

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.



Innova Junior College

[Turn over

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
$^{39}_{19}\text{K}$	19	20	19	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
$^{40}_{19}\text{K}^+$	19	21	18	$1s^2 2s^2 2p^6 3s^2 3p^6$

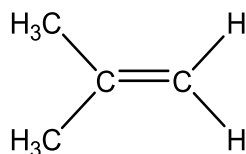
[4]

- (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.

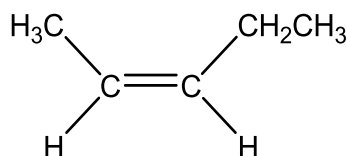
- (i) products: CO_2 and $(\text{CH}_3)_2\text{CO}$

Original alkene:



- (ii) products: $\text{CH}_3\text{CO}_2\text{H}$ and $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$

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.

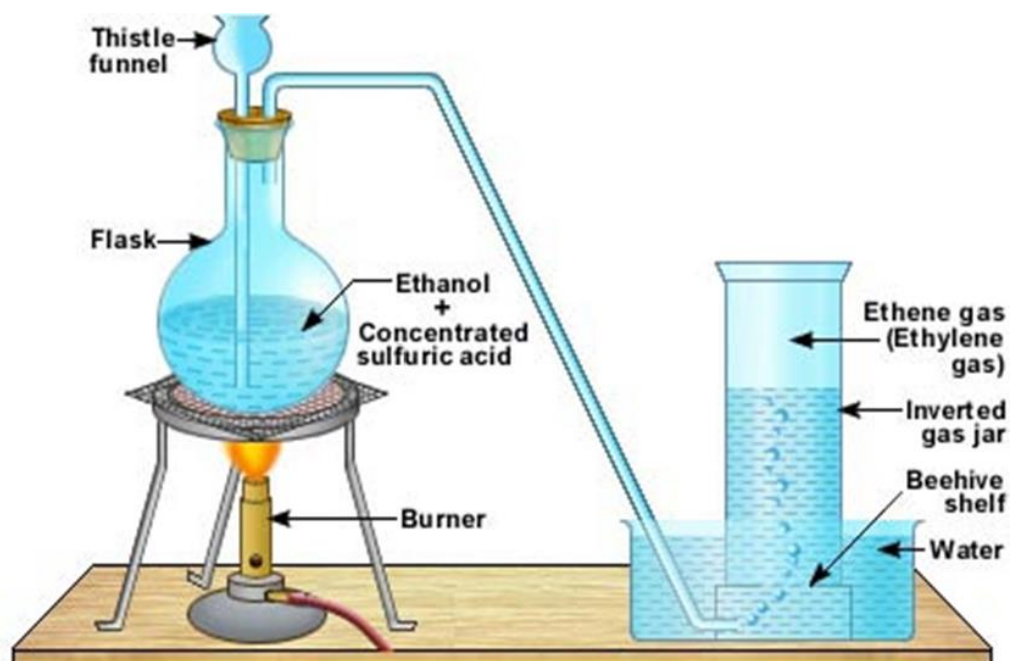


Figure 1.1

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 Na₂CO₃.

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, CH₂(OH)CH₂(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 KMnO₄, in dilute H₂SO₄(aq) or NaOH(aq)

[1]

- (iv) What changes do you expect to observe to reagent **B**?

Purple KMnO₄ 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 I₂, NaOH(aq) to each compound, warm

(Accept aqueous alkaline iodine)

Ethanol: yellow precipitate.

Ethane-1,2-diol: no precipitate.

OR

Add KMnO₄(aq), dil H₂SO₄(aq) to each compound, heat

Ethanol: Purple KMnO₄ turns colourless

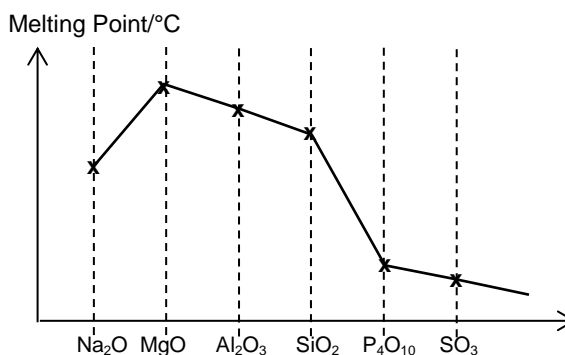
Ethane-1,2-diol: Purple KMnO_4 turns colourless. Effervescence is observed, when evolved gas is reacted with aqueous $\text{Ca}(\text{OH})_2$, a white precipitate is observed.

[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
- $\text{P}_4\text{O}_{10}/\text{P}_4\text{O}_6$ 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 strength 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, $\text{H}_3\text{PO}_4(\text{aq})$.

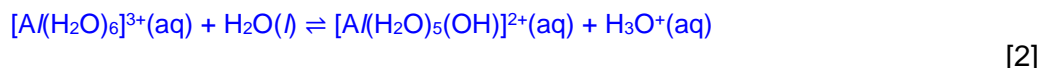
AlCl_3 also hydrolyses in water to produce an acidic solution.

- (i) Write a balanced equation to show the reaction between PCl_5 and water.



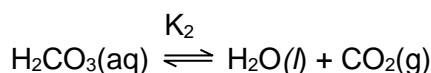
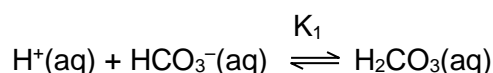
- (ii) Explain using equation(s) why AlCl_3 undergoes hydrolysis with water to produce an acidic solution.

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.



[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.



- (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**.

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]

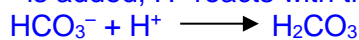
- (ii) Define the term *buffer*.

A buffer solution is one which resists changes in pH when small amounts of acid and base are added.

[1]

- (iii) Explain how carbonic acid-bicarbonate acts as a buffer using relevant equations.

When small amount of H^+ is added, H^+ reacts with the conjugate base HCO_3^- .



$[\text{H}^+]$ remains relatively constant/ pH remains fairly constant.

When base amount of OH^- is added, OH^- reacts with the acid H_2CO_3 .



$[\text{OH}^-]$ remains relatively constant/ pH remains fairly constant.

[3]

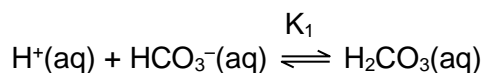
- (b) During exercise, our body expends the energy in glucose and produces large amounts of CO_2 and H^+ . This causes the pH of our blood to drop and may lead to a medical condition known as acidosis. Increased breathing during exercise will help to reverse this drop in pH.

- (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 concentration of H_2CO_3 and decrease concentration of H^+ (from the blood).

[3]

- (c) With reference to the equilibrium below, answer the following questions.



- (i) Write an expression for the equilibrium constant of this reaction, K_1 , stating clearly its units.

$$K_1 = \frac{[H_2CO_3]}{[HCO_3^-][H^+]}$$

Units: $\text{mol}^{-1} \text{dm}^3$

[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.

$$\text{pH} = \text{pK} - \log_{10} \left(\frac{[HCO_3^-]}{[CO_2]} \right)$$

Where pK is the negative logarithm of K (where $K = K_1 \cdot K_2$).

- (i) Given the value of pK is 6.1, calculate the ratio of $[CO_2]$ and $[HCO_3^-]$ in our blood.

$$7.4 = 6.1 - \log \left(\frac{[HCO_3^-]}{[CO_2]} \right)$$

$$\log \left(\frac{[HCO_3^-]}{[CO_2]} \right) = -1.3$$

$$\left(\frac{[HCO_3^-]}{[CO_2]} \right) = 0.0501$$

$$\text{OR } \frac{[CO_2]}{[HCO_3^-]} = 19.95 = 20.0$$

[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} ?

$$[\text{HCO}_3^-] = 12 \text{ millimole per litre} = 12 \times 10^{-3} \text{ mol dm}^{-3}$$

$$[\text{CO}_2] = \frac{12 \times 10^{-3}}{0.0501}$$

$$= 0.239 \text{ mol dm}^{-3}$$

$$\text{OR } [\text{CO}_2] = 19.95 \times [\text{HCO}_3^-]$$

[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.

$$\begin{aligned} \text{No. of mol. Of } \text{HCO}_3^- \text{ needed} &= 12 \times 10^{-3} \text{ mol} \\ \text{Mass of } \text{NaHCO}_3 \text{ needed} &= 84.0 (\text{Mr of } \text{NaHCO}_3) \times 12 \times 10^{-3} \\ &= 1.01 \text{ g} \end{aligned}$$

[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)

$\text{K}_2\text{Cr}_2\text{O}_7$, 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 $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{OH}$, 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]

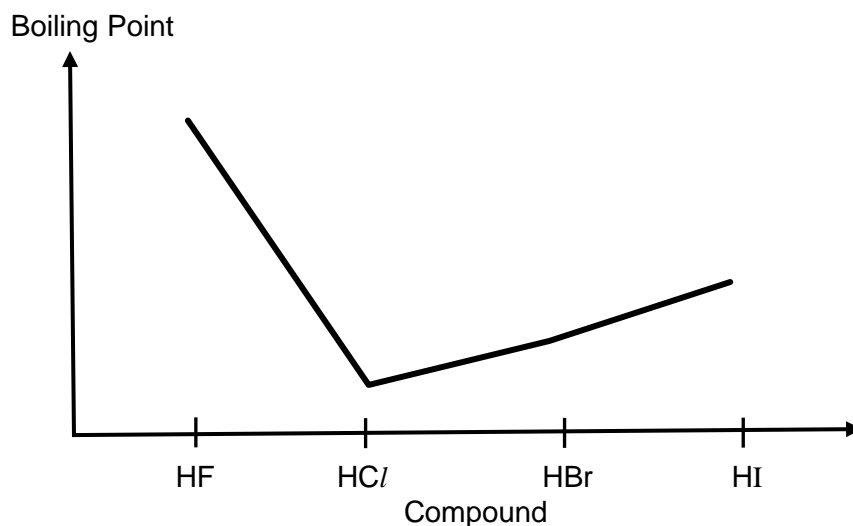
[Total:16]

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 HCl/ HBr and HI molecules.

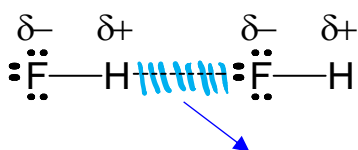
- (ii) Explain why the boiling points of hydrogen halides increase from HCl to HI.

[2]

The size of electron cloud increases from HCl to HI. Polarisability of the electron cloud of the molecules increase and strength of instantaneous dipole-induced dipole between molecules also increases from HCl 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

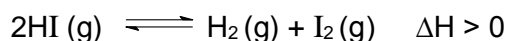
- labelling of hydrogen bonding

(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:



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 $3.10 \times 10^{-5} \text{ mol dm}^{-3}$.

(d) (i) Determine the concentrations of HI (g) in this equilibrium mixture at 500K.

[1]

$$[H_2] = [I_2] = 3.1 \times 10^{-5} \text{ mol dm}^{-3}$$

$$K_c = \frac{[H_2][I_2]}{[HI]^2}$$

$$[HI] = 3.92 \times 10^{-4} \text{ mol dm}^{-3}$$

(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}

$$[HI]_{\text{initial}} = 3.92 \times 10^{-4} + 2(3.10 \times 10^{-5})$$

$$= 4.54 \times 10^{-4} \text{ mol dm}^{-3}$$

(iii) Suggest and explain how the value of K_c would change if the temperature of the glass tube was raised.

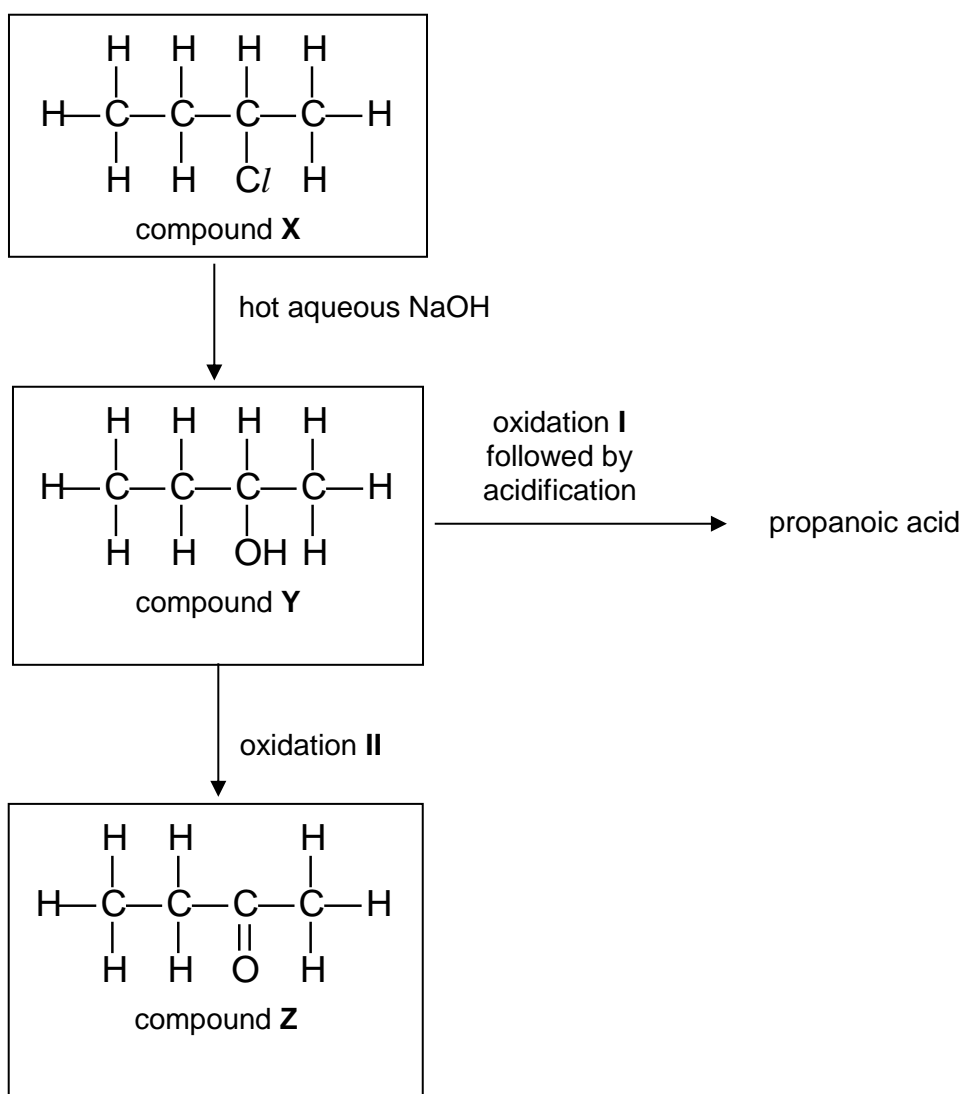
[2]

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.



- (ii) State the reagents and conditions for oxidation I and oxidation II.

[2]

Oxidation I: NaOH(aq) , $\text{I}_2(\text{aq})$, warm

Oxidation II: KMnO_4 OR $\text{K}_2\text{Cr}_2\text{O}_7$, $\text{H}_2\text{SO}_4(\text{aq})$, heat

- (iii) Predict the shape and bond angle about $\text{Cl}-\text{C}-\text{H}$ in compound X, $\text{C}_4\text{H}_9\text{Cl}$.

[2]

Shape : tetrahedral Bond angle : 109.5°

- (iv) State and explain whether compound X, $\text{C}_4\text{H}_9\text{Cl}$ is polar or non-polar.

[2]

$\text{C}_4\text{H}_9\text{Cl}$ is polar/ $\text{C}-\text{Cl}$ 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]

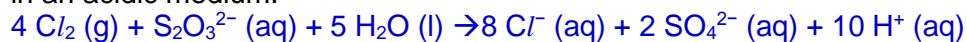
5 This question is about chlorine.

- (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, $\text{Na}_2\text{S}_2\text{O}_3$.

- (i) When chlorine gas was absorbed by sodium thiosulfate found in the “hypo helmet”, chlorine was reduced to chloride while thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$ was oxidised to sulfate ions, SO_4^{2-} .

Write a balanced equation for the reaction between chlorine and thiosulfate ions in an acidic medium.



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 $\text{S}_2\text{O}_3^{2-}$ to be 2 : 3 if you are not able to write the equation between Cl_2 and $\text{S}_2\text{O}_3^{2-}$]

$$\text{No. of moles of chlorine in } 500 \text{ cm}^3 = (500 \times 10^{-3}) / 24 = 0.0208 \text{ mol}$$

$$\text{No. of moles of thiosulfate needed} = 0.0208 / 4 = 5.208 \times 10^{-3} \text{ mol [ECF from wrong mole ratio]}$$

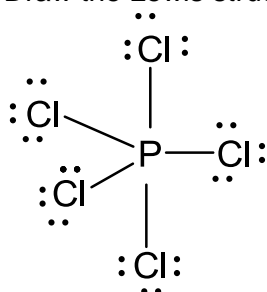
$$\begin{aligned} \text{Conc of thiosulfate} &= \text{mole/vol} = (5.208 \times 10^{-3}) / (700 \times 10^{-3}) \\ &= 7.44 \times 10^{-3} \text{ mol dm}^{-3} \end{aligned}$$

[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/ $^{\circ}\text{C}$	714	178	161

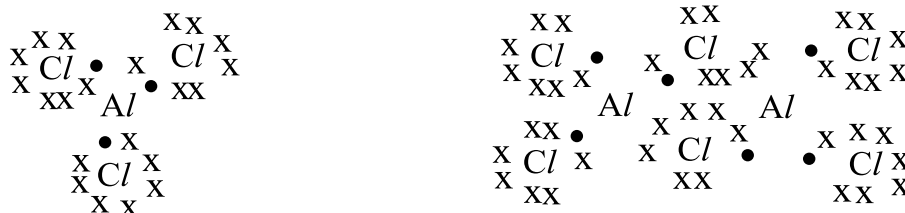
- (i) Draw the Lewis structure of phosphorus pentachloride.



Must show correct axial and equatorial position
Must show lone pair of electrons on chlorine

[1]

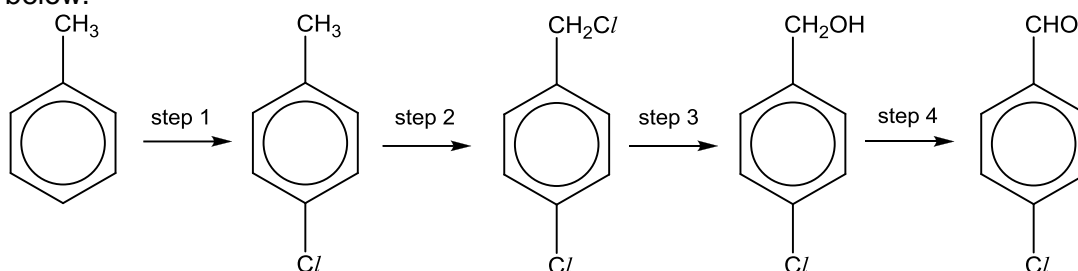
- (ii) AlCl_3 can undergo dimerisation to form Al_2Cl_6 . Draw the dot-and-cross diagram for AlCl_3 and Al_2Cl_6 . Hence, or otherwise, deduce, with reasoning, whether the dimerisation reaction is endothermic or exothermic.



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: $\text{Cl}_2(\text{g})$, or Cl_2 in CCl_4 , anhydrous FeCl_3 catalyst, room temp in the dark (to prevent FRS) (For catalyst, can use Fe or AlCl_3)

Step 2: $\text{Cl}_2(\text{g})$, or Cl_2 in CCl_4 , uv light

Step 4: $\text{K}_2\text{Cr}_2\text{O}_7$, 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, RCI reacted with aqueous sodium hydroxide.

Expt	Initial $[\text{NaOH}] / \text{mol dm}^{-3}$	Initial $[\text{RCI}] / \text{mol dm}^{-3}$	Initial rate / $\text{mol dm}^{-3} \text{s}^{-1}$
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 [RCI] constant, rate increases by 1.5 time. Order wrt NaOH is 1.

Comparing expt 1 & 2

When [RCI] increases by 1.5 times, keeping [NaOH] constant, rate increases by 1.5 time. Order wrt RCI is 1.

Rate = $k [\text{NaOH}][\text{RCI}]$ [ECF based on order]

[3]

- (ii) In Expt 4, the initial concentrations of NaOH and RCI are 0.06 mol dm^{-3} and 0.03 mol dm^{-3} respectively. Calculate the initial rate for Expt 4.

Comparing expt 1 & 4

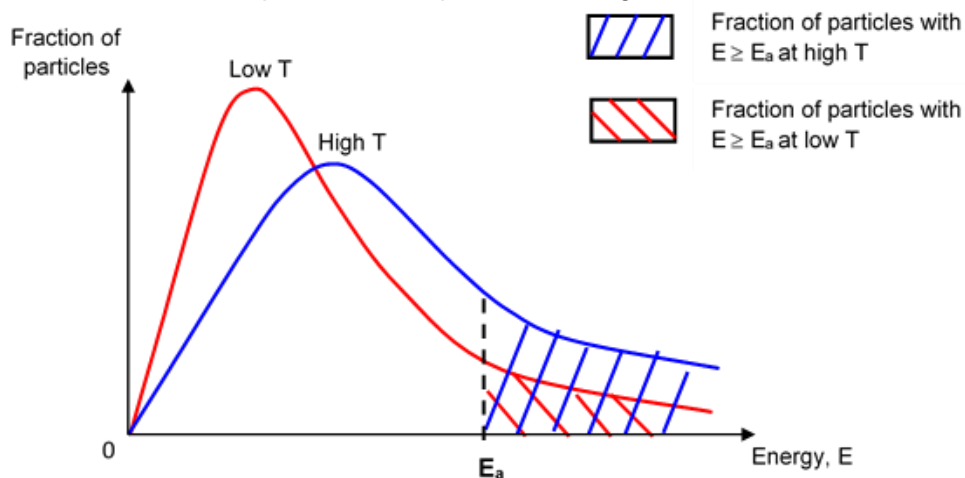
[NaOH] increases by 3 and [RCI] increases by 2

Therefore rate increases by 6

$$x = (3 \times 2 \times 4.0 \times 10^{-4}) \\ = 2.4 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$$

[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
- ✓ E_a & correct shading
- ✓ Correct legend & corresponding shading

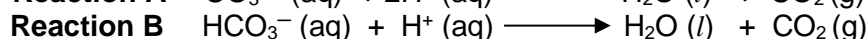
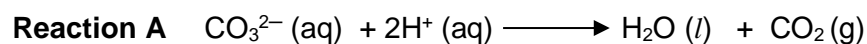
At a higher temperature, the average kinetic energy of the particles increases. There is an increase in the fraction of particles with energy equal to or greater than the activation energy, E_a .

This results in an increase in the frequency of effective collisions, hence the reaction rate increases as the rate of reaction is proportional to the frequency of effective collisions.

[4]

[Total: 20m]

- (a) Carbonates, CO_3^{2-} and hydrogencarbonates, HCO_3^{2-} react with acids in the following manner.



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, $\text{HNO}_3(\text{aq})$. The temperature fell by 1.5°C .

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**.

	$\Delta H_f^\theta / \text{kJ mol}^{-1}$
$\text{H}_2\text{O}(\text{l})$	-285.8
$\text{CO}_2(\text{g})$	-393.5
$\text{HCO}_3^-(\text{aq})$	-692
$\text{CO}_3^{2-}(\text{aq})$	-677
$\text{H}^+(\text{aq})$	0.0

[2]

Using the ΔH_f^θ values (theoretical data):

$$\Delta H_{rxn}^\theta \text{ of A} = \sum n\Delta H_f^\theta (\text{products}) - \sum m\Delta H_f^\theta (\text{reactants})$$

$$= (-285.8 - 393.5) - (-677)$$

$$= (-679.3) + 677 = -2.30 \text{ kJ mol}^{-1}$$

$$\Delta H_{rxn}^\theta \text{ of B} = \sum n\Delta H_f^\theta (\text{products}) - \sum m\Delta H_f^\theta (\text{reactants})$$

$$= (-679.3) - (-692) = -679.3 + 692 = +12.7 \text{ kJ mol}^{-1}$$

- (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):

$$\Delta H_{rxn}^\theta \text{ of A} = -2.30 \text{ kJ mol}^{-1}$$

$$\Delta H_{rxn}^\theta \text{ of B} = +12.7 \text{ kJ mol}^{-1}$$

$$\text{Heat absorbed} = mc\Delta T = (80)(4.18)(1.5) = 501.6 \text{ J}$$

$$\text{Moles of } \text{H}^+ = \frac{40}{1000} \times 1.0 = 0.04 \text{ mol}$$

$$\text{Moles of } \text{CO}_3^{2-} \text{ or } \text{HCO}_3^- = \frac{40}{1000} \times 1.0 = 0.04 \text{ mol}$$

In both cases, H^+ is the limiting reagent. (Note that this is not a marking point)

$$\Delta H_{\text{rxn}}^{\theta} \text{ of A} = + \frac{501.6}{0.02} = +25080 \text{ J mol}^{-1} = +25.1 \text{ kJ mol}^{-1}$$

$$\Delta H_{\text{rxn}}^{\theta} \text{ of B} = + \frac{501.6}{0.04} = +12540 \text{ J mol}^{-1} = +12.5 \text{ kJ mol}^{-1}$$

Since the experimental value of the $\Delta H_{\text{rxn}}^{\theta}$ of B is similar to the theoretical value, equation **B** has occurred.

2 – 1mark

Alternative answer

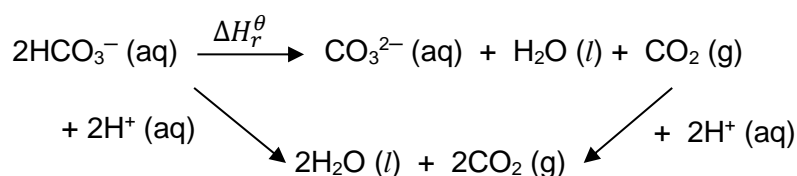
Using the ΔH_f^{θ} values (theoretical data):

$$\Delta H_{\text{rxn}}^{\theta} \text{ of A} = -2.30 \text{ kJ mol}^{-1}$$

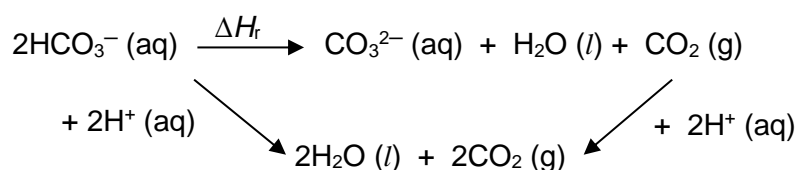
$$\Delta H_{\text{rxn}}^{\theta} \text{ of B} = +12.7 \text{ kJ mol}^{-1}$$

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_r^{θ} for the following reaction.



[2]



$$\Delta H_{\text{rxn}}^{\theta} \text{ of A} = -2.3 \text{ kJ mol}^{-1}$$

$$\Delta H_{\text{rxn}}^{\theta} \text{ of B} = +12.7 \text{ kJ mol}^{-1}$$

From the energy cycle, using Hess' law,

$$\begin{aligned}
 \Delta H_{\text{rxn}}^{\theta} &= 2 \times \Delta H_{\text{rxn}}^{\theta} \text{ of B} - \Delta H_{\text{rxn}}^{\theta} \text{ of A} \\
 &= 2 \times +12.7 - (-2.3) = +27.7 \text{ kJ mol}^{-1}
 \end{aligned}$$

Sign must be seen for answer.

ECF if the student's calculation for $\Delta H_{\text{rxn}}^{\theta}$ of A and $\Delta H_{\text{rxn}}^{\theta}$ of B are wrong in part (a).

- (c) Propanoic acid, $\text{CH}_3\text{CH}_2\text{COOH}$, can also react with carbonates and hydrogencarbonates.

- (i) Explain in terms of its structure why 2-chloropropanoic, $\text{CH}_3\text{CH}(\text{Cl})\text{COOH}$ acid is more acidic than propanoic acid.

[2]

Compare $\text{CH}_3\text{CH}(\text{Cl})\text{COOH}$ vs $\text{CH}_3\text{CH}_2\text{COOH}$

$\text{CH}_3\text{CH}(\text{Cl})\text{COOH}$ is more acidic than $\text{CH}_3\text{CH}_2\text{COOH}$ because the electron withdrawing Cl atom is present. The negative charge on O atom of anion is more dispersed and hence the anion $\text{CH}_3\text{CH}(\text{Cl})\text{COO}^-$ is more stabilised than the $\text{CH}_3\text{CH}_2\text{COO}^-$ anion.

- (ii) Describe how you would convert propanoic acid to propan-1-ol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$. Include the reagents and equation in your answer.

[2]

React propanoic acid with LiAlH_4 with dry ether at room temperature.

Equation: $\text{CH}_3\text{CH}_2\text{COOH} + 4[\text{H}] \longrightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + \text{H}_2\text{O}$

- (d) How will propanal, $\text{CH}_3\text{CH}_2\text{CHO}$ 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]

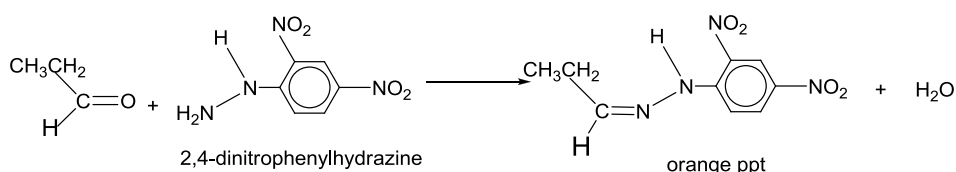
Type of reaction: addition

$\text{CH}_3\text{CH}_2\text{CHO} + \text{HCN} \longrightarrow \text{CH}_3\text{CH}_2\text{CH}(\text{CN})\text{OH}$

- (ii) 2,4-dinitrophenylhydrazine reagent,

[2]

Type of reaction: condensation



- (ii) Sodium borohydride, NaBH_4

[2]

Type of reaction: reduction

$\text{CH}_3\text{CH}_2\text{CHO} + 2[\text{H}] \longrightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$

- (e) Describe one simple chemical test that could distinguish between propanoic acid and propan-1-ol.

[3]

Test: add $\text{Na}_2\text{CO}_3(\text{aq})$ to each sample at room temp

Observation:

For propanoic acid, effervescence seen & gas evolved gives white ppt with $\text{Ca}(\text{OH})_2(\text{aq})$ 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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