2 + C*l*$^-$ + A^-
Number of moles of HC*l* = number of moles of HA
= number of moles of CO_2
= (0.40 x 0.025)
= 1.00×10^{-2}
Volume of CO_2 evolved (in total) = 1.00×10^{-2} x 24000
= 240 cm^3

[2]

[Total: 20

6 **(a)** Potassium reacts with ammonia to give a compound of KNH_2 as shown in the given equation:

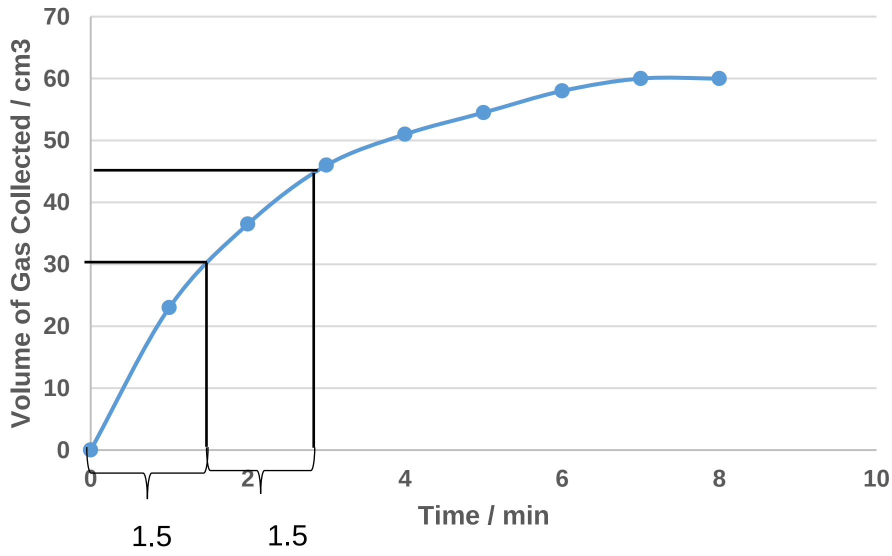
$$2K + 2NH_3 \rightarrow 2KNH_2 + H_2$$

The rate of the reaction was investigated by using a freshly cut piece of potassium which was weighed and added to a large excess of ammonia. The experiment was conducted at room temperature and pressure.

The total volume of gas evolved at every minute was recorded and shown below.

Time / min	0	1	2	3	4	5	6	7	8
Total volume of gas / cm^3	0	23.0	36.5	46.0	51.0	55	58.0	60	60

(i) Plot the experimental results on graph paper.



Axes and units
Smooth curve
Graph more than ½ page
Construction lines to show 2 constant half-lives

[2]

(ii) Hence deduce the order of reaction with respect to potassium.

Since <u>half-life is constant at 1.5 min</u>, it is <u>first order wrt to potassium</u>.

[1]

(iii) Write a rate equation for the reaction and calculate the rate constant, stating its units.

Rate = k[K]

$t_{1/2} = \frac{\ln 2}{k} = 1.5$ hence $k = \frac{\ln 2}{1.5} = \frac{0.693}{1.5} = \bullet\ 0.462\ min^{-1}$

[2]

(iv) In this experiment, the kinetics appear to be zero order with respect to ammonia. Suggest a reason for this.

The ammonia was in large excess hence its change in concentration will not be significant.

[1]

(v) Calculate the mass of potassium used in the experiment.

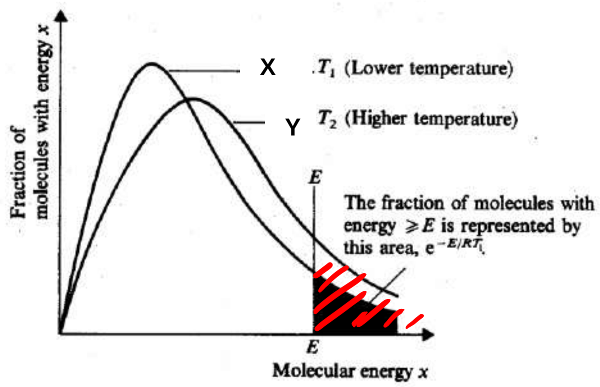
Amount of hydrogen evolved = 60 / 24000 = 2.50×10^{-5} mol
Amount of potassium used = 2 x 2.50×10^{-5} = 5.00×10^{-5} mol
Mass of potassium = 5.00×10^{-5} x 39.1 = 0.196 g

[2]

(b) Ammonia is an important starting material in the manufacture of fertilisers as well as explosives and plastics. The Haber process is used to form ammonia as shown in the equation below:

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

(i) Draw a Maxwell Boltzmann distribution curve for the reactants at temperature **T_1**. Label this curve **X**. Mark the position of the activation energy with a line. Label this as **E_a**.



Axes labelled correctly
Start from 0 and correct shape
Indicate E_a
Shade area under curve

[2]

(ii) On the axes that you have drawn, draw a **second** distribution curve that represents the reaction at a higher temperature **T_2**. Label this curve **Y**.

Use curves **X** and **Y** to describe and explain the effects of an increase in temperature on the rate of a reaction.

Correct shape and position of new curve.
When temperature increases, average kinetic energy of the molecules increases. Proportion of molecules with minimum E_a also increases. Hence frequency of effective collisions increases leading to an increase in rate.

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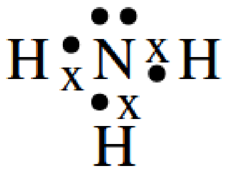
[3]

(iii) Name a catalyst that can be used for the Haber Process.

Iron [OR aluminium oxide]

[1]

(c) **(i)** Draw a dot-and-cross diagram to show the bonding in an ammonia molecule.



[1]

(ii) By using the Valence Shell Electron Pair Repulsion theory, state the shape and bond angle in the ammonia molecule and explain in details how it arises.

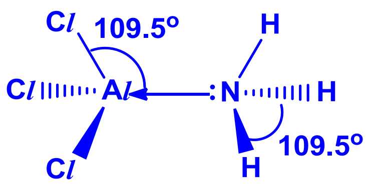
107^{o} and trigonal pyramidal in shape
Presence of 3 bond pairs and 1 lone pair electrons
Degree of repulsion according to VSEPR theory is lone pair–lone pair > lone pair–bond pair > bond pair–bond pair
The electron pairs will maximise their distance apart in order to minimise repulsion hence lone pair pushes 3 bond pairs closer together.

[2]

(iii) When ammonia is mixed with aluminium chloride in a 1:1 ratio, a new single compound is formed.

Suggest the type of bond that is formed between ammonia and aluminium chloride, explaining your answer clearly. Draw a ***displayed*** structure of the product formed, indicating the bond angle with respect to nitrogen and aluminium.

Dative bond is formed when lone pair of electrons on nitrogen of ammonia is shared with the electron-deficient aluminium atom which has energetically accessible empty orbitals.

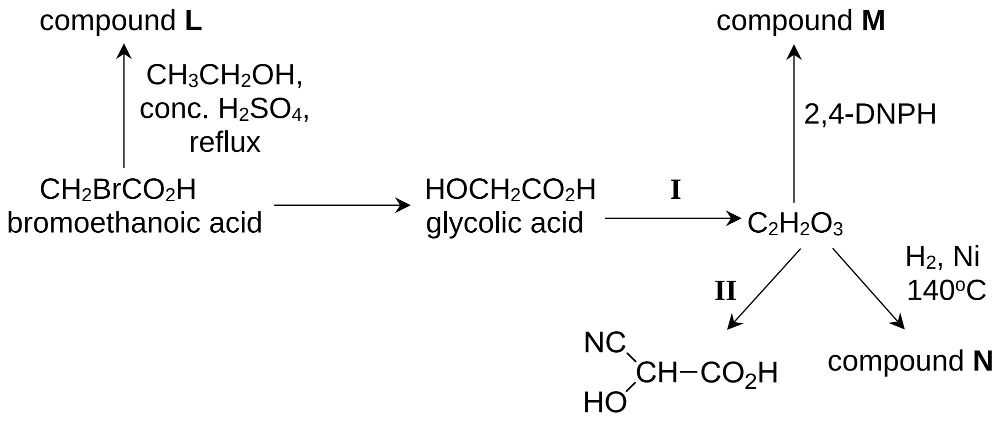


[3]

[Total: 20]

7 **(a)** Glycolic acid, $HOCH_2CO_2H$, is a colourless, odourless and hygroscopic crystalline solid which is used in various skin-care products.

The reaction scheme below shows some reactions involving glycolic acid.



(i) State the reagents and conditions for reactions **I** and **II**.

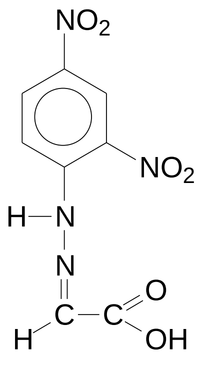
Reaction I: $K_2Cr_2O_7$(aq), H_2SO_4(aq), distil

Reaction II: HCN, NaCN (catalyst), room temperature

[2]

(ii) Draw the structural formulae for compounds **L**, **M** and **N**.

L: $BrCH_2COOCH_2CH_3$ **M:**



N: $HOCH_2CO_2H$

for each correct structure

[3]

(iii) The K_a of bromoethanoic acid is 1.38×10^{-3} mol dm^{-3}.

Predict, with reasons, whether the K_a of chloroethanoic acid would be greater or less than that of bromoethanoic acid.

The electron–withdrawing inductive effect of chlorine is greater than that of bromine due to its higher electronegativity. Hence, this leads to a greater extent of dispersal of negative charge in carboxylate ion, making the anion more stable.

Hence, chloroethanoic acid would be a stronger acid. Its K_a value will therefore be greater than 1.38×10^{-3} mol dm^{-3}.

[3]

(b) Bromoethane is used as a solvent, an anaesthetic in medicine and a refrigerant. It is also a useful intermediate for making other organic compounds, such as carboxylic acid.

(i) Bromoethane reacts with aqueous NaOH under heating condition.

How would you expect the rate of this reaction to compare to that of the reaction of iodoethane with aqueous NaOH? Explain your answer.

2-iodobutane will have a faster reaction with NaOH(aq). I has a larger atomic radius than C*l*, hence, C–I has a longer bond length / weaker bond strength. C–I bond will be broken more easily and 2-iodobutane will therefore undergo substitution more easily.

[3]

(ii) Bromoethane can be used to prepare propanal under laboratory conditions, using propanoic acid as an intermediate.

Suggest a synthesis involving not more than 4 steps for this conversion. Include reagents and conditions for each step, as well as the structures of the intermediate compounds formed.

$$CH_3CH_2Br \xrightarrow{\text{alcoholic KCN, reflux}} CH_3CH_2CN \xrightarrow{H_2SO_4(aq),\ \text{reflux}} CH_3CH_2CO_2H$$

$$CH_3CH_2CO_2H \xrightarrow{LiAlH_4 \text{ in dry ether, room temp OR } NaBH_4 \text{ in ethanol}} CH_3CH_2CH_2OH$$

$$CH_3CH_2CH_2OH \xrightarrow{K_2Cr_2O_7(aq),\ H_2SO_4(aq),\ \text{distil}} CH_3CH_2CHO$$

[5]

(c) Propose appropriate test-tube reactions which would enable you to distinguish between the following compounds. Include expected observations for each compound in your answer.

I. bromoethane and iodoethane

Test: Add NaOH(aq), heat, followed by addition of excess HNO_3(aq) and $AgNO_3$(aq).

Observation: A cream ppt of AgBr is formed for bromoethane, while a yellow ppt of AgI is formed for iodoethane.

[2]

II. $CH_3CH_2CO_2CH_3$ and $CH_3CH_2CO_2CH_2CH_3$

Test: Add H_2SO_4 (aq), heat, followed by $KMnO_4$(aq)

Observation:
For $CH_3CH_2CO_2CH_3$, there is a decolourisation of purple $KMnO_4$ and an effervescence of CO_2 which forms white ppt with limewater.

For $CH_3CH_2CO_2CH_2CH_3$, there is a decolourisation of purple $KMnO_4$ without effervescence.

OR
Test: Add NaOH (aq), heat, followed by I_2(aq), NaOH (aq), warm < 70°C.

Observation:
For $CH_3CH_2CO_2CH_3$, there is no pale yellow ppt of CHI_3 formed.

For $CH_3CH_2CO_2CH_2CH_3$, there is pale yellow ppt CHI_3 formed.

[2]

[Total : 20]

CANDIDATE'S NAME: ______________________________ **CTG:** ____________

YISHUN JUNIOR COLLEGE

2017 JC2 PRELIMINARY EXAMINATION

CHEMISTRY **8872/01**

HIGHER 1

Paper 1 Multiple Choice Questions

FRIDAY 15 SEPTEMBER 2017
0800hrs − 0850hrs
(50 minutes)

Additional Materials: Optical Mark Sheet (OMS)
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Write your name, CTG, and NRIC / FIN number on the Optical Mark Sheet (OMS), and shade the corresponding boxes for your NRIC / FIN number.

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.

Section A

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct and shade your choice on the answer sheet provided.

1 Calcium nitrate, $Ca(NO_3)_2$, is added to fireworks to give a red colouration. When ignited, it reacts with carbon to produce calcium oxide, CaO, and three gases; CO_2, CO and Z. The three gases are produced in a mole ratio of 2 : 1 : 1 respectively.

What is gas Z?

A N_2 **B** N_2O **C** NO **D** NO_2

2 Naturally occurring silicon is a mixture of three isotopes, ^{28}Si, ^{29}Si and ^{30}Si. The relative atomic mass of silicon is 28.109.

What could be the relative abundance of each of the three isotopes?

A 91.1% ^{28}Si; 7.9% ^{29}Si; 1.0% ^{30}Si

B 92.2% ^{28}Si; 4.7% ^{29}Si; 3.1% ^{30}Si

C 95.0% ^{28}Si; 3.2% ^{29}Si; 1.8% ^{30}Si

D 96.3% ^{28}Si; 0.3% ^{29}Si; 3.4% ^{30}Si

3 The reaction of hydrogen sulfide and sulfur dioxide gives sulfur as one of the products.

$$H_2S(aq) \rightleftharpoons S(s) + 2H^+(aq) + 2e^-$$

$$SO_2(aq) + 4H^+ + 4e^- \rightleftharpoons S(s) + 2H_2O(l)$$

How many moles of hydrogen sulfide are needed to react with sulfur dioxide to produce 1 mole of sulfur?

A 2 mol **B** $\frac{3}{2}$ mol **C** 1 mol **D** $\frac{2}{3}$ mol

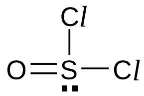
4 *Use of Data Booklet is relevant to this question.*

In research on the atomic nucleus, scientists have been comparing the stability of isotopes with the same neutron : proton ratio.

Which isotope has the same neutron : proton ratio as ^{10}B?

A ^{40}Ar **B** ^{40}K **C** ^{32}P **D** ^{32}S

5 Thionyl chloride, $SOCl_2$, can be used to convert alcohols into chloroalkanes.

Thionyl chloride can be represented as 

What value does Valence Shell Electron Pair Repulsion theory suggest for the bond angle in thioyl chloride?

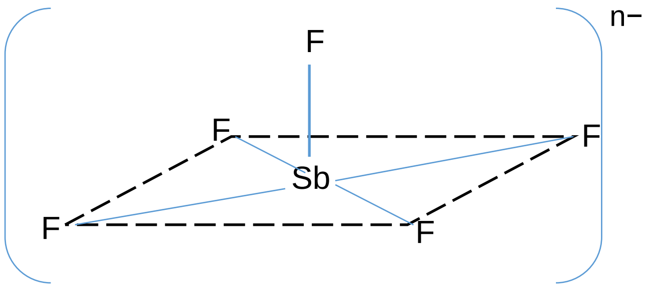
A 90° exactly

B 107° approximately

C 118° approximately

D 120° exactly

6 Antimony, Sb, is in Group 15 of the Periodic Table. It forms a series of salts which contain the SbF_5^{n-} anion, the structure of which is a square-based pyramid.



Deduce the value of n.

A 1 **B** 2 **C** 3 **D** 4

7 Pressurising butane in a cylinder causes it to liquify. It is then sold as 'liquidfied petroleum gas', LPG. Under the same conditions, methane remains as a gas.

Which best explains why butane is more easily liquified than methane?

A Its molecule contains more electrons than that of methane.

B Its molecue contains more atoms than that of methane.

C Its molecular mass is higher than that of methane.

D Its molecule has a dipole moment, whereas methane does not.

8 Which row of the table is correct?

	least exothermic lattice energy	⟶	most exothermic lattice energy
A	sodium sulfide	lithium sulfide	lithium oxide
B	lithium sulfide	lithium oxide	sodium sulfide
C	lithium oxide	sodium sulfide	lithium sulfide
D	lithium oxide	lithium sulfide	sodium sulfide

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

Trichloromethane, $CHCl_3$, commonly known as chloroform, was used as an anaesthetic in surgery. One reason for it not being used today is that it naturally oxidises to phosgene, $COCl_2$, which is highly toxic.

$$2CHCl_3 + O_2 \rightarrow 2\ O{=}\overset{\overset{\textstyle Cl}{|}}{C}{-}Cl\ + 2HCl$$

What is the enthalpy change, ΔH, for this reaction?

A -2342 kJ mol^{-1} **B** -346 kJ mol^{-1}

C $+75$ kJ mol^{-1} **D** $+1996$ kJ mol^{-1}

10 The table shows the enthalpy change of neutralisation per mole of water formed, ΔH, for various acids and bases.

acid	base	ΔH / kJ mol^{-1}
hydrochloric acid	sodium hydroxide	−57.0
P	sodium hydroxide	−54.0
hydrochloric acid	Q	−52.0
nitric acid	R	−57.0

What are P, Q and R?

	P	Q	R
A	ethanoic acid	ammonia	potassium hydroxide
B	ethanoic acid	sodium hydroxide	ammonia
C	sulfuric acid	ammonia	potassium hydroxide
D	sulfuric acid	sodium hydroxide	ammonia

11 What is meant by the term *dynamic equilibrium*?

A an equilibrium that is constantly changing its position

B an equilibrium where the forward and reverse reactions are taking place at different rates

C an equilibrium where the forward and reverse reactions are taking place at the same rate

D an equilibrium which has not yet settled to a constant rate

12 Each of the following equilibria is subjected to two changes which are 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 $I_2(g) + H_2(g) \rightleftharpoons 2HI(g)$ $\Delta H = +53$ kJ mol^{-1}

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

C $3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -92$ kJ mol^{-1}

D $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$ $\Delta H = -950$ kJmol^{-1}

13 Values for 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}
30	1.44×10^{-14}

What is correct for pure water at 30 °C?

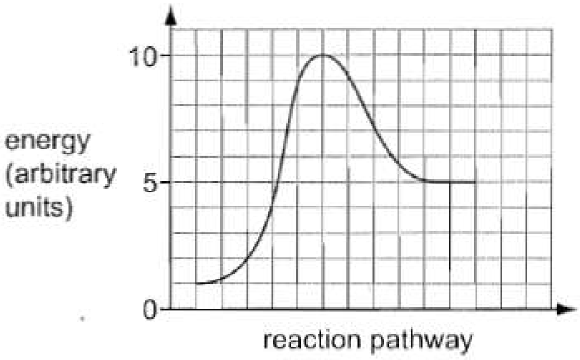
A $[H^+] > [OH^-]$

B pH = 1.44×10^{-7}

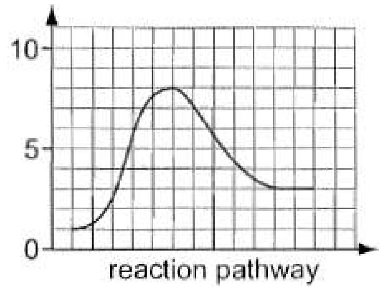
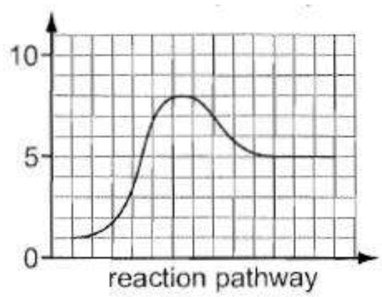
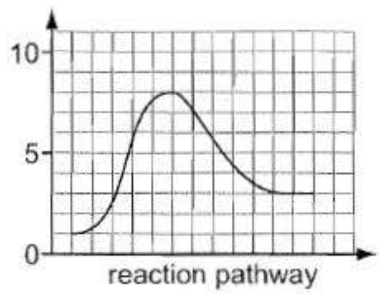
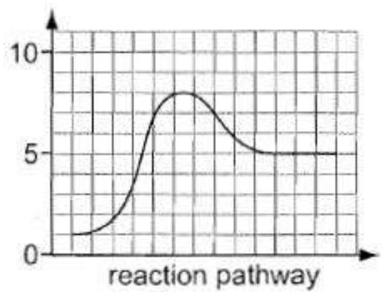
C pH < 7

D pH > 7

14 The diagram shows the reaction pathway diagram for an uncatalysed reaction.



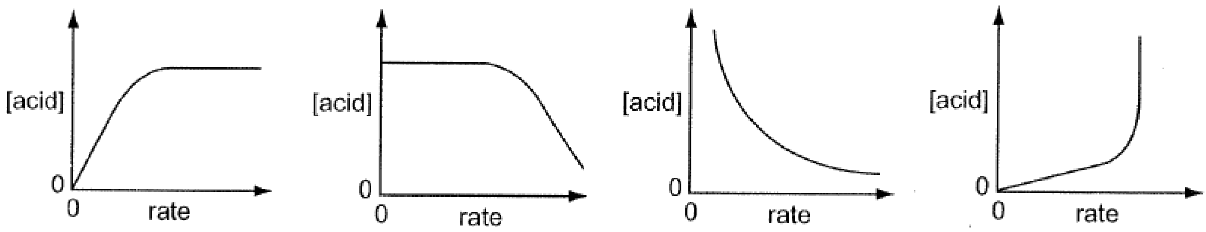
The reaction is then catalysed.
What are the changes in the rate constant and the reaction pathway diagram?

	rate constant	energy profile
A	decrease	
B	decrease	
C	increase	
D	increase	

15 In the reaction between aqueous sodium thiosulfate and dilute acid, the reaction is found to be first order with respect to acid at low concentrations of acid, but zero order with respect to acid when the acid concentration is high.

Which graph represents the experimental results?

A **B** **C** **D**



16 The ionic radii of Na^{+}, Mg^{2+} and Al^{3+} are 0.095 nm, 0.065 nm and 0.050 nm respectively.

Which of the following statements correctly explains the decrease in radius from Na^{+} to Al^{3+}?

A an increase in the nuclear charge and total number of electrons

B an increase in the nuclear charge and constant total number of electrons

C an increase in total number of electrons while nuclear charge remains constant

D a decrease in nuclear charge while total number of electrons remains constant

17 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

18 How many esters have the molecular formula $C_4H_8O_2$?

A 2 **B** 3 **C** 4 **D** 5

19 The Russian composer Borodin was widely respected for his work as a chemist. In 1869, he discovered a reaction in which two ethanol molecules combine to form a new β-hydroxy carbonyl compound. A similar reaction is shown below.

I $2CH_3COCH_3 \rightarrow CH_3COCH_2C(OH)(CH_3)_2$

II $CH_3COCH_2C(OH)(CH_3)_2 \rightarrow CH_3COCH{=}C(CH_3)_2 + H_2O$

Which of the following best describes reactions I and II?

	I	II
A	addition	elimination
B	substitution	elimination
C	addition	reduction
D	condensation	elimination

20 Which statement about an ethene molecule is **not** correct?

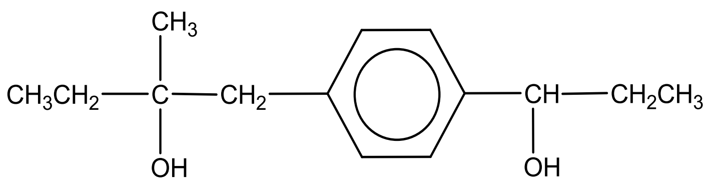
A It has all its atoms in the same plane.

B It has an empirical formula of CH_2.

C It has bond angles of 109°.

D It has five σ bonds and one π bond.

21 The compound shown below is a derivative of ibuprofen, which is a painkiller.



Which of the following reagents and conditions will react with only one alcohol group in the derivative of ibuprofen?

A anhydrous PCl_5

B concentrated H_2SO_4, 170 °C

C I_2 dissolved in NaOH (aq), warm

D $Cr_2O_7^{2-}$, H_2SO_4 (aq), heat

22 Which compound could **not** be a product of a single reaction of 2-bromobutane?

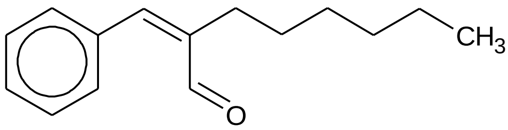
A but-1-ene

B butan-2-ol

C butane

D butyl-2-amine

23 Hexyl cinnamaldehyde is found in the essential oil of chamomile and is commonly used as a perfume.



If hexyl cinnamaldehyde is reacted with $NaBH_4$, what would be the M_r of the resultant product?

A 204 **B** 218 **C** 220 **D** 226

24 Compound X, $C_4H_6O_2$, which is responsible for giving butter its characteristic flavour, gives the following experimental observations.

- On reduction, X produces $C_4H_{10}O_2$.
- With hydrogen cyanide and aqueous sodium cyanide, X produces $C_6H_8N_2O_2$.
- On warming X with Fehling's solution, the solution remains blue.

What could be the structural formula of X?

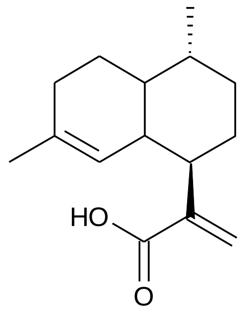
A CH_2=$CHCOCH_2OH$

B CH_3COCH=$CHOH$

C $CH_3COCOCH_3$

D CH_3COCH_2CHO

25 Artemisinic acid is a useful intermediate for making the anti-malarial drug, artemisin.



artemisinic acid

Which statement about this compound is **not** correct?

A It can exhibit geometric isomerism around a double bond.

B It can be esterified by ethanol, in the presence of H^+ ions.

C It has a molecular formula of $C_{15}H_{22}O_2$.

D It will decolourise cold, dilute MnO_4^- ions.

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to pick a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	**B**	**C**	**D**
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 The diagram illustrates the energy changes for a set of reactions.

$$\begin{tikzcd} R \arrow[r, "\Delta H = -134\ \text{kJ mol}^{-1}"] \arrow[d] & S \arrow[d, "\Delta H = +92\ \text{kJ mol}^{-1}"] \\ T \arrow[r, "\Delta H = -75\ \text{kJ mol}^{-1}"] & U \end{tikzcd}$$

Which statements are correct?

1 The enthalpy change for the transformation R → T is +33 kJ mol^{-1}

2 The enthalpy change for the transformation T → S is endothermic.

3 S has a higher energy content than U.

27 Which statements about order of reaction are correct?

1 Only first order reactions have constant half-lives.

2 Measurements of the initial rates of reaction can be used to determine the overall order of a reaction.

3 The units of a rate constant are independent of the order of the reaction.

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

28 When 0.10 mol of chloride of a Period 3 element, A, is reacted with a limited amount of water, white fumes are observed. Upon dissolving the white fumes in water, the resultant solution is found to react with 0.30 mol of aqueous sodium hydroxide.

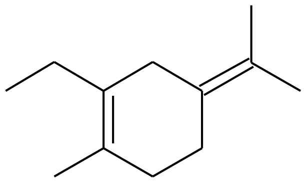
Which Groups of the Periodic Table can A belong to?

1 15

2 13

3 14

29 Compound N has the following structure.



compound N

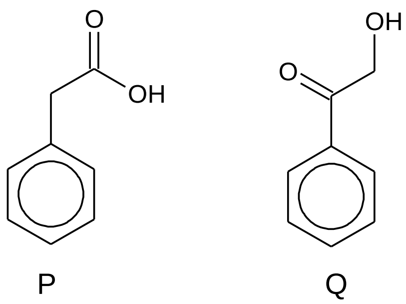
Which of the following statements are correct when compound N is treated with $KMnO_4$ in the presence of hot dilute sulfuric acid?

1 The products contain at least one carbonyl functional group.

2 The products contain at least one carboxylic acid functional group.

3 There is only one organic product.

30 Which of the following reagents can be used to distinguish the following two compounds, P and Q?



1 2,4-DNPH, warm

2 hot acidified $K_2Cr_2O_7$

3 Na_2CO_3 (aq)

~ END OF PAPER ~

Paper 1 Worked Solutions

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

1 Bearing in mind the mole ratio of the three gases when writing the balanced equation, you should be able to conclude that 1 mole of $Ca(NO_3)_2$ requires 3 moles of C:

$$Ca(NO_3)_2 + 3C \rightarrow CaO + 2CO_2 + CO + Z$$

It should also be clear that all the number of O atoms on both sides of the equation are already equal (i.e. balanced), and thus Z have to be N_2 so that the number of N atoms (the only remaining element to be balanced) on both sides are equal:

$$Ca(NO_3)_2 + 3C \rightarrow CaO + 2CO_2 + CO + \mathbf{N_2}$$

Answer: **A**

2

A: $A_r = \dfrac{91.1(28)+7.9(29)+1.0(30)}{100} = 28.099$

B: $A_r = \dfrac{92.2(28)+4.7(29)+3.1(30)}{100} = 28.109$

C: $A_r = \dfrac{95.0(28)+3.2(29)+1.8(30)}{100} = 28.068$

D: $A_r = \dfrac{96.3(28)+0.3(29)+3.4(30)}{100} = 28.071$

Answer: **B**

3 To get the balanced equation:

$$\begin{array}{r} H_2S(aq) \rightarrow S(s) + 2H^+(aq) + 2e^- \ (\times 2) \\ \underline{SO_2(aq) + 4H^+ + 4e^- \rightarrow S(s) + 2H_2O(l)} \\ 2H_2S(aq) + SO_2(aq) \rightarrow 3S(s) + 2H_2O(l) \end{array}$$

Dividing throughout by 3, we get:

$$\frac{2}{3}H_2S(aq) + \frac{1}{3}SO_2(aq) \rightarrow S(s) + \frac{2}{3}H_2O(l)$$

Answer: **D**

4 For ^{10}B: number of protons = 5;
number of neutrons = 10 − 5 = 5
⇒ ratio of proton : neutron = 1 : 1

A: ^{40}Ar: number of protons = 18;
number of neutrons = 40 − 18 = 22
⇒ ratio of proton : neutron = 9 : 11

B: ^{40}K: number of protons = 19;
number of neutrons = 40 − 19 = 21
⇒ ratio of proton : neutron = 19 : 21

C: ^{32}P: number of protons = 15;
number of neutrons = 32 − 15 = 17
⇒ ratio of proton : neutron = 15 : 17

D: ^{32}S: number of protons = 16;
number of neutrons = 32 − 16 = 16
⇒ ratio of proton : neutron = 1 : 1

Answer: **D**

5 Around the S-atom, there are 3 bond pairs and 1 lone pair of electrons (a double bond is considered one bond pair).
By VSEPR theory, the four electron pairs will space themselves as far apart as possible to minimise repulsion, leading to an electronic geometry of tetrahedral, and a bond angle of 109°. However, as the lone pair-bond pair repulsion are stronger than bond pair-bond pair repulsion, the bond angle will be smaller than 109°, ⇒ approximately 107°.

Answer: **B**

6 In order for the anion to have a square pyramidal shape, it must have 5 bond pairs and 1 lone pair of electrons. Since Sb is from group 15, it has 5 valence electrons, which are used to form normal single bond with the five F-atoms (i.e. 5 bond pairs). Hence Sb must receive **two electrons** from external sources, in order to have one lone pairs of electrons.
⇒ n = 2, i.e. the anion is SnF_5^{2-}.

Answer: **B**

7 Since both butane and methane are made up of non-polar molecules, only id-id interactions exist between their respective molecules. As butane has more electrons than methane, its electron cloud is more polarisable, and so the instantaneous dipole-induced dipole interactions between its molecules are stronger, and hence it is easier to liquify butane than methane.

Answer: **A**

8 $L.E. = \left| \dfrac{q_+ \times q_-}{r_+ + r_-} \right|$

Cationic radii: $Li^+ < Na^+$
Anionic radii: $O^{2-} < S^{2-}$
sodium sulfide, Na_2S, has the least exothermic lattice energy while lithium oxide, Li_2O, has the most exothermic lattice energy.

Answer: **A**

9 Bond breaking: 2(C−H) +6(C−C*l*) + (O=O)
= 2(+410)+6(+340)+(+496)
= +3356 kJ mol^{-1}
Bond forming: 2(C=O) +4(C−C*l*) + 2(H−C*l*)
=2(−740)+4(−340)+2(−431)
=−3702 kJ mol^{-1}
ΔH = (+3356) + (−3702) = −346 kJ mol^{-1}

Answer: **B**

10 For the first pair of acid and base, we learnt that ΔH for a strong acid (HC*l*) and a strong base (NaOH) is −57.0 kJ mol^{-1}.

Since the magnitude of ΔH for the second pair of acid and base is smaller than 57.0 kJ mol^{-1}, a weak acid must have reacted with NaOH.
⇒ P must be ethanoic acid (option **A** or **B**).

Since the magnitude of ΔH for the third pair of acid and base is smaller than 57.0 kJ mol^{-1}, HC*l* must have reacted with a weak base.
⇒ Q must be ammonia (option **A** or **C**).

Since ΔH for the fourth pair of acid and base is also − 57.0 kJ mol^{-1}, nitric acid must have reacted with a strong base.
⇒ R must be potassium hydroxide (option **A** or **C**).

Answer: **A**

11 Definition of a dynamic equilibrium: an equilibrium where the forward and reverse reactions are continuing at the **same rate** (or that the forward and reverse reaction are taking place, but the rate is not equals to zero).

Answer: **C**

12 When pressure is reduced at constant temperature, equilibrium position will shift to the side with a larger number of moles of gases to increase pressure (option **B** or **D**).

When temperature is increased, the endothermic reaction will occur to a greater extent to absorb heat (option **A** or **B**)

Answer: **B**

13 $K_w = [H^+][OH^-]$ (by definition)

At 30 °C, $K_w = 1.44 \times 10^{-14}$ mol^2 dm^{-6}
⇒ $[H^+][OH^-] = 1.44 \times 10^{-14}$

Since $[H^+] = [OH^-]$ for pure water,
⇒ $[H^+]^2 = 1.44 \times 10^{-14}$
⇒ $[H^+] = 1.2 \times 10^{-7}$

pH = −log [H$^+$] = −log (1.2×10^{-7}) = 6.92 (< 7)

Answer: **C**

14 Catalyst increases the rate constant (options **C** and **D**).

Catalyst lowers the activation energy (all four options).

Catalyst does not alter the energy level of the reactants and the products (options **B** and **D**).

Answer: **D**

15 When [acid] is low, reaction is first order with respect to acid
⇒ rate increases linearly as [acid] increases (options **A** or **D**).

When [acid] is high, reaction is zero order with respect to acid.
⇒ rate remains the same as [acid] increases i.e. the graph approaches a verticlal line (option **D**).

Answer: **D**

16 Number of protons increases from Na^+ to Al^{3+}, and hence nuclear charge increases.

Na^+, Mg^{2+} and Al^{3+} have the same total number of electrons.

As a result, the effective nuclear charge (net electrostatic force of attraction between the nucleus and valence electrons) increases from Na^+ to Al^{3+}, and so ionic radii decreases.

Answer: **B**

17 Since MgO will react with and dissolve in HC*l* (as a soluble salt is formed):

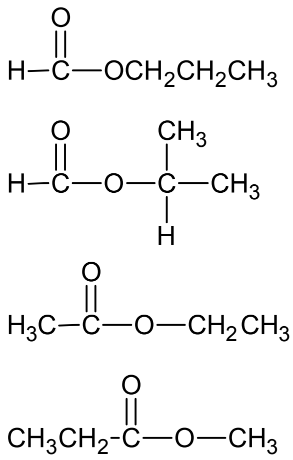
$$MgO + 2HCl \rightarrow MgCl_2 + H_2O$$

and Si will not react with or dissolve in HC*l*. Hence Si can be removed from the solution by filtration. ⇒ Method 1 will work (option **A** or **B**).

Since both MgO and Si have very high melting and boiling points, neither of them will vapourise on gentle heating.
⇒ Method 2 will **not** work (option **B** or **D**).

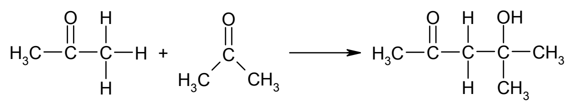
Answer: **B**

18 The four possible isomers with molecular formula $C_4H_8O_2$ are:

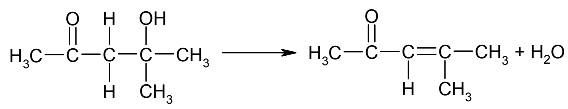


Answer: **C**

19 I is an <u>addition</u> reaction as the first propanone molecule is added across the C=O double bond of the second propanone molecule to produce an alcohol:



II is an <u>elimination</u> reaction as an unsaturated alkene is formed with the elimination of a water molecule from the alcohol:



Answer: **A**

20 **A**: Correct. Since there are 3 bond pair and 0 lone pair of electrons around each of the two C-atoms, the shape around each C-atom is trigonal planar. Hence all two C-atoms and four H-atoms lie on the same plane.

B: Correct. Molecular formula of ethane is C_2H_4, and so the empirical formula (showing the lowest mole ratio) is CH_2.

C: Not correct. As the shape around each C-atom is trigonal planar, the bond angle is 120°.

D: Correct. Each of the two C-atoms forms one σ-bond with two H-atoms (total of four σ-bonds), and there is one σ-bond and one π-bond between the two C-atoms.

Answer: **C**

21 **A**: Incorrect. Both alcohol groups can undergo substitution with PCl_5.

B: Incorrect. Both alcohol groups can undergo elimination of water.

C: Incorrect. Neither alcohols contain the −CH(OH)CH_3 group.

D: Correct. Only one of the alcohol is a secondary alcohol and can be oxidised by $Cr_2O_7^{2-}$; the other is a tertiary alcohol and cannot be oxidised.

Answer: **D**

22 **A**: Incorrect. But-1-ene can be formed from 2-bromobutane by the elimination of HBr using hot ethanolic KOH.

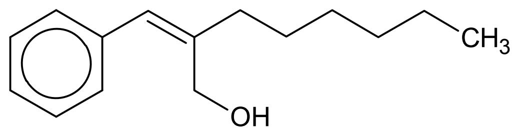
B: Incorrect. Butan-2-ol can be formed from 2-bromobutane by (nucleophilic) substitution using hot NaOH(aq).

C: Correct. A 2-bromobutane cannot be converted to butane in one step.

D: Incorrect. Butan-2-amine can be formed from 2-bromobutane by (nucleophilic) substitution using ethanolic NH_3, heat in sealed tube.

Answer: **C**

23 Only the aldehyde can be reduced by $NaBH_4$ to form a primary alcohol. The C=C is not reduced. The product is shown below:



$C_{15}H_{22}O$

$M_r(C_{15}H_{22}O) = 218$

Answer: **B**

24 **A**: Incorrect. Although CH_2=CHCOCH_2OH can be reduced (using H_2(g), Pt) to form CH_3CH_2CH(OH)CH_2OH - $C_4H_{10}O_2$, and it does not react with Fehling's solution (as it does not contain an aldehyde group), when treated with HCN and NaCN, it will not form $C_6H_8N_2O_2$, as it only has one ketone group (it will form CH_2=CHC(CN)(OH)CH_2OH instead).

B: Incorrect. Although CH_3COCH=CHOH can be reduced (using H_2(g), Pt) to form CH_3CH(OH)CH_2CH_2OH - $C_4H_{10}O_2$, and it does not react with Fehling's solution (as it does not contain an aldehyde group), when treated with HCN and NaCN, it will not form $C_6H_8N_2O_2$, as it only has one ketone group (it will form CH_3C(CN)(OH)CH=CHOH instead).

C: Correct. $CH_3COCOCH_3$ can be reduced to form $CH_3CH(OH)CH(OH)CH_3$ - $C_4H_{10}O_2$, react with HCN and NaCN to form $CH_3C(CN)(OH)C(CN(OH)CH_3$ - $C_6H_8N_2O_2$, and it does not react with Fehling's solution (as it does not contain an aldehyde group)

D: Incorrect. Although CH_3COCH_2CHO can be reduced to form $CH_3CH(OH)CH_2CH_2OH$ - $C_4H_{10}O_2$, react with HCN and NaCN to form $CH_3C(CN)(OH)CH_2CH(CN)OH$ - $C_6H_8N_2O_2$, it will form a brick red ppt with Fehling's solution (as it contains an aldehyde group)

Answer: **C**

25 **A**: Incorrect. Although artemisinic acid have two C=C double bond, it is not able to exhibit geometric (cis-trans) isomerism. This is because one of the C=C is within a ring ($\Rightarrow$ the two carbon groups that are part of the ring, must be placed in the cis-position relative to each other), and for the other C=C, there are two H-atoms on one of the C-atom.

B: Correct. As artemisinic acid have a carboxylic acid group, it can react with ethanol to form an ester with (with conc H_2SO_4 as a catalyst).

C: Correct. Artemisinic acid have a molecular formula of $C_{15}H_{22}O_2$.

D: Correct. As artemisinic acid have two alkene functional groups, it can undergo mild oxidation with cold dilute MnO_4^- to form diols.

Answer: **A**

26 **1**: Correct: $-134 = \Delta H_{R\to T} + (-75) - (+92)$

$\Delta H_{R\to T} = (-134) + 75 + 92 = +33 \text{ kJ mol}^{-1}$

2: Incorrect. $\Delta H_{T\to S} = (-75) - (+92)$

$= -167 \text{ kJ mol}^{-1}$ (exothermic)

3: Incorrect. From **S** $\rightarrow$ **U**, 92 kJ of energy is absorbed per mole of reaction.
$\Rightarrow$ **U** has a higher energy content than **S**.

Answer: **D**

27 **1**: Correct statement.

2: Correct statement.

3: Incorrect. **Units of rate constant = (mol dm^{-3})$^{1-n}$ s^{-1}**
(where n= overall order of reaction)

Answer: **B**

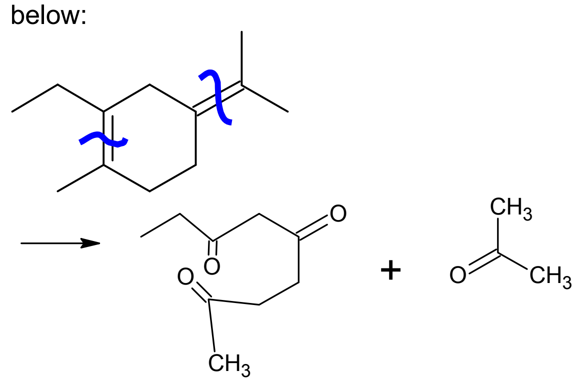
28 The chloride of element A reacts with water to form white fumes of HCl. Since HCl reacts with NaOH in a 1 : 1 ratio, 1 mole of chloride produces 3 moles of HCl.

$AlCl_3(s) + 3H_2O(l) \rightarrow Al(OH)_3(s) + 3HCl(g)$
$PCl_3(l) + 3H_2O(l) \rightarrow H_3PO_3(aq) + 3HCl(aq)$

Element A can either belong to Group 13 or 15.

Answer: **B**

29 Compound N undergoes oxidative cleavage as below:



1: Correct. Both products are ketones.

2: Incorrect. There is no carboxylic acid formed.

3: Incorrect. There are two products (and both are organic).

Answer: **D**

30 **1**: Correct. Q is a ketone and will give orange precipitate with 2,4-DNPH, while no ppt will be formed with P.

2: Correct. Q is a primary alcohol and will turn $Cr_2O_7^{2-}$ from orange to green, while $Cr_2O_7^{2-}$ will remain orange with P. (Note that $Cr_2O_7^{2-}$ is not a strong enough oxidising agent to cause side chain oxidation to occur in P).

3: Correct. P is a carboxylic acid and will give effervescence which forms white precipitate with limewater, while no effervescence will be produced with Q.

Answer: **A**

Parent's Signature:

CANDIDATE'S NAME: ________________________________ **CTG:** ____________

YISHUN JUNIOR COLLEGE

2017 JC2 PRELIMINARY EXAMINATION

CHEMISTRY **8872/02**
HIGHER 1

Paper 2 Structured and Free Response Questions **THURSDAY 24 AUGUST 2017**
1400hrs − 1600hrs
(2 hours)

Candidates answer Section A on the Question Paper

Additional Materials: Writing Paper
Data Booklet

INSTRUCTIONS TO CANDIDATES

Write your name and CTG in the spaces at the top of this page and 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 paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** the questions

Section B
Answer **two** questions on separate writing paper.

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	
Total	**/ 30**
Paper 2	
Section A	/ 40
B5	/ 20
B6	/ 20
B7	/ 20
Total	**/ 80**
Overall	**/ 110**

Section A

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

1 Antacids can be taken to relieve symptoms of indigestion, heartburn or stomach ulcer by neutralising gastric acid, and commonly contain sodium bicarbonate, magnesium hydroxide, aluminium hydroxide or calcium carbonate. The acidity of gastric acid is contributed mainly by hydrochloric acid.

(a) Sodium bicarbonate, $NaHCO_3$, is a very quick-acting antacid, but it should only be used for temporary relief. This is because its excessive use will lead to an increase in the pH value of the gastric juices above 7, which will lead to rebound acid secretion by the cells in the lining of the stomach.

Aluminium hydroxide, $Al(OH)_3$, and calcium carbonate, $CaCO_3$, are the active ingredients in the more popular antacids available in the market.

(i) Write an equation to illustrate how aluminium hydroxide relieves acid indigestion.

.... [1]

(ii) Suggest a possible advantage of using aluminium hydroxide or calcium carbonate as an antacid compared to sodium bicarbonate.

....

.... [1]

(b) A popular brand of antacid has the following drug facts on its label.

Drug Facts

Active ingredient (in each tablet)	**Purpose**
Calcium carbonate 500 mg	Antacid

Warnings

Ask a doctor or pharmacist before use if you are now taking a prescription drug. Antacids may interact with certain prescription drugs.
When taking this product do not exceed 15 tablets daily or use the maximum dosage for more than 2 weeks.
Keep out of reach of children.

Directions chew 2 to 4 tablets as symptoms occur

Other information

- each tablet contains calcium 215 mg and magnesium 5 mg
- store at 20 °C − 25 °C

Supplementary Facts
Serving size: 2 Tablets (1.30 g per tablet), Servings: 150,
Amount Per Serving: Total Carb 1 g, Sugars 1 g, Calcium 430 mg

Calcium carbonate reacts with hydrochloric acid to produce carbon dioxide gas as shown in the following equation.

$$CaCO_3(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

A student was given an antacid tablet and tasked to verify the mass of calcium carbonate claimed by the manufacturer on the drug facts label. She crushed five tablets with a pestle and mortar to form a powder and reacted with 100.0 cm^3, an excess, of 0.50 mol dm^{-3} hydrochloric acid. The carbon dioxide produced was collected and found to occupy 550 cm^3 at s.t.p..

(i) Calculate the number of moles of carbon dioxide produced.

number of moles of CO_2 = ... [1]

(ii) Assuming that calcium carbonate is the only ingredient in the antacid tablet that reacts with hydrochloric acid, calculate the mass of calcium carbonate reacted.

mass of calcium carbonate reacted = ... [2]

(iii) Hence, deduce whether the mass of calcium carbonate claimed by the manufacturer on the drug facts label is valid.

....

....

.... [2]

[Total: 7]

2 The Periodic Table we currently use is derived from that proposed by Mendeleev in 1869 after he had noticed patterns in the chemical properties of the elements.

Use the third period of the modern Periodic Table, sodium to chlorine, to answer the following questions.

(a) **(i)** Describe how the melting point of these elements varies across the period.

....

....

.... [2]

(ii) Describe and explain the trend in atomic radius for the elements sodium to chlorine.

trend ....

....

explanation ....

.... [2]

(b) State the structure and bonding present in the elements sodium, silicon and chlorine.
How does the bonding present help to explain the variation in electrical conductivity of these elements?

sodium ....

....

....

silicon ....

....

....

chlorine ....

....

[6]

(c) **(i)** Describe the structure of a ^{35}Cl atom, in terms of number and type of sub-atomic particles.

....

.... [2]

(ii) State the electronic configuration of a chloride ion, Cl^-.

.... [1]

(d) Chlorine forms a compound, ClO_2, with oxygen, which exist as covalent molecules.

(i) Draw a dot-and-cross diagram to illustrate the bonding in a ClO_2 molecule, showing the outermost shell electrons only.

[1]

(ii) Explain why ClO_2 is a non-linear molecule.

....

....

.... [2]

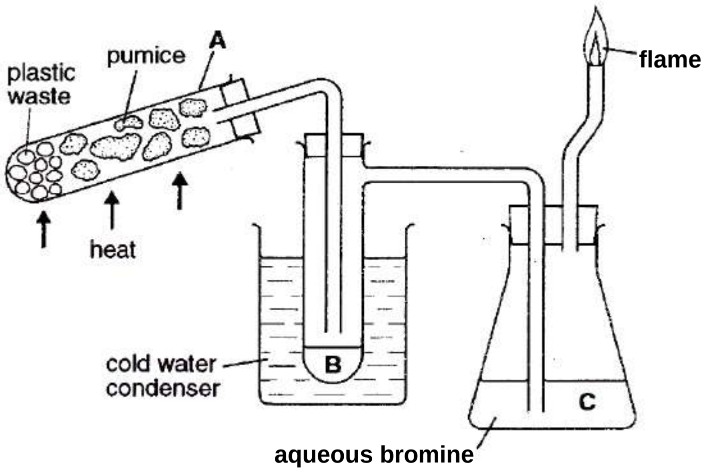
[Total: 16]

3 **(a)** In some countries, combustion is used in the disposal of plastic waste containing poly(ethene) and poly(propene).

(i) Construct an equation for the complete combustion of poly(propene), taking its formula to be $C_{3n}H_{6n}$, where *n* is the number of repeat units in a polymer molecule.

.... [1]

One method of recycling plastic waste to produce useful organic products involves heating the plastic waste strongly and passing the vapours over a hot inert surface such as pumice. This process can be demonstrated in the laboratory as shown in the diagram below.



The products of heating poly(propene) are given in the table.

product	percentage
hydrogen	12
methane	24
ethene	12
propene	16
benzene	20
methylbenzene	10
carbon	6

(ii) What will be the main constituent of the residue left in tube **A**, after it has been heated for an extended period of time?

.... [1]

(iii) What are the products that will be collected in tube **B** with the side-arm?

.... [1]

(iv) What will you observe in flask **C** after tube **A** has been heated for some time?

....

Write a balanced equation for the reaction that may have occurred in flask **C**.

.... [2]

(v) Suggest an advantage (economical or environmental) of this method of plastic waste disposal over the combustion method.

....

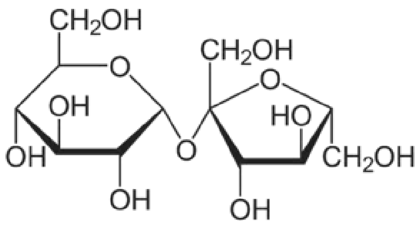
.... [1]

(b) Using an alkene with six carbon atoms, draw labelled structures to illustrate *cis-trans* isomerism.

[2]

[Total: 8]

4 Sugar is composed of sucrose, $C_{12}H_{22}O_{11}$. It is used as a sweetener in many foods and drinks. Carbonated soft drinks typically contain about 110 g of sucrose per dm^3.



sucrose

Carbonated drinks are often sold in 330 cm^3 cans.

(a) **(i)** Calculate the mass of sucrose, in grams, that is present in a can of carbonated soft drink.

mass of sucrose = ... [1]

(ii) Calculate the number of moles of sucrose in your answer to **(a)(i)**.

number of moles of sucrose = ... [2]

When the body uses sucrose in respiration, it does so by first breaking down the sucrose into glucose, $C_6H_{12}O_6$, and then releasing energy according to the following equation.

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

However, the respiration of sucrose can be represented as follows.

$$C_{12}H_{22}O_{11}(s) + 12O_2(g) \rightarrow 12CO_2(g) + 11H_2O(l)$$

The data for some enthalpy changes of formation are in the table below.

compound	$\Delta H^{\ominus}_f$ / kJ mol^{-1}
$C_6H_{12}O_6(s)$	−1271
$CO_2(g)$	−394
$H_2O(l)$	−286
$C_{12}H_{22}O_{11}(s)$	−2226

The energy content of most carbonated soft drinks is usually stated with units of 'calories' on the nutrition information label. One calorie has the value of 4.2 kJ. On average, the daily calorie intake for men should be 2500 and for woman 2000.

(b) **(i)** Calculate the standard enthalpy change, in kJ mol^{-1}, for the respiration of sucrose.

$\Delta H^{\ominus}$ = ... [3]

(ii) Use your results from **(a)(ii)** and **(b)(i)** to calculate the quantity of energy that is available from the sucrose contained in a can of carbonated soft drink.

energy = [1]

(iii) Calculate the percentage of a man's recommended daily calorie intake he will consume by drinking a can of carbonated soft drink.

percentage = ... [2]

[Total: 9]

Section B

Answer **two** questions from this section on separate answer paper.

5 The reaction between propanoic acid and ethanol in the presence of concentrated sulfuric acid to form ethyl propanoate is a *reversible reaction*.

$$\underset{\text{propanoic acid}}{CH_3CH_2COOH(l)} + \underset{\text{ethanol}}{CH_3CH_2OH(l)} \rightleftharpoons \underset{\text{ethyl propanoate}}{CH_3CH_2COOCH_2CH_3(l)} + H_2O(l)$$

(a) **(i)** What is meant by the term *reversible reaction*? [1]

(ii) Write an expression for the equilibrium constant, K_c, for the reaction between propanoic acid and ethanol shown above. [1]

(iii) Calculate the concentration of ethanol at equilibrium when the concentrations of $CH_3CH_2COOH(l)$, $CH_3CH_2COOCH_2CH_3(l)$ and $H_2O(l)$ are 0.18 mol dm^{-3}, 1.15 mol dm^{-3} and 1.15 mol dm^{-3} respectively.

The numerical value of K_c for this reaction is 3.94. [2]

(b) Propanoic acid can be made from different classes of compounds. Apart from an ester, choose **two** starting organic compounds that have **different** functional groups that can be converted to propanoic acid. Describe the reactions to form propanoic acid including reagents, equations and any observations in your answer. [8]

(c) When a small piece of sodium is added to propanoic acid, a steady flow of bubbles is produced and a sodium salt is formed. Potassium will react with propanoic acid in a similar way.

(i) Write an equation for the reaction of potassium with propanoic acid. [1]

(ii) State what type of reaction this is. [1]

(iii) State how you would identify the gas evolved. [1]

(iv) Predict how the observations for this reaction compare with that of sodium.
Suggest an explanation in terms of atomic structure. [2]

(d) Methyl butanoate is isomeric with ethyl propanoate. Write equations to show how methyl butanoate undergoes hydrolysis using $HCl(aq)$ and $NaOH(aq)$. [3]

[Total: 20]

6 **(a)** Explain the terms *order of reaction* and *half-life*. [2]

(b) A chemist investigated the reaction between H_2(g) and NO(g) at 300 °C.

$$2H_2(g) + 2NO(g) \rightarrow 2H_2O(g) + N_2(g)$$

The following data were obtained.

experiment	initial concentration of H_2(g) / mol dm^{-3}	initial concentration of NO(g) / mol dm^{-3}	initial rate / mol dm^{-3} h^{-1}
1	2.0×10^{-3}	3.0×10^{-3}	3.0×10^{-3}
2	2.0×10^{-3}	6.0×10^{-3}	1.2×10^{-2}
3	4.0×10^{-3}	6.0×10^{-3}	2.4×10^{-2}

(i) Use the data above to deduce the order of reaction with respect to each of the two reagents, showing how you arrive at your answers.

Hence, write a rate equation for the reaction. [3]

(ii) Calculate a value for the rate constant and state its units. [2]

(c) The chemist repeated experiment 1 at 310 °C and found that the initial rate of reaction was approximately double of that at 300 °C.

(i) Draw a graph to show the **energy distribution** of gas molecules at 300 °C.
Label this curve 300 °C. [1]

(ii) On the same axes, sketch the energy distribution of the same gas molecules at a temperature of 310 °C.
Clearly label this curve 310 °C. [1]

(iii) Indicate an activation energy on your graph. [1]

(iv) Use the sketches that you have drawn **and** the collision theory to explain why an increase in temperature causes an increase in the rate of the reaction. [3]

(d) In water, NO(g) reacts with oxygen and water to form nitrous acid, HNO_2, which is a *weak* acid.

(i) What is meant by the term *weak* acid?
Illustrate your answer with an equation. [2]

(ii) Write an expression for the acid dissociation constant. K_a, of nitrous acid, and state its units. [2]

(ii) Calculate the hydrogen ion concentration, [H^+], of a solution of nitrous acid of pH 3.72. [1]

(e) A solution containing nitrous acid, HNO_2, and sodium nitrite, $NaNO_2$, can act as a buffer solution.

Write two equations to show how such a solution behaves as a buffer when a small amount of acid or alkali is added. [2]

[Total: 20]

7 **(a)** Carbon is a major constituent of organic compounds, often combined with the elements, hydrogen and oxygen. One such compound is **D**, which contains C, 66.7%; H, 11.1%; O, 22.2% by mass. The relative molecular mass of **D** is 72.0.

(i) Determine the empirical formula and the molecular formula of **D**. [3]

(ii) **D** is a ketone. Draw its displayed formula. [1]

(b) Compound **E** has the molecular formula C_3H_8O. When **E** is heated with acidified potassium dichromate(VI), $K_2Cr_2O_7$, it forms compound **F**.

F gives a yellow precipitate in the presence of alkaline aqueous iodine, and an orange precipitate in the presence of 2,4-dinitrophenylhydrazine.

When **E** is heated with aqueous sodium bromide and concentrated sulfuric acid, it forms compound **G**. When a solution of silver nitrate in ethanol is added to **G**, a pale cream precipitate appears after a few minutes. When **G** is heated under reflux with concentrated sodium hydroxide in ethanol, compound **H** is formed.

H decolourises aqueous bromine.

Identify and suggest structures for **E**, **F**, **G** and **H**. Show how you deduced these structures, write equations for all of the reactions described above and suggest the types of reactions that are occurring. [10]

(c) Methylbenzene is an important intermediate in organic synthesis. It can undergo two different types of reactions with chlorine, depending on the conditions of the reaction.

For each type of reaction, give the conditions used and draw the structural formulae of the organic product formed. [4]

(d) Chlorofluoroalkanes, CFCs, have been banned as refrigerants and aerosol propellants in many countries since the mid-1990s. Suggest why CFCs have been banned and why fluoroalkanes such as CH_2FCF_3 are used as their replacements. [2]

[Total: 20]

~ END OF PAPER ~

2017 H1 Chemistry 8872 Preliminary Examinations Suggested Answers

Paper 2 Section A: Structured Questions

1 **(a)** **(i)** $Al(OH)_3 + 3H^+ \rightarrow Al^{3+} + 3H_2O$
(or $Al(OH)_3$ reacting with HCl)

(ii) Aluminium hydroxide or calcium carbonate is **insoluble in water** and therefore **will not increase the pH** of blood.

(b) **(i)**
$$n_{CO_2} = \frac{550}{22400} = 0.024554 = 0.0246 \text{ mol}$$

(ii)
$$n_{CaCO_3} = n_{CO_2} = 0.0246 \text{ mol}$$
$$m_{CaCO_3} = 0.024554 \times \{40.1 + 12.0 + 3(16.0)\} = 0.024554 \times 100.1 = 2.4565 = 2.46 \text{ g}$$

(iii) mass of $CaCO_3$ in one tablet = $\frac{2.4565}{5} = 0.491 \text{ g}$
The claim is valid, as the mass if $CaCO_3$ is approximately the same as what was claimed by the manufacturer

[Total: 7 marks]

2 **(a)** **(i)** The melting point of the elements **increases from Na to Si** (with Si significantly higher than that for A*l*),
The melting point **decreases drastically from Si to P** and is relatively low from P to C*l* (or the melting point of P to C*l* is much lower than that for the Na to Si).

(ii) trend: atomic radius **decreases** from Na to C*l*
explanation: **nuclear charge increases** and **shielding effect remains constant**

(b) sodium:
metallic bonding and **giant metallic structure**
'sea' of delocalised electrons are available to conduct electricity and so it has **high electrical conductivity**

silicon:
covalent bonding and **giant molecular structure or giant covalent structure**
In the giant molecular structure, there are some free electrons and 'holes' which can be used to conduct electricity, and so **silicon is a semi-conductor**

chlorine:
covalent bonding and **simple molecular structure**
There are **no mobile electrons** to conduct electricity, and so chlorine is a **non-conductor**

(c) **(i)** There are **17 protons and 18 neutrons** concentrated (within a very small volume) **at the nucleus / centre of the atom**
There are **17 electrons surrounding the nucleus** and moving randomly

(ii) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

(d) **(i)**

(ii) There are **<u>two bond pairs and two lone pairs</u>** of electrons (allow e.c.f.)
Hence the **<u>electron pairs spread themselves out as far apart as possible to minimise repulsion</u>** giving rise to the **<u>bent</u>** shape.

[Total: 16 marks]

3 **(a)** **(i)** $\mathbf{C_{3n}H_{6n}} + \frac{9n}{2}\mathbf{O_2} \rightarrow (3n)\mathbf{CO_2} + (3n)\mathbf{H_2O}$

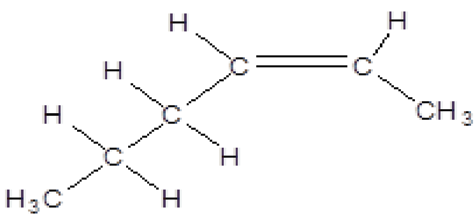
(ii) carbon (soot)

(iii) benzene and methyl benzene

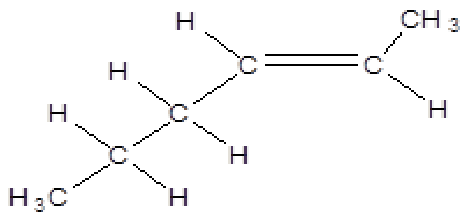
(iv) brown $Br_2(aq)$ is decolourised
$CH_2CH_2 + Br_2 + H_2O \rightarrow BrCH_2CH_2OH + HBr$
or
$CH_2CH_2 + Br_2 \rightarrow BrCH_2CH_2Br$
(accept equations involving propene as well)

(v) hydrogen and methane collected can be used as fuels.
or
benzene collected (in tube B) can be used to manufacture styrene and phenol
or
reduce the emission of $CO_2(g)$ to the atmosphere
(accept any other reasonable answer)

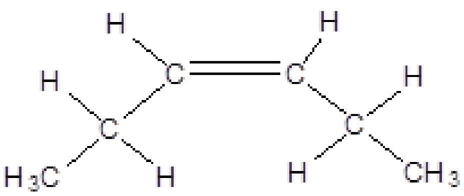
(b)



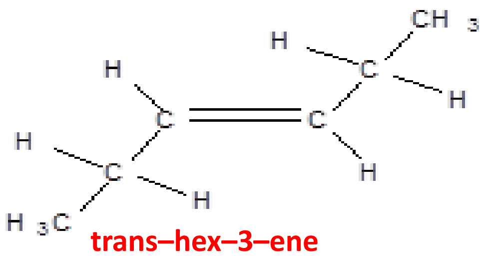
cis–hex–2–ene



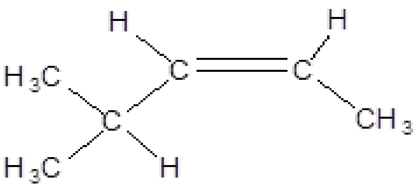
trans–hex–2–ene



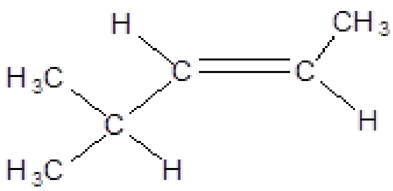
cis–hex–3–ene



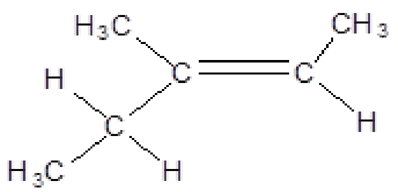
trans–hex–3–ene



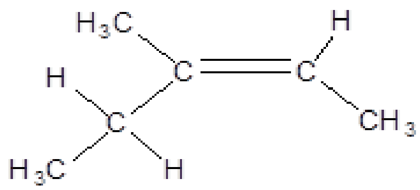
cis–4–methylpent–2–ene



trans–4–methylpent–2–ene



cis–3 – methylpent – 2 – ene



trans–3 – methylpent – 2 – ene

[Total: 8 marks]

4 **(a)** **(i)** mass of sucrose = $110 \times 330 \times 10^{-3} = 36.3 \text{ g}$

(ii) M_r of sucrose = $12(12.0) + 22.0 + 11(16.0) = 342.0$

number of moles of sucrose = $\dfrac{36.3}{342.0} = 0.10614 = 0.106 \text{ mol}$

(b) **(i)** $\mathbf{\Delta H_{rxn}^{\ominus} = \Sigma\Delta H_f^{\ominus}(products) - \Sigma\Delta H_f^{\ominus}(reactants)}$

$= 12\Delta H_f^{\ominus}(CO_2) + 11\Delta H_f^{\ominus}(H_2O) - \Delta H_f^{\ominus}(C_{12}H_{22}O_{11})$

$= 12(-394) + 11(-286) - (-2226)$

$= -7874 + 2226$

$= -5648$ kJ mol^{-1} (or -5650 kJ mol^{-1} to 3 s.f.)

[1] for correct equation, i.e. coefficient of the terms (for sucrose, not glucose)
[1] for correct substitution of the values (regardless of correct equation or not)
[1] for correct final answer with units

(ii) quantity of energy = $5648 \times 0.10614 = 599.48 = 599 \text{ kJ}$ (allow e.c.f.)

(iii) number of 'calories' = $\dfrac{599.48}{4.2} = 142.73$

percentage = $\dfrac{142.73}{2500} \times 100\% = 5.71\%$

[Total: 9 marks]

Paper 2 Section B: Free Response Questions

5 **(a)** **(i)** A reversible reaction is one that can proceed in both the forward and the backward direction.

(ii)
$$K_c = \frac{[CH_3CH_2COOCH_2CH_3][H_2O]}{[CH_3CH_2COOH][CH_3CH_2OH]}$$

(iii)
$$K_c = \frac{[CH_3CH_2COOCH_2CH_3][H_2O]}{[CH_3CH_2COOH][CH_3CH_2OH]}$$

$$3.94 = \frac{(1.15)(1.15)}{(0.18)[CH_3CH_2OH]}$$

$$\Rightarrow [CH_3CH_2OH] = \frac{(1.15)(1.15)}{(0.18)(3.94)} = 1.86 \text{ mol dm}^{-3}$$

(b)

$$CH_3CH_2CH_2OH + 2[O] \xrightarrow[H_2SO_4(aq),\ \text{heat under reflux}]{KMnO_4 \text{ or } K_2Cr_2O_7} CH_3CH_2CO_2H + H_2O$$

Observation:
Purple $KMnO_4$ is decolourised.
Or Orange $K_2Cr_2O_7$ turns green.

$$CH_3CH_2CHO + [O] \xrightarrow[H_2SO_4(aq),\ \text{heat under reflux}]{KMnO_4 \text{ or } K_2Cr_2O_7} CH_3CH_2CO_2H$$

Observation:
Purple $KMnO_4$ is decolourised.
Or Orange $K_2Cr_2O_7$ turns green.

$$CH_3CH_2CN + 2H_2O + H^+ \xrightarrow{H_2SO_4(aq),\ \text{heat under reflux}} CH_3CH_2CO_2H + NH_4^+$$

Observation:
No visible observation.

$$CH_3CH_2CH{=}CH_2 + 5[O] \xrightarrow[H_2SO_4(aq),\ \text{heat under reflux}]{KMnO_4} CH_3CH_2CO_2H + H_2O + CO_2$$

Observation:
Purple $KMnO_4$ is decolourised. Effervescence is observed, and gas evolved forms white precipitate with limewater.

(c) **(i)** $2K + CH_3CH_2COOH \rightarrow 2CH_3CH_2COO^-K^+ + H_2$

(ii) Redox reaction (accept acid-metal / base reaction)

(iii) The gas will **<u>'pop' with a lighted splint</u>**

(iv) The effervescence / bubbling will be more vigourous
As K is a bigger atom than Na (or K has a larger atomic radius than Na, or the outermost electron of K is further away from the nucleus than Na), **<u>the outermost electron of K is more loosely held by the nucleus</u>** (or the attractive force between the outermost electron and the nucleus of K is weaker) than Na,
$\Rightarrow$ K **<u>undergoes oxidation</u>** to form K^+ **<u>more easily</u>**

(d) Using HC*l*(aq):

$$CH_3CH_2CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-O-CH_3 + H_2O \rightleftharpoons CH_3CH_2CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-OH + CH_3-OH$$

Using NaOH(aq):

$$CH_3CH_2CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-O-CH_3 + NaOH \longrightarrow CH_3CH_2CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-O^-Na^+ + CH_3-OH$$

correct structure of methylbutanoate

[Total: 20 marks]

6 (a) **order of reaction** with respect to a given reactant is the **power** to which the **concentration of that reactant is raised** in **an experimentally determined rate equation**
or
In an experimentally determined rate equation : Rate = k [A] ^{m}
m = order of reaction with respect to reactant A
The **half-life** of a reaction, $t_{1/2}$, is the time taken for the concentration of a reactant to fall to **exactly half** its value

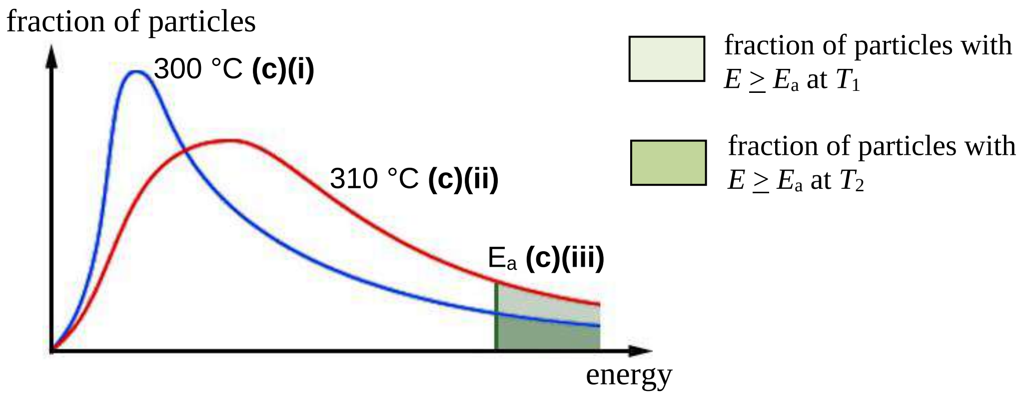
(b) (i) Comparing experiment 1 and 2,
When [NO] is doubled, the initial rate is quadrupled
$\Rightarrow$ order of reaction with respect to NO is 2
Comparing experiment 2 and 3,
When [H_2] is doubled, the initial rate is doubled
$\Rightarrow$ order of reaction with respect to H_2 is 1
rate = k [H_2] [NO]^2

(ii) Using the values from experiment 1:
$3.0\times10^{-3} = k(2.0\times10^{-3})(3.0\times10^{-3})^2$

$$\Rightarrow k = \frac{3.0\times10^{-3}}{(2.0\times10^{-3})(3.0\times10^{-3})^2} = 1.67\times10^{5}\ \text{mol}^{-2}\ \text{dm}^{6}\ \text{h}^{-1}$$

[1] for correct value, [1] for units (allow e.c.f. for both)

(c) (i)-(iii)



(iv) When temperature increases, the reactant particles have **greater average kinetic energies**, and the frequency of collisions increase

As seen from the diagram, **a larger fraction of the reactant particles** will have kinetic **energies greater than or equal to the activation energy**, and so the **frequency of effective collisions increases**

Hence, the **rate constant, *k*, increases** leading to the increase in the rate of the reaction.

(d) (i) A *weak* acid is one that dissociates partially in water
$HNO_2 \rightleftharpoons H^+ + NO_2^-$

(ii)
$$K_a = \frac{[H^+][NO_2^-]}{[HNO_2]}$$
units = mol dm^{-3}

(iii) $[H^+] = 10^{-3.72} = 1.91\times10^{-4}\ \text{mol dm}^{-3}$

(e) $HNO_2 + OH^- \rightarrow NO_2^- + H_2O$

$NO_2^- + H^+ \rightarrow HNO_3$ (accept if students use H_3O^+)

[Total: 20 marks]

7 (a) (i)

	C	H	O
mass ratio	66.7	11.1	22.2
mole ratio	$\frac{66.7}{12.0} = 5.5583$	$\frac{11.1}{1.0} = 11.1$	$\frac{22.2}{16.0} = 1.3875$
	$\frac{5.5583}{1.3875} = 4.00$	$\frac{11.1}{1.3875} = 8.00$	$\frac{1.3875}{1.3875} = 1.00$

$\Rightarrow$ empirical formula of **D** is C_4H_8O

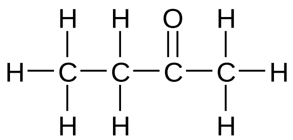
molecular formula = $(C_4H_8O)_n$

$\Rightarrow M(C_4H_8O)_n = n \times \{4(12.0)+8.0+16.0\} = 72.0$

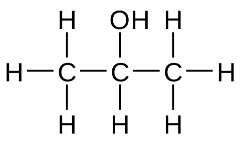
$\Rightarrow n \times (72.0) = 72.0$

$\Rightarrow n = 1$

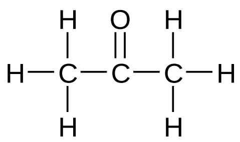
(ii)



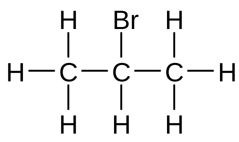
(b)



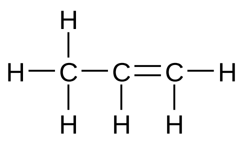
E



F



G



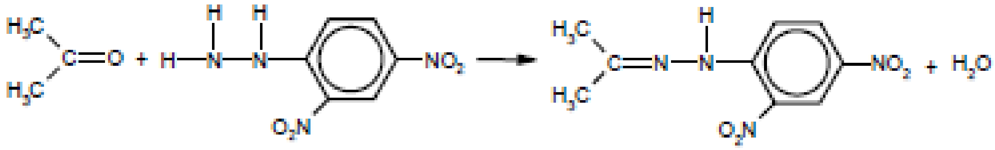
H

[1] each

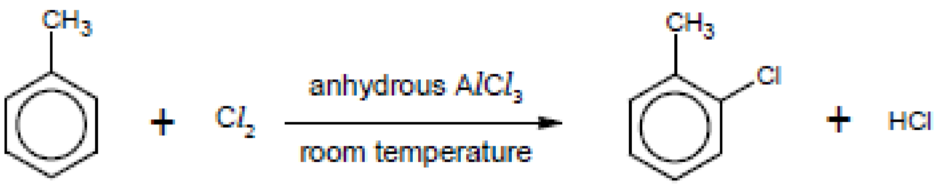
	information	type of reaction	deductions
1	When **E** is heated with acidified potassium dichromate(VI), $K_2Cr_2O_7$, it forms compound **F**	oxidation	**E** must be an alcohol (its formula is C_3H_8O), and **F** must be either a ketone or carboxylic acid (as no mention of immediate distillation)
2	**F** gives a yellow precipitate in the presence of alkaline aqueous iodine	oxidation	**F** must be a ketone that has the structure $-COCH_3$ (not an alcohol due to pt 1)
3	**F** gives an orange precipitate in the presence of 2,4-dinitrophenylhydrazine.	condensation	**F** must be a ketone (not an aldehyde due to pt 1&2)
4	When **E** is heated with aqueous sodium bromide and concentrated sulfuric acid, it forms compound **G**	(nucleophilic) substitution	**E** must be an alcohol and **G** must be a bromoalkane

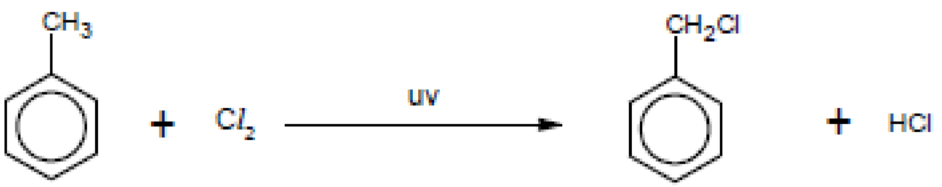
5	When a solution of silver nitrate in ethanol is added to G, a pale cream precipitate appears after a few minutes	(nucleophilic) substitution + precipitation	G must be a bromoalkane, (as it undergo hydrolysis (there is usually water present) to produce Br^- ion, which forms a cream ppt with $AgNO_3$)
6	When G is heated under reflux with concentrated sodium hydroxide in ethanol, compound **H** is formed	elimination (of HBr)	G must be a bromoalkane and **H** must be an alkene
7	**H** decolourises aqueous bromine.	(electrophilic) addition	**H** must be an alkene

Equations:

1. $CH_3CH(OH)CH_3 + [O] \rightarrow CH_3COCH_3 + H_2O$
2. $H_3C{-}\overset{O}{\overset{\|}{C}}{-}CH_3 + 3I_2 + 4OH^- \longrightarrow H_3C{-}\overset{O}{\overset{\|}{C}}{-}O^- + CHI_3 + 3I^- + 3H_2O$
3. 
4. $CH_3CHOHCH_3 + HBr \rightarrow CH_3CHBrCH_3 + H_2O$
5. $CH_3CH_2Br + H_2O \rightarrow CH_3CH_2OH + HBr$
   and $Ag^+ + Br^- \rightarrow AgBr$
6. $CH_3CH(OH)CH_3 \rightarrow CH_3CH{=}CH_2 + H_2O$
7. $CH_3CH{=}CH_2 + Br_2 + H_2O \rightarrow CH_3CH(OH)CH_2Br + HBr$
   or
   $CH_3CH{=}CH_2 + Br_2 \rightarrow CH_3CH(Br)CH_2Br$

(c)





(d) CFCs cause the depletion of the ozone layer (or caused the hole in the ozone layer)
Fluoroalkanes such as CH_2FCF_3 does not have $C-Cl$ bonds, which will break easily under uv light to produce $Cl\cdot$ radicals (or does not have Cl-atoms, and so will not produce $Cl\cdot$ radicals)

[Total: 20 marks]

~ **END OF SUGGESTED ANSWERS** ~