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**Pearson Edexcel Level 3 GCE**

**Friday 21 June 2024**

Morning (Time: 2 hours 30 minutes)

Paper reference **9CH0/03**

**Chemistry**

**Advanced**

**PAPER 3: General and Practical Principles in Chemistry**

**You must have:**  
Scientific calculator, Data Booklet, ruler

Total Marks

## Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided  
– *there may be more space than you need.*

## Information

- The total mark for this paper is 120.
- The marks for **each** question are shown in brackets  
– *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (\*), marks will be awarded for your ability to structure your answer logically, showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

## Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ►

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**Pearson**

**Answer ALL questions.**

**Write your answers in the spaces provided.**

**1** Relative isotopic mass is an important concept in chemistry.

(a) Define relative isotopic mass.

(2)

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(b) A sample of hydrogen gas is formed from atoms of three isotopes,  $^1\text{H}$ ,  $^2\text{H}$  and  $^3\text{H}$ .

Deduce the number of peaks due to molecular ions,  $\text{H}_2^+$ , in the mass spectrum of this sample.

(1)

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**(Total for Question 1 = 3 marks)**

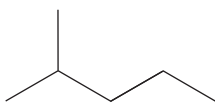


2 This question is about the intermolecular forces in organic compounds.

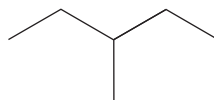
The structures of four isomeric alkanes are shown.



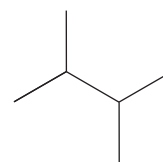
compound **A**



compound **B**



compound **C**



compound **D**

The only significant intermolecular forces between molecules of these compounds are London forces.

(a) Explain how London forces arise.

(3)

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(b) Explain which of the compounds **A–D** will have the highest boiling temperature.

(2)

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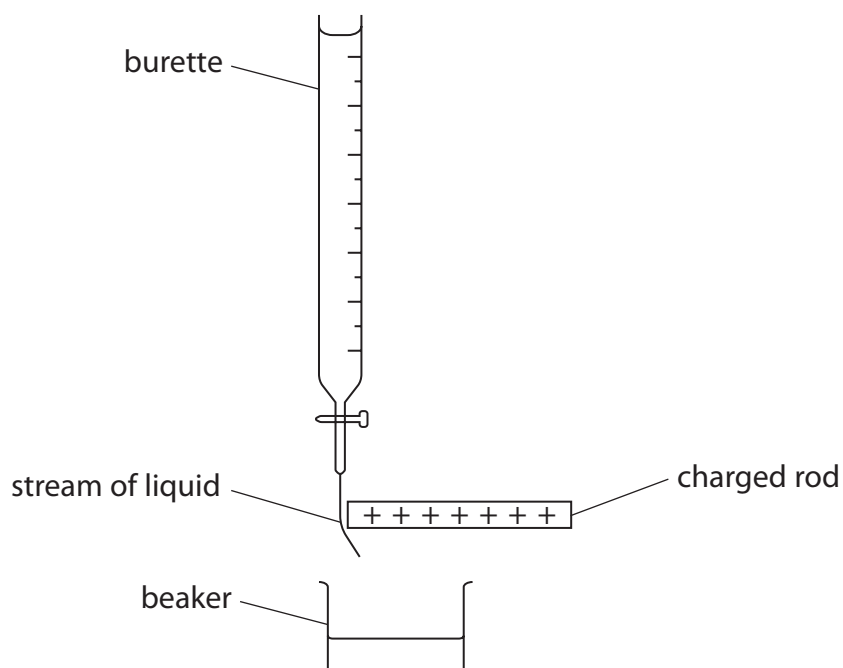
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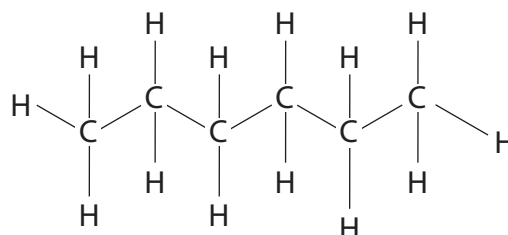
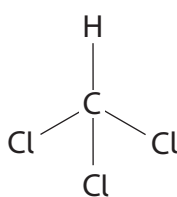
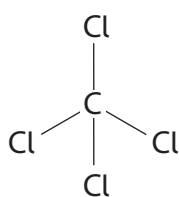


P 7 4 4 5 5 A 0 3 3 2

- (c) The apparatus shown may be used in an experiment to compare how far, if at all, a charged rod deflects different liquids.



The structures of three liquids are shown.



Explain whether or not each of these liquids will be deflected in this experiment.

(3)

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(Total for Question 2 = 8 marks)

- 3 A student carried out an experiment to identify the Group 1 metal ion,  $M^+$ , in a sulfate,  $M_2SO_4$ .

### Procedure

- Step 1 A 0.48 g sample of  $M_2SO_4$  was added to about  $50\text{ cm}^3$  of deionised water in a beaker. The mixture was stirred with a glass rod until the sample dissolved completely.
- Step 2 An excess of acidified barium chloride solution,  $BaCl_2(aq)$ , was added very slowly to the solution from Step 1 to ensure the crystals of barium sulfate that formed were as large as possible.
- Step 3 The barium sulfate crystals were collected by gravity filtration onto a dry filter paper of known mass.
- Step 4 The crystals were rinsed using deionised water.
- Step 5 The filter paper containing the crystals was dried in a warm oven for an hour and then weighed.

### Results

Mass of dry filter paper = 0.17 g

Mass of dry filter paper and barium sulfate crystals = 1.19 g

- (a) Give a reason, with reference to the filtration in Step 3, why the formation of **extremely** small crystals in Step 2 would lead to a lower mass of dry barium sulfate in Step 5.

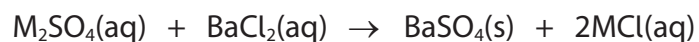
(1)

- (b) Explain why the crystals are rinsed in Step 4.

(2)



- (c) Calculate the relative formula mass of  $M_2SO_4$  and hence identify M.



$[M_r \text{ of } BaSO_4 = 233.4]$

(3)

- (d) Another student carrying out the experiment placed the glass rod on the laboratory bench when the stirring was complete in Step 1.

- (i) Explain what effect this would have on the calculated value of the relative formula mass of  $M_2SO_4$ .

(2)

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- (ii) Describe how the student should amend the procedure.

(1)

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(e) Another way to identify a metal ion is a flame test.

(i) Explain what causes the flame colour in such a test.

(2)

(ii) Give one advantage and one disadvantage of using a flame test to identify a metal cation, rather than the method followed by the students in Steps 1–5.

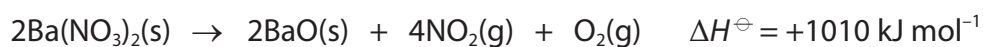
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**(Total for Question 3 = 13 marks)**



4 This question is about the white crystalline solid, barium nitrate.

- (a) Barium nitrate decomposes under suitable conditions to form barium oxide, nitrogen dioxide and oxygen.



Standard molar entropy data related to this reaction are shown.

| Substance                            | Standard molar entropy, $S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$ |
|--------------------------------------|-----------------------------------------------------------------------|
| $\text{Ba}(\text{NO}_3)_2(\text{s})$ | 213.8                                                                 |
| $\text{BaO}(\text{s})$               | 70.4                                                                  |
| $\text{NO}_2(\text{g})$              | 240.0                                                                 |
| $\text{O}_2(\text{g})$               | 205.0                                                                 |

- (i) Show that barium nitrate is thermally stable at 298 K.

(5)



- (ii) Calculate the **minimum** temperature, in °C, at which it is thermodynamically feasible for barium nitrate to decompose.

Give your answer to an appropriate number of significant figures.

(3)

- (b) Explain why calcium nitrate is less thermally stable than barium nitrate.

(3)

- (c) A qualitative test for nitrate ions involves heating an alkaline solution of the suspected nitrate with aluminium.

- (i) Complete the ionic equation for this redox reaction, using oxidation numbers. State symbols are not required.

(1)



- (ii) Describe a test to confirm that ammonia,  $\text{NH}_3$ , has been produced.

(1)

(Total for Question 4 = 13 marks)



P 7 4 4 5 5 A 0 9 3 2

- \*5 Compare and contrast the reactions of bromine with benzene and of bromine with cyclohexene.

Consider the types of reaction that occur, the products that form, and any special conditions that may be required.  
Justify your answers.

Detailed mechanisms for the reactions are **not** required.

(6)

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(Total for Question 5 = 6 marks)



6 An ester **Q** has the molecular formula  $C_8H_{16}O_2$ .

- (a) When hydrolysed, 2.07 g of **Q** formed a carboxylic acid with a 78 % yield. Once separated, the carboxylic acid was neutralised using excess sodium hydrogencarbonate solution.



In this reaction,  $269\text{ cm}^3$  of carbon dioxide gas was produced at room temperature and pressure.

Show that these data confirm that the relative molecular mass of **Q** is 144.

(3)

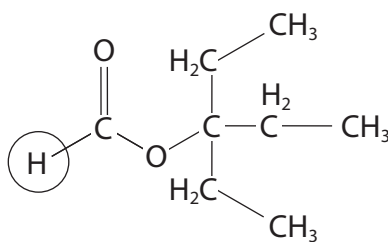
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- (b) The high resolution proton NMR spectrum of ester **Q** was obtained.  
The structure of the ester **Q** is shown.



proton environment A

- (i) Explain the expected splitting pattern for the peak due to proton environment A circled in the structure.

(2)

- (ii) Label the structure to indicate the remaining equivalent proton environments in ester **Q**.

(1)

- (iii) Predict the chemical shifts, relative peak areas and splitting patterns in the high resolution proton NMR spectrum, due to the proton environments you have labelled.

Do not consider proton environment A.

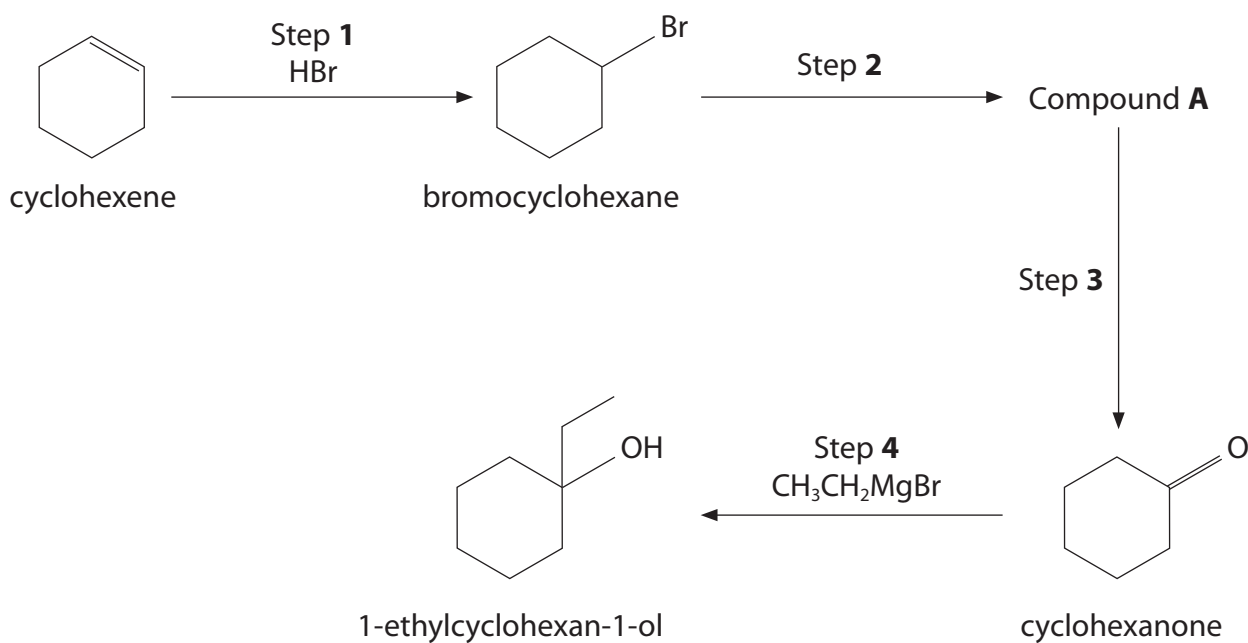
(3)

(Total for Question 6 = 9 marks)



P 7 4 4 5 5 A 0 1 3 3 2

- 7 The alcohol 1-ethylcyclohexan-1-ol can be synthesised from cyclohexene using the reaction scheme shown.



- (a) Draw the mechanism for Step 1.  
Include curly arrows, and relevant lone pairs and dipoles.

(4)



- (b) Devise a reaction scheme for Step **2** and Step **3** of the synthesis.  
Include in your answer all reagents and conditions, the type of reaction in each step, and the structure of **A**.

(5)

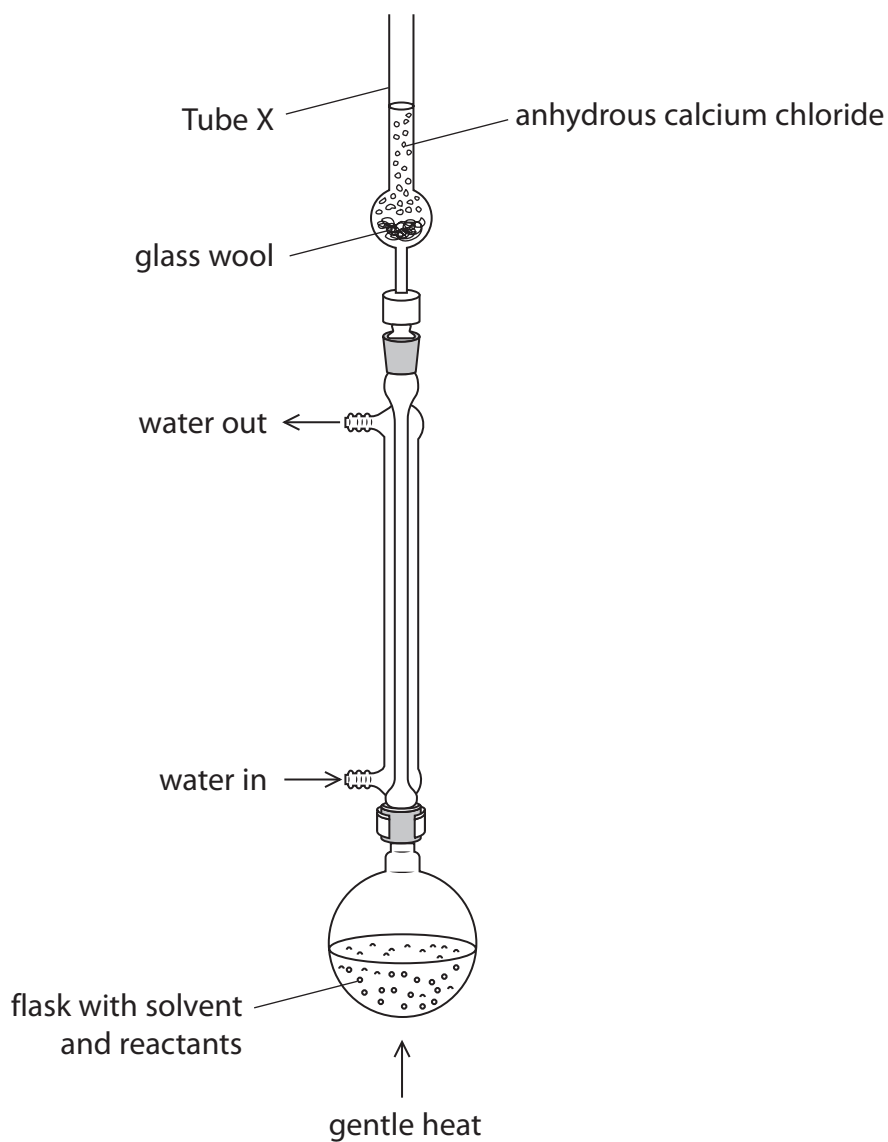
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- (c) The reaction to produce the  $\text{CH}_3\text{CH}_2\text{MgBr}$  used in Step 4 requires bromoethane and magnesium to be warmed under reflux with a suitable solvent. The apparatus used for this reaction is shown.



- (i) Name the solvent used.

(1)

(ii) Explain why the anhydrous calcium chloride in Tube X is necessary.

(2)

(iii) Give a reason why it is best practice for the water in the condenser to flow in the direction shown in the diagram.

(1)

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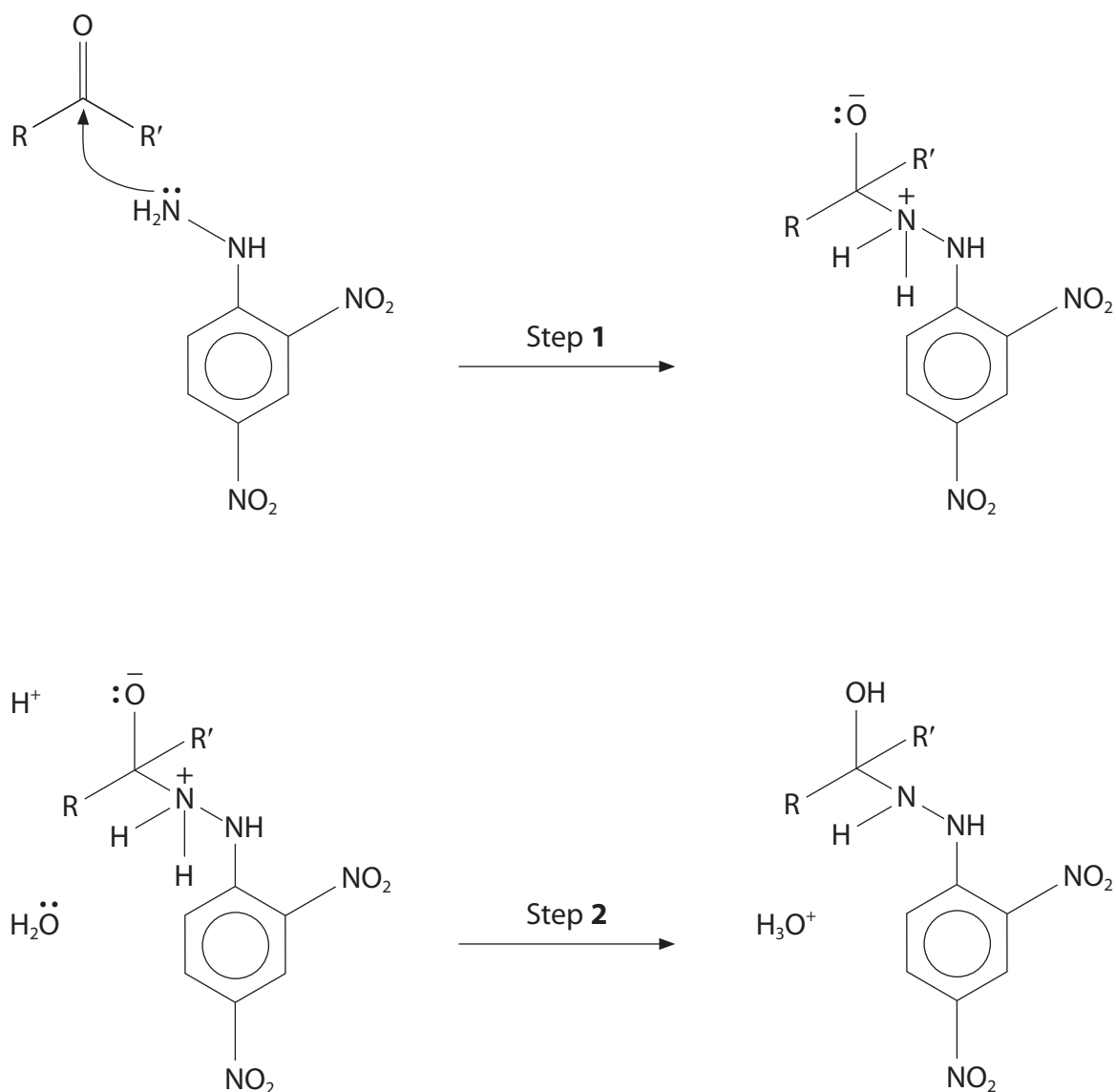
(d) Carbonyl compounds such as cyclohexanone can be identified by the reaction with 2,4-dinitrophenylhydrazine.

(i) Give the colour of the precipitate formed in this reaction.

(1)

(ii) Complete the simplified mechanism for the first two steps of this reaction by adding **four** curly arrows.

(4)



(iii) Describe how you would obtain pure dry crystals from the precipitate.

(4)

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(Total for Question 7 = 22 marks)



8 This question is about acids and bases.

- (a) A student devised a method to determine the acid dissociation constant,  $K_a$ , of ethanoic acid,  $\text{CH}_3\text{COOH}$ , using a solution of the acid of unknown concentration.

The student's outline procedure is shown.

Step 1 Titrate  $25.0\text{ cm}^3$  of the ethanoic acid solution with a solution of ammonia of known concentration, using phenolphthalein to find the end-point.

Step 2 Add a further  $25.0\text{ cm}^3$  of the same ethanoic acid solution to the mixture from Step 1.

This gives a solution where the acid has been half-neutralised.

Step 3 Record the pH of the solution from Step 2.

- (i) Explain why this procedure would give invalid results.

(3)

- (ii) State how Step 1 should be amended to give valid results.

(1)

- (iii) Show that when the solution has been half-neutralised, the acid dissociation constant is given by the expression

$$K_a = 10^{-\text{pH}}$$

(3)



- (b) Calculate the mass of sodium ethanoate needed to be dissolved in  $250\text{ cm}^3$  of  $0.520\text{ mol dm}^{-3}$  ethanoic acid to form a buffer solution with  $\text{pH} = 4.48$

$[K_a \text{ for ethanoic acid} = 1.74 \times 10^{-5} \text{ mol dm}^{-3}]$

(5)

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- (c) A student mixes  $50.0 \text{ cm}^3$  of  $0.900 \text{ mol dm}^{-3}$   $\text{NaOH(aq)}$  with  $20.0 \text{ cm}^3$  of  $0.400 \text{ mol dm}^{-3}$   $\text{H}_2\text{SO}_4\text{(aq)}$ .

Calculate the pH of the resultant solution.

[Ionic product of water,  $K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ ]

(5)

(Total for Question 8 = 17 marks)



- 9 Acidity in wine is mainly due to the dicarboxylic acid tartaric acid,  $C_4H_6O_6$ .

Sulfur dioxide is added to wine as an antioxidant, to prevent the colour and flavour of the wine from deteriorating. It also inhibits the growth of bacteria.

The concentration of tartaric acid and the concentration of sulfur dioxide present in wine can both be determined by titrations.

- (a) The procedure to find the total amount of tartaric acid in a white wine is shown.

Step 1 Pipette a  $20.0\text{ cm}^3$  sample of the wine into a conical flask.

Step 2 Add anti-bumping granules to the flask, and then place it on a preheated hot plate.

Step 3 Boil the sample to remove any dissolved gases and allow it to cool.

Step 4 Use  $0.100\text{ mol dm}^{-3}$  sodium hydroxide solution,  $\text{NaOH(aq)}$ , in a burette to titrate the sample using a suitable indicator.

- (i) State a precaution you would take in carrying out Step 3.  
Justify your answer.

(2)

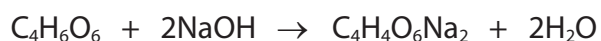
- (ii) Explain what effect the omission of Step 3 would have on the titre.

(2)



(iii) A mean titre of  $20.60 \text{ cm}^3$  was obtained.

Calculate the concentration, in  $\text{g dm}^{-3}$ , of tartaric acid in the white wine.



(3)

(iv) A student carrying out the experiment forgot to remove an air bubble from the tip of the burette **before** carrying out a titration. During the titration, the air bubble escaped.

Explain the effect this mistake would have on the value of this titre.

(2)

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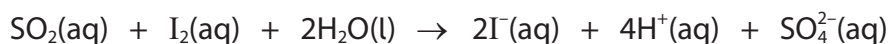
(b) A procedure to find the amount of sulfur dioxide,  $\text{SO}_2$ , in a wine is shown.

**Step 1**  $50.0 \text{ cm}^3$  of a white wine is added to a conical flask containing  $5 \text{ cm}^3$  of dilute sulfuric acid and a few drops of starch indicator.

**Step 2** A spatula measure of sodium hydrogencarbonate is then added to reduce the loss of sulfur dioxide from the flask.

**Step 3** The contents of the flask are titrated rapidly using  $0.0100 \text{ mol dm}^{-3}$  iodine solution,  $\text{I}_2(\text{aq})$ .

The equation for the reaction that takes place is shown.



- (i) A student carrying out the experiment obtained a titre of  $11.80 \text{ cm}^3$ .  
The maximum permitted level of sulfur dioxide in white wine in the UK is  $200 \text{ mg dm}^{-3}$ .

Show by calculation that the concentration of sulfur dioxide in the white wine is below the permitted maximum.

(4)



- (ii) Explain how the addition of sodium hydrogencarbonate in Step 2 reduces the loss of sulfur dioxide from the flask.

(2)

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(Total for Question 9 = 15 marks)



**10** The progress of the reaction between ethyl ethanoate and water with a hydrochloric acid catalyst can be followed in an experiment using a titrimetric method. An outline procedure is shown.

**Step 1** Add  $100\text{ cm}^3$  of  $0.500\text{ mol dm}^{-3}$   $\text{HCl(aq)}$  to a conical flask.

**Step 2** Using a pipette, add  $5.0\text{ cm}^3$  of ethyl ethanoate to the conical flask while mixing.

**Step 3** Immediately remove a  $5.0\text{ cm}^3$  sample of the reaction mixture from **Step 2** and add it to a separate conical flask containing crushed ice.

**Step 4** Titrate the removed sample using  $0.200\text{ mol dm}^{-3}$   $\text{NaOH(aq)}$ .

**Step 5** Repeat **Steps 3** and **4**, removing  $5.0\text{ cm}^3$  samples every 10 minutes.

**Step 6** After 60 minutes, heat the remaining reaction mixture under reflux for 15 minutes.

**Step 7** Remove a  $5\text{ cm}^3$  sample of the reaction mixture after completing **Step 6**, titrating this sample with  $0.200\text{ mol dm}^{-3}$   $\text{NaOH(aq)}$ .

(a) (i) Explain the purpose of the crushed ice in **Step 3**.

(2)

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(ii) Explain why **Step 6** is carried out before the final sample is removed and titrated in **Step 7**.

(2)

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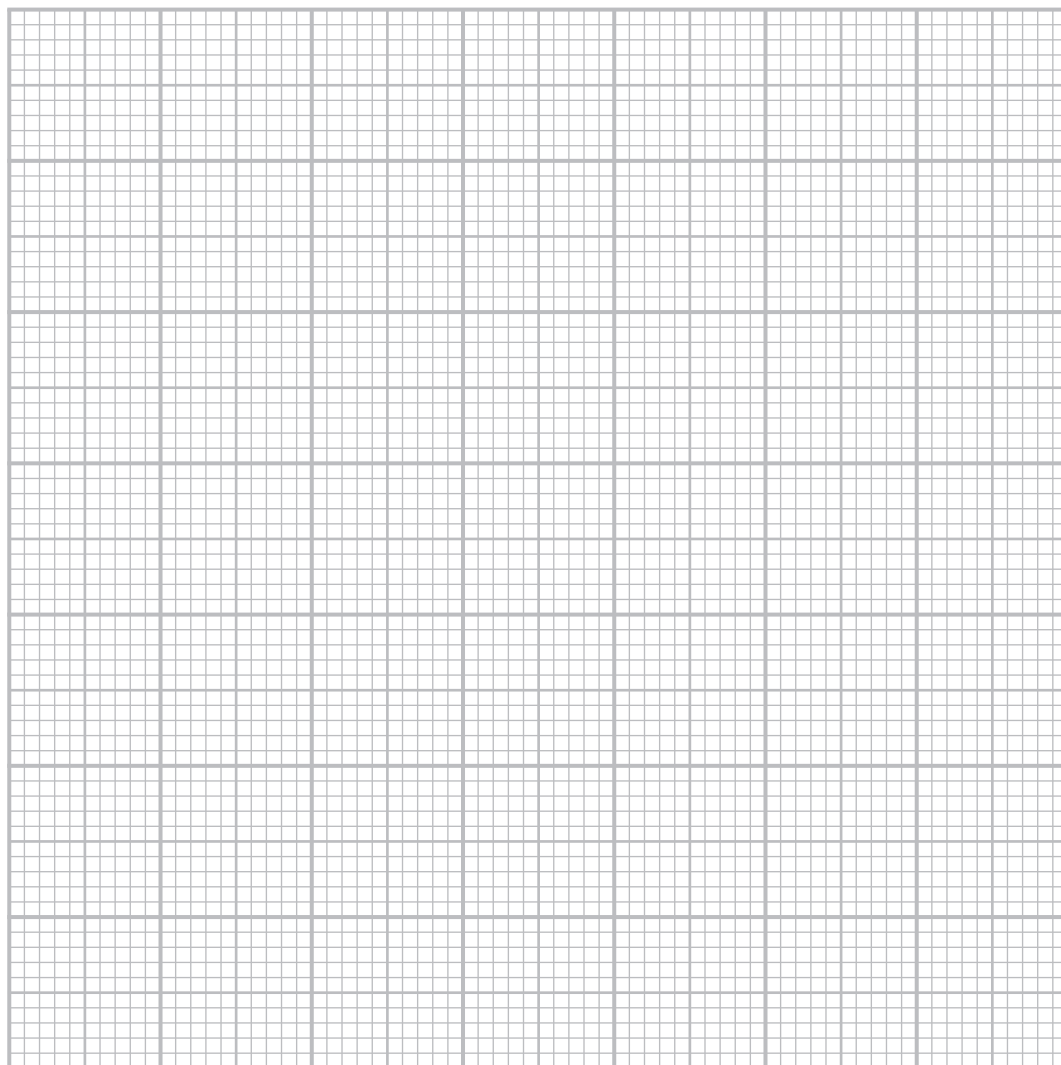


- (b) Some data from the experiment are shown.  $V_{\text{final}}$  is the titre volume from Step 7,  $V_t$  is the titre volume at time  $t$ .

| Time reaction sample is added to crushed ice / min           | 0     | 10   | 20   | 30   | 40   | 50   | 60   |
|--------------------------------------------------------------|-------|------|------|------|------|------|------|
| $V_{\text{final}} - V_t$ of sodium hydroxide / $\text{cm}^3$ | 11.60 | 6.50 | 3.80 | 1.80 | 0.90 | 0.80 | 0.80 |

- (i) Plot a graph of the  $V_{\text{final}} - V_t$  of sodium hydroxide against the time the reaction sample is added to the crushed ice.

(3)



- (ii) Explain why  $V_{\text{final}} - V_t$  is plotted rather than the concentration of sodium hydroxide solution for each titre.

(2)

- (iii) Determine two half-lives for the reaction, showing your working on the graph.

(2)

- (iv) Deduce the order of the reaction, using your answer from (b)(iii) to justify your deduction.

(1)

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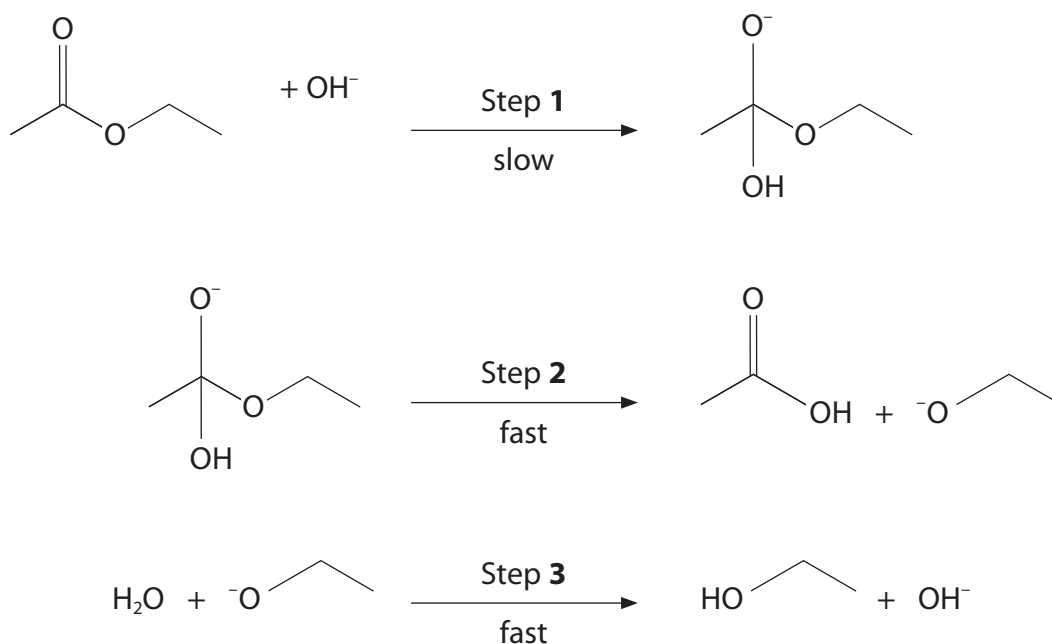
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(c) Ethyl ethanoate can also be hydrolysed under alkaline conditions.

A student researching the mechanism for the reaction found this example.



Deduce a rate equation that is consistent with this reaction mechanism.  
Justify your answer.

(2)

(Total for Question 10 = 14 marks)

TOTAL FOR PAPER = 120 MARKS



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## 32

Elements with atomic numbers 112-116 have been reported but not fully authenticated

\* Actinide series

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|-----|----|---------|----|-------|----|--------------|----|-----|----|-----------|----|-------|----|------------|----|-------|----|-----------|----|-------|----|-----------|----|-------|----|------------|----|-------|----|-----------|----|-------|----|-------------|----|-------|----|-------------|----|-------|----|---------|-----|-------|----|-----------|-----|-------|----|-----------|-----|-------|----|------------|-----|
| 140 | Ce | cerium  | 58 | 141   | Pr | praseodymium | 59 | 144 | Nd | neodymium | 60 | [147] | Pm | promethium | 61 | 150   | Sm | samarium  | 62 | 152   | Eu | europium  | 63 | 157   | Gd | gadolinium | 64 | 159   | Tb | terbium   | 65 | 163   | Dy | dysprosium  | 66 | 165   | Ho | holmium     | 67 | 167   | Er | erbium  | 68  | 169   | Tm | thulium   | 69  | 173   | Yb | ytterbium | 70  | 175   | Lu | lutetium   | 71  |
| 232 | Th | thorium | 90 | [231] | Pa | protactinium | 91 | 238 | U  | uranium   | 92 | [237] | Np | neptunium  | 93 | [242] | Pu | plutonium | 94 | [243] | Am | americium | 95 | [247] | Cm | curium     | 96 | [245] | Bk | berkelium | 97 | [251] | Cf | californium | 98 | [254] | Es | einsteinium | 99 | [253] | Fm | fermium | 100 | [256] | Md | mercurium | 101 | [254] | No | nobelium  | 102 | [257] | Lr | lawrencium | 103 |

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