ST ANDREW'S JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATIONS

HIGHER 1

CANDIDATE NAME					
CLASS	2	4	S		

CHEMISTRY **8873/02**

Paper 2 Structured Questions **02 September 2025**

Candidates answer on the Question Paper. **2 hours**

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work that you hand in.

Write in dark blue or black pen.

You may use a HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Section A

Answer **all** questions in the **spaces provided** on the Question Paper.

Section B

Answer **one** question.

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

A Data Booklet is provided.

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.

For Examiner's Use		
Section A		
Q1		**25**
Q2		**12**
Q3		**12**
Q4		**11**
Section B		
Q5		**20**
Q6		**20**
Total		**80**

This document consists of **26** printed pages (including this cover page).

1 (a) Aluminium oxide, Al_2O_3, is a white, crystalline solid with high thermal stability and hardness.

(i) Complete the electronic configuration of an aluminium atom.

$1s^2$ …………………………………… **[1]**

(ii) Explain why the first ionisation energy of Al is lower than the first ionisation energy of Mg. **[2]**

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(iii) Draw the 'dot-and-cross' diagram of Al_2O_3. **[1]**

(iv) The ionic radius of Al^{3+} is 0.050 nm and Ga^{3+} is 0.062 nm.

Explain the difference in ionic radii between Al^{3+} and Ga^{3+}. **[2]**

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(a) **(v)** The melting point of Al_2O_3 is 2072 °C while the melting point of Ga_2O_3 is 1720 °C. Explain the difference in melting points of these two oxides. **[2]**

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(b) **(i)** Aluminium oxide, Al_2O_3 and silicon dioxide, SiO_2, are both solid ceramic materials with high melting points and are electrical insulators.
Explain how differences in their structure and bonding account for their high melting points and poor electrical conductivity. **[3]**

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(ii) Al_2O_3 and SiO_2 have different acid-base behaviour.
With the aid of equations, explain the difference in the acid and base behaviour of these two oxides. **[4]**

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(b) **(ii)**

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(c) The pH values of two Period 3 chloride solutions are given below.

Compound	pH of 1.0 mol dm^{-3} solution
$AlCl_3$	3.0
$SiCl_4$	2.0

[4]

Suggest explanations for the pH values of the two chloride solutions.

Include appropriate equation(s) in your answer.

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(d) Name the shapes and state the bond angles of $SiCl_4$ and PCl_3.

Explain your answers using the Valence Shell Electronic Pair Repulsion (VSEPR) Theory. Draw diagrams to illustrate your answers.

	$SiCl_4$	PCl_3
Diagram		
Shape		
bond angle		

[6]

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2 Manganese can form ions that are bonded to oxygen atoms in different oxidation states.

Two examples are MnO_4^{2-} and MnO_4^-.

(a) Both ions of manganese differ in their oxidation number.

State the oxidation of each ion. **[2]**

Oxidation state of Mn in MnO_4^{2-} : …….

Oxidation state of Mn in MnO_4^- : …….

(b) To standardise $Na_2S_2O_3$ solution, 25.0 cm^3 of 0.025 mol dm^{-3} $KMnO_4$ was added to an excess of acidified KI solution. The iodine liberated required 22.40 cm^3 of $Na_2S_2O_3$ for reduction.

(i) Use the *Data Booklet* to write an equation for

1. the reaction between and MnO_4^- ions and I^-
2. the reaction between and I^- and $S_2O_3^{2-}$ **[2]**

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(ii) Calculate the concentration of $Na_2S_2O_3$, in mol dm^{-3}. **[2]**

(c) When K_2MnO_4 is dissolved in water, the solution appears green. Upon acidification, the green solution, MnO_4^{2-}, slowly turns into purple MnO_4^-. This equilibrium is represented by the following equation:

$$3MnO_4^{2-}(aq) + 4H^+(aq) \rightleftharpoons 2MnO_4^-(aq) + MnO_2(s) + 2H_2O(l)$$

The equilibrium concentrations are shown in Table 2.1.

Table 2.1

Temperature/ °C	$[MnO_4^{2-}]$/ mol dm^{-3}	$[H^+]$/ mol dm^{-3}	$[MnO_4^-]$/ mol dm^{-3}
25	0.010	0.020	0.005

(i) Write the expression for K_c and give its units. **[2]**

(ii) Calculate the value of K_c at 25°C. **[1]**

(iii) Explain the colour change upon acidification of aqueous K_2MnO_4. **[1]**

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(c) **(iv)** When the equilibrium is established at a lower temperature, the value of K_c increases. Deduce whether the reaction is exothermic or endothermic. Explain your answer. **[2]**

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3 Ozone, O_3, plays a crucial role in the Earth's atmosphere by absorbing harmful ultraviolet radiation. It is also widely used for its oxidising and disinfecting properties. For example, ozone can be dissolved in ground water or drinking water for disinfection and water quality enhancement.

(a) By considering the number of bonding and non–bonding electron pairs, draw a diagram to show the shape of ozone. In your diagram, clearly state a value of the bond angle. **[2]**

(b) The overall reaction for the decomposition of ozone can be represented as follows:

$$2O_3 \rightarrow 3O_2$$

The rate of decomposition of ozone in ground water, at pH 8, was investigated and the following results were obtained as shown in Fig. 3.1. The reaction is first order with respect to ozone.

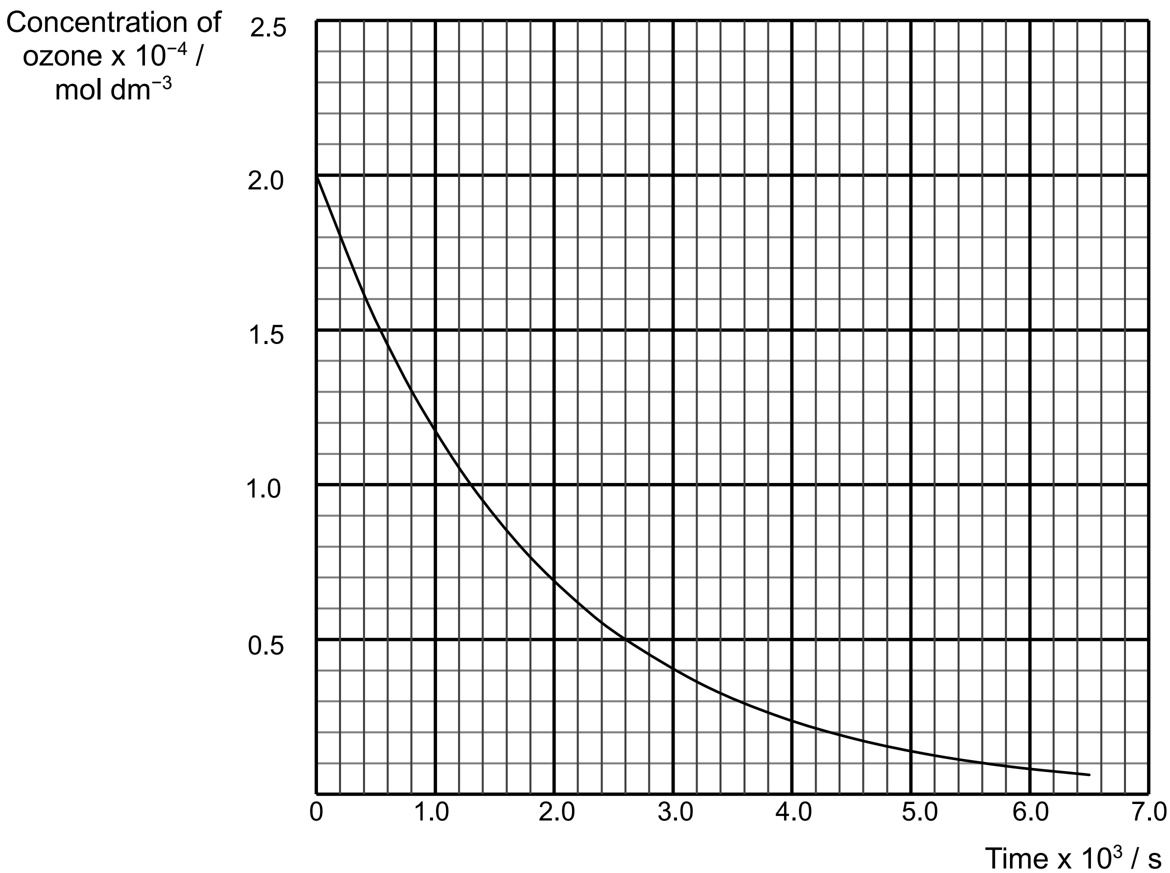

Fig. 3.1

[TURN OVER

(b) **(i)** Define the term *order of reaction*. **[1]**

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(ii) Use the graph in Fig. 3.1 to show that the overall order of reaction is first order. **[1]**

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(iii) Write the rate equation for this reaction and give the units for rate constant, *k*. **[1]**

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(iv) The decomposition of ozone was found to be faster in the presence of OH^-. Explain, with the aid of a Boltzmann distribution curve, how the rate of decomposition of ozone changes when OH^- is added.
(Temperature and pressure are kept constant.) **[3]**

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(c) The ozone layer plays a crucial role in protecting life on Earth by absorbing a significant portion of the sun's harmful UV radiation. Human activities, such as the use of certain chemicals like chlorofluorocarbons (CFCs), have historically led to ozone depletion, particularly in the Antarctic, where an "ozone hole" has been observed.

(i) CF_3CH_2F has been used as a replacement for CFCs such as $CFCl_3$, CCl_2F_2 and $C_2Cl_2F_4$ as they cause ozone depletion. With the aid of relevant data from *Data Booklet*, explain why CF_3CH_2F is a suitable replacement. **[2]**

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(ii) Suggest a simple chemical test to distinguish between $C_2Cl_2F_4$ and CF_3CH_2F. State the observations for both compounds. **[2]**

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4 (a) Define *polymer*. **[1]**

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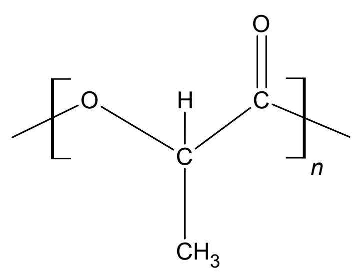
(b) Polylactic Acid (PLA) is a biodegradable thermoplastic made from renewable resources such as corn starch or sugarcane. It has a wide range of applications due to its biocompatibility, transparency, and environmentally friendly profile.



PLA

(i) Name the functional group present in the thermoplastic polymer PLA and classify the type of polymerisation used to make it. **[2]**

Functional group: ………………………

Classification of polymerisation: ………………………

(ii) Draw the **displayed formula** of the monomer and give its systematic name. **[2]**

Systematic name: ……………………………..

(c) PLA is a biodegradable thermoplastic commonly used in medical implants such as dissolvable stitches. Over time, it interacts with water in the body and gradually breaks down.

(i) Explain the meaning of the term *thermoplastic*. **[1]**

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(ii) With the aid of a diagram, explain how PLA interacts with water. **[1]**

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(iii) Describe how PLA degrades naturally in medical applications such as dissolvable stitches. **[1]**

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(iv) Medical implants must accommodate tissue movement without causing discomfort. Suggest a reason why PLA is suitable for this function. **[1]**

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(d) PLA can be processed into polymeric nanoparticles for use in drug delivery and tissue engineering.

(i) Define the term *nanoparticles*. **[1]**

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(ii) Suggest why nanoparticles are advantageous in drug delivery and tissue engineering. **[1]**

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Section B

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

5 **(a)** Calcium carbide, CaC_2, is an ionic compound primarily used in industry to generate acetylene gas, C_2H_2, which has numerous applications in welding, cutting and chemical synthesis.

$CaC_2\,(s) + 2H_2O\,(l) \rightarrow Ca(OH)_2\,(s) + C_2H_2\,(g)$ reaction 1

The structure of the carbide ion is as shown:

$$[C{\equiv}C]^{2-}$$

(i) State the number of σ and π bonds in one carbide ion. **[1]**

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(ii) Draw a labelled diagram to show the formation of one π bond in carbide ion. **[1]**

(iii) Explain, in terms of structure and bonding, why C_2H_2 is a gas at room temperature. **[1]**

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(b) Calcium carbide reacts vigorously and explosively with water.

Using the data in Table 5.1, calculate the standard enthalpy change of reaction for reaction 1.

$CaC_2\,(s) + 2H_2O\,(l) \rightarrow Ca(OH)_2\,(s) + C_2H_2\,(g)$ reaction 1

Table 5.1

compound	$\Delta H_f^\ominus$ / kJ mol^{-1}
$CaC_2\,(s)$	– 59.0
$H_2O\,(l)$	–285.8
$Ca(OH)_2\,(s)$	– 985.2
$C_2H_2\,(g)$	+ 226.6

[2]

(c) When fighting fires near calcium carbide storage, extreme caution is required due to its violent reaction with water, which produces flammable acetylene, C_2H_2, gas and poses explosion risks.

(i) Define the term *standard enthalpy change of combustion*, $\Delta H_c^\ominus$, of C_2H_2. **[1]**

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(c) **(ii)** The structure of acetylene, C_2H_2, is H–C≡C–H.

The following equation represents the standard enthalpy change of combustion of combustion, $\Delta H_c^\ominus$ of C_2H_2.

$$C_2H_2\,(g) + \frac{5}{2}O_2\,(g) \rightarrow 2CO_2\,(g) + H_2O\,(l)$$

Use bond energy values from the *Data Booklet* to calculate the standard enthalpy change of combustion, $\Delta H_c^\ominus$ of C_2H_2. **[2]**

(iii) The experimental standard enthalpy change of combustion of acetylene, C_2H_2 is -1280.7 kJ mol^{-1}.

Suggest **one reason** for the difference between the experimental value and the value calculated in **(c)(ii)**. **[1]**

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(c) **(iv)** Suggest an appropriate storage method for calcium carbide to minimise risks. **[1]**

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(d) Acetylene, C_2H_2, is a weak acid.

$$C_2H_2\,(aq) \rightleftharpoons C_2H^-\,(aq) + H^+(aq)$$

(i) Write an expression for the acid dissociation constant, K_a, of C_2H_2, including its units. **[2]**

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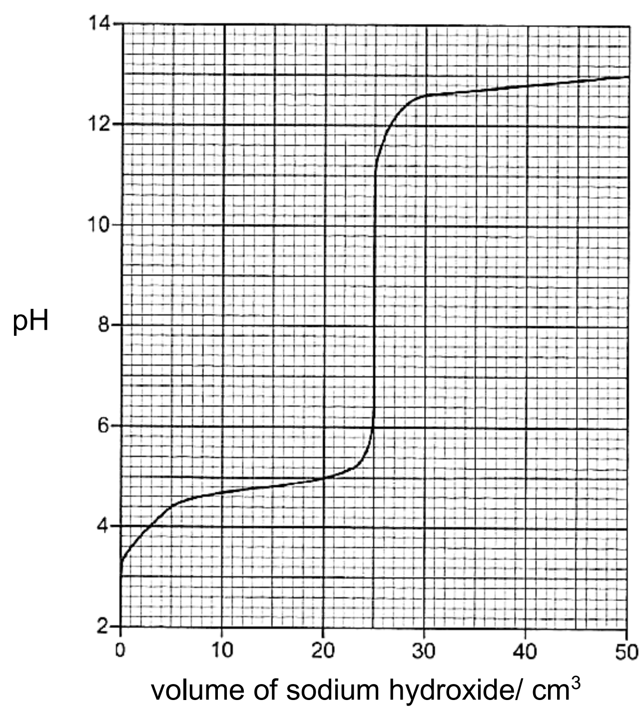
The graph shows the pH changes during the titration of 25.0 cm^3 of 0.05 mol dm^{-3} C_2H_2 with 0.05 mol dm^{-3} sodium hydroxide. During this titration, sodium hydroxide is added gradually, from a burette, until a total volume of 50.00 cm^3 has been added to the acid.



(d) **(ii)** Using the pH from the graph, calculate the concentration of hydrogen ions, in mol dm^{-3}, in the mixture when 20.00 cm^3 of sodium hydroxide has been added. **[2]**

(iii) The *equivalence point* of a titration is the point at which the acid and the alkali have been mixed in stoichiometric proportions. An indicator for this titration would be chosen so that it changes colour as close as possible to the equivalence point. At this point one drop of sodium hydroxide, when added to the acid, will change the colour of the indicator permanently. This is called the *end-point*.

Suggest which indicator should be used for this titration, using information from the graph and the table below.

State the colour change of your chosen indicator at the end-point of this titration. **[2]**

Indicator	Colour		pH range for colour change (working range)
	Acid	Base	
2,4-dinitrophenol	Colourless	Yellow	2.4 – 4.0
Screened methyl orange	Violet	Green	3.2 – 4.4
Phenolphthalein	Colourless	Pink	8.2 – 10.0

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(e) During the addition of the first 25.00 cm^3 of sodium hydroxide, the mixture is behaving as a buffer.

(i) What is meant by the term *buffer solution*? **[1]**

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(ii) How does the shape of the graph show this? **[1]**

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(iii) Explain how the mixture is behaving as a buffer at this stage of the titration when small amount of OH^- is added.
Include an equation in your answer. **[2]**

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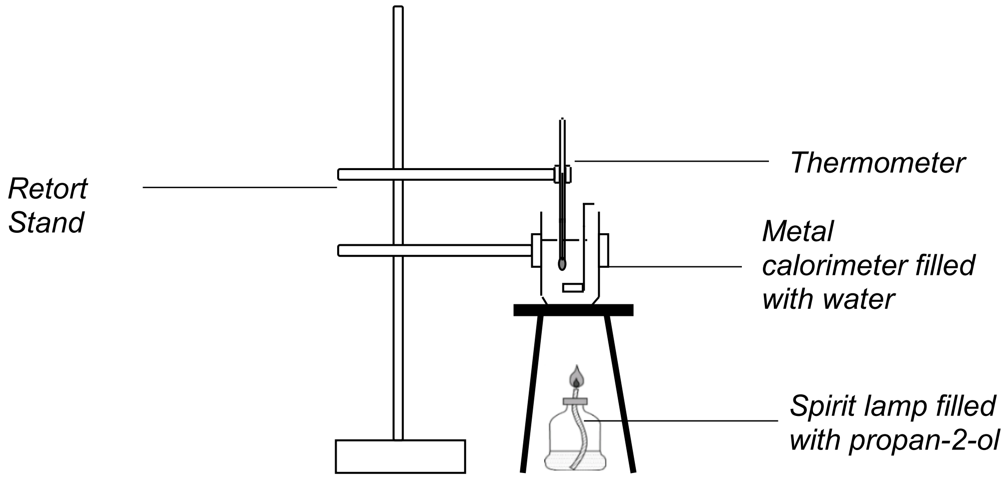
[Total: 20]

6 Propan-2-ol, $CH_3CH(OH)CH_3$, is commonly used in industrial and household applications as a solvent.

(a) A student used the apparatus below to determine the enthalpy change of combustion of propan-2-ol.



The student burns the propan-2-ol for 10 minutes.

Table 6.1 shows the data recorded by the student.

Table 6.1

Mass of water/ g	50
Mass of spirit lamp and propan-2-ol before combustion/ g	172.55
Mass of spirit lamp and propan-2-ol after combustion/ g	171.70
Temperature of water in calorimeter before combustion/ ^{o}C	30.5
Temperature of water in calorimeter after combustion/ ^{o}C	44.0

The specific heat capacity of water is 4.18 $Jg^{-1}K^{-1}$ and density of water is 1.0 g cm^{-3}.

(i) Calculate the temperature change and hence, the heat absorbed by the water, $\mathbf{Q_{water}}$, in kJ. **[2]**

[TURN OVER

(a) **(ii)** The heat capacity of the metal calorimeter, C, is 1410 J K^{-1}.

The heat absorbed by the calorimeter can be calculated by

$$\mathbf{Q_{calorimeter} = C\Delta T}$$

Using the temperature change in **(a)(i)**, calculate this value in kJ. **[1]**

(iii) The energy evolved from the combustion of propan-2-ol was transferred to both the calorimeter and water.

$$\mathbf{Q_{total} = Q_{calorimeter} + Q_{water}}$$

Calculate the total energy evolved from the combustion of propan-2-ol, $\mathbf{Q_{total}}$.

Hence, calculate enthalpy change of combustion of propan-2-ol in kJ mol^{-1}. **[2]**

(iv) Although the heat absorbed by the calorimeter is taken into account in the experiment, the enthalpy change of combustion of propan-2-ol is still different from the theoretical value of – 2006 kJ mol^{-1}.

Suggest a reason for the difference. **[1]**

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(b) A student constructed an energy cycle to calculate the standard enthalpy change of formation of propan-2-ol, $\Delta H_1^{\ominus}$.

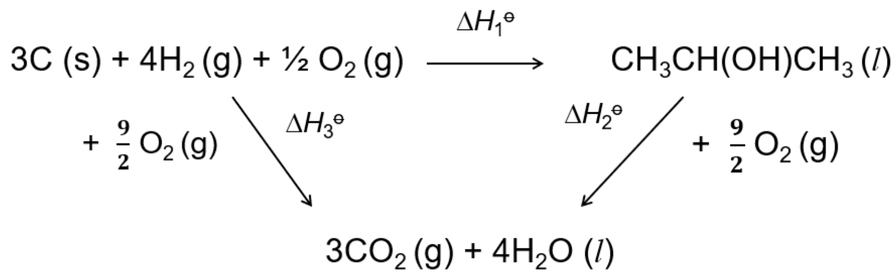

Fig. 6.1

(i) Define the *standard enthalpy change of formation.* **[1]**

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(ii) State the standard enthalpy change represented by $\Delta H_2^{\ominus}$. **[1]**

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(iii) Calculate the standard enthalpy change of formation of propan-2-ol, $\Delta H_1^{\ominus}$, using the energy cycle in Fig. 6.1 and data in Table 6.2.

Table 6.2

$\Delta H_c^{\ominus}$ (propan-2-ol(l)) / kJ mol^{-1}	–2006
$\Delta H_c^{\ominus}$ (C(s)) / kJ mol^{-1}	–394
$\Delta H_c^{\ominus}$ (H_2(g)) / kJ mol^{-1}	–286

[2]

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(c) Propan-2-ol reacts with ethanoic acid in the presence of an acid catalyst, concentrated H_2SO_4, to form an ester.

Propan-2-ol + ethanoic acid → ester + water

The order of reaction with respect to the $[H_2SO_4]$ is zero.

A chemist performs three different experiments at 25 °C to find out how the initial rate is affected by the initial concentrations of propan-2-ol and ethanoic acid.

For all the experiments, the total volume is kept constant by adding water in order for the concentrations of the reactants to be proportional to the volumes of reactants.

Expt	Volume of propan-2-ol /cm^3	Volume of ethanoic acid /cm^3	Volume of water /cm^3	Initial rate / $mol\ dm^{-3}\ min^{-1}$
1	50	50	0	6.0×10^{-3}
2	50	25	25	3.0×10^{-3}
3	25	40	35	2.4×10^{-3}

(i) Draw the structure of the ester formed. **[1]**

(c) **(ii)** Sketch on Fig. 6.2 the graph of [H_2SO_4] against time that represents the order of reaction with respect to [H_2SO_4] is zero. **[1]**

Fig. 6.2

(iii) Deduce the order of reaction with respect to [ethanoic acid] and [propan-2-ol]. **[2]**

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(iv) Hence, write the rate equation for the reaction and state the overall order of reaction. **[2]**

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(c) (v) State and provide reason for any change in the rate constant value in experiment 1 and experiment 2. **[1]**

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(vi) When propan-2-ol is reacted with hydrobromic acid, HBr, is formed. Write an equation to show the thermal decomposition of HBr and explain how the thermal stability of the Group 17 hydrides varies down the group. **[3]**

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