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	
1	**/ 15**
2	**/ 10**
3	**/ 16**
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.

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.

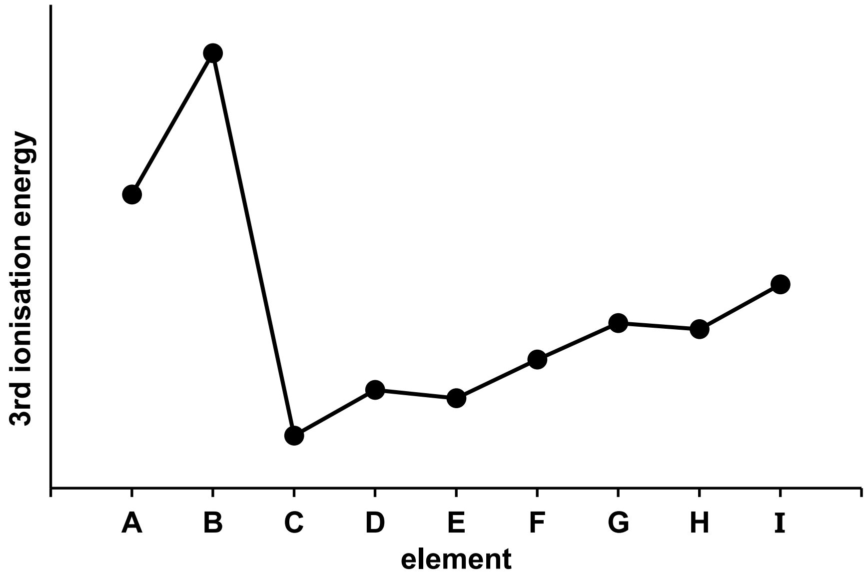

Fig. 1.1

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

....

....

....

.... [2]

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

....

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....

.... [2]

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

....

....

.... [1]

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

....

....

....

.... [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
$^{53}_{24}X^{3+}$				$1s^2$ ....

[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*.

....

.... [1]

(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.

....

....

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.... [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.

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.... [3]

[Total: 15]

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2 When baking bread, a mixture of ingredients including table salt ($NaCl$), 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) $NaCl$ 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 $NaCl$.

....

.... [1]

(ii) Compare the electrical conductivities of $NaCl$ in the solid and molten states. Explain your answer.

....

....

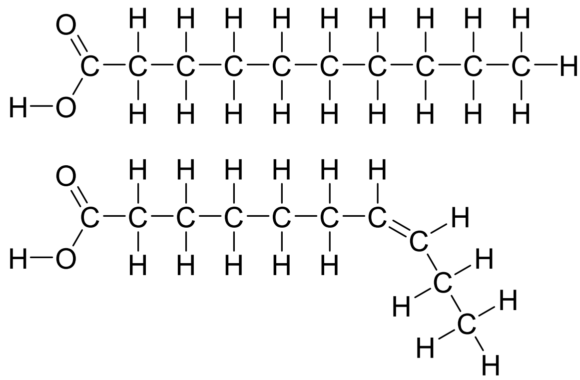
.... [2]

(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.

.... [1]

(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.

....

....

....

....

....

.... [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.

....

....

....

.... [2]

[Total: 10]

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*.

....

....

.... [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.

[3]

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.

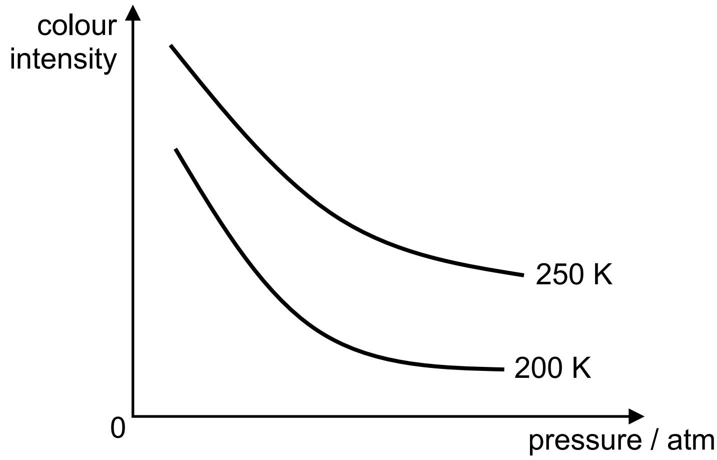


Fig. 3.1

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

....

.... [1]

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

....

....

.... [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.

....

....

....

.... [2]

(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.

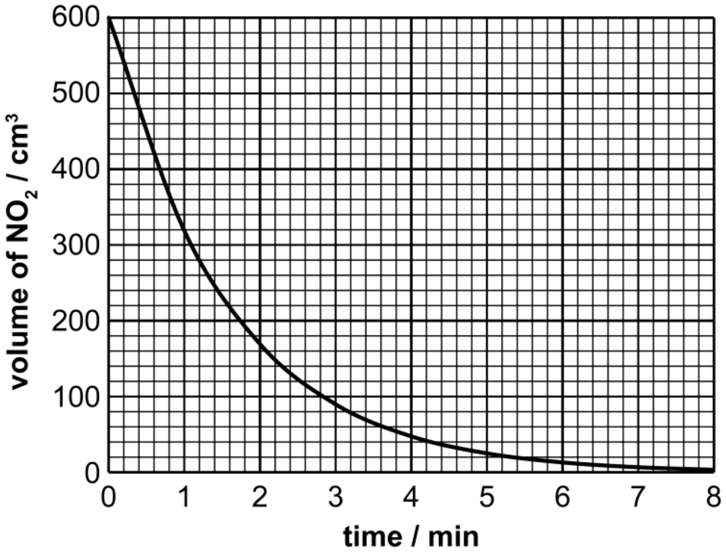


Fig. 3.2

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

....

.... [1]

(ii) Deduce the order with respect to NO_2.

Explain how you arrived at your answer.

....

....

.... [2]

(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 ....

phosphorus pentoxide ....

sulfur trioxide ....

[3]

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

....

.... [1]

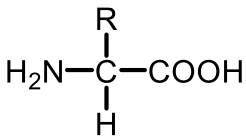
(iii) State the property of aluminium oxide that fits this trend.

....

.... [1]

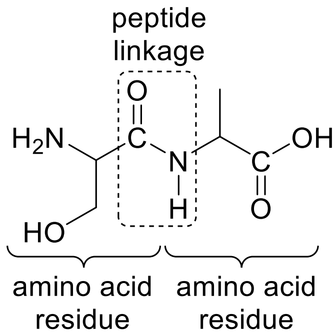
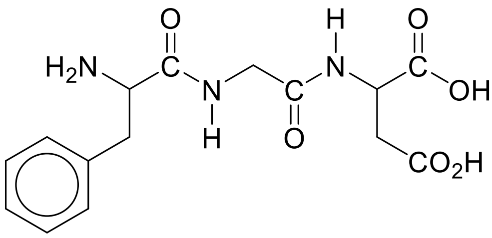
[Total: 16]

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.

.... [1]

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

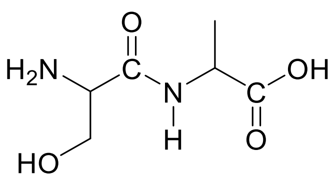
.... [1]

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

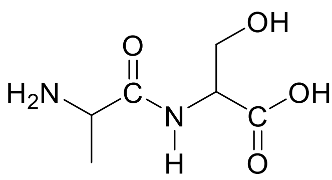
[3]

(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.

.... [1]

(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.

[1]

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

[1]

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

[1]

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

[1]

[Total: 10]

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) $K_{a1} = 3.48 \times 10^{-4}$ mol dm^{-3}

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

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

[1]

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

....

.... [1]

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

....

.... [1]

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

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

....

.... [1]

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

....

....

....

....

.... [2]

(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.

[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.

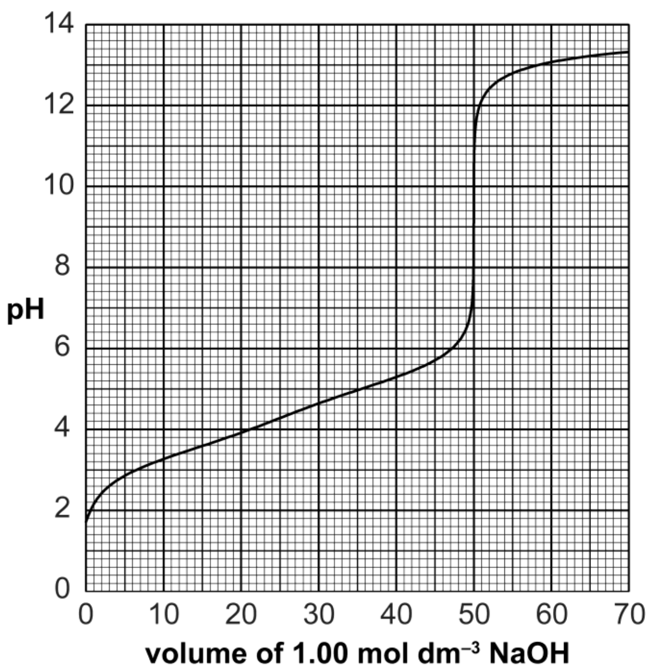


Fig. 5.1

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.

(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

....

.... [1]

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

[1]

[Total: 9]

Section B

Answer **<u>one</u>** 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	
3	4.0	1.0		2.53×10^{-4}
4		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.

[2]

(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.

....

....

....

....

....

....

.... [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.

....

.... [1]

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

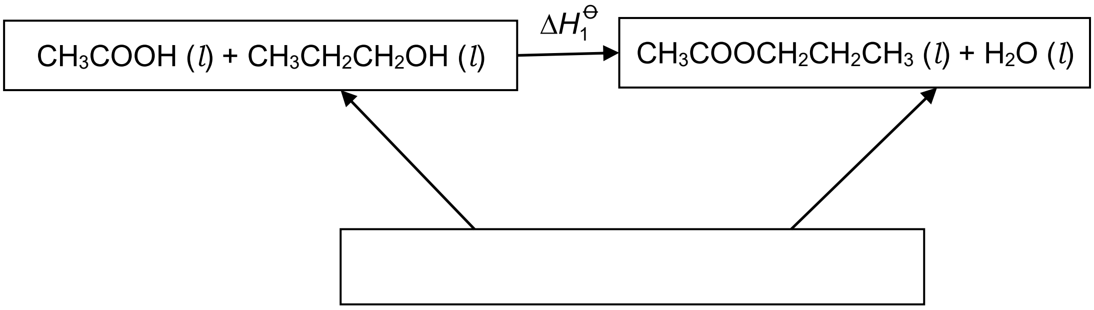


Fig. 6.1

[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
$CH_3COOCH_2CH_2CH_3$ (l)	–576
H_2O (l)	–286

[2]

(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 $CH(CH_2OH)=C(CH_2OH)CH_3$.

[2]

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

....

....

.... [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.

....

.... [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]

[Total:20]

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 +........ H_2O $\rightarrow$ .... + ... H^+ + ... e^-

Overall equation: ....

[2]

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

[1]

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

[2]

(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".

[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 $C_6H_{12}O_6(s) \rightarrow 2CO_2(g) + 2CH_3CH_2OH(l)$

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

Table 7.1

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

[2]

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 brand **X** beer and energy produced per mole of ethanol.

[2]

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

[2]

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

....

.... [1]

(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 °C. 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			25.0	20

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

....

....

.... [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*.

[2]

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

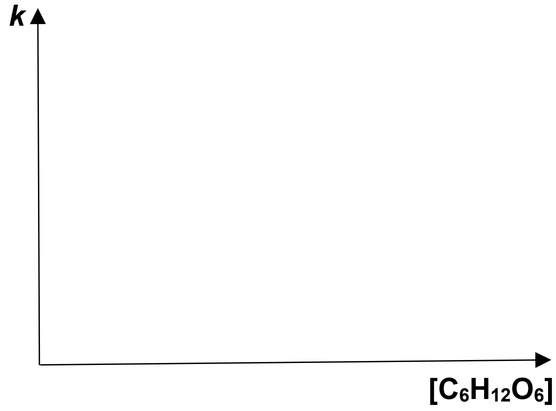


Fig. 7.1

[1]

[Total: 20]

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