EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2024
General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME										
CIVICS GROUP	2	3	–			INDEX NUMBER				

CHEMISTRY

8873/02

Paper 2 Structured Questions

10 September 2024
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	**/ 11**
2	**/ 15**
3	**/ 11**
4	**/ 11**
5	**/ 12**
Section B	
6 / 7	**/ 20**
Total	**/ 80**

This document consists of **24** printed pages.

Section A

Answer all questions in this section.

For Examiner's Use

1 This question is regarding Period 3 elements.

(a) The second ionisation energy shows a general increase across Period 3 of the Periodic Table, from Mg to Ar.

(i) Define the term *second ionisation* energy.

.....

.....

..... [1]

(ii) Write an equation to represent the second ionisation energy of silicon.

..... [1]

(iii) State the electronic configurations of Si^+ and Al^+.
Hence, explain why the second ionisation energy of silicon is found to be lower than that of aluminium.

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..... [2]

(b) The second ionisation energies of 8 successive elements **F** to **M** from both Periods 2 and 3 of the Periodic Table are shown in Fig. 1.1.

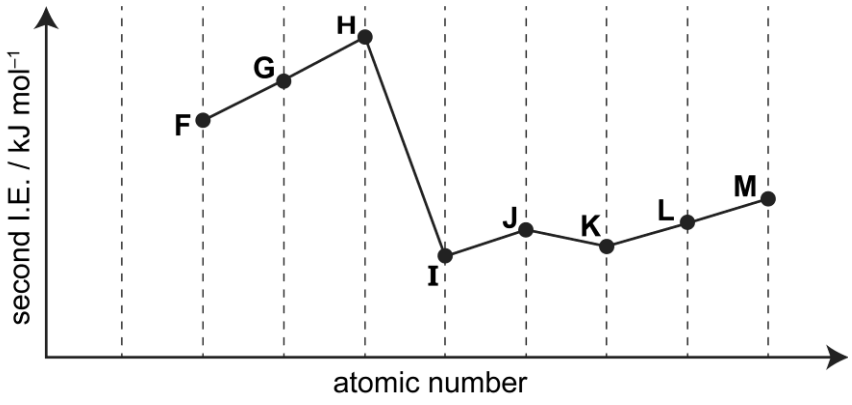

Fig. 1.1

For Examiner's Use

(i) Explain why there is a sudden drop in the second ionisation energy from element **H** to **I**.

.....

.....

.....

.....

..... [2]

(ii) Identify the element which represents silicon.

..... [1]

(iii) Element **E** has one proton less than element **F**.
Using a cross '×', plot the relative position of the second ionisation energy of element **E** on Fig. 1.1. [1]

(c) (i) State the formulae of the chlorides of the elements Na to P where the element is in its highest oxidation state.

.....

..... [1]

(ii) The chlorides of Si and P in **(c)(i)** react with water.

Write an equation for each reaction and state the expected pH of the products.

.....

..... [2]

[Total: 11]

For Examiner's Use

2 Phosgene, $Cl_2C{=}O$, is a colourless, toxic gas. It is used in the production of pesticides, rubbers and adhesives.

(a) In phosgene, the carbon atom is in the centre of the molecule and is attached to both chlorine atoms and oxygen atom.

(i) Draw the dot-and-cross diagram of the phosgene molecule.

[1]

(ii) State and explain, with reference to the Valence Shell Electron Pair Repulsion theory, the shape of a phosgene molecule.

.....

.....

.....

.....

.....

..... [2]

(iii) Suggest the Cl–C–Cl bond angle in the $COCl_2$ molecule.

..... [1]

For Examiner's Use

(b) Table 2.1 shows the electronegativity values of the atoms in phosgene.

Table 2.1

atom	electronegativity/Pauling units
carbon	2.5
chlorine	3.0
oxygen	3.5

(i) Explain what is meant by electronegativity.

.....

.....

..... [1]

(ii) With reference to Table 2.1, explain why $COCl_2$ is a polar molecule.
Hence, state all the possible intermolecular forces which could exist between phosgene molecules.

.....

.....

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.....

.....

..... [2]

For Examiner's Use

(c) Phosgene can be formed readily from carbon monoxide and chlorine.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g) \qquad \Delta H < 0$$

An experiment was carried out with 1:1 molar ratio of carbon monoxide and chlorine in a 2 dm^3 vessel at 25 ºC. Graph **A** in Fig 2.1 shows how the amount of $COCl_2$ changes with time.

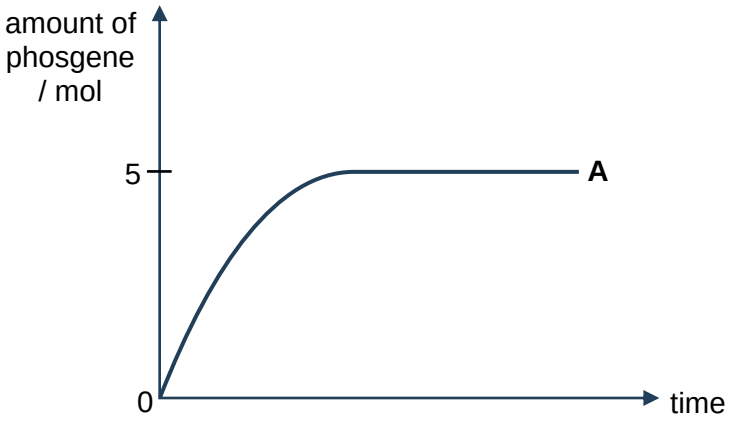

Fig. 2.1

(i) On Fig. 2.1, mark using a cross '×', the point on graph **A** that represents the time at which equilibrium is first reached. [1]

(ii) Write an expression for the equilibrium constant, K_c, for the reaction above.

..... [1]

(iii) The value of K_c for the reaction at 25 ºC is 1.20×10^{12}.
Using Fig. 2.1 and the information given, calculate the equilibrium concentration of $COCl_2$.
Hence, determine the amount of carbon monoxide present in the mixture when equilibrium is reached.

[2]

For Examiner's Use

(iv) A similar experiment was carried out with 1:1 molar ratio of carbon monoxide and chlorine at the same temperature, but in a 5 dm^3 vessel.

State and explain how the change affects the amount of phosgene present in the equilibrium mixture.

.....

.....

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.....

..... [2]

(v) On Fig 2.1, sketch how the graph would look like if the the same experiment was carried out in a 2 dm^3 vessel,

- At a higher temperature. Label this line as "**B**" [1]
- In the presence of a catalyst. Label this line as "**C**". [1]

[Total: 15]

For Examiner's Use

3 (a) Nitric acid, HNO_3, is a strong acid. It is a useful chemical used in the production of fertilisers and nitrogen containing organic compounds.

Nitric acid can be produced industrially through the Ostwald process using ammonia and oxygen as raw materials.

$$NH_3 + 2O_2 \rightarrow HNO_3 + H_2O$$

(i) State and explain in terms of oxidation numbers, which element is being oxidised and which element is being reduced in the Ostwald process.

.....

.....

.....

..... [2]

(ii) Hence, suggest why nitric acid can only act as an oxidising agent.

.....

.....

..... [1]

(iii) Calculate the pH of 0.0264 mol dm^{-3} nitric acid.
Give your answer to three significant figures.

[1]

(b) Another nitrogen containing acid, nitrous acid, HNO_2, is a weak acid.

(i) Explain the meaning of the terms *acid* and *weak acid*, in terms of the Brønsted-Lowry theory of acids.

.....

..... [2]

For Examiner's Use

(ii) Write an equation to show the reaction of nitrous acid with water.

..... [1]

(iii) Identify the two different conjugate acid-base pairs in the reaction occurring in **(b)(ii)**.

acid..... conjugate base.....

base..... conjugate acid.....

[1]

(c) Nitrogen naturally consists of two stable isotopes, ^{14}N and ^{15}N. A sample of pure nitrogen atoms has a relative atomic mass of 14.23.

(i) Define the term *relative atomic mass* of an element.

.....

..... [1]

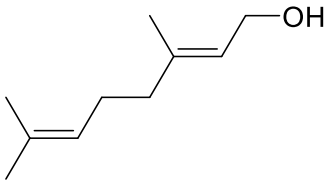
(ii) Calculate the percentage abundances of both ^{14}N and ^{15}N in this sample.

[2]

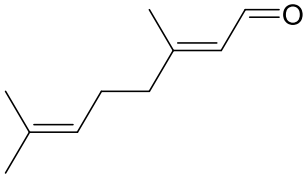
[Total: 11]

For Examiner's Use

4 Geraniol and citral are colourless oils which are responsible for aromas in perfumes. They can be extracted from plants.



geraniol



citral

(a) (i) Define the term *molecular formula*.

.....

..... [1]

(ii) Deduce the molecular formula of citral.

..... [1]

(b) (i) Identify the functional group common to geraniol and citral.

..... [1]

(ii) Describe a chemical test to confirm the presence of this functional group using a reagent that will **not** react with the other functional groups present.

.....

..... [2]

For Examiner's Use

(c) Compound **A** is a constitutional isomer of citral, containing the same functional groups. Fig. 4.1 shows a reaction scheme involving compound **A**.

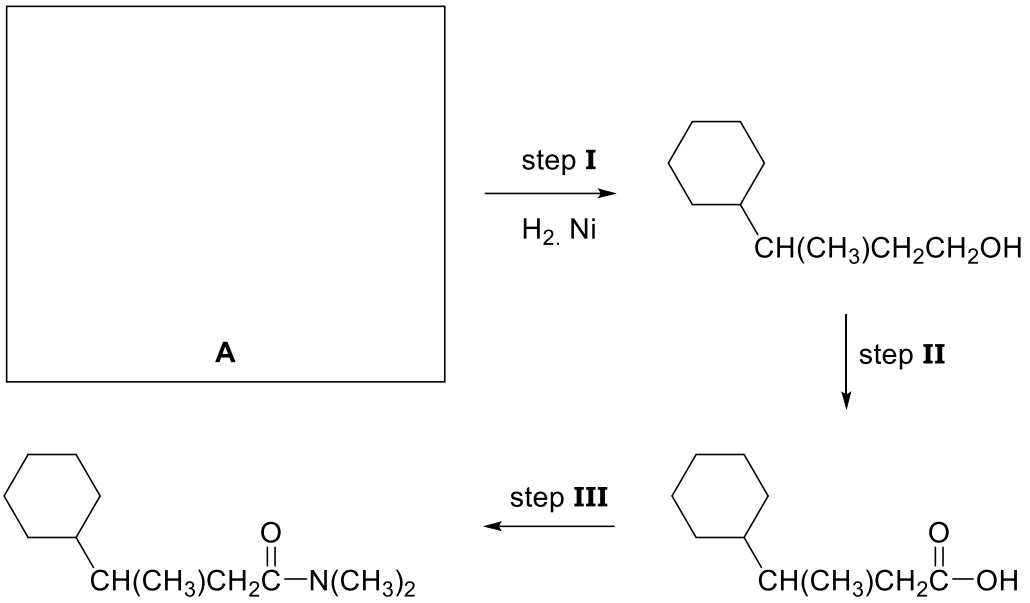


Fig. 4.1

(i) Compound **A** exists as a pair of *cis-trans* isomers.
Explain why compound **A** can exhibit *cis-trans* isomerism.

.....

.....

.....

..... [2]

(ii) Hence, with reference to your answer in **(a)(ii)**, draw the structural formula of one of the isomers of compound **A** in Fig. 4.1. [1]

(iii) State the reagents and conditions necessary for steps **II** and **III**.

step **II** : .....

step **III** : .....
[2]

(iv) State the type of reaction for step **III**.

..... [1]

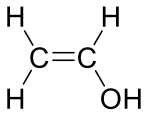
[Total: 11]

For Examiner's Use

5 (a) Laundry and dishwashing detergent pods have gained popularity in the market over the past years for the convenience they offer.

The pods are small capsules which consist of detergent and other cleaning ingredients enclosed in a water-soluble film. Upon contact with water in the washing machine, the film dissolves and releases the cleaning agents within the capsule.

The water-soluble film is made up of polyvinyl alcohol (PVA). It is made from the monomer as shown.



(i) State the type of polymerisation that produces PVA and name the type of covalent bond formed during this polymerisation.

..... [1]

(ii) Draw one repeat unit of PVA.

[1]

For a material to be suitable for use as the film in the pods, it must remain intact while containing alkaline cleaning agents, but dissolve quickly and completely in water.

(iii) Explain why PVA is able to contain alkaline cleaning agents.

.....

..... [1]

For Examiner's Use

(iv) Explain how PVA dissolves in water.

Include a labelled diagram in your answer.

.....

.....

..... [3]

One pod is sufficient for one wash in the washing machine. Some users have complained that the film of the pod does not dissolve completely in one washing cycle, leaving behind some residue.

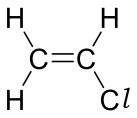
(v) Suggest one possible change that the user can make to help increase the solubility of the film.

.....

..... [1]

(vi) Poly(vinyl chloride), PVC, is a polymer that has a similar structure to PVA.

It is made from the monomer chloroethene.



In recent years, the use of PVC has declined due to health and environmental concerns when it is burnt. Considering the atoms in the polymer, suggest a reason for such concerns.

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..... [1]

For Examiner's Use

(b) A car manufacturer wants to select a polymer to make the headlight lenses for his new line of cars. These lenses are transparent covers that protect the front lights of a car.

Table 5.1 shows properties of 4 polymers.

Table 5.1

polymer	heat resistance	light transmission	UV resistance	impact strength
A	medium	92%	high	medium
B	high	90%	low	low
C	high	50%	low	high
D	high	90%	medium	high

- The higher the light transmission value for a polymer, the more transparent the polymer is.
- Prolonged exposure to UV light can cause yellowing in polymers. UV resistance is a measure of the polymer's life span when used outdoors.
- Impact strength is a measure of the polymer's ability to resist sudden and forceful impacts.

The car manufacturer needs to consider the ability of the polymer to withstand prolonged exposure under the sun, transparency of the material and overall safety of the car.

State which polymer would the car manufacturer select for making headlight lenses.

Explain your choice by considering each of the 4 properties listed in Table 5.1.

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..... [4]

[Total: 12]

Section B

For Examiner's Use

Answer **one** question in this section.

6 At the commercial scale, methanol can be synthesised from methane and steam over $Cu/ZnO/Al_2O_3$ catalyst at a pressure of 50–100 bar and temperature of 220–300 ºC.

$$CH_4(g) + H_2O(g) \rightarrow H_2(g) + CH_3OH(g) \qquad \Delta H = +115 \text{ kJ mol}^{-1}$$

(a) A chemist carries out a series of experiments to determine the rate equation for the reaction.

experiment	$[CH_4]$ / mol dm^{-3}	$[H_2O]$ / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
1	5.0×10^{-2}	1.5×10^{-1}	1.19×10^{-5}
2	5.0×10^{-2}	3.0×10^{-1}	2.38×10^{-5}
3	1.0×10^{-1}	6.0×10^{-1}	9.52×10^{-5}

(i) Determine the order of reaction with respect to CH_4 and H_2O. Hence, write the rate equation.

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..... [3]

(ii) Using the data from experiment 1, calculate the rate constant, k, for the reaction. State the units, if any.

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..... [2]

For Examiner's Use

(iii) With the aid of a suitable diagram, explain how the catalyst increases the rate of reaction.

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.....

..... [3]

(b) Elemental copper nanoparticles are used as a heterogeneous catalyst for the synthesis of methanol in the laboratory. Copper was found to be more effective as nanoparticles than in its bulk form.

(i) Define the term nanoparticles.

.....

..... [1]

(ii) Briefly explain why copper in its nanoparticle form works as a better catalyst than in its bulk form.

.....

..... [1]

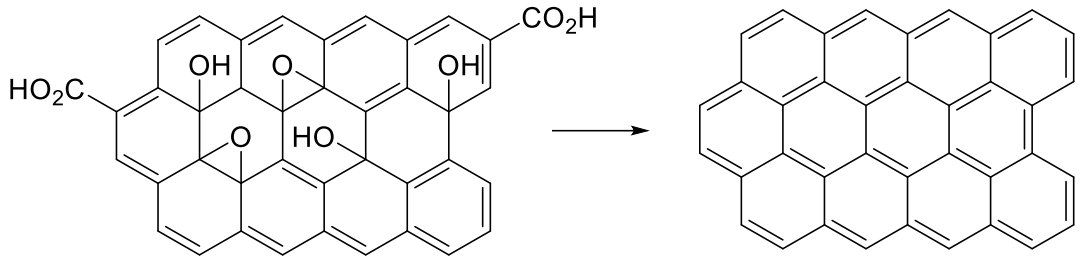
(iii) Explain why protective gloves must be worn when handling the copper nanoparticles.

.....

..... [1]

For Examiner's Use

(c) The hydrogen gas produced during the synthesis of methanol is stored in gas tanks packed with graphene nanotubes. Graphene oxide can be reduced to graphene to get large sheets of graphene which is then converted to the tubular form.



graphene oxide graphene

(i) Explain why the electrical conductivity of graphene oxide is low.

.....

.....

.....

..... [1]

(ii) Other than safety considerations, suggest and describe clearly **two** advantages of using a fuel tank packed with carbon nanotubes over the use of liquid hydrogen.

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.....

.....

..... [2]

(d) The energy cycle shown in Fig. 6.1 on page 18 can be used to calculate the standard enthalpy change of combustion of methanol, using standard enthalpy change of formation data.

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

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.....

.....

..... [1]

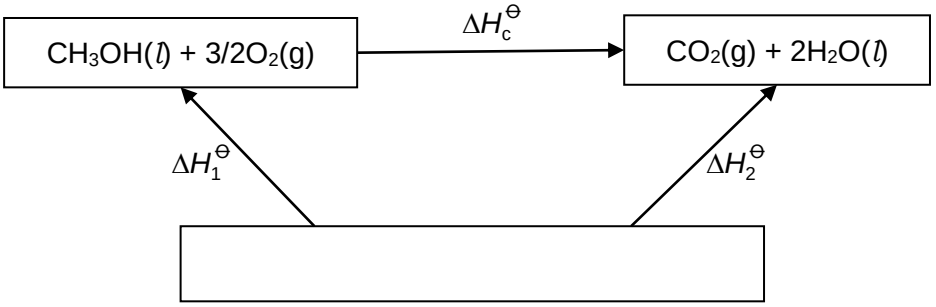

Fig. 6.1

(ii) Complete the energy cycle in Fig. 6.1. [1]

(iii) Use Fig. 6.1 and the data in Table 6.1 to calculate the standard enthalpy change of combustion of methanol, $\Delta H_c^{\ominus}$.

Table 6.1

	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$CO_2(g)$	–393.5
$H_2O(l)$	–285.8
$CH_3OH(l)$	–239.1

[2]

(iv) Using bond energy data, the standard enthalpy change of combustion of methanol can also be determined. However, the value obtained is found to be different from that calculated in **(d)(iii)**.

With reference to the energy cycle in Fig. 6.1, suggest **two** reasons for the difference in the two calculated values.

.....

.....

.....

..... [2]

[Total: 20]

For Examiner's Use

7 (a) The standard enthalpy change of neutralisation reaction is commonly determined experimentally using a coffee-cup calorimeter, which comprises styrofoam cups and a thermometer. The cross-section of such a calorimeter is shown in Fig. 7.1.

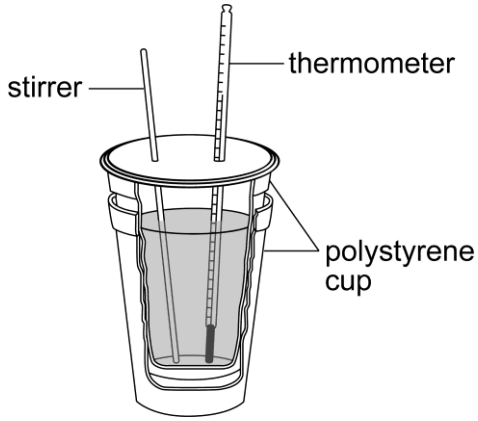

Fig. 7.1

(i) With the aid of an equation, define the term standard enthalpy change of neutralisation between ethanoic acid and potassium hydroxide.

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..... [2]

20 cm^3 of 1.50 mol dm^{-3} ethanoic acid and 30 cm^3 of 1.50 mol dm^{-3} potassium hydroxide were mixed in the calorimeter at 4 min and the temperature of the solution was recorded at regular time intervals. The results are shown in Fig. 7.2.

For Examiner's Use

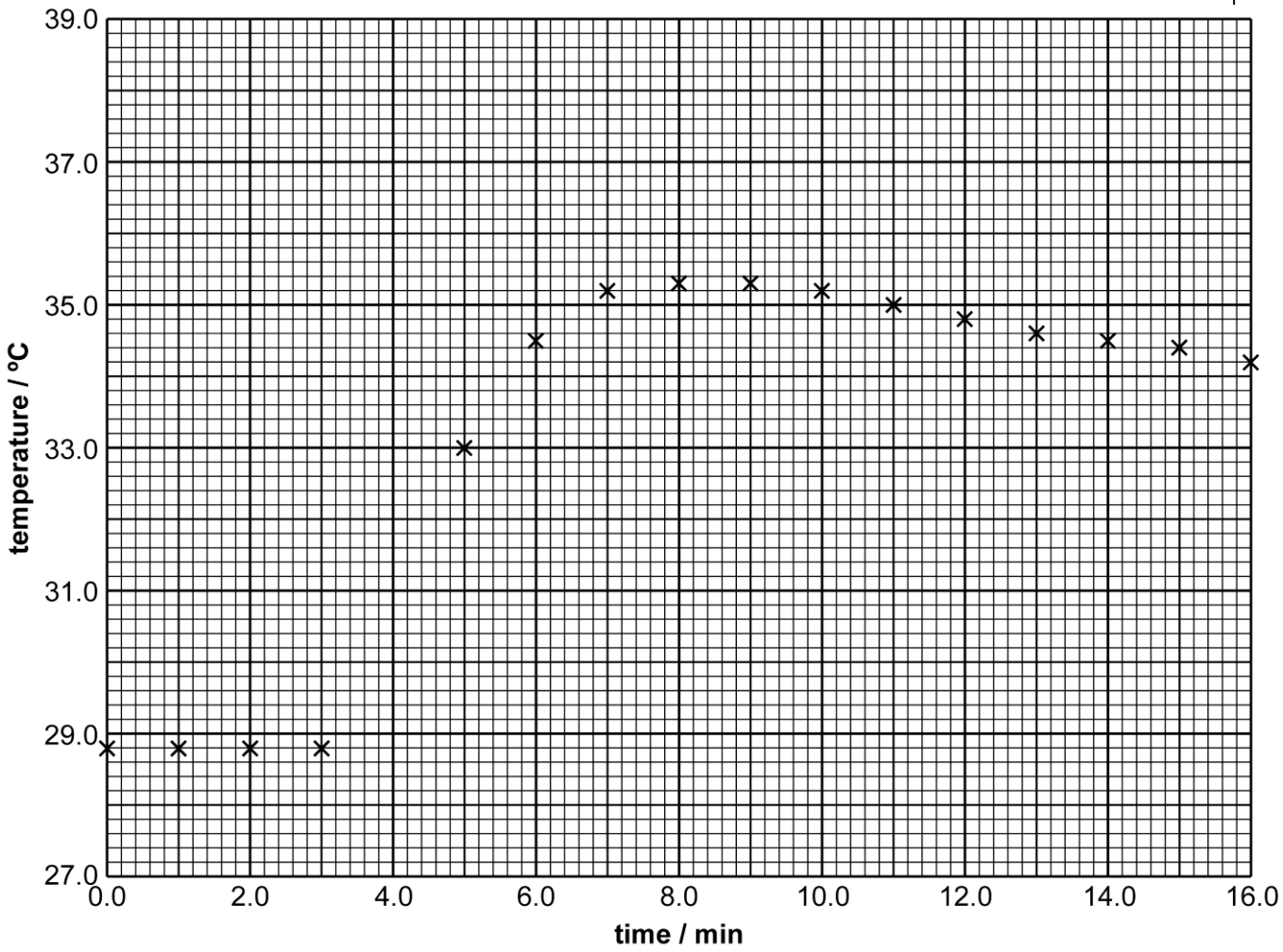

Fig. 7.2

(ii) To account for heat loss to the surroundings, two straight lines of best fit can be drawn to obtain the theoretical maximum temperature rise, ΔT_{max}.

Draw two separate straight lines of best fit.

- The first line should take into account the temperatures before reaction starts at t = 4 min.
- The second line should take into account the decreasing temperatures.

Extend both lines until t = 4 min.

Use the graph to determine ΔT_{max} of this experiment. Show your working.

ΔT_{max} = ...

[2]

For Examiner's Use

(iii) Using your answers to **(a)(ii)**, calculate the enthalpy change of neutralisation between ethanoic acid and potassium hydroxide.

[2]

(iv) Hence, draw a labelled energy profile diagram for the neutralisation reaction between ethanoic acid and potassium hydroxide.

[2]

For Examiner's Use

(b) Crystal violet, $C_{25}H_{30}N_3Cl$, is a synthetic dye with a vibrant purple colour. An experiment to determine the rate equation of the reaction between crystal violet and excess sodium hydroxide was carried out using a colourimeter.

$$C_{25}H_{30}N_3Cl\,(aq) + NaOH(aq) \rightarrow C_{25}H_{31}ON_3(aq) + NaCl(aq)$$

In the experiment, only crystal violet is responsible for the absorbance of light. As such, the concentration of crystal violet is proportional to the absorbance of the solution.

The experimental graph generated by the colourimeter is shown in Fig. 7.3.

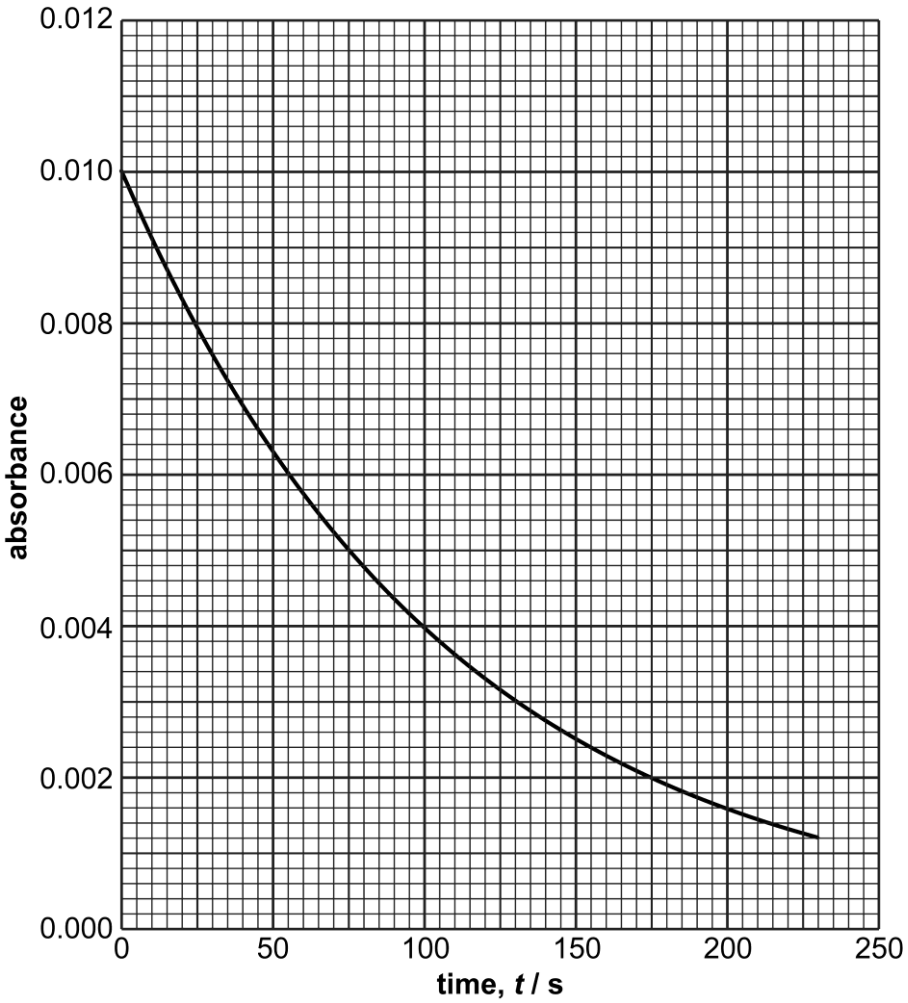

Fig. 7.3

The order with respect to crystal violet is one.

(i) Explain using the shape of the graph in Fig. 7.3, why the reaction is not zero order with respect to crystal violet.

.....

.....

..... [1]

For Examiner's Use

(ii) By drawing tangent at $t = 0$, calculate the initial rate of the experiment.

[1]

(iii) When the experiment was repeated using a different concentration of NaOH, the same graph was obtained.

State and explain the order of reaction with respect to NaOH.

.....

.....

..... [1]

(iv) Hence, write the rate equation.

..... [1]

(v) A solid compound **X,** was found to be able to catalyse the reaction between crystal violet and sodium hydroxide.

State the type of catalysis and outline the mode of action.

.....

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.....

.....

.....

.....

..... [3]

For Examiner's Use

(c) Compound **P** is a sweet-smelling liquid formed from methanoic acid, HCO_2H, and a tertiary alcohol, $C_5H_{12}O$.

(i) State the functional group present in compound **P**.

..... [1]

(ii) Name the tertiary alcohol.

..... [1]

(iii) Draw the skeletal formula of compound **P**.

[1]

(iv) Use the table of characteristic values for infra-red absorption in the *Data Booklet* to answer this question.

Infra-red absorptions are useful in identifying functional groups present in molecules. For example, the tertiary alcohol in **(c)(ii)** shows absorptions at 970–1260 cm^{-1} and 3200–3600 cm^{-1}.

Use the table to identify two infra-red absorption ranges that will be shown by the functional group identified in **(c)(i)**.

range 1: ..... cm^{-1}

range 2: ..... cm^{-1}

[2]

[Total: 20]