Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 CHEMISTRY 9729/03

Paper 3 Free Response Questions

21 September 2023
2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper. If additional space is required, you should use the pages at the end of this booklet. The question number must be clearly shown.

Section A
Answer **all** questions.

Section B
Answer **one** question.

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	
1	**/ 20**
2	**/ 15**
3	**/ 25**
Section B	
4 / 5	**/ 20**
Total	**/ 80**

This document consists of **25** printed pages and **1** blank page.

Section A

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

1 (a) Group 2 salts, such as carbonates, decompose when heated. Table 1.1 shows information of some Group 2 salts that undergo thermal decomposition.

Table 1.1

Group 2 salt	thermal decomposition temperature / °C
$MgCO_3$	350
$CaCO_3$	825

(i) Explain the difference in thermal decomposition temperature of $MgCO_3$ and $CaCO_3$. [2]

(ii) Hence predict the thermal decomposition temperature for $SrCO_3$. [1]

(iii) Write an equation for the thermal decomposition of $CaCO_3$. Include state symbols in your answer. [1]

(iv) State and explain the sign of ΔS for the thermal decomposition of $CaCO_3$. Hence explain how spontaneity of the reaction changes as temperature increases. [2]

(v) Outline a suitable experiment to verify that the thermal decomposition of a sample of $Mg(OH)_2$ is complete.

No details regarding use of specific glassware are required. [2]

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(b) Group 2 carbonates are sparingly soluble in water. Table 1.2 shows the solubility product, K_{sp}, of two Group 2 carbonates.

Table 1.2

Group 2 carbonate	K_{sp}
$MgCO_3$	2.61×10^{-3}
$CaCO_3$	5.83×10^{-5}

(i) Write an expression for K_{sp} of $MgCO_3$, giving its units. [1]

(ii) Describe and explain how the solubility of $MgCO_3$ is affected by the addition of ethanoic acid. [2]

Excess solid magnesium nitrate and calcium nitrate were added to a solution containing carbonate ions. The mixture was stirred and left to equilibrate at room temperature.

(iii) Calculate the $[Mg^{2+}]/[Ca^{2+}]$ ratio in the resulting mixture. [1]

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(c) Magnesium is also used in the pinacol coupling reaction. A new C–C bond is formed between two carbonyl compounds, as shown in Fig. 1.1.

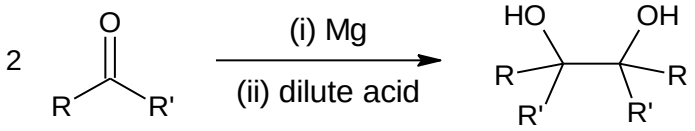
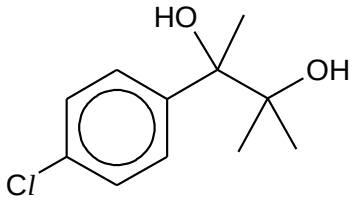


Fig. 1.1

(i) When butanone undergoes the pinacol coupling reaction, a mixture of 3 stereoisomers are formed.

Draw the structure of the product that does **not** rotate plane-polarised light, showing the stereochemistry of the molecule clearly. [1]

(ii) Phenaglycodol is a sedative. It can be synthesised from compounds **P** and **Q** using the pinacol coupling reaction.



Phenaglycodol

Suggest possible structures for **P** and **Q**. [2]

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(d) Compound **R**, $C_8H_8O_2$, reacts with Fehling's reagent and aqueous bromine. It is also soluble in NaOH(aq). When **R** is heated with acidified potassium manganate(VII), $C_8H_8O_3$, is first formed. Further heating produces 4-hydroxybenzoic acid.

For each reaction, state the type of reaction described and explain what the information tells you about the functional groups present in **R**. Hence suggest a possible structure for **R**.

[5]

[Total: 20]

2 (a) (i) State the two main assumptions of ideal gases. [1]

(ii) Explain why a real gas will deviate more from ideality at a lower temperature.

[1]

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(b) Pure hydrogen iodide, HI, partially dissociates into hydrogen and iodine as shown in the equation below.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

The reaction was carried out at 500 K. At the start of the reaction, 9.0×10^{-4} mol of HI were introduced into a 2 dm^3 vessel. When equilibrium was established, it was found that 85% of the hydrogen iodide was left.

(i) Write an expression for the equilibrium constant, K_c, for the dissociation of HI.

[1]

(ii) Determine the equilibrium constant, K_c, for this reaction at 500 K. [2]

(iii) When the temperature was increased to 700 K, it was found that only 70% of the hydrogen iodide was left.

Deduce from this information whether the forward reaction is endothermic or exothermic. Explain your reasoning. [2]

(iv) Explain why gaseous hydrogen chloride does not undergo a similar

dissociation like that of hydrogen iodide at 500 K. [1]

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(c) Both hydrogen chloride and hydrogen bromide dissolve readily in water.

Describe a chemical test, which does **not** involve silver nitrate, that could distinguish between aqueous solutions of these two gases.
[2]

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(d) The chloro–alkali industry generates commercially useful substances such as chlorine, hydrogen and sodium hydroxide. Saturated sodium chloride solution, known as brine, is electrolysed in the diaphragm cell as shown in Fig. 2.1.

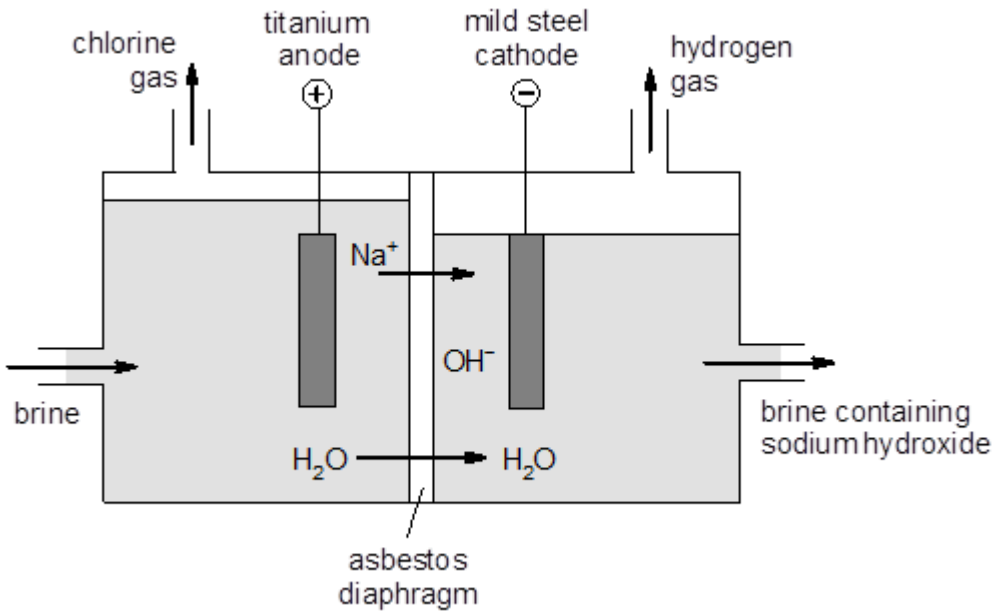

Fig. 2.1

During the electrolysis process, a steady current of 5000 A was passed through the cell. 8.30×10^5 cm^3 of chlorine gas was produced at 30 °C and 1.5 atm.

(i) Write ionic equations for the reactions occurring at the anode and at the cathode. [2]

(ii) Determine the amount, in moles, of chlorine gas produced. [1]

(iii) Hence, calculate the time taken to produce the amount of chlorine gas in **(d)(ii)**. [2]

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[Total: 15]

3 In this question, R and R' can be H or any alkyl group.

Terminal alkynes, R−C≡C−H, react with aldehydes, R'CHO, to form allenes, RCH=C=CHR'. An example of this reaction is shown in Fig. 3.1, which occurs in the presence of a weak base and copper(I) bromide.

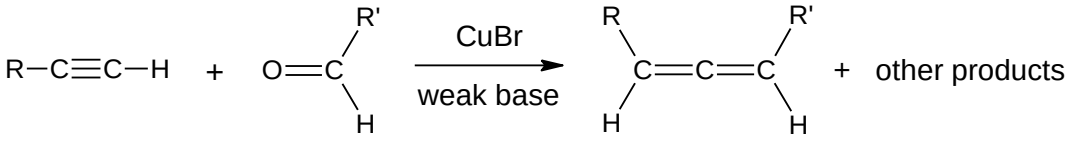

Fig. 3.1

(a) By reference to the electronic configuration of the relevant ion, explain how copper(I) bromide acts as a Lewis acid catalyst for this reaction.
[2]

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(b) **(i)** State the hybridisation of the central carbon atom in the C=C=C group of the allene product. Hence describe the orbital overlap involved in the formation of the sigma bonds in the C=C=C group. [1]

(ii) Fig. 3.2 shows the plane in which the carbon atoms in the C=C=C group of the allene product lie.

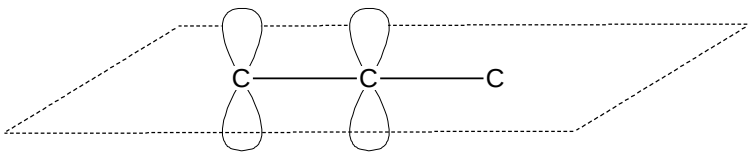

Fig. 3.2

By considering your answer in **(b)(i)**, complete Fig. 3.2 to show the arrangement of the *p* orbitals in the C=C=C group. [1]

(iii) By considering your answer in **(b)(ii)**, draw the 3-dimensional structure of the allene, $H_2C=C=CH_2$.

Show the carbon atoms in the C=C=C bond in the plane of the paper and use wedged ◄ and dashed ····· bonds to the relevant hydrogen atoms to show the stereochemistry. [1]

(iv) Predict and explain the relative rate of reaction of the allene,

C*l*CH=C=CHC*l*, and 1,3−dichloropropane with excess NaOH(aq).
[2]

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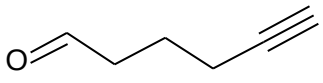
(c) **(i)** Compound **E** has the following structure. When **E** alone undergoes a reaction similar to that in Fig. 3.1, it forms a cyclic allene product.



E

Predict the cyclic allene product formed in this reaction. [1]

(ii) The cyclic allene product formed in **(c)(i)** is highly strained. Suggest an explanation for this using the Valence Shell Electron Pair Repulsion theory. [2]

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(d) The weak base used in Fig. 3.1 is diisopropylamine, $(CH_3)_2CHNHCH(CH_3)_2$.

(i) Using the Brønsted-Lowry theory, explain what is meant by the term *weak base*. [1]

(ii) Diisopropylamine is one of the organic products formed when an excess of a compound **X** (M_r = 122.9) is heated with ammonia in a sealed tube.

Draw the structure of **X** and suggest the identity of one other organic product formed in the reaction. [2]

Diisopropylamine, $(CH_3)_2CHNHCH(CH_3)_2$, has a pK_b of 3.43 at 298 K.

You may use **R_2NH** to represent diisopropylamine.

(iii) Calculate the percentage of diisopropylamine molecules that are dissociated in 0.25 mol dm^{-3} diisopropylamine. [2]

(iv) Some HNO_3 is added to 1 dm^3 of the diisopropylamine solution in **(d)(iii)**.

Identify the two major organic species present in this solution when the pH is 10.3. Hence determine the amount, in moles, of HNO_3 added. [3]

Diisopropylamine and heptane have similar molar masses.

(v) Explain why the boiling point of diisopropylamine is lower than that of heptane.

molecule	structural formula	boiling point
diisopropylamine	$(CH_3)_2CHNHCH(CH_3)_2$	357
heptane	$CH_3(CH_2)_5CH_3$	371

[2]

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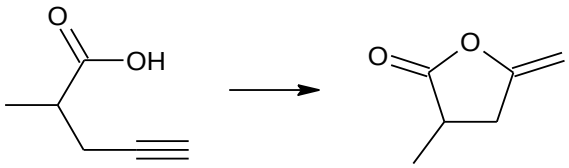
Under suitable conditions, alkynes react with carboxylic acids to form esters. An example is shown in Fig. 3.3.



P

Fig. 3.3

(e) **(i)** Identify the type(s) of stereoisomerism that product **P** exhibits and hence, state the number of stereoisomers that **P** has. [1]

(ii) Draw the stereoisomers of **P**.

[1]

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P undergoes a two−step reaction as shown in Fig. 3.4.

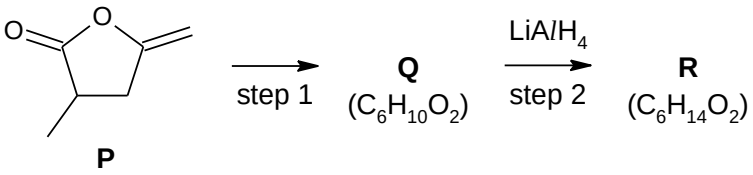

Fig. 3.4

(f) Predict the structures of **Q** and **R**. Suggest reagents and conditions for step 1.

[3]

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[Total: 25]

Section B

Answer **one** question from this section.

4 (a) Magnesium, aluminium and phosphorous are three elements in period 3 of the periodic table.

(i) Describe what you would observe when water is added to separate samples of the oxides of these three elements, MgO, Al_2O_3 and P_4O_{10}.

Suggest the pH of the resulting solutions and write equations where appropriate. [3]

(ii) By quoting data from the *Data Booklet*, explain in detail the differences in the reactions of water with magnesium oxide and with aluminium oxide. [3]

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(b) **(i)** 0.80 g of liquid **T**, $C_{10}H_{18}$, was burned under a container filled with 100 cm^3 of water. The container of water has an initial temperature of 25 °C. The process is known to be 80% efficient and the enthalpy change of combustion of **T** is $-5500\ kJ\ mol^{-1}$.

Using the *Data Booklet*, calculate the final temperature of water when 0.80 g of liquid **T** is completely burnt. [3]

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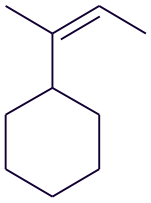
(ii) Compound **U** is an isomer of **T** and its skeletal structure is shown below.



U

The major product, **W**, is formed when compound **U** is mixed with dry hydrogen bromide gas.

Draw the skeletal structure of **W** and explain why **W** is the major product of this reaction. [3]

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(c) Compound **V** has the molecular formula C_6H_{12}. Aqueous bromine remained orange when added to **V**. However, **V** forms three different mono-brominated products when reacted with bromine in UV light.

(i) Deduce the structure of **V**. Explain your reasoning. [3]

(ii) Using the structure you have deduced in **(c)(i)**, draw the mechanism of the reaction between **V** and bromine in UV light.

You should show how a secondary alkyl bromide is formed in your mechanism. [3]

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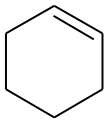
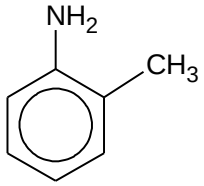
(d) The structures of compound **X** and **Y** are shown below.



X



Y

Suggest the reagents and conditions for a reaction that could be used to distinguish between compounds **X** and **Y**. Describe the observations in each case. [2]

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[Total: 20]

5 Iron is a lustrous, ductile, malleable, silver-grey metal. It is the most used of all metals and it exists in more than one oxidation state.

(a) Pale yellow aqueous iron(III) chloride undergoes the following reactions shown in Fig. 5.1.

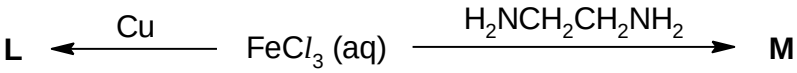

Fig. 5.1

(i) Explain why aqueous iron (III) chloride is coloured. [3]

(ii) Solution **L** is formed when copper metal is added to iron(III) chloride solution.

By selecting appropriate $E^{\ominus}$ values from the *Data Booklet*, explain why the reaction occurs.

Hence, write a balanced ionic equation for this reaction. [2]

Fig. 5.2 shows how the colour intensity of a solution containing 0.01 mole of iron(III) chloride varies as increasing amounts of $H_2NCH_2CH_2NH_2$ is added.

The colour intensity due to the complex ion **M** formed is measured with a colorimeter. The colour intensity is directly proportional to the concentration of **M**.

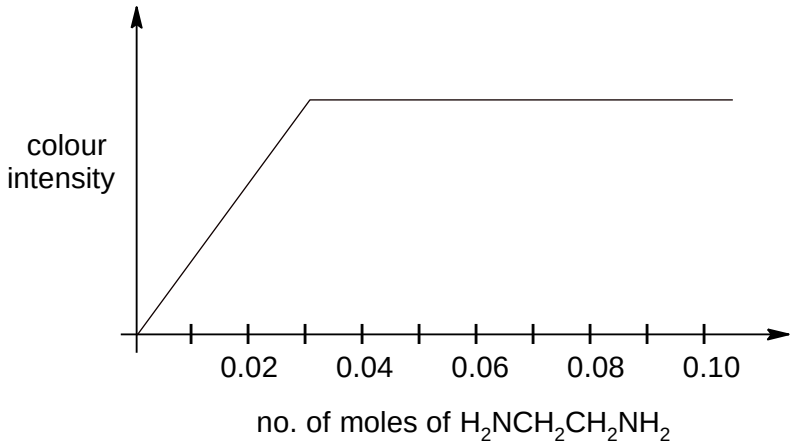

Fig. 5.2

(iii) Use Fig. 5.2 to deduce the mole ratio of Fe^{3+} and $H_2NCH_2CH_2NH_2$ in complex **M**.
[1]

(iv) Draw the structure of complex **M**. [1]

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(b) Fig. 5.3 shows two reactions of benzylamine, one of which involves the use of solid $FeCl_3$ as a catalyst.

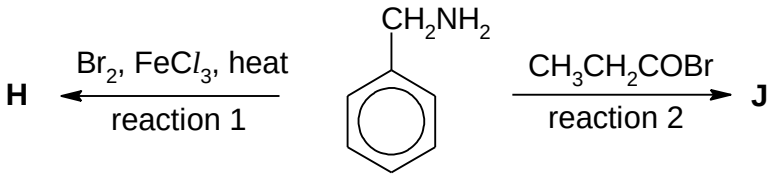

Fig. 5.3

(i) Suggest the structures of compounds **H** and **J**. [2]

(ii) Name the type of reaction for reaction 2. [1]

(iii) Name and draw a mechanism for reaction 1. Show clearly
- any intermediates that may be formed
- the movement of electron pairs by using curly arrows
- how $FeCl_3$ acts as a catalyst [3]

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QUESTION 5 CONTINUES ON THE NEXT PAGE.

(c) Hydrogen peroxide decomposes slowly in aqueous solution according to the following equation:

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

A H_2O_2 solution of original concentration of 4.66 mol dm^{-3} was placed in a bottle contaminated with Fe^{3+} ions for some time. The Fe^{3+} ions catalyse the decomposition of H_2O_2.

10 cm^3 of H_2O_2 is withdrawn from the contaminated bottle and the rate of decomposition is measured by collecting the oxygen gas produced over time at room temperature and pressure.

Fig. 5.4 shows the volume of oxygen gas produced recorded against time for this experiment.

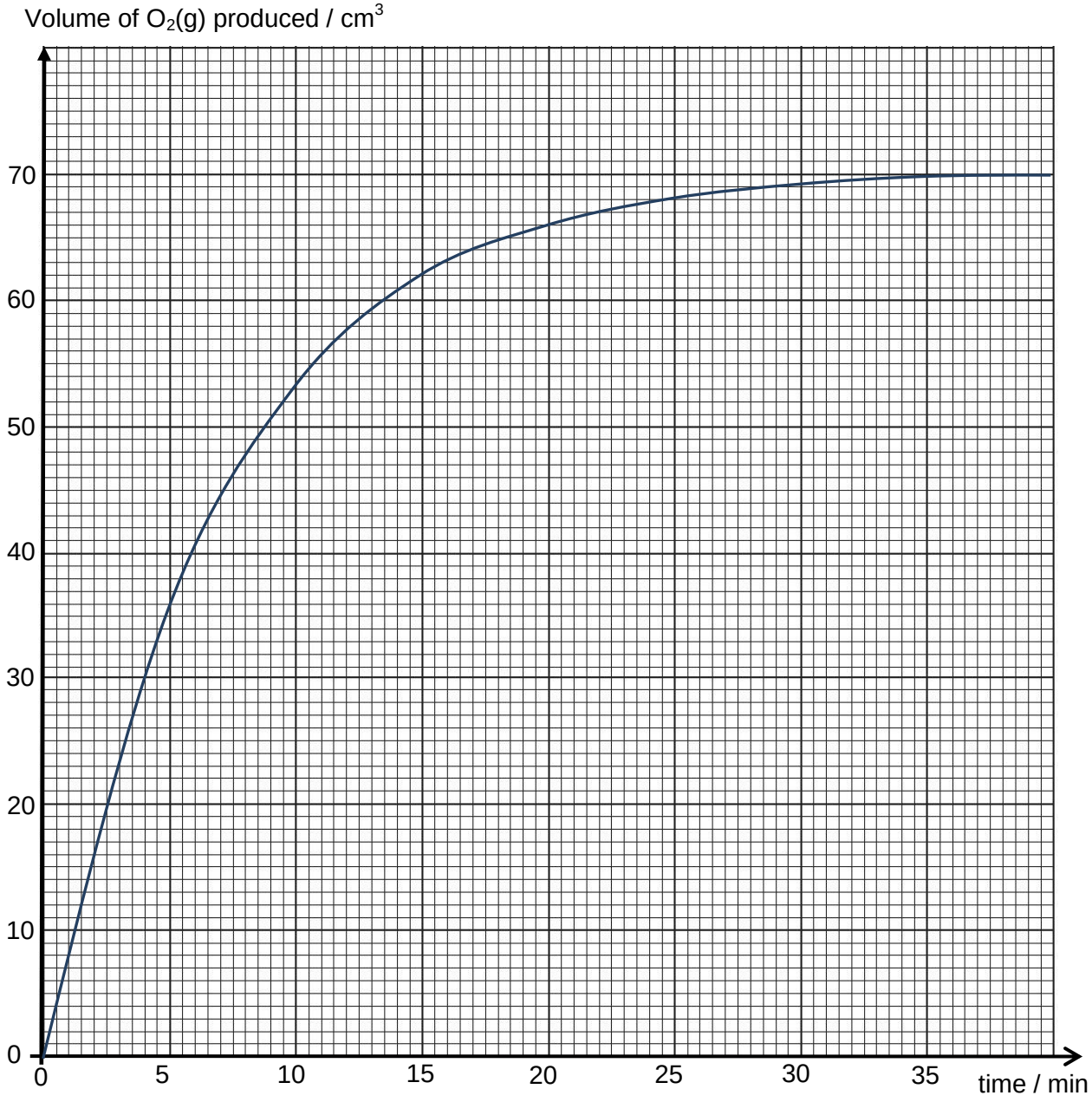

Fig. 5.4

(i) Using Fig. 5.4, prove that the reaction is first order with respect to hydrogen peroxide. Show your working clearly. [2]

(ii) Using your answer in **(c)(i)**, calculate the rate constant for the catalysed decomposition of hydrogen peroxide. [1]

(iii) Using Fig. 5.4, calculate the concentration of hydrogen peroxide at the start of this experiment. Hence, calculate how long the hydrogen peroxide had been in the contaminated bottle. [3]

(iv) Suggest a method whereby the shelf-life of uncontaminated hydrogen peroxide solution could be increased. [1]

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Additional answer space

If you use the following pages to complete the answer to any question, the question number must be clearly shown.