

**CATHOLIC JUNIOR COLLEGE**  
**JC2 PRELIMINARY EXAMINATIONS**  
Higher 1

# MARK SCHEME

CANDIDATE  
NAME

CLASS

2T

## CHEMISTRY

Paper 2

**8872/02**

**Monday 22 August 2016**  
**2 hours**

Candidates answer Section A on the Question Paper.

Additional Materials: Answer Paper

Data Booklet

Graph Paper (2 sheets)

### READ THESE INSTRUCTIONS FIRST

Write your name and HT group 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.

#### Section A

Answer **all** the questions.

#### Section B

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

You are advised to show all working in calculations.

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

For Examiner's Use			
Section A	A1		10
	A2		5
	A3		4
	A4		6
	A5		15
			40
Section B	B6		20
	B7		20
	B8		20
			40
TOTAL			80

## Section A

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

- 1 (a) Magnesium, aluminium and sulfur are all elements in Period 3 of the Periodic Table. With reference to their structure and bonding, explain the variation observed in their melting points.

Sulfur has simple molecular structure where molecules are held together by weak van der Waals' forces of attraction. ..... 1..

Both sodium and aluminium have giant metallic structures where strong metallic bonds are present between metal cations and sea of mobile delocalised electrons. ....

Thus, sulfur has a lower melting point than sodium and aluminium. ....

Aluminium has a higher melting point than sodium as it has stronger metallic bonding due to higher number of valence electrons available for delocalisation and charge density. ....

- (b) When the oxides of the above three elements are added to water, solutions of different pH values are obtained. State the pH values of the solutions obtained and explain your answer with the aid of relevant equations.

$\text{MgO(s)} + \text{H}_2\text{O(l)} \rightleftharpoons \text{Mg(OH)}_2\text{(aq)}$  .....

MgO dissolves in water to give a weakly alkaline solution of pH = 9 as MgO is only partially soluble in water. ....

$\text{Al}_2\text{O}_3$  does not dissolve in water due to its high magnitude lattice energy, thus the solution remains at pH = 7 .....

$\text{SO}_3\text{(g)} + \text{H}_2\text{O(l)} \rightarrow \text{H}_2\text{SO}_4\text{(aq)}$  OR  $\text{SO}_2\text{(g)} + \text{H}_2\text{O(l)} \rightarrow \text{H}_2\text{SO}_3\text{(aq)}$  .....

$\text{SO}_3$  reacts violently with water to form  $\text{H}_2\text{SO}_4$  of pH = 1 .....

OR  $\text{SO}_2$  reacts violently with water to form  $\text{H}_2\text{SO}_3$  of pH = 1 ..... [5]

- (c) Aluminium oxide is *amphoteric*. Write equations to illustrate this property.

$\text{Al}_2\text{O}_3 + 6\text{H}^+ \rightarrow 2\text{Al}^{3+} + 3\text{H}_2\text{O}$  .....

$\text{Al}_2\text{O}_3 + 2\text{OH}^- + 3\text{H}_2\text{O} \rightarrow 2[\text{Al(OH)}_4]^-$  .....

..... [2]

[Total: 10]

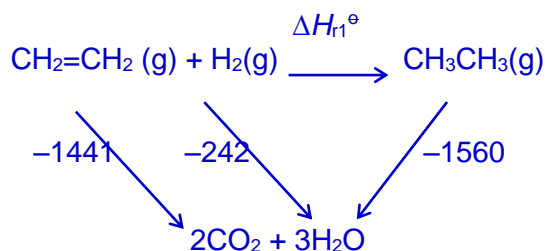
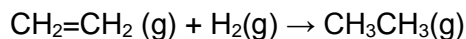
2 (a) Using the following  $\Delta H^\circ$  values at 298K,

$$\Delta H_c^\circ \text{ of } \text{CH}_3\text{CH}_3(\text{g}) = -1560 \text{ kJ mol}^{-1}$$

$$\Delta H_c^\circ \text{ of } \text{CH}_2=\text{CH}_2(\text{g}) = -1411 \text{ kJ mol}^{-1}$$

$$\Delta H_f^\circ \text{ of } \text{H}_2\text{O}(\text{l}) = -242 \text{ kJ mol}^{-1}$$

calculate the enthalpy change of reaction for the reduction of ethene to ethane,  $\Delta H_{r1}^\circ$ .



$$\Delta H_{r1}^\circ + (-1560) = -1411 + (-242)$$

$$\Delta H_{r1}^\circ = -93 \text{ kJ mol}^{-1}$$

- (b) (i) By referring to the bond energy values in the Data Booklet, calculate the enthalpy change of the same reaction for the reduction of ethene to ethane,  $\Delta H_{r2}^\circ$ . [2]

Bonds broken (endothermic)

$$1 \text{ C}=\text{C} \quad (+610)$$

$$1 \text{ H}-\text{H} \quad (+436)$$

Bonds formed (exothermic)

$$1 \text{ C}-\text{C} \quad (-350)$$

$$2 \text{ C}-\text{H} \quad 2(-410)$$

$$\Delta H_{r2}^\circ = +1046 + (-1170) = -124 \text{ kJ mol}^{-1}$$

- (ii) Explain why this calculated value in (b)(i) is different from the values obtained from the method using  $\Delta H^\circ$  values in (a). [2]

Bond energies in the Data Booklet used for calculation are merely average bond energy values and may not be a true reflection of actual bond energies in the molecules.

Thus the enthalpy changes calculated using bond energies are only an approximation. [1]

[Total: 5]

3

name	structure	boiling point / °C
Pentane	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$	36
2,2-dimethylpropane	$\begin{array}{c} \text{CH}_3 \\   \\ \text{CH}_3-\text{C}-\text{CH}_3 \\   \\ \text{CH}_3 \end{array}$	10
Propane	$\text{CH}_3\text{CH}_2\text{CH}_3$	- 42

- (a) In terms of its bonding, explain why the boiling point of pentane is higher than that of propane.

Pentane has more electrons than propane

The instantaneous dipole-induced dipole interactions / van der Waal's forces of attraction between the pentane molecules are stronger than that of propane. Thus, more energy is required to break the stronger van der Waals' forces of attraction between pentane than propane, leading to higher boiling point of pentane. ....[2]

- (b) In terms of its bonding, explain why the boiling point of pentane is higher than that of 2,2-dimethylpropane.

Pentane has a larger surface area of contact between its molecules as compared to 2,2-dimethylpropane (which has the same no of electrons.) Therefore the instantaneous dipole-induced dipole interactions / van der Waal's forces of attraction between the pentane molecules are more extensive and requires more energy to be broken. ....[2]

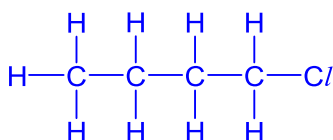
[Total: 4]

- 4 (a) But-1-ene is synthesised from butane in a two-step reaction as shown below.



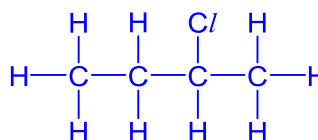
- (i) In the space given below, draw the displayed formulae of the two possible structures of intermediate, **X**. Suggest the ratio in which they might be formed. [2]

**monobromobutanes are also accepted**



**3**

**:**



**2**

- (ii) State the types of reaction that are taking place in reactions I and II.

Reaction I: (Free radical) Substitution.....

Reaction II: Elimination..... [1]

- (iii) State the reagents and conditions for reactions I and II.

Reaction I: limited  $\text{Cl}_2(\text{g})$  or  $\text{Br}_2(\text{g})$ , UV light.....

Reaction II: alcoholic  $\text{NaOH}$ , heated under reflux..... [2]

- (b) Suggest a reason why this synthetic route often results in low yield of but-1-ene

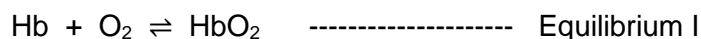
There is a possibility of the formation of but-2-ene with the intermediate 2-chlorobutane, resulting in a low yield.

OR

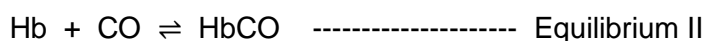
Substitution of  $\text{Cl}$  is random and thus gives a mixture of different products, which results in a low yield. [1]

[Total: 6]

- 5 In a healthy human body, oxygen,  $\text{O}_2$ , is transported around the body by haemoglobin, as represented by  $\text{Hb}$ , which is present in blood. Oxyhaemoglobin,  $\text{HbO}_2$ , carry the  $\text{O}_2$  to individual cells in the body tissue where the  $\text{O}_2$  molecules are then released. This reversible process can be represented by this equation:



Carbon monoxide,  $\text{CO}$ , is considered a toxic gas as it starves the human body of  $\text{O}_2$ .  $\text{CO}$  interferes with the oxygen-carrying capacity of blood by preferentially binding with the haemoglobin according to the following equilibrium:



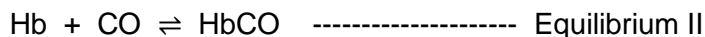
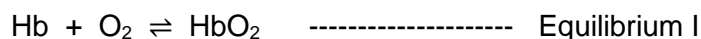
$\text{CO}$  can be harmful even at very low concentrations. A concentration of 500 ppm (parts per million) for an hour can be fatal. If a person is suspected of having  $\text{CO}$  poisoning, he can be treated by being given pure  $\text{O}_2$  to breathe.

- (a) (i) Write an expression for the equilibrium constant,  $K_c$ , for either equilibrium I or equilibrium II.

$$K_c = \frac{[\text{HbO}_2]}{[\text{Hb}][\text{O}_2]} \quad \text{OR} \quad K_c = \frac{[\text{HbCO}]}{[\text{Hb}][\text{CO}]}$$

[1]

- (ii) The values of the equilibrium constants of equilibria I and II are not given, but based on information given in the passage, state and explain which equilibrium is expected to have a larger  $K_c$  value.



Equilibrium II

CO starves the body of oxygen / CO preferentially bonds to haemoglobin / low

concentrations of CO can be harmful, thus indicating that the **position of**

**equilibrium II lies to the right.** Hence  $K_c$  expected to be larger.

[2]

- (b) A concentration of 500 ppm of CO is equivalent to 500 cm<sup>3</sup> of CO in 1 million cm<sup>3</sup> of air. Calculate the concentration of CO in terms of mol dm<sup>-3</sup> at r.t.p.

$$\begin{aligned} \text{Amount of CO in 500 cm}^3 &= \frac{500}{24\,000} \\ &= 0.0208 \text{ mol} \end{aligned}$$

Since 1 million cm<sup>3</sup> = 1000 dm<sup>3</sup>

$$\begin{aligned} [\text{CO}] \text{ in mol dm}^{-3} &= \frac{0.0208}{1\,000} \\ &= 2.08 \times 10^{-5} \text{ mol dm}^{-3} \end{aligned}$$

[2]

- (c) (i) State Le Chatelier's Principle.

Le Chatelier's Principle states that if a change is made to a **system at dynamic**

**equilibrium**, the system will respond in such a way so as to **minimise the effect of**

the change and a **new equilibrium** is formed.

[2]

- (ii) Using Le Chatelier's Principle and making reference to both equilibria I and II, explain why pure oxygen is able to treat a person suffering from CO poisoning.

The addition of pure oxygen shifts position of Eqm I to the right to remove O<sub>2</sub>,

leading to more HbO<sub>2</sub> being produced

Thus, the concentration of Hb falls.

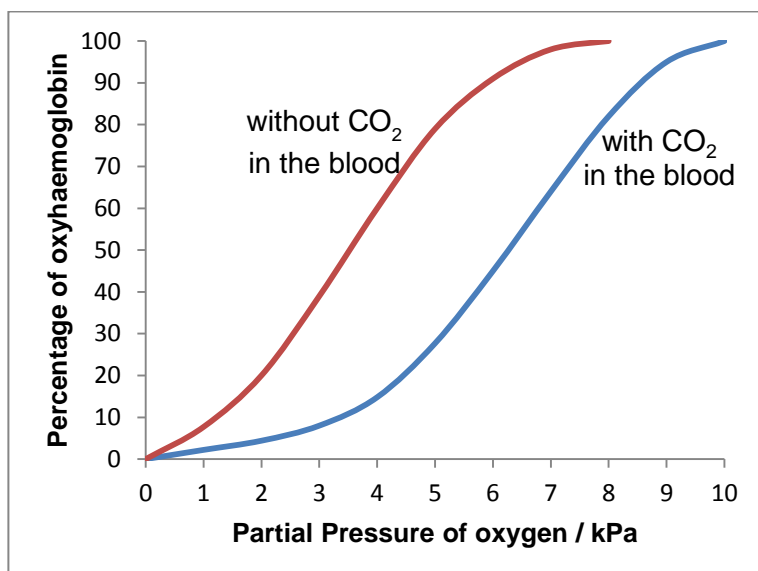
This will cause position of eqm II to shift to the left, increasing the dissociation of

CO from HbCO.

[3]

Haemoglobin can also bind to carbon dioxide,  $\text{CO}_2$ .  $\text{CO}_2$  is a waste product of respiration and its concentration is high in respiring cells. However, it is not considered to be toxic.

The graph below has two curves which show how the percentage of oxyhaemoglobin,  $\text{HbO}_2$ , varies with and without  $\text{CO}_2$  as the partial pressure of  $\text{O}_2$  in the blood increases. Partial pressure of  $\text{O}_2$  is directly proportional to the concentration of  $\text{O}_2$  in the blood.



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- (d) State the oxidation number of carbon in both  $\text{CO}_2$  and  $\text{CO}$ . [2]

Oxidation number of C in  $\text{CO}_2$ : .....+4.....

Oxidation number of C in  $\text{CO}$ : .....+2.....

- (e) (i) With reference to the graph, find the percentage of  $\text{HbO}_2$  with and without  $\text{CO}_2$  in the blood at 5 kPa of  $\text{O}_2$ . Give your answer to the nearest 10%.

Percentage of  $\text{HbO}_2$  with  $\text{CO}_2$  in the blood: .....30%.....

Percentage of  $\text{HbO}_2$  without  $\text{CO}_2$  in the blood: .....80%..... [1]

- (ii) Hence, suggest how the presence of  $\text{CO}_2$  affects Equilibrium I. Briefly explain your answer.

The presence of  $\text{CO}_2$  causes position of equilibrium I to lie to the left.....

since percentage of  $\text{HbO}_2$  is much lower in the presence of  $\text{CO}_2$ .....

.....[2]

[Total: 15]

## Section B

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

- 6 Carboxylic acids are an important class of organic molecules that are used in the production of many chemical compounds. The chemical reactions to form these compounds depend on the acidity of the carboxylic acids chosen, as well as the final intended purposes of the chemical compounds.

- (a) (i) Explain, in terms of its structure, why ethanoic acid is acidic. [2]

Ethanoic acid dissociates in water to give  $\text{H}^+$  and the ethanoate ion. The negative charge on O is delocalised/dispersed onto the ethanoate ion ( $\text{CH}_3\text{CO}_2^-$ ) thus stabilising the ethanoate ion.

- (ii) Ethanoic acid is described as a *weak acid*. Explain the term *weak acid*. [1]

Weak acids partially dissociate in water to give  $\text{H}^+$  ions.

- (iii) When titrating against sodium hydroxide to find out the concentration of a weak acid, state and explain which indicator should be used. [2]

For weak acid-strong base reactions use phenolphthalein whose pH range for colour change (7 – 10) lies within the pH range of rapid change of the titration.

- (b) Describe and explain why the acidity of 4-chlorobenzoic acid differs from that of benzoic acid. [2]

4-chlorobenzoic acid is a stronger acid than benzoic acid.

4-chlorobenzoic acid has an electron-withdrawing Cl atom. Thus, the negative charge on O is dispersed to a greater extent compared to benzoic acid. The conjugate base ion (chlorobenzoate) is more stable than benzoate.

OR

4-chlorobenzoic acid has an electron-withdrawing Cl atom. Thus, O–H bond is polarised and weakened to a larger extent compared to that of benzoic acid. Thus 4-chlorobenzoic acid dissociates  $\text{H}^+$  more easily.

- (c) Esters are an important class of organic compounds that can be naturally occurring or synthesised in a laboratory. The most distinctive feature is that they are usually sweet smelling, and one of their most important features in modern society is their use in polyester (PET) plastics.

Esters are formed by the reaction between alcohols and carboxylic acids in the presence of concentrated sulfuric acid catalyst. The ester, ethyl decadienoate, is one such example that gives the smell of pears.



- (i) Name the alcohol and carboxylic acid used in the production of this ester. [2]

Ethanol and decadienoic acid.

- (ii) Construct the equation to represent the esterification reaction, using  $\text{RCH}_2\text{OH}$  as the alcohol and  $\text{R}'\text{CO}_2\text{H}$  as the acid. [1]

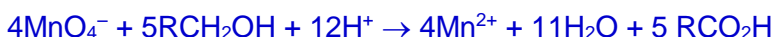
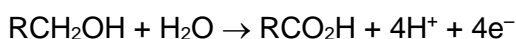


- (iii) Apart from its role as a catalyst, state and explain another effect of concentrated sulfuric acid in the above reaction. [2]

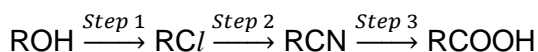
Concentrated sulfuric acid is a dehydrating agent and removes water from the above equilibrium. This causes the position of equilibrium to shift to the right to replace the water removed. Hence more ester will be formed.

- (d) There are multiple pathways to obtain the desired acids for the production of esters.

- (i) Given the following half-equation for the oxidation of a primary alcohol to a carboxylic acid, construct the balanced equation when the oxidising agent used is acidified potassium manganate(VII). [1]



If the primary alcohol is not available, a step-up reaction may be used to obtain the acid.



- (ii) State the reagents and conditions for Steps 2 and 3. [2]

Step 2: alcoholic NaCN, heat under reflux

Step 3:  $\text{H}_2\text{SO}_4(\text{aq})$ , heat under reflux

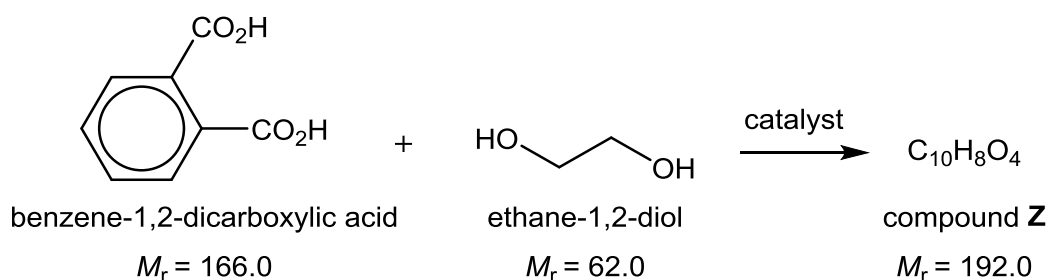
- (iii) State the type of reaction for Step 3. [1]

Step 3: (acid-catalysed) hydrolysis

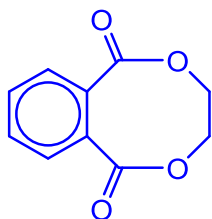
- (e) Benzene-1,2-dicarboxylic acid, although limited in its industrial use, is an important starting material to synthesise phthalic anhydride, a versatile intermediate in organic chemistry.

In a reaction, benzene-1,2-dicarboxylic acid is heated with ethane-1,2-diol in a presence of a suitable catalyst to produce compound **Z**,  $\text{C}_{10}\text{H}_8\text{O}_4$ .

Given the following reaction scheme,



- (i) Predict the structure of compound **Z** [1]



- (ii) Calculate the mass of compound **Z** formed if 100 g of each reactant is used in the reaction. You may represent benzene-1,2-dicarboxylic acid as  $\text{C}_6\text{H}_4(\text{COOH})_2$  and ethane-1,2-diol as  $\text{C}_2\text{H}_6\text{O}_2$  in your working. [3]

$$100 \text{ g of } \text{C}_6\text{H}_4(\text{COOH})_2 = (100/166) = 0.602 \text{ mol}$$

$$100 \text{ g of } \text{C}_2\text{H}_6\text{O}_2 = (100/62) = 1.61 \text{ mol}$$

$$\text{Since } \text{C}_6\text{H}_4(\text{COOH})_2 \equiv \text{C}_2\text{H}_6\text{O}_2$$

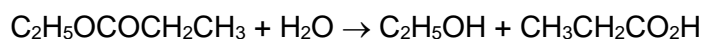
$$\text{C}_6\text{H}_4(\text{COOH})_2 \text{ is the limiting reagent.}$$

$$\text{Since } \text{C}_6\text{H}_4(\text{COOH})_2 \equiv \text{C}_2\text{H}_6\text{O}_2 \equiv \text{Z}$$

$$\text{Amt of compound Z produced} = 0.602 \text{ mol}$$

$$\begin{aligned} \text{mass of compound Z produced} &= 0.602 \times 192 \\ &= 116 \text{ g (3.s.f)} \end{aligned}$$

- 7 (a) Ethyl propanoate, an ester, is found naturally in apple juice and strawberries. Ethyl propanoate can be hydrolysed according to the following equation.



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. Sufficient water was then added to raise the total volume to  $1 \text{ dm}^3$  and the mixture was kept at a constant temperature of  $35^\circ\text{C}$ .

$10 \text{ cm}^3$  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 <sup>-3</sup>
0	0.000
1	0.084
2	0.140
3	0.178
4	0.195

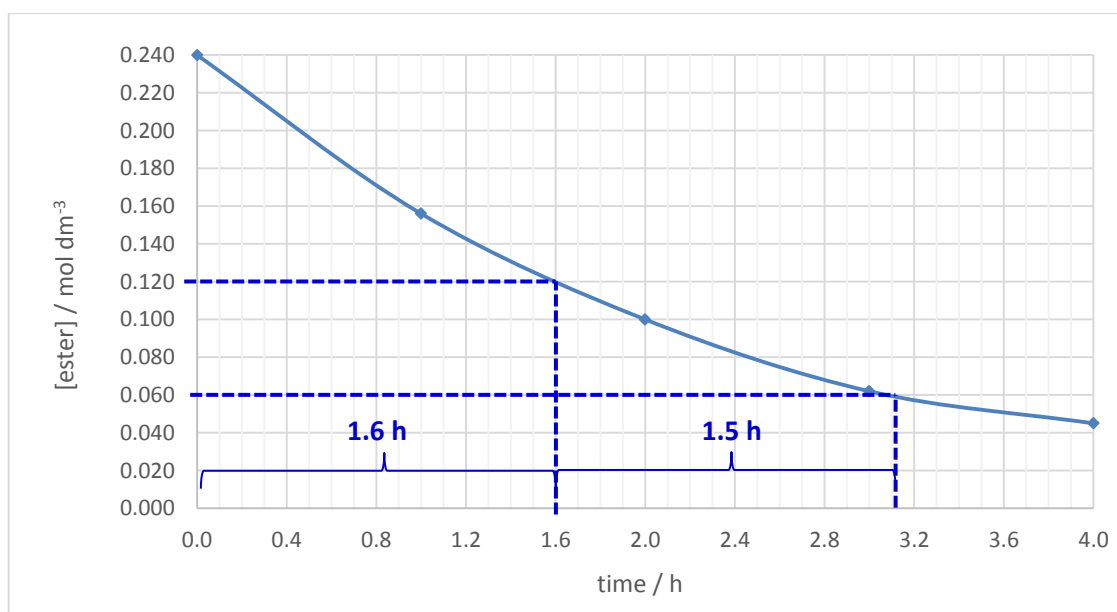
- (i) Identify the role of the cold water used prior to the titration and explain why it is necessary. [2]

The cold water is a quenching agent / meant to quench the reaction. 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.

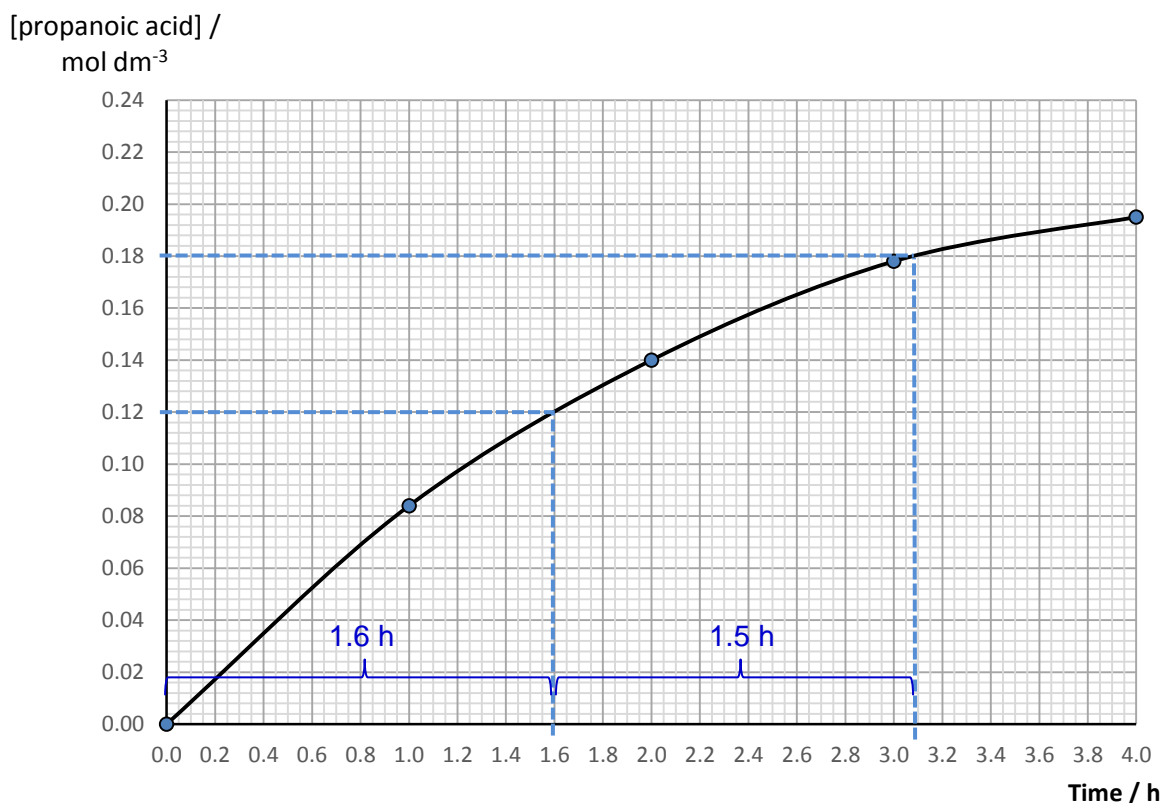
- (ii) By using a suitable graphical method, determine the half-life of the reaction and hence show that the hydrolysis reaction is first order with respect to the ester. [4]

Time / h	Concentration of propanoic acid / mol dm <sup>-3</sup>	Concentration of ester / mol dm <sup>-3</sup>
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



The half life is constant, hence it is first order with respect to the ester.

**[Product]-time graph**

Assuming the reaction goes into completion, the 0.24 mol dm<sup>-3</sup> of the ester would form 0.24 mol dm<sup>-3</sup> of propanoic acid. The first half-life of a product-time graph would be the time taken to form half the total amount of propanoic acid (0.12 mol dm<sup>-3</sup>) and the time subsequently taken to form 3/4 of the total amount of propanoic acid (0.18 mol dm<sup>-3</sup>).

(iii) Calculate the rate constant for the above hydrolysis, stating the units clearly. [1]

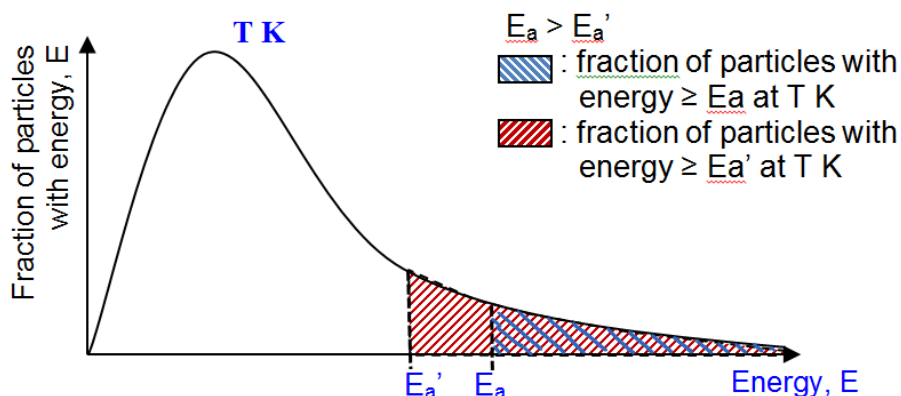
(half life is approximately 1.65 h, or 99 min or 5940 s.)

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k} = \frac{0.693}{1.65}$$

$$= 0.420 \text{ hr}^{-1} \text{ (or } 7.00 \times 10^{-3} \text{ min}^{-1} \text{ or } 1.17 \times 10^{-4} \text{ s}^{-1})$$

(iv) Explain the role of catalyst in the experiment with the aid of a Boltzmann distribution curve. [3]

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.



With a catalyst, as shown by the Boltzmann distribution,

there is a higher fraction of molecules with energy  $\geq$  lowered activation energy, this also increases frequency of effective collisions between molecules, and the rate of reaction increases.

- (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	Initial [NaOH] / mol dm <sup>-3</sup>	Initial [ester] / mol dm <sup>-3</sup>	Initial rate / mol dm <sup>-3</sup> s <sup>-1</sup>
1	0.020	0.015	$2.70 \times 10^{-3}$
2	0.030	0.015	$4.05 \times 10^{-3}$
3	0.060	0.020	<i>r</i>

- (i) Use the data above to deduce the order of reaction with respect to NaOH. [2]

Comparing expt 1 and 2,

when [OH<sup>-</sup>] increased by 1.5 times while keeping [ester] constant, initial rate increased by 1.5 times.

Hence, order of reaction wrt [OH<sup>-</sup>] is 1.

- (ii) Given that the reaction is first order with respect to the ester, calculate the initial rate of reaction, *r*, for Experiment 3. [1]

Comparing expts 2 and 3,

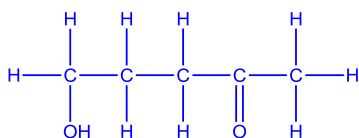
$$r = \left( \frac{0.06}{0.03} \times \frac{0.02}{0.015} \times 4.05 \times 10^{-3} \right) = 0.0108 \text{ mol dm}^{-3} \text{ s}^{-1}$$

- (c) Compound **A** is an isomer of ethyl propanoate (C<sub>5</sub>H<sub>10</sub>O<sub>2</sub>). No precipitate is seen when **A** is warmed with Fehling's solution. However, when **A** is warmed with alkaline aqueous iodine, a yellow precipitate of CHI<sub>3</sub> is observed.

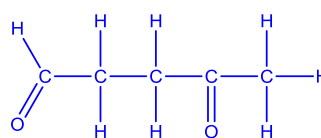
Heating **A** with acidified  $K_2Cr_2O_7$  followed by immediate distillation gives compound **B**. Tollen's reagent gives a silver mirror when warmed with **B**. When **B** is warmed with 2,4-dinitrophenylhydrazine, an orange precipitate is observed.

- (i) Identify and suggest structures for **A** and **B**. Show how you deduced these structures and suggest the types of reactions that are occurring. [6]

No.	Information / observation	Type of reaction	Functional group present
1	No precipitate is seen when <b>A</b> is warmed with Fehling's solution.	Absence of mild oxidation	Absence of aldehyde group in <b>A</b> .
2	when <b>A</b> is warmed with alkaline aqueous iodine, a yellow precipitate of $CHI_3$ is observed.	Mild oxidation / Triiodomethane test	Presence of $\left[ \begin{array}{c} CH_3 \\   \\ H-C- \\   \\ OH \end{array} \right]$ or $\left[ \begin{array}{c} H_3C \\   \\ C=O \end{array} \right]$ functional group in <b>A</b> .
3	heating <b>A</b> with acidified $K_2Cr_2O_7$ followed by immediate distillation gives compound <b>B</b>	Strong oxidation	Presence of primary alcohol in <b>A</b> .
4	Tollen's reagent gives a silver mirror when warmed with <b>B</b>	Mild oxidation	Presence of aldehyde group in <b>B</b> .
5	When <b>B</b> is warmed with 2,4-dinitrophenylhydrazine, an orange precipitate is observed.	Condensation reaction	Presence of ketone and / or aldehyde functional groups in <b>B</b> .



Compound A



Compound B

- (ii) State the type of isomerism present between **A** and ethyl propanoate. [1]

Functional group isomerism

[Total: 20]

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

Some organic compounds contain chlorine, bromine or iodine in addition to carbon and hydrogen. They are classified as halogenoalkanes. One such compound is 2-iodobutane.

**(a)** 2-iodobutane reacts with ammonia.

**(i)** State the type of reaction occurring.

Type of reaction: (nucleophilic) substitution

**(ii)** Write a balanced equation for the reaction and;



**(iii)** State the conditions required for the reaction to occur. [3]

Condition: concentrated  $\text{NH}_3$  in ethanol, heated in sealed tube

**(b)** 2-iodobutane also undergoes reaction with potassium hydroxide.

Given that only two geometric isomers are formed

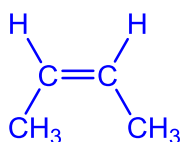
**(i)** State the type of reaction that occurred [1]

Elimination

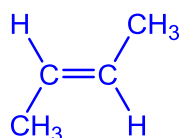
**(ii)** State the conditions required for the reaction to occur. [1]

Ethanol KOH, heat under reflux

**(iii)** Draw the structural formulae of the products and state how this isomerism arises. [3]



cis-but-2-ene



trans-but-2-ene [

The products formed have restricted rotation about the C=C bond and both C in the C=C has 2 different substituents attached to it.

**(c)** In an experiment, 2-iodobutane was reacted with aqueous silver nitrate at room temperature. A second experiment was carried out using 2-bromobutane instead.

Describe, as much as possible, how the reaction would differ from that of 2-iodobutane. Explain your answer.

Yellow coloured ppt of  $\text{AgI}$  was formed from 2-iodobutane while cream coloured ppt of  $\text{AgBr}$  was formed from 2-bromobutane. Precipitation occurred almost immediately upon addition of  $\text{AgNO}_3$  for 2-iodobutane but precipitation took a while to occur for 2-bromobutane. C-I bond ( $240 \text{ kJ mol}^{-1}$ ) in 2-iodobutane is weaker than C-Br bond ( $280$

$\text{kJ mol}^{-1}$ ) in [1] 2-bromobutane, thus a shorter amount of time is required to break the weaker C-I bond, and precipitation of AgI occurred at a faster rate.

[4]

(d) In a separate experiment, 2-chlorobutane is reacted to form butan-2-ol. Butan-2-ol is then oxidised to form butanone.

- (i) To distinguish between butanone and 2-chlorobutane, a student heated separate samples of each compound with aqueous iodine in the presence of sodium hydroxide. However, this method failed to work. Suggest an explanation why this is so. [2]

2-chlorobutane will undergo substitution with NaOH to form butan-2-ol which in turn undergoes mild oxidation via tri-iodomethane test. Thus, both butanone and 2-chlorobutane (butan-2-ol) will result in the same observation where precipitation of yellow  $\text{CHI}_3$  is observed.

- (ii) Other than aqueous silver nitrate, suggest a simple chemical test that can be used to distinguish between butanone and 2-chlorobutane. In your answer, state the reagent and conditions used and observations made. [2]

To separate test tubes of each compound, add 2,4-dinitrophenylhydrazine and heat. Orange ppt will be observed for butanone while no such precipitation will be observed for 2-chlorobutane.

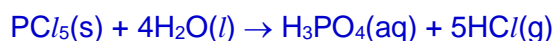
- (iii)  $\text{KMnO}_4$  was used in the oxidation process to form butanone under acidic conditions. Identify the manganese containing species present at the end of the experiment and write its electronic configuration. [2]

$\text{Mn}^{2+}$ .

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$ .

- (iv) 2-chlorobutane can also be obtained from butan-2-ol by reacting it with anhydrous phosphorous pentachloride. Explain why phosphorous pentachloride must be anhydrous for the reaction to occur. Include in your answer, any equations necessary. [2]

$\text{PCl}_5$  will undergo hydrolysis when reacted with water to give phosphoric(V) acid and hydrogen chloride gas.



[Total: 20]