TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME	
CIVICS GROUP	

H1 CHEMISTRY **8873/02**

Paper 2 Structured Questions **2 September 2025**

2 hours

Candidates answer on the Question Paper.

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and civics group in the spaces provided at the top of this page.
Write in dark blue or black pen on both sides of the paper. You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

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

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

Examiner's Use		
Paper 1	**MCQ**	**/ 30**
Paper 2	**Section A**	
	Q1	**/ 10**
	Q2	**/ 13**
	Q3	**/ 14**
	Q4	**/ 11**
	Q5	**/ 12**
	Section B	
	Q6	**/ 20**
	Q7	**/ 20**
		/ 80
Total		**/ 100**
Grade		

Section A

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

1 **(a)** Aluminium is the most abundant Group 13 element. Compounds, such as $Al(OH)_3$, can be used for different purposes such as food additives and pharmaceuticals.

(i) Write down the electronic configurations for Al and Al^{3+}.

Al : $1s^2$.....

Al^{3+} : $1s^2$..... [2]

(ii) In an experiment, a sample of aluminium was vapourised, ionised and passed through an electric field. It was observed that a beam of $^{27}Al^{3+}$ ions gives an angle of deflection of +5° as shown in Fig. 1.1 below.

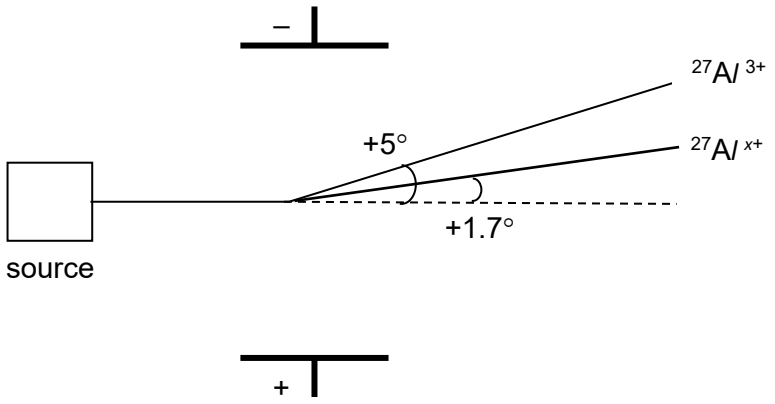


Fig. 1.1

Using the same set-up, another aluminium atom was vaporised and ionised to give an unknown ion, $^{27}Al^{x+}$.

Based on the information given, determine the value of x.

[2]

(iii) Al^{3+} is a commonly formed ion of aluminium. However, under special conditions, it can briefly exist as Al^{+} and Al^{2+} ions.

Complete Table 1.1 for each subatomic particle of the two ions.

Table 1.1

	number of protons	number of neutrons	number of electrons
$^{27}_{13}Al^{+}$			
$^{27}_{13}Al^{3+}$			

[2]

(b) Both $Al(OH)_3$ and $Mg(OH)_2$ are antacids. They are used to treat symptoms of increased stomach acid, such as heartburn and acid indigestion.

(i) Suggest why the melting point of $Al(OH)_3$ is likely to be higher than that of $Mg(OH)_2$.

……

……

……

……

…… [2]

(ii) Based on experimental data, the melting point of $Al(OH)_3$ is found to be lower than that of $Mg(OH)_2$. Suggest a possible reason for this.

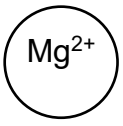
……

……

……

…… [1]

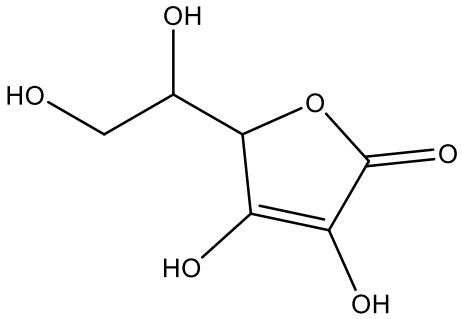
(iii) $Mg(OH)_2$ is sparingly soluble in water. Complete and label the diagram, showing clearly the interaction between Mg^{2+} ion and one water molecule, to illustrate why $Mg(OH)_2$ can dissolve in water.



[1]

[Total: 10]

2 Vitamin C, also known as ascorbic acid ($C_6H_8O_6$), is an essential nutrient for humans. It functions as an antioxidant and supports the immune system. The structure of ascorbic acid is shown below.



ascorbic acid, $C_6H_8O_6$

(a) Name the functional groups, excluding hydroxy group (−OH), present in ascorbic acid.

…… [1]

A student carried out an experiment to verify the ascorbic acid content stated on an orange juice carton. The label claims that the orange juice contains 120 mg of ascorbic acid per 100 cm^3.

The student carried out the following titration to verify if the claim is true. In this experiment, 25.0 cm^3 of the orange juice was used. The procedure was carried out as follows:

1. excess potassium iodate (KIO_3) was reacted with potassium iodide (KI) in an acidic medium. 1.50 x 10^{-4} mol of iodine (I_2) was produced as a result of this reaction.

$$IO_3^- + 5I^- + 6H^+ \longrightarrow 3I_2 + 3H_2O$$

2. The iodine (I_2) produced reacted with ascorbic acid solution.

$$C_6H_8O_6 + I_2 \longrightarrow C_6H_6O_6 + 2HI$$

3. The excess unreacted iodine (I_2) required 29.60 cm^3 of 5.00 x10^{-4} mol dm^{-3} sodium thiosulfate for titration to reach the end-point.

$$I_2 + 2S_2O_3^{2-} \longrightarrow 2I^- + S_4O_6^{2-}$$

(b) **(i)** Calculate the amount of $C_6H_8O_6$ that is present in 25.0 cm^3 of the orange juice sample.

[2]

(ii) Given that the molar mass of ascorbic acid is 176 g mol^{-1}, calculate the mass of ascorbic acid, in mg, per 100 cm^3 of orange juice. Based on your result, deduce whether the manufacturer's claim is accurate.

[2]

(c) **(i)** Draw a dot-and-cross diagram of IO_3^- ion.

[1]

(ii) State and explain, with reference to VSEPR theory, the shape and bond angle of IO_3^- ion.

……

……

……

……

…… [2]

(d) **(i)** When the chlorides of Period 3 elements are added to water, they produce solutions with different pH values. Complete Table 2.1 below.

Table 2.1

Compound	pH
NaCl	
$MgCl_2$	
$AlCl_3$	
$SiCl_4$	

[2]

(ii) Describe what happens when $AlCl_3$ is added to water.
Include equations for any reaction(s) that occur.

……

……

……

……

…… [2]

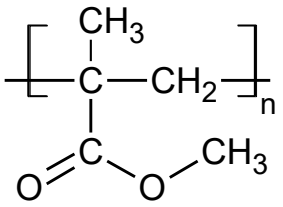
(iii) Gallium and aluminium are elements in Group 13 of the Periodic Table.
Gallium oxide, Ga_2O_3 has similar acid-base behaviour as aluminium oxide.
Write a balanced equation for the reaction that occurs when Ga_2O_3 reacts with NaOH(aq).

……

…… [1]

[Total:13]

3 **(a)** Poly methyl methacrylate (PMMA) is a commonly used material in modern dentistry, such as in the fabrication of dental prosthetics. PMMA can be repeatedly softened by heating and solidified by cooling, making it easily moldable into various dental appliances. The repeat unit of PMMA is shown below.



(i) State the type of polymerisation used to make PMMA and draw the structure of the monomer used to make this polymer.

Type of polymerisation: ……

Monomer:

[2]

(ii) Based on the polymer's behaviour upon heating, state whether it is a thermoplastic or a thermoset.

…… [1]

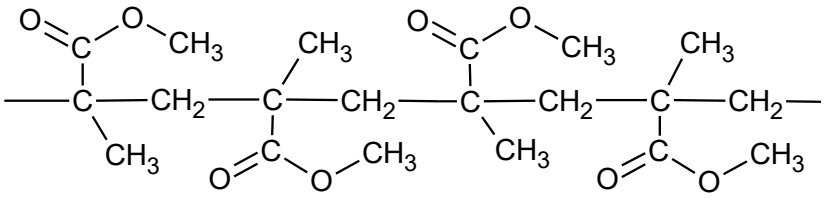
(iii) Chemical agents can be added to PMMA to form cross-linked PMMA polymers which are used in dental fillings. Explain why cross-linked polymers are suitable for use in dental fillings.

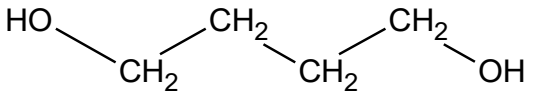
……

…… [1]

(iv) In other uses, 1,4-butanediol can form hydrogen bonds with PMMA which may improve the polymer's compatibility and performance in applications like coatings and adhesives.

Complete the diagram below to show how a hydrogen bond can be formed between 1,4–butanediol and a PMMA polymer chain.





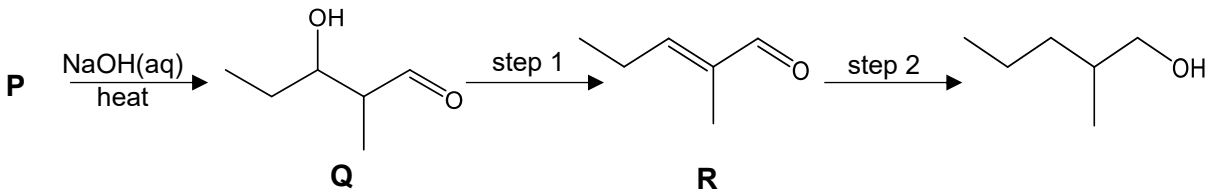
[1]

(v) UV light is sometimes used in dental procedures, such as for disinfection purposes. Suggest one possible safety concern associated with the use of UV light in this process.

.....

..... [1]

(b) A reaction sequence is shown below.



(i) Draw the structure of **P**.

[1]

(ii) State the reagents and conditions required for steps 1 and 2.

step 1: .....

step 2: ..... [2]

(iii) Give the IUPAC name of compound **Q**.

..... [1]

(iv) Draw a labelled diagram to illustrate the orbital overlap between the two carbon atoms in the C=C bond in compound **R**.

[2]

(v) Suggest a simple chemical test to distinguish between compounds **Q** and **R**.

.....

.....

.....

..... [2]

[Total: 14]

[Turn over

4 Instant cold packs are commonly used in first aid as a convenient alternative to ice for treating injuries. These packs typically consist of two compartments: an inner pouch containing water and an outer pouch containing a solid ionic salt. When the pack is squeezed firmly, the inner pouch breaks, allowing the water to mix with the ionic salt and dissolve it, thereby initiating an endothermic process that absorbs heat from the surroundings and produces a cooling effect.

Ammonium nitrate, NH_4NO_3 is commonly used in the instant cold pack. When solid NH_4NO_3 dissolves in water, it absorbs heat from the surroundings. The standard enthalpy change of solution is the amount of heat taken in when 1 mole of NH_4NO_3 dissolves completely in water under standard conditions.

The following shows the equation for the dissolution of solid NH_4NO_3.

$$NH_4NO_3(s) \longrightarrow NH_4^+(aq) + NO_3^-(aq)$$

Company **S** has been researching on the cost effectiveness of using either NH_4NO_3 or NH_4Cl as the ionic salt in its instant cold packs containing 100 cm^3 of water. For the instant ice pack to be effective, the overall temperature of the cold pack must decrease by at least 7.0 °C.

The prices and molar masses of both ionic salts are listed in the Table 4.1 below.

Table 4.1

ionic salt	cost of 1000 g of salt / $
NH_4NO_3	22.50
NH_4Cl	13.90

(a) Using the data given below, calculate the standard enthalpy change of solution of NH_4NO_3.

compound	$\Delta H_f^{\ominus}$/ kJ mol^{-1}
$NH_4NO_3(s)$	–365
$NH_4^+(aq)$	–132
$NO_3^-(aq)$	–207

[2]

(b) **(i)** Using your answer in **(a)**, calculate the minimum mass of solid NH_4NO_3 that company **S** would need to add to the outer bag to make one effective cold pack. The specific heat capacity of water is 4.18 J g^{-1} K^{-1}.

[2]

(ii) Suggest why the expected temperature drop will be less than 7.0 °C when the cold pack is used.

……..

……..

…… [1]

(c) Cold packs are often used in emergency medical kits. Suggest one other chemical or physical property the salt used should have. Justify your answer.

……

……

……[1]

(d) It was found that at least 10.64 g of NH_4Cl was required to make one effective cold pack. Using Table 4.1 and your answer in **(b)(i)**, calculate the respective minimum costs of NH_4NO_3 and NH_4Cl required to make one instant cold pack of each type. Hence, state which cold pack is more cost-effective.

[2]

(e) In recent times, most companies no longer use NH_4NO_3 in instant cold packs. The use of NH_4NO_3 poses a safety risk as it is readily decomposed when heated to release a great amount of heat and gases. The products in this reaction are nitrogen gas, oxygen gas and water.

(i) Write a balanced equation for the thermal decomposition of NH_4NO_3.

…….. [1]

(ii) Calculate the volume of gaseous products formed at room temperature and pressure when 0.200 mol of NH_4NO_3 was decomposed.

[2]

[Total: 11]

5(a) Lactic acid is a monoprotic *weak acid* which is an important flavouring component of many foods such as cheese and pickled cabbage.

$$CH_3CH(OH)CO_2H(aq) \rightleftharpoons CH_3CH(OH)CO_2^-(aq) + H^+(aq)$$

(i) State what is meant by the term *weak acid*.

……...

…….. [1]

(ii) Write an expression for the acid dissociation constant of lactic acid, K_a.

[1]

(iii) Fig. 5.1 shows the pH changes when 0.200 mol dm^{-3} lactic acid is added dropwise to 20.0 cm^3 of 0.150 mol dm^{-3} KOH(aq) in a conical flask at 25 °C.

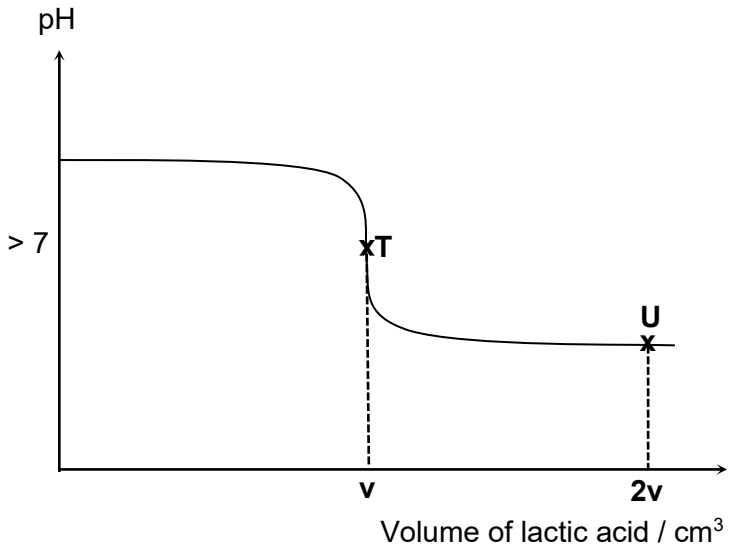


Fig. 5.1

Calculate the initial pH of the KOH(aq) in the conical flask.

[1]

(iv) Determine the volume of lactic acid required for complete neutralisation of the KOH(aq).

Lactic acid ≡ KOH

Moles of lactic acid needed = 0.020 x 0.150 = 0.003 mol **[1]**

Volume of lactic acid needed = 0.003 ÷ 0.200 = 0.0150 dm^3 **[1]**

[2]

(v) Suggest and explain which indicator should be used for this titration, using information from Fig. 5.1 and Table 5.1 below.
State the colour change of your chosen indicator at the end–point (point **T**) of this titration.

Table 5.1

indicator	pH range for colour change	colour in acidic pH	colour in basic pH
methyl orange	3–5	red	yellow
phenolphthalein	8–10	colourless	pink
trinitrobenzoic acid	12–13.4	colourless	orange–red

Phenolpthalein, because the pH working range of the indicator lies within the region of rapid pH change over the equivalence point. **[1]**

Colour at end-point: pink to colourless **[1]**

[2]

(vi) A buffer solution is present at point **U** of the titration due to the presence of lactic acid and potassium lactate salt.

$CH_3CH(OH)CO_2H(aq) \rightleftharpoons CH_3CH(OH)CO_2^-(aq) + H^+(aq)$

$CH_3CH(OH)CO_2K \longrightarrow CH_3CH(OH)CO_2^-(aq) + K^+(aq)$

Write an equation to show what happens when a small amount of aqueous hydrochloric acid is added to the buffer solution.

You may represent lactic acid as HA.

The mixture contains lactic acid (weak acid) and potassium lactate (conjugate base).

When a small amount of H^+ is added:

$H^+ + CH_3CH(OH)CO_2^- \rightarrow CH_3CH(OH)CO_2H$ **[1]**

(or A- + H^+ ⟶ HA)

The added H^+ is removed as H_2O.
$[H^+]$ is slightly changed hence pH remains fairly constant. **[1]**

[1]

(b) Researchers have developed a new sunscreen formulation containing zinc oxide particles engineered to be spheres of less than 100 nm in size.

(i) Suggest whether the zinc oxide in this sunscreen should be classified as a nanoparticle or nanomaterials, giving a reason for your answer.

……...

…….. [1]

(ii) Explain why using nano-sized zinc oxide particles are used in sunscreen formulations.

……...

…….. [1]

(iii) Explain why zinc oxide sunscreen should not be formulated with an acidic solvent.

……...

…….. [1]

(iv) Suggest one safety or environmental concern associated with the use of nano-sized particles in consumer products such as sunscreen.

……...

…….. [1]

[Total: 12]

Section B

Answer **one** question from this section in the spaces provided.

6 **(a)** NO reacts with O_2 according to the following equation:

reaction I $\quad 2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

The reaction between NO and O_2 is studied at constant temperature.
The kinetics data for the reaction is provided in Table 6.1.

Table 6.1

experiment	initial concentration of NO / mol dm^{-3}	initial concentration of O_2 / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
1	0.006	0.006	1.93
2	0.006	0.001	0.322
3	0.012	0.006	7.73

(i) Deduce the order of reaction with respect to NO and O_2, explaining your answer clearly.

[2]

(ii) Using the data from Experiment 1, calculate the value of the rate constant *k*, include its units.

[2]

(iii) On the axes provided in Fig. 6.1, sketch a graph to show how the rate of reaction varies with concentration of NO.

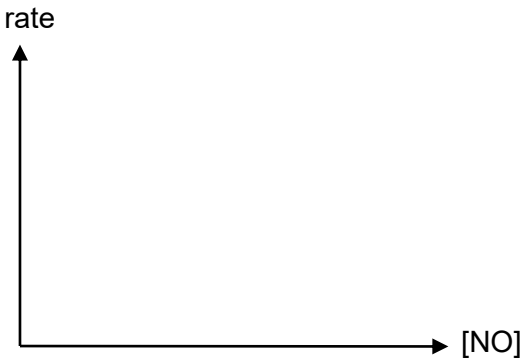


Fig. 6.1

[1]

(iv) With the aid of a Boltzmann distribution diagram, explain how an increase in temperature affects the rate of this reaction.

……

……

……

……

……[3]

(b) Reaction I is proposed to proceed via the following two–step mechanism.

stage 1 $NO(g) + O_2(g) \longrightarrow NO_3(g)$ slow

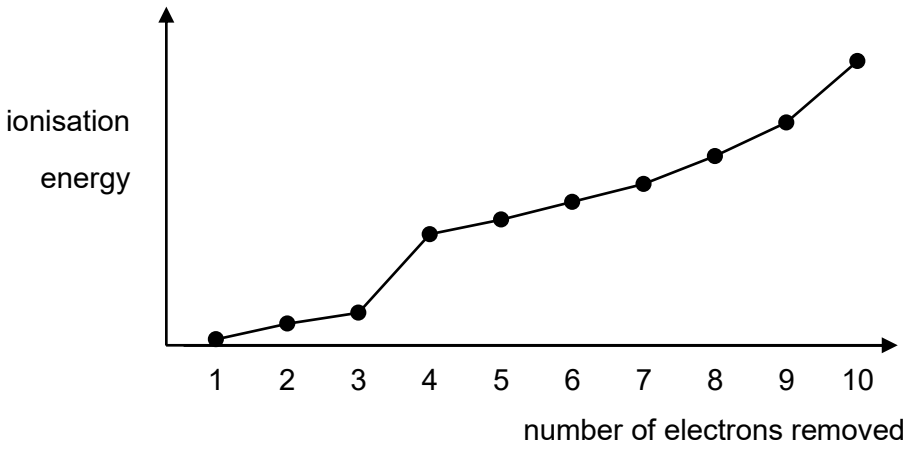
stage 2 $NO(g) + NO_3(g) \longrightarrow 2NO_2(g)$ fast

Given that reaction I is an exothermic reaction ($\Delta H < 0$), draw a fully labelled energy profile diagram for the overall reaction between NO and O_2, showing these two stages.

[2]

(c) Element **X** is found in the p-block of the Periodic Table.

The graph below shows the successive ionisation energies for the removal of the first ten electrons of **X**.



(i) State and explain which group element **X** belongs to in the Periodic Table.

……..

……..

……..

……..

…… [2]

(ii) Explain why there is an increase in the successive ionisation energies of element **X**.

……..

……..

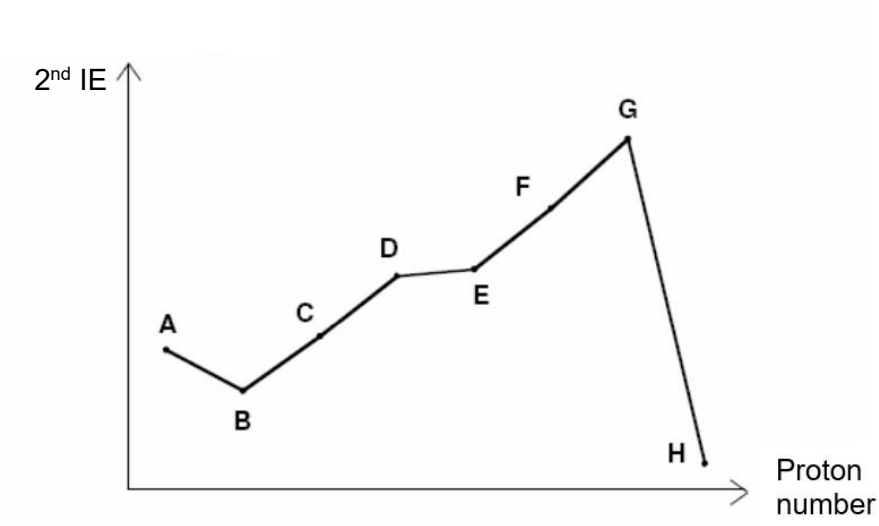
……..

……..

…… [2]

(iii) Sulfur is another element found in the p-block of the Periodic Table.

The graph below shows the second ionisation energies of eight elements with consecutive proton number.



State which element **A** to **H** could be sulfur.

…… [1]

(d) A reaction scheme involving cycloalkanes is given in Fig. 6.2.

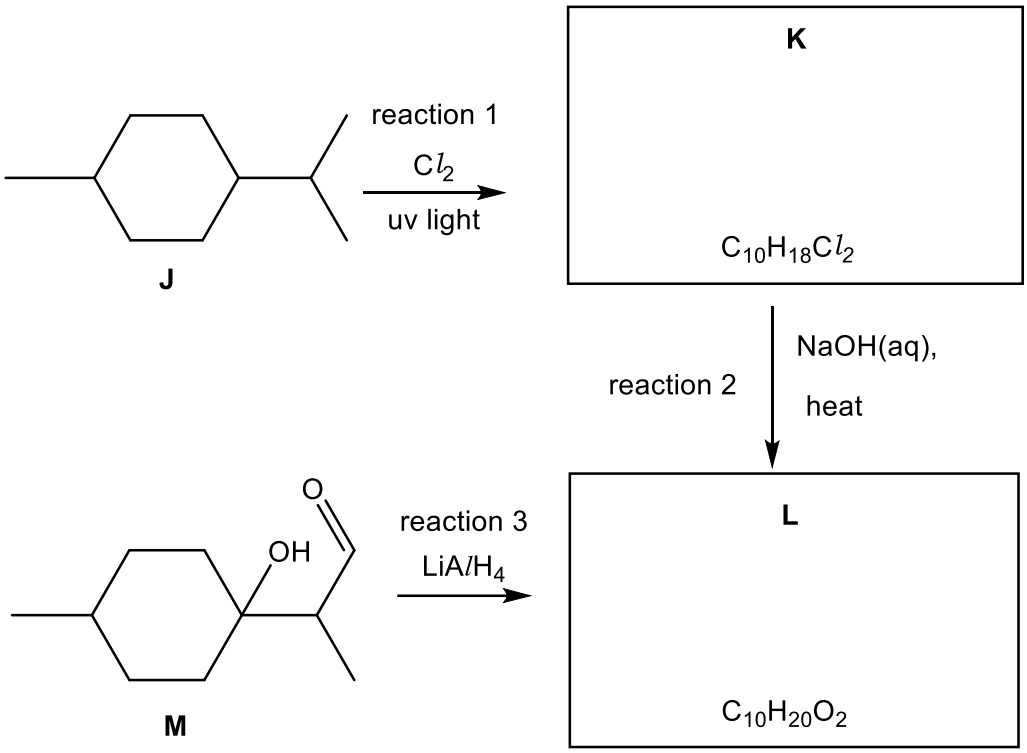


Fig. 6.2

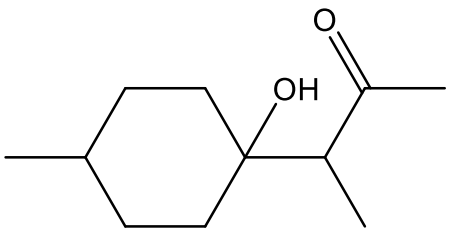
(i) State the type of reaction for reaction 2.

…… [1]

(ii) Draw the structures of **K** and **L** in the boxes provided in Fig. 6.2.

[2]

(iii) Describe a simple chemical test to distinguish between **M** and **N**.



N

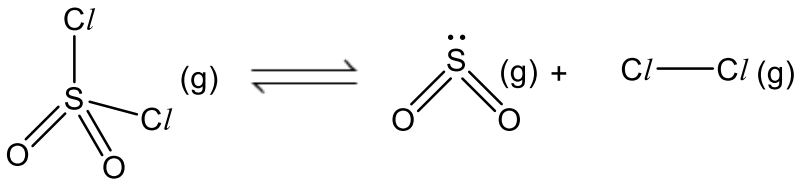
……..

……..

…… [2]

[Total: 20]

7 Sulfuryl chloride, SO_2Cl_2, is often used as a source to form halogens such as Cl_2 for various organic reactions. When heated, it decomposes as follows.



(a) When the halogens are reacted with hydrogen gas, hydrogen halides (HX) are produced. When the hydrogen halides are strongly heated, they decompose to form back the halogens and hydrogen gas.

(i) Write an equation for the thermal decomposition of HBr.

2HBr → H_2 + Br_2 [1] ..... [1]

(ii) State and explain the trend in thermal stabilities of the hydrogen halides, HX.

Down the Group, **thermal stability**√ of the Group 17 hydrides **decreases.** Down the group, H−X bond strength **decreases**√. **Less** energy√ is required to break the H−X bond in order to decompose HX.

3√ = [2], 2√ = [1], 1√ and below = [0]

..... [2]

(b) In an experiment, the decomposition of SO_2Cl_2 was carried out at 300 °C in a 10.0 dm^3 vessel. At the start of the reaction, 3 moles of SO_2Cl_2 was introduced into the vessel. When *dynamic equilibrium* was established, it was found that 30% of SO_2Cl_2 was left.

(i) Define what is meant by *dynamic equilibrium*.

Dynamic Equilibrium is achieved for a **reversible reaction** when **rate of forward reaction** is equal to **rate of reverse reaction. [1].** The substances are **still reacting together** although the **concentrations** of the **reactants and products** remain **constant**. **[1]**

(ii) Write the expression for the equilibrium constant, K_c, for this equilibrium, stating its units.

$K_c = \frac{[SO_2][Cl_2]}{[SO_2Cl_2]}$ **[1]** Units: **mol dm^{-3} [1]**

[2]

(iii) Calculate the equilibrium concentrations of the three gases.

[3]

(iv) Calculate the equilibrium constant, K_c, for this reaction at 300 °C.

[2]

(c) (i) Using data from the *Data Booklet*, calculate the enthalpy change of the forward reaction for the decomposition of SO_2Cl_2.

[2]

(ii) The theoretical value for the enthalpy change of the forward reaction is different from the value calculated in **(c)(i)**. State a reason why there is a discrepancy in the values.

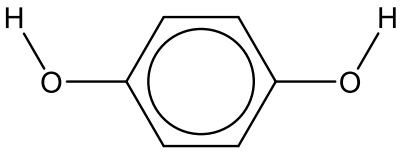
……..

…… [1]

(d) Sulfuryl chloride also reacts with hydroquinone to form halogenated derivatives.

In hydroquinone, the C–O bond behaves like a double bond. As a result, hydroquinone can exhibit cis-trans isomerism, just like alkenes.

The structure of *cis*-hydroquinone is shown below.



cis-hydroquinone

(i) Draw the structure of *trans*-hydroquinone.

[1]

(ii) Suggest, with a reason, whether *cis*-hydroquinone is polar or non-polar.

……..

…… [1]

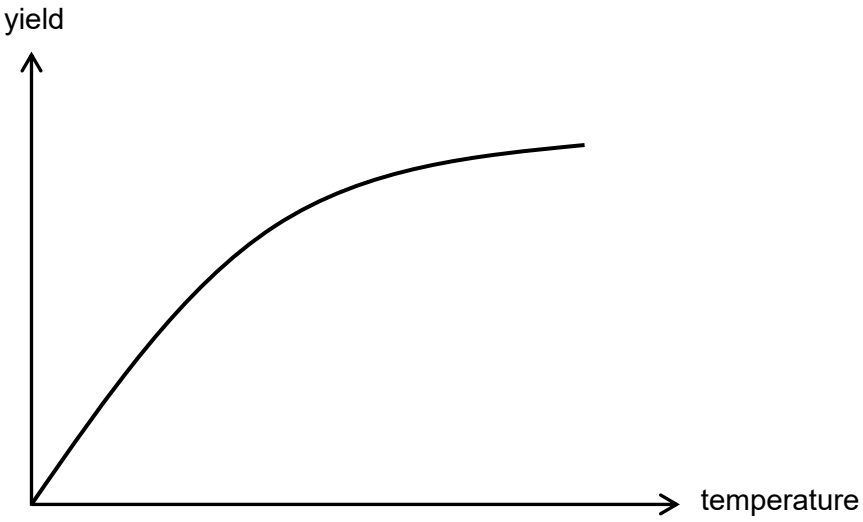
(iii) Suggest a reason why the presence of C–O bond enables hydroquinone to exhibit cis-trans isomerism.

……..

…… [1]

(e) A different reaction that involved a mixture of gaseous reactants and products was allowed to reach equilibrium.

The graph below illustrates how the equilibrium yield of the products changes with temperature.



Suggest, with reasoning, whether the forward reaction is an endothermic or exothermic reaction.

According to the graph, when **temperature is increased, yield increases**√, hence **equilibrium position has shifted right**√. Since **temperature increase favours endothermic reaction to absorb heat**√, the **forward reaction is endothermic**√.

4 points = [2], 2,3 points = [1], 1 and below = [0]

[2]

[Total:20]

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