EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2025
General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME	

CIVICS GROUP	2	4	–			INDEX NUMBER		

CHEMISTRY **8873/02**

Paper 2 Structured Questions

02 September 2025
2 hours

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not use paper clips, highlighters, glue or correction fluid.
Write your name, civics group, registration number on all the work you hand in.

Write in **dark blue or black pen**.
You may use an HB pencil for any diagrams or graphs.

Section A
Answer **all** questions.

Section B
Answer **one** question.

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

A Data Booklet is provided.
The use of an approved scientific calculator is expected, where appropriate.

For Examiner's Use	
Section A	
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2	**/ 10**
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4	**/ 10**
5	**/ 9**
Section B	
6 / 7	**/ 20**
Total	**/ 80**

This document consists of **25** printed pages and **3** blank pages.

Section A

Answer all questions in this section.

For Examiner's Use

1 (a) Fig. 1.1 shows the trend for the third ionisation energies of a series of consecutive elements from the second and third period of the Periodic Table.

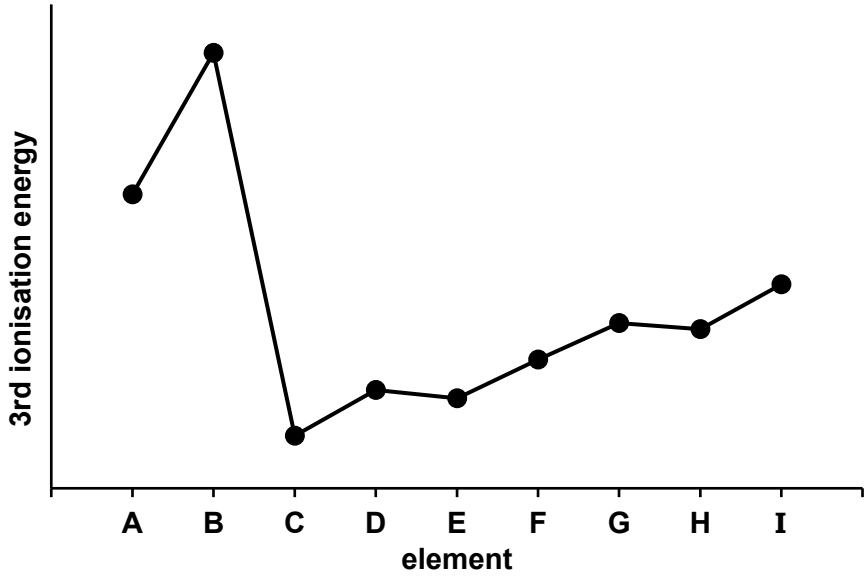


Fig. 1.1

(i) Define the term *third ionisation energy*, with the aid of an equation for element **A**.

Energy absorbed to **remove 1 mole of electrons** from **1 mole of doubly-charged, gaseous cation** to form **1 mole of triply-charged, gaseous cation**.

$A^{2+}(g) \rightarrow A^{3+}(g) + e^-$

..... [2]

(ii) Explain the general trend in the 3rd ionisation energy from element **C** to **I**.

3rd IE generally increases from elements C to I. Nuclear charge increases. Shielding effect remains relatively constant due to same number of quantum shells. Effective nuclear charge increases resulting in a stronger electrostatic attraction between valence electron and nucleus. ..... [2]

For Examiner's Use

(iii) Explain the decrease in the 3rd ionisation energy from element **D** to **E**.

The electron is removed from the **2p subshell for E^{2+} is of higher energy** than that of the electron in **2s subshell for D^{2+}**. Hence, **less energy** is required to remove the valence 2p electron. [1]

(iv) Deduce which group element **C** is found in.

The sharp drop in 3rd IE for C indicates that C^{2+} has its **valence electron removed from a principal quantum shell further from the nucleus**, i.e. ns^1.

Hence, C is in **group 13.** [2]

(b) **^{53}X** is an element produced by the decay of the radioactive isotope **^{53}Y**.

Complete Table 1.1.

Table 1.1

species	number of protons	number of neutrons	number of electrons	electronic configuration
$^{53}_{24}X^{3+}$	**24**	**29**	**21**	$1s^2$ **$2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$**

[2]

(c) Catalytic converters are essential components in vehicle exhaust systems designed to reduce air pollution. It reduces harmful emissions from vehicle exhaust by using metals such as platinum, palladium, and rhodium as catalysts.

(i) The metal catalysts in the catalytic converter are applied in the form of nanoparticles**.** Define the term *nanoparticles*.

Nanoparticles are discrete particles with **all three dimensions in the size range between 1 to 100 nm.** [1]

For Examiner's Use

(ii) Suggest how the catalytic converter, using the metals in nanoparticle form, is expected to reduce the cost of the converter while maximising its efficiency.

Nanoparticles have **high surface area to volume ratios** so the higher surface energy allows for **more effective collisions** with reactant particles hence efficiency is not compromised. Because of this, **less metal is needed** to achieve the same level of efficiency and hence the cost is reduced. [2]

(iii) The harmful gases in the catalytic converters include carbon monoxide, nitrogen and unburnt hydrocarbons.

State the type of catalysis and outline the mode of action as the metal catalysts convert the harmful gases into less harmful emissions.

Heterogeneous catalysis. The harmful gases physically **adsorb** onto the active sites of the metal catalyst surface, **increasing the local concentration of reactants.** The weak intermolecular forces of attraction formed between the reactant molecules and the active sites **weaken the covalent bonds** in the reactant molecules. Adjacent ethene and hydrogen molecules react to form products. After the reaction, the adsorbed ethane molecules **desorb** from the catalyst.

..... [3]

[Total: 15]

For Examiner's Use

2 When baking bread, a mixture of ingredients including table salt (NaC*l*), sugar, water, butter and yeast are combined and then heated in an oven.

During baking, both chemical and physical changes involving different types of bonding occur.

(a) NaC*l* is added for flavour enhancement and to contribute to the structure, texture and overall quality of the bread.

(i) State and define the type of bonding in solid NaC*l*.

Ionic bonding. Ionic bonds are **strong electrostatic forces of attraction between oppositely charged** Na^+ and Cl^- **ions**. [1]

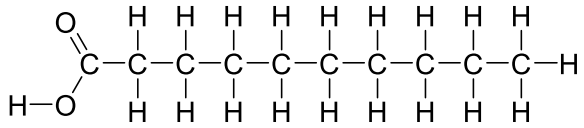
(ii) Compare the electrical conductivities of NaC*l* in the solid and molten states. Explain your answer.

NaC*l* is able to **conduct electricity in the molten state, but not in the solid state**. In solid state, the ions can only vibrate about fixed positions, but in the molten state, the **ions are mobile, which can act as charge carriers to conduct electricity**. [2]

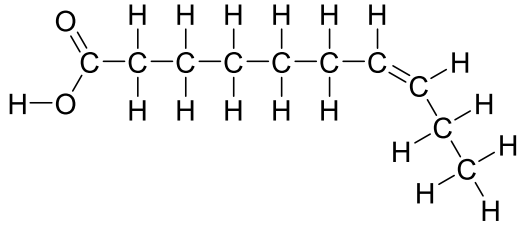
(b) Fats in bread makes it softer and helps to keep the bread fresh for longer. Different types of fats can be added, like butter or margarine.

Butter usually has a higher percentage of saturated fatty acids, while margarine usually has a highly percentage of unsaturated fatty acids.

saturated



unsaturated



(i) The main type of intermolecular forces of attraction that exists between fatty acid molecules is determined by its long hydrocarbon chain.

Identify this main type of interaction.

Instantaneous dipole-induced dipole interactions [1]

For Examiner's Use

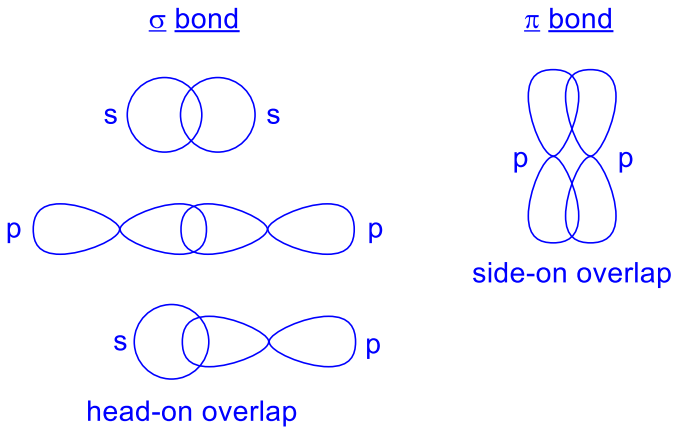
(ii) Given that the fatty acid molecules of butter and margarine have a similar number of electrons, explain why butter still has a higher melting point of 38 ºC than margarine of 34 ºC.

Saturated fats in butter have **straight chains that pack closely**, **greater surface area of contact**, **stronger instantaneous dipole-induced dipole interactions (id-id) forces of attraction** and hence higher melting point. Unsaturated fats in margarine have **kinks due to C=C bonds/branched chains, pack in an irregular manner**, **lower surface area of contact**, **weaker id-id** interactions and **lower melting point**. [2]

(c) Yeast functions as a leavening agent, causing the dough to rise by producing CO_2 gas through fermentation. This gas gets trapped within the dough, creating air pockets that give bread its light and airy texture.

(i) Bonds in a CO_2 molecule are made using s orbitals and p orbitals.

Draw labelled diagrams to show the ways in which these two orbitals can be used to make a σ bond and a π bond.



[2]

(ii) Deduce whether CO_2 is a polar molecule. Explain your answer.

CO_2 consists of **2 C=O bonds arranged in a linear arrangement** around the C atom. Although the **C=O bonds are polar**, the **polarity of the bonds cancels off**. Hence it is a **non-polar molecule**.

[2]

[Total: 10]

For Examiner's Use

3 (a) Dinitrogen tetroxide, N_2O_4, is a colourless gas that dissociates into nitrogen dioxide, NO_2, a brown gas, according to the following reversible reaction:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

(i) Define the term *dynamic equilibrium*.

Dynamic equilibrium refers to a **reversible process at equilibrium** in which the **rate of the forward reaction equals to the rate of backward reaction** and the **concentrations of reactants and products do not change**. [1]

(ii) An experiment is carried out where 0.120 mol of N_2O_4 is introduced into the 2.00 dm^3 container and allowed to reach equilibrium at a fixed temperature. At equilibrium, the concentration of NO_2 is found to be 0.080 mol dm^{-3}.

Calculate the value of K_c, stating its units.

	$N_2O_4(g)$ ⇌	$2NO_2(g)$
initial concentration / mol dm^{-3}	0.120 / 2 = 0.06	0
change in concentration / mol dm^{-3}	–0.04	+0.08
eqm concentration / mol dm^{-3}	0.02	0.08

$$K_c = \frac{0.08^2}{0.02} = 0.320 \text{ mol dm}^{-3}$$

[3]

For Examiner's Use

In a separate experiment, a given amount of N_2O_4 is added to a container at varying pressure but at two different temperatures of 200 K and 250 K. The variation in colour intensity was monitored over a period of time.

Fig. 3.1 shows the variation of the colour intensity with pressure at temperatures of 200 K and 250 K.

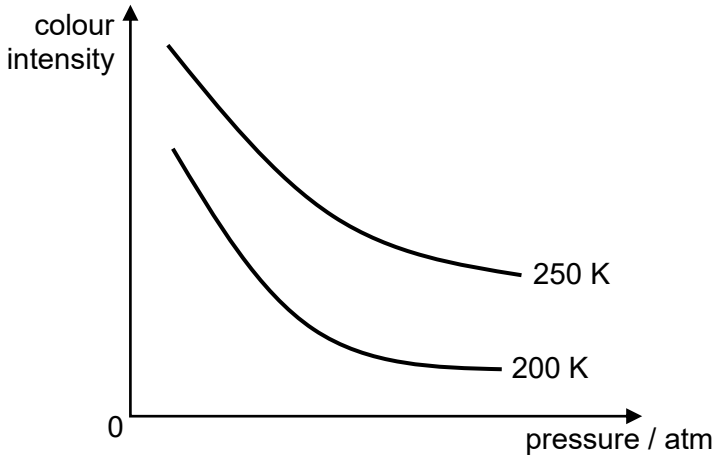


Fig. 3.1

(iii) State the relationship between the colour intensity and the concentration of NO_2.

Colour intensity indicates the concentration of NO_2. **The greater the colour intensity, the higher the concentration of NO_2.** [1]

(iv) Explain why colour intensity of the reaction mixture decreases with increasing pressure.

As pressure increases, the **position of equilibrium shifts to the left to reduce the number of gaseous molecules** to reduce pressure. Hence, more N_2O_4 is formed which is colourless, thus colour intensity decreases. [1]

(v) Using information from the graph, state and explain whether the dissociation of N_2O_4 to form NO_2 is an endothermic or exothermic reaction.

Since **colour intensity/[NO_2] increases as temperature increases**, this means formation of NO_2 (forward rxn) is favoured. **Position of equilibrium shifts to the right to absorb heat**. Hence, the formation of NO_2 is an **endothermic** process.

[2]

For Examiner's Use

(b) Nitrogen dioxide, NO_2, decomposes into nitrogen monoxide and oxygen.

$$2NO_2(g) \rightarrow 2NO(g) + O_2(g)$$

The kinetics of this reaction was studied and a set of results is shown in Fig. 3.2.

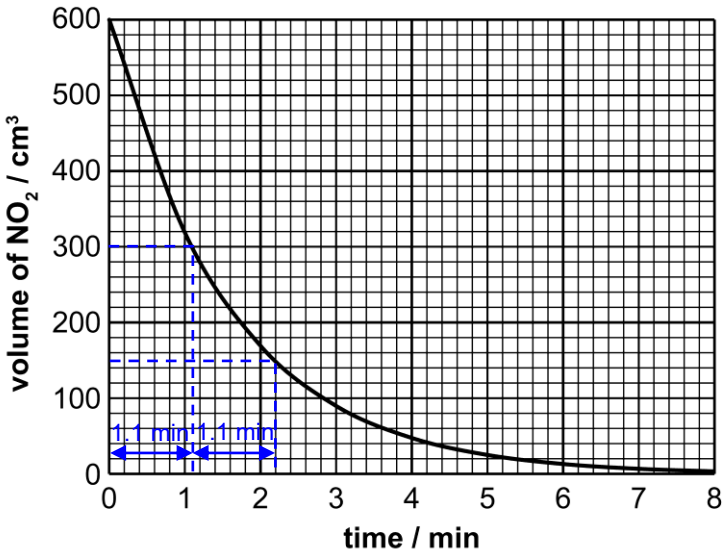


Fig. 3.2

(i) Explain the term *half-life*.

Half-life of a reaction is the **time taken** for the **concentration of the reactant to fall to half its initial value**. [1]

(ii) Deduce the order with respect to NO_2.

Explain how you arrived at your answer.

Since half-life of the reaction is **constant at 1.1 min** , it is **first order** with respect to NO_2.

[2]

For Examiner's Use

(c) The oxides of the third period show periodic trends.

(i) Each of the following oxides can react with either sodium hydroxide or hydrochloric acid. For each oxide, write a balanced equation for its reaction with either sodium hydroxide or hydrochloric acid, where applicable.

sodium oxide $Na_2O + 2HCl \rightarrow 2NaCl + H_2O$

phosphorus pentoxide $P_4O_{10} + 12NaOH \rightarrow 4Na_3PO_4 + 6H_2O$

sulfur trioxide $SO_3 + 2NaOH \rightarrow Na_2SO_4 + H_2O$

[3]

(ii) State the periodic trend shown by the reactions you have given in **(c)(i)**.

The nature of the oxides changes from **basic to acidic** across the period.

[1]

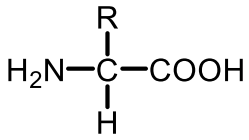
(iii) State the property of aluminium oxide that fits this trend.

Aluminium oxide is an **amphoteric oxide** since it is between sodium and sulfur across period three. [1]

[Total: 16]

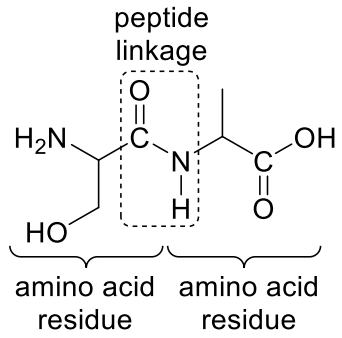
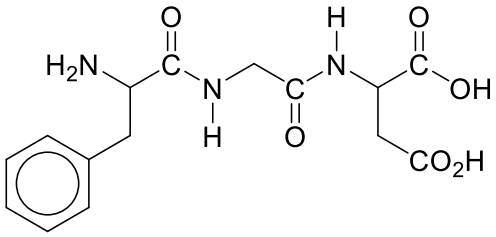
For Examiner's Use

4 Proteins are natural polymers that comprise one or more long chains of α-amino acid residues. The basic structure of an α-amino acid contains an amine group ($–NH_2$), a carboxylic acid group (–COOH), and a variable R-group (side chain) that gives each amino acid its unique properties.



A chain of many α-amino acid residues is called a polypeptide. Short polypeptides are rarely considered to be proteins and are called peptides. The structures of two peptides are shown in Table 4.1.

Table 4.1

type of peptide	structure	M_r
dipeptide		176
tripeptide		337

(a) The peptide linkage is formed in a similar way as how amide linkages are formed, by the reaction between an amine and a carboxyl functional group.

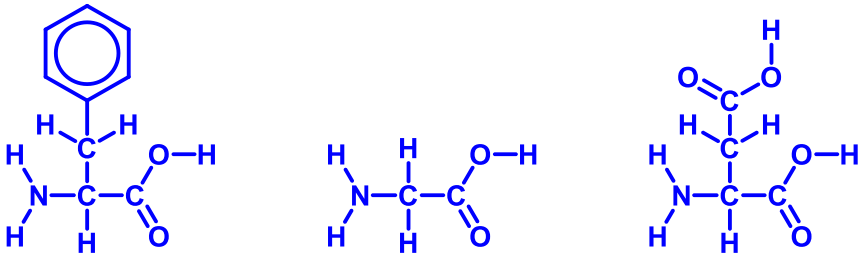
(i) Name the type of polymerisation for the peptides shown in Table 4.1.

Condensation polymerisation ..... [1]

(ii) Suggest the reagent used to join amino acids in laboratory synthesis of peptides.

Dicyclohexylcarbodiimide, DCC ..... [1]

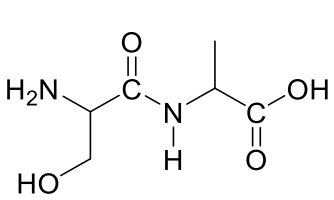
(iii) Draw the structural formulae of the three amino acids used to make the tripeptide shown in Table 4.1.



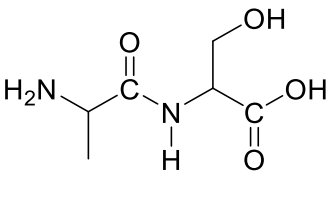
[3]

(iv) The exact sequence of α-amino acids in a peptide makes a difference in its properties.

For example, two α-amino acids can be sequenced differently to produce two different dipeptides as shown.



dipeptide A



dipeptide B

Deduce the number of different tripeptides that can be formed using three different α-amino acids.

3 × 2 = 6 ..... [1]

For Examiner's Use

(b) A 0.0528 g sample of the tripeptide in Table 4.1 was dissolved in deionised water and made up to 250 cm^3 in a volumetric flask. 25.0 cm^3 of the solution required 24.80 cm^3 of 0.00100 mol dm^{-3} NaOH for complete neutralisation.

(i) Given 2 moles of NaOH reacts with 1 mole of the tripeptide, calculate the amount of the tripeptide present in the 25.0 cm^3 solution.

$$\text{amount of NaOH} = \frac{24.80}{1000} \times 0.00100$$
$$= 2.48 \times 10^{-5} \text{ mol}$$

$$\text{amount of tripepetide in 25.0 cm}^3 = \frac{1}{2} \times \text{amount of NaOH}$$
$$= \frac{1}{2} \times 2.48 \times 10^{-5} = 1.24 \times 10^{-5} \text{ mol}$$

[1]

(ii) Calculate the amount of the tripeptide dissolved in the 250 cm^3 volumetric flask.

$$\text{amount of tripeptide in 250 cm}^3 = \frac{250}{25} \times 1.24 \times 10^{-5} \text{ mol}$$
$$= 1.24 \times 10^{-4} \text{ mol}$$

[1]

(iii) Calculate the mass of the tripeptide in the sample.

$$\text{mass of tripeptide in sample} = 1.24 \times 10^{-4} \times 337$$
$$= 0.0418 \text{ g}$$

[1]

(iv) Calculate the percentage purity of the sample of the tripeptide.

$$\% \text{ purity} = \frac{0.0418}{0.0528} \times 100 = 79.2\%$$

[1]

[Total: 10]

For Examiner's Use

5 Malic acid is an organic compound made by all living organisms. It contributes to the sour taste of fruits, and is used as a food additive.

It is a dibasic acid which can be expressed as H_2A. Its K_a values are as shown.

$H_2A\ (aq) \rightleftharpoons H^+(aq) + HA^-\ aq)$ $\quad K_{a1} = 3.48 \times 10^{-4}$ mol dm^{-3}

$HA^-(aq) \rightleftharpoons H^+(aq) + A^{2-}(aq)$ $\quad K_{a2} = 8.00 \times 10^{-6}$ mol dm^{-3}

(a) (i) Write an expression for K_{a2} of malic acid.

$$K_{a2} = \frac{[H^+][A^{2-}]}{[HA^-]}$$

[1]

(ii) State and explain what the small value of K_{a1} tells you about the strength of malic acid.

The small value of K_{a1} indicates that **very little of malic acid had dissociated** at equilibrium, thus it is a **weak acid**. [1]

(iii) Explain why the value of K_{a2} is smaller than that of K_{a1}.

It becomes **increasingly difficult** to remove a H^+ from an **increasingly negative conjugate base/negatively charge ion**, thus $K_{a2} < K_{a1}$. [1]

A buffer is made by mixing solutions of HA^- and A^{2-}.

(b) (i) Define the term *buffer*.

A buffer is a solution which is able to **resist pH changes** when **small amount of acid or base** is added to it. [1]

(ii) With the aid of equations, explain how the buffer works.

When H^+ is added,

$H^+(aq) + A^{2-}(aq) \rightarrow HA^-(aq)$

When OH^- is added,

$OH^-(aq) + HA^-(aq) \rightarrow A^{2-} + H_2O$

pH remains approximately constant. [2]

For Examiner's Use

(iii) 1 mol of HA^- and 1 mol of A^{2-} was mixed in 1 dm^3 of deionised water to make a buffer.

Using your answer to **(a)(i)**, calculate the pH of this buffer.

$$K_{a2} = \frac{[H^+][A^{2-}]}{[HA^-]} = \frac{[H^+] \times \left(\frac{1}{1}\right)}{\left(\frac{1}{1}\right)}$$

$$[H^+] = K_{a2}$$

$$pH = pK_{a2} = -\lg\left(8.00 \times 10^{-6}\right) = \underline{\mathbf{5.10}}$$

[1]

(c) The changes in pH during the titration of 25.0 cm^3 of 1.00 mol dm^{-3} malic acid against 1.00 mol dm^{-3} sodium hydroxide is as shown in Fig. 5.1.

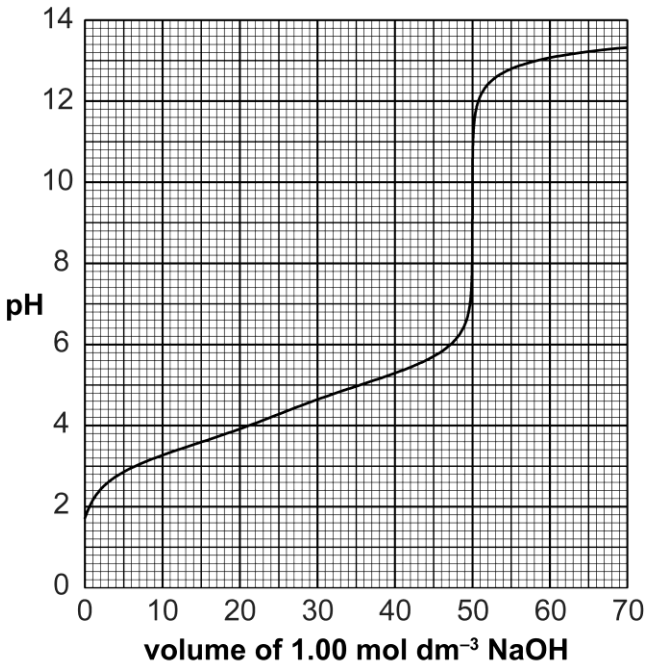


Fig. 5.1

There is no suitable indicator for the first end-point as there is no region of distinct sharp change in pH over its equivalence point.

For Examiner's Use

(i) With the aid of Fig. 5.1, suggest which indicator from Table 5.1 should be used to determine the second end-point. Give a reason for your choice.

Table 5.1

indicator	pH range over which the colour changes
chlorophenol red	4.8 – 6.7
phenol red	6.8 – 8.1
phenolphthalein	8.2 – 10.0

Phenolphthalein. Its **working range coincides with the range of rapid/distinct**

pH change over the equivalence point. [1]

(ii) With reference from Fig. 5.1, calculate the concentration of H^+ ions at the second end-point.

pH at end-point when 50 cm^3 of NaOH is added = 9.4 (accept 9.0–9.8)

Since pH = $-\log[H^+]$,
$[H^+] = 10^{-9.4}$ = **2.51×10^{-5} mol dm^{-3}**

[1]

[Total: 9]

For Examiner's Use

Section B

Answer **one** question in this section.

6 Propyl ethanoate, $CH_3COOCH_2CH_2CH_3$, is a sweet-smelling ester used in fragrance oils. It is produced by heating ethanoic acid, CH_3COOH, and propan-1-ol, $CH_3CH_2CH_2OH$, in the presence of an acid catalyst, H^+.

reaction 1 $CH_3COOH + CH_3CH_2CH_2OH \xrightarrow{H^+} CH_3COOCH_2CH_2CH_3 + H_2O$

(a) The reaction was studied at constant temperature.

The rate equation was found to be

$$\text{rate} = k[CH_3COOH][CH_3CH_2CH_2OH][H^+]$$

(i) Given the rate equation above, complete Table 6.1 for experiments 2, 3 and 4.

Table 6.1

experiment	initial $[CH_3COOH]$ / mol dm^{-3}	initial $[CH_3CH_2CH_2OH]$ / mol dm^{-3}	initial $[H^+]$ / mol dm^{-3}	initial rate / mol dm^{-3} min^{-1}
1	1.0	2.0	0.1	6.32×10^{-5}
2	2.0	1.0	0.2	**1.26×10^{-4}**
3	4.0	1.0	**0.2**	2.53×10^{-4}
4	**3.0**	1.0	0.1	9.48×10^{-5}

[3]

(ii) Use data from experiment 1 to calculate a value for the rate constant k. State the units for k.

rate = $k[CH_3COOH][\ CH_3CH_2CH_2OH][H^+]$

$6.32 \times 10^{-5} = k\ (1.0)\ (2.0)\ (0.1)$

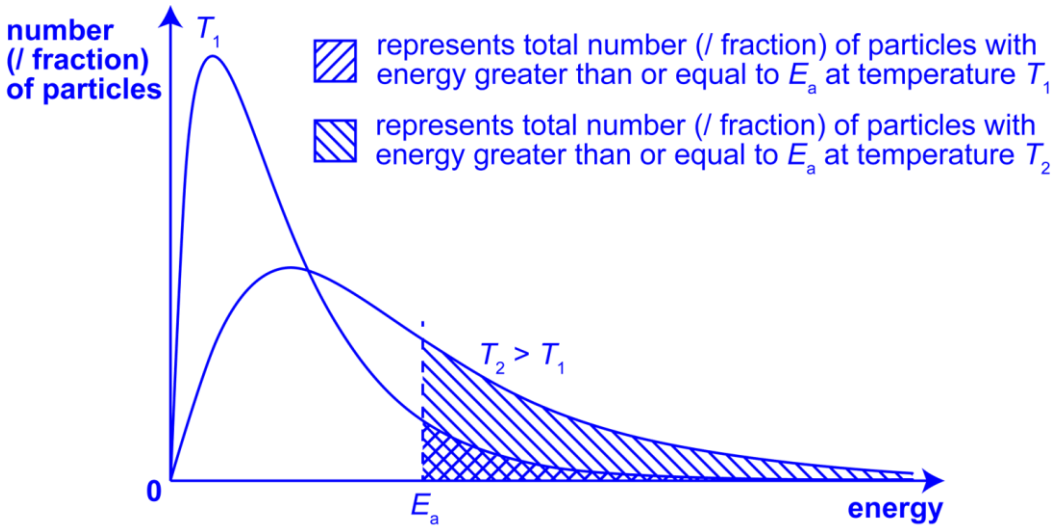
$k = 3.16 \times 10^{-4}$ mol^{-2} dm^6 min^{-1}

[2]

For Examiner's Use

(b) The same reaction can be carried out at a higher temperature.

Explain, with the aid of a labelled Maxwell-Boltzmann distribution diagram, the effect on the rate constant, *k*, when temperature of the reaction was increased.



When temperature is increased, the **average kinetic energy of particles increases,** this results in **increase in frequency of collisions**. In addition, the **number of particles with energy greater than or equals to activation energy, E_a, increases**. Together, both results in an **increase in the frequency of effective collisions**, and **hence an increase in the rate constant**. [3]

(c) The enthalpy change of **reaction 1**, $\Delta H_1^{\ominus}$ **,** can be calculated using enthalpy change of formation data.

(i) Define the term *standard* enthalpy change of formation.

It is the **energy change** when **1 mole of a substance in its standard state** is formed from its **constituent elements in their standard states**, usually at a specified temperature of 298K. [1]

(ii) With reference to the definition in **(c)(i)**, complete the box in energy cycle in Fig. 6.1. Include appropriate state symbols. [1]

For Examiner's Use

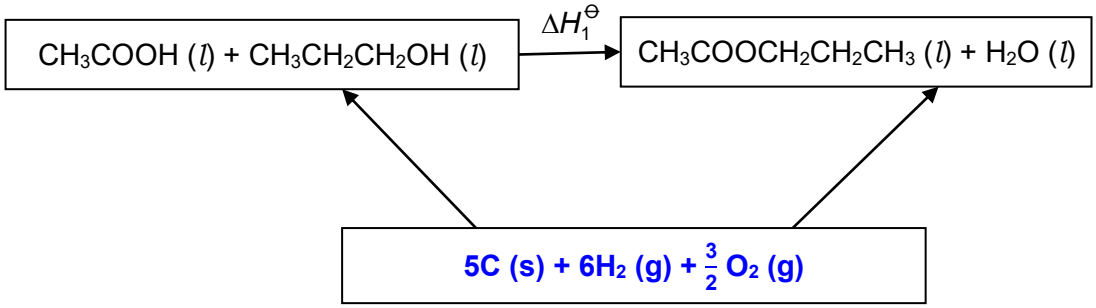


Fig. 6.1

(iii) Use Fig. 6.1 and the data in Table 6.1 to calculate $\Delta H_1^{\ominus}$.

Table 6.1

substance	standard enthalpy change of formation / kJ mol^{-1}
CH_3COOH (l)	–484
$CH_3CH_2CH_2OH$ (l)	–327
$C_5H_{10}O_2$ (l)	–576
H_2O (l)	–286

$\Delta H_1^{\ominus} = \Sigma\Delta H_f$(products) – $\Sigma\Delta H_f$(reactants)

= [–576 + (–286)] – [–484 + (–327)]

= (–862) – (–811) = **–51 kJ mol^{-1}**

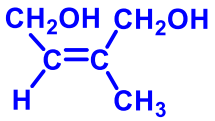
[2]

For Examiner's Use

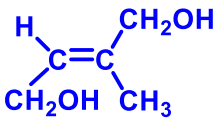
(d) There can be many organic molecules with the same molecular formula as propyl ethanoate, but with different functional groups.

(i) One of such molecules is $CH(CH_2OH)=C(CH_2OH)CH_3$.

Draw and identify the *cis* and *trans* isomers of $CH(CH_2OH)=C(CH_2OH)CH_3$.



cis



trans

[2]

(ii) State two features of $CH(CH_2OH)=C(CH_2OH)CH_3$ that allows it to show *cis-trans* isomerism.

First feature is the **restricted rotation about C=C**. The second feature is that there are **2 different groups attached to one C atom of the C=C**.

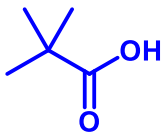
..... [2]

(iii) Suggest a chemical test to confirm the presence of the alkene functional group in $CH(CH_2OH)=C(CH_2OH)CH_3$ and state what would be observed.

Add **Br_2 in CCl_4** to the sample at room temperature. There will be **decolourisation of the orange-red Br_2**. [2]

(iv) There are four isomeric carboxylic acids with the molecular formula $C_5H_{10}O_2$.

Draw and name the structure of the isomer which has the most highly branched carbon chain.



2,2-dimethylpropanoic acid

[2]

[Total:20]

For Examiner's Use

7 (a) Typical alcoholic content of beers range between 4 and 6%. The alcohol by volume (ABV) of beers can be determined by calculating the percentage by volume of pure ethanol, CH_3CH_2OH, in the beer at room temperature.

$$\text{ABV} = \frac{\text{volume of ethanol}}{\text{total volume of beer}} \times 100\%$$

A new beer brand **X** is marketed as a "low alcohol beer" of less than 3% ABV. Each can of beer contains 355 cm^3 of the beverage.

To determine its ABV, 10.0 cm^3 of the beer brand **X** was titrated with 0.200 mol dm^{-3} acidified potassium manganate(VII). It was found that 17.80 cm^3 of potassium manganate(VII) was required to reach the end-point.

(i) Complete the half-equation to represent the oxidation of ethanol by potassium manganate(VII), and hence write the overall equation for the titration.

[O]: CH_3CH_2OH + ...1... $H_2O \rightarrow$ .....CH_3COOH..... + ...4... H^+ + ...4... e^-

Overall equation: $4MnO_4^- + 5CH_3CH_2OH + 12H^+ \rightarrow 4Mn^{2+} + 5CH_3COOH + 11H_2O$

[2]

(ii) Calculate the amount of ethanol that reacted with potassium manganate(VII) during the titration.

Amount of $KMnO_4$ = 0.200 × 17.80/1000 = 0.00356 mol

Amount of CH_3CH_2OH (in 10 cm^3) = 0.00356 × 5/4 = **0.00445 mol**

[1]

(iii) Use your answer in **(a)(ii)** to determine the mass of ethanol in one can of beer brand **X**.

Amount of CH_3CH_2OH (in 355 cm^3) = 0.00445 x 355/10 = 0.1580 mol

Mass of ethanol in 355 cm^3 = 0.1580 × (2 × 12 + 6 × 1 + 16) = 7.268 g
= **7.27 g**

[2]

For Examiner's Use

(iv) Given that the density of ethanol is 0.789 g cm^{-3}, determine the ABV of brand **X** beer. Use your result to comment if brand **X** is indeed a "low alcohol beer".

Given density = mass/volume,
Volume of ethanol per can of beer = 7.268/0.789 = 9.212 cm^3

ABV of brand **X** beer = (9.212/355) × 100% = **2.59%**

Brand **X** beer **is 'low alcohol beer'** as the **ABV is less than 3%.**

[2]

(b) Beer is often referred to as "liquid bread" because both beer and bread are made from similar raw ingredients such as barley or wheat, which are rich in starch. In the brewing of beer, yeast is added to break down the starch from barley or wheat into glucose, $C_6H_{12}O_6$, which is further converted to carbon dioxide and ethanol.

reaction 1 $C_6H_{12}O_6$ (s) → $2CO_2$(g) + $2CH_3CH_2OH(l)$

(i) Use the data in Table 7.1 to calculate the standard enthalpy change of **reaction 1**.

Table 7.1

compound	ΔH_f / kJ mol^{-1}
$C_6H_{12}O_6$(s)	–1270
CO_2(g)	–394
$CH_3CH_2OH(l)$	–278

ΔH_r = (2 × –394 + 2 × –278) – (–1270)
= **–74 kJ mol^{-1}**

[2]

For Examiner's Use

Both beer and bread are considered high energy sources. Bread provides energy primarily from carbohydrates while beer provides energy primarily from ethanol. Each gram of ethanol providing 29.7 kJ of energy when metabolised in the body. The metabolism of ethanol in the human body is essentially similar to combustion.

reaction 2 $CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

(ii) With reference to your answer in **(a)(iii)**, calculate the energy content of one can of beer brand **X** and energy produced per mole of ethanol.

1 g of ethanol → 29.7 kJ of energy

From **(a)(iii)**, one can of beer has 7.27 g and 0.1580 mol of ethanol,
energy content in one can of beer brand **X** = 7.27 × 29.7 = **216 kJ**

energy produced per mole of ethanol = 216/0.1580 = **1370 kJ mol^{-1}**

[2]

(iii) Use bond energy data from the *Data Booklet* to calculate the enthalpy change of **reaction 2**.

ΔH_r = [5 × 410 + 1 × 350 + 1 × 360 + 1 × 460 + 3 × 496] – [4 × 805 + 6 × 460]
= **–1272 kJ mol^{-1}**

[2]

(iv) Comment of the difference between the magnitude of the enthalpy changes calculated in **(b)(ii)** and **(b)(iii)**.

Bond energy values from the *Data Booklet* are **average values**./**Enthalpy changes of vapourisation** of ethanol and water **were not taken into account**.

[1]

For Examiner's Use

(c) The open chain structure of glucose contains the aldehyde functional group. To confirm the presence of the aldehyde group, glucose is reacted with bromine water to form gluconic acid.

$$C_6H_{12}O_6 + Br_2 + H_2O \rightarrow C_6H_{12}O_7 + 2HBr$$

To study the kinetics of this experiment, different volumes of glucose solution was added to a fixed volume of bromine water in separate experiments while keeping the total volume constant. All experiments were performed at 25 ºC. The time taken for the bromine water to decolourise was recorded in Table 7.2.

Table 7.2

experiment	volume of Br_2 added / cm^3	volume of $C_6H_{12}O_6$ added / cm^3	volume of H_2O added / cm^3	time taken for decolourisation / s
1	10.0	5.0	35.0	40
2	10.0	15.0	25.0	13
3	10.0	25.0	25.0	8
4	20.0	5.0	25.0	20

(i) Use the information to determine the order of reaction with respect to $C_6H_{12}O_6$.

Comparing **experiments 1 and 2**, when **$[C_6H_{12}O_6] \times 3$, the rate of reaction $\times 3$**

, hence the **order of reaction w.r.t. $C_6H_{12}O_6$ is one.**

..... [2]

(ii) Propose suitable volumes of Br_2 and $C_6H_{12}O_6$ to be added for experiment 4 by filling in the blanks in Table 7.2, to prove that the order of reaction with respect to Br_2 is one. [1]

(iii) Write the rate equation and derive the units for the rate constant, *k*.

rate = $k[Br_2][C_6H_{12}O_6]$

mol dm^{-3} s^{-1} = *k* (mol dm^{-3})^2
units for *k* = **mol^{-1} dm^3 s^{-1}**

[2]

For Examiner's Use

(iv) Complete Fig. 7.1 to show how the rate constant, *k*, varies with concentration of $C_6H_{12}O_6$, at constant temperature.

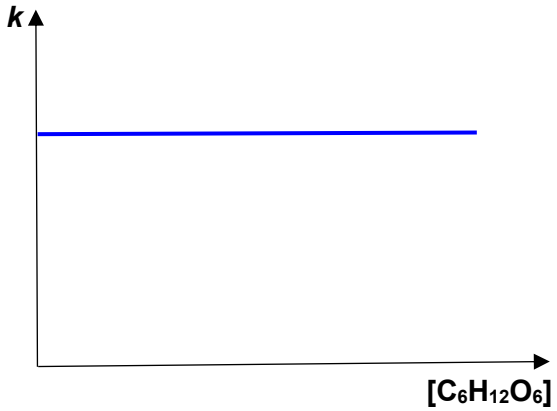


Fig. 7.1

[1]

[Total: 20]