

Cambridge International A2 Level Chemistry

# Question Papers

Paper #5



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## Cambridge International AS & A Level

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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**May/June 2021**

**1 hour 15 minutes**

You must answer on the question paper.

No additional materials are needed.

### INSTRUCTIONS

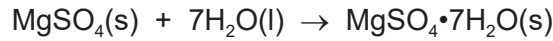
- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working, use appropriate units and use an appropriate number of significant figures.

### INFORMATION

- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **12** pages. Any blank pages are indicated.

- 1 A student is asked to find the enthalpy change for the reaction between anhydrous magnesium sulfate and water.



This enthalpy change cannot be measured directly.

- (a) Predict whether the enthalpy change for this reaction is positive or negative. Explain the reason for your prediction.

prediction .....

explanation .....

..... [1]

- (b) The student decided to do two separate experiments.

**Experiment 1**

To find the enthalpy change of solution of anhydrous magnesium sulfate,  $\text{MgSO}_4(\text{s})$ , 0.0250 moles of  $\text{MgSO}_4(\text{s})$  are dissolved in  $50.0\text{ cm}^3$  distilled water.

**Experiment 2**

To find the enthalpy change of solution of hydrated magnesium sulfate,  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}(\text{s})$ , 0.0250 moles of  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}(\text{s})$  are dissolved in  $50.0\text{ cm}^3$  distilled water.

The results for **Experiment 1** are shown in the graph of temperature against time on page 3.

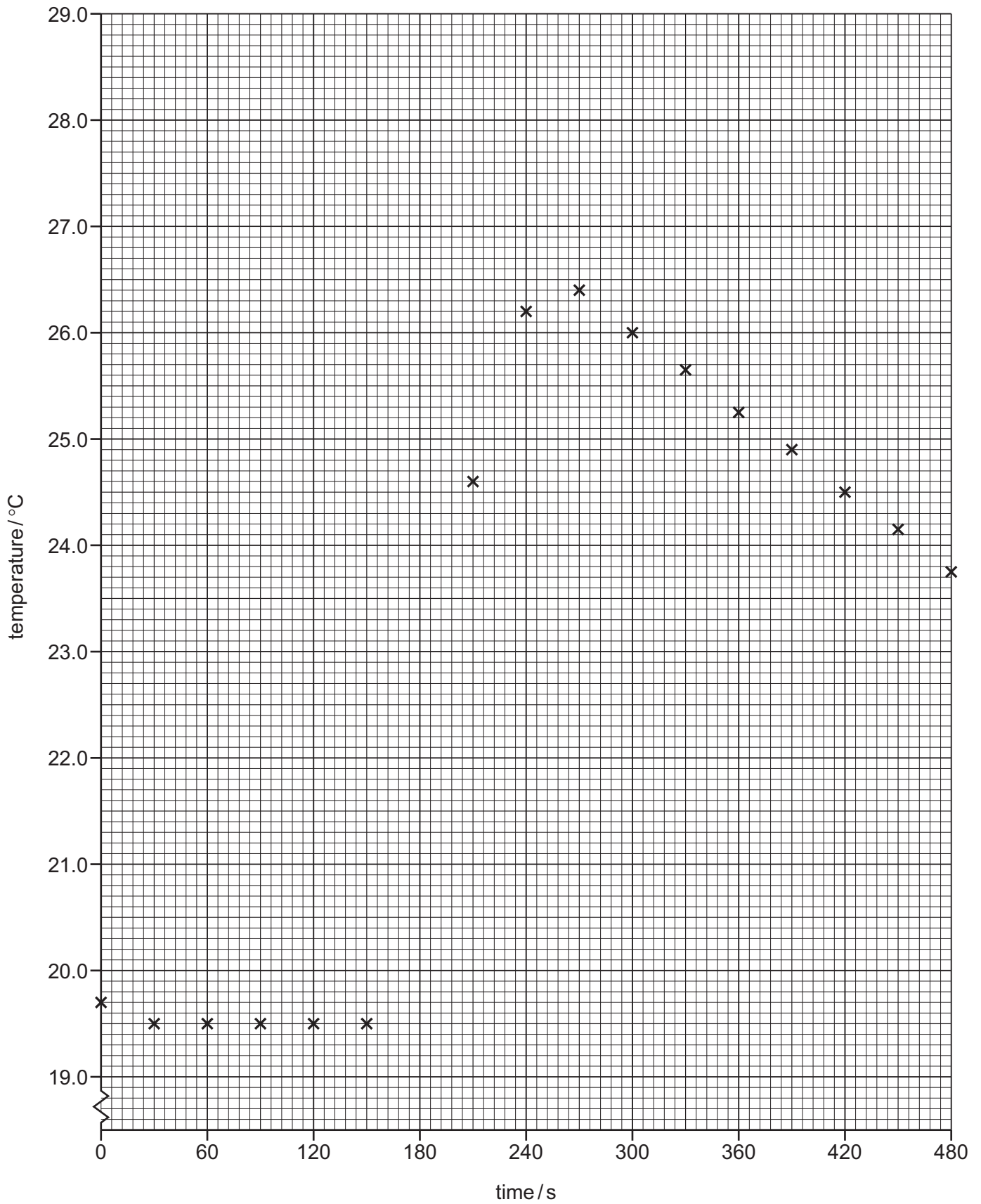
- (i) Draw and extrapolate the cooling curve back to 180 seconds. Determine the temperature change during the reaction.

temperature change = ..... °C [1]

- (ii) The anhydrous magnesium sulfate was not added when the timing started.

Explain why.

.....  
 ..... [1]



(iii) 3.01 g (0.0250 mol) of anhydrous magnesium sulfate is weighed.

Outline the next steps that should be taken in order to obtain the results in **Experiment 1**.

Write your answer using a series of numbered steps.

.....  
.....  
.....  
.....  
.....  
.....  
..... [4]

(c) (i) The student realised that when dissolving 0.0250 moles  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}(\text{s})$ , the amount of water present in the compound alters the total volume of water used in **Experiment 2**.

Calculate the volume of distilled water needed to make the total volume of water  $50.00 \text{ cm}^3$  in **Experiment 2**.

Give your answer to the nearest  $0.05 \text{ cm}^3$ .

Assume that  $1.00 \text{ cm}^3$  of distilled water has a mass of 1.00 g.

[A<sub>r</sub>: O, 16.0; H, 1.0]

volume of distilled water = .....  $\text{cm}^3$  [1]

(ii) State which piece of apparatus should be used to measure the volume of distilled water in (c)(i).

Explain your answer.

apparatus .....  
explanation .....

[2]

- (d) The temperature change when 0.0250 moles of  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}(\text{s})$  is added to the water is very small.

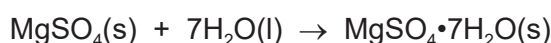
Suggest how the student should modify the experimental procedure to make the temperature change larger.

..... [1]

- (e) (i) The energy released by 0.0250 moles of  $\text{MgSO}_4(\text{s})$ , in **Experiment 1**, is 2125 J. The energy absorbed by 0.0250 moles of  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}(\text{s})$ , in **Experiment 2**, is 477.5 J.

Calculate the enthalpy change,  $\Delta H$ , for the reaction.

Include a sign in your answer. Give your answer to **one** decimal place.



enthalpy change,  $\Delta H = \dots\dots\dots \text{kJ mol}^{-1}$  [2]

- (ii) The student noticed that some  $\text{MgSO}_4(\text{s})$  in **Experiment 1** was left undissolved.

State and explain the effect this would have on the value of the enthalpy change for the reaction in **Experiment 1**.

effect .....

explanation .....

[1]

[Total: 14]

- 2 A student is asked to determine the acid dissociation constant,  $K_a$ , for butanoic acid,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ .

$$K_a = \frac{[\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}]}$$

The student is told to measure the pH of eight buffer solutions containing  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$  and the salt sodium butanoate,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-\text{Na}^+$ . The salt provides butanoate ions,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-$ , as the base.

Each buffer solution contains a different ratio of  $[\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}]$  to  $[\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-]$ .

Each buffer solution is prepared by mixing different volumes of distilled water,  $2.00 \text{ mol dm}^{-3}$   $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$  and  $2.00 \text{ mol dm}^{-3}$   $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-\text{Na}^+$ .

- (a) Pure butanoic acid must be kept away from naked flames.

Explain why.

..... [1]

- (b) (i) What is the maximum volume of a  $2.00 \text{ mol dm}^{-3}$  solution that can be prepared using 55.0 g of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-\text{Na}^+(\text{s})$ ?

[ $A_r$ : Na, 23.0; O, 16.0; C, 12.0; H, 1.0]

volume = .....  $\text{cm}^3$  [1]



- (ii) A student is given 55.0 g of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-\text{Na}^+(\text{s})$  in a beaker.

Describe the next steps the student should take to make a  $2.00\text{ mol dm}^{-3}$  solution of the volume calculated in (b)(i).

Give the name and capacity of any key apparatus which should be used.

Write your answer as a series of numbered steps.

.....

.....

.....

.....

.....

.....

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.....

.....

.....

.....

.....

.....

..... [3]

- (iii) Complete the table to show the volumes of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-\text{Na}^+(\text{aq})$  and distilled water that would be needed to provide the stated number of moles of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$  and  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-$  for a  $50.0\text{ cm}^3$  buffer solution.

moles of $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$	volume of $2.00\text{ mol dm}^{-3}$ $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ / $\text{cm}^3$	moles of $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-$	volume of $2.00\text{ mol dm}^{-3}$ $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-\text{Na}^+$ / $\text{cm}^3$	volume of distilled water / $\text{cm}^3$
0.050	25.0	0.005		
0.050	25.0	0.008		
0.050	25.0	0.010		
0.050	25.0	0.025		
0.030	15.0	0.050		
0.010	5.0	0.050		
0.006	3.0	0.050		
0.004	2.0	0.050		

[2]

(c) The pH of each buffer solution is measured.

The value of the pH is recorded in the table along with the number of moles of the  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$  and  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-$  in each  $50\text{ cm}^3$  solution of buffer.

(i) Complete the table. Give your values of  $-\log\left(\frac{[\text{acid}]}{[\text{base}]}\right)$  to **two** decimal places.

moles of acid, $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$	moles of base, $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-$	ratio of [acid]/[base]	$-\log\left(\frac{[\text{acid}]}{[\text{base}]}\right)$	pH
0.050	0.005	10.00		3.82
0.050	0.008	6.25		4.01
0.050	0.010	5.00		4.12
0.050	0.025	2.00		4.70
0.030	0.050	0.60		5.04
0.010	0.050	0.20		5.52
0.006	0.050	0.12		5.74
0.004	0.050	0.08		5.91

[1]

(ii) Plot a graph of pH (y-axis) against  $-\log\left(\frac{[\text{acid}]}{[\text{base}]}\right)$  (x-axis) on the grid on page 9.

Use a cross (x) to plot each data point. Draw a line of best fit.

[2]

(iii) Circle the point on the graph you consider to be most anomalous.

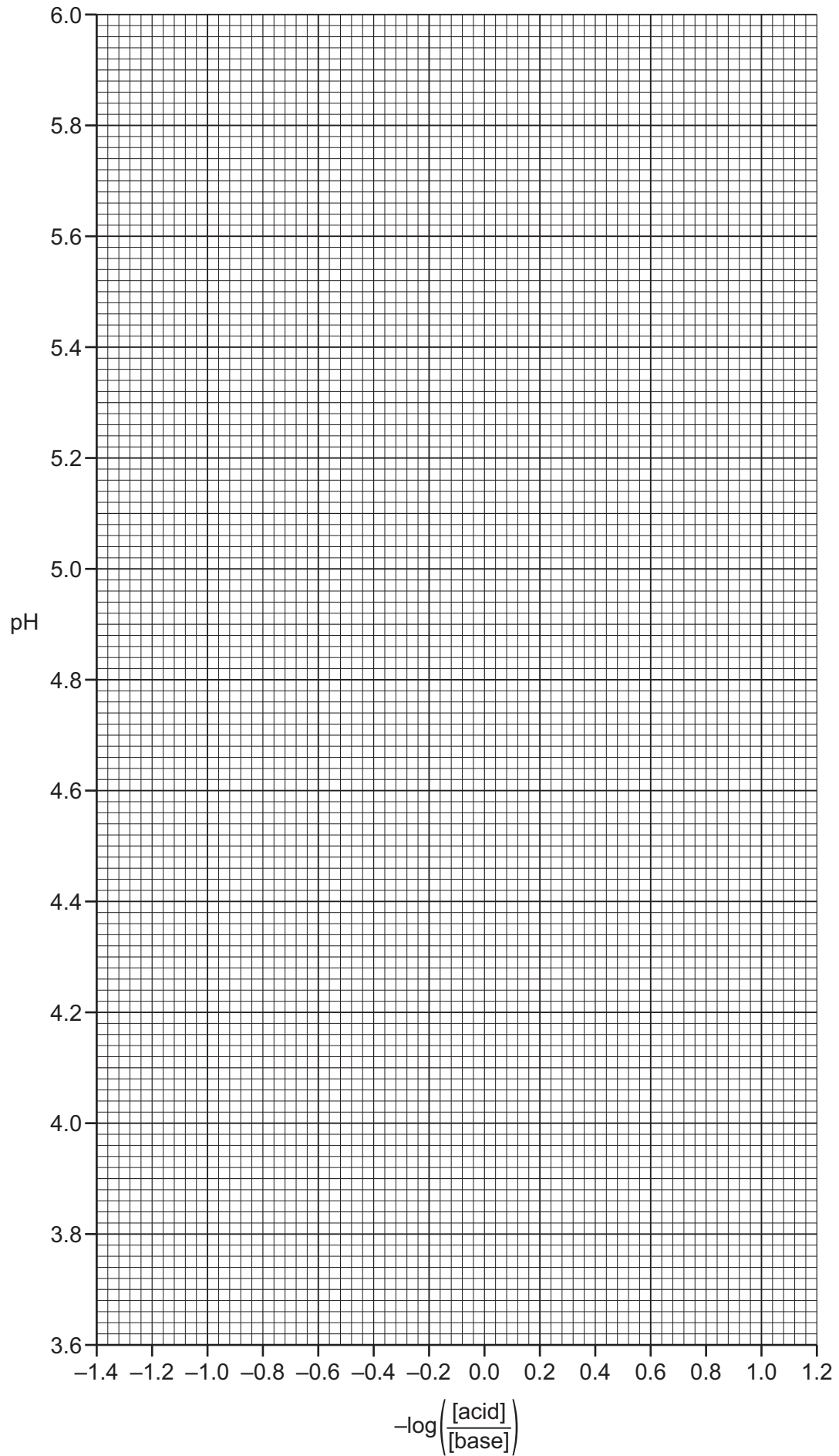
Suggest **one** reason why this anomaly may have occurred during this experimental procedure. Assume no error was made in recording the pH.

.....  
 ..... [2]

(iv) When the concentration of acid is equal to the concentration of base,  $\text{pH} = \text{p}K_a$ .

Use this information and your graph to find the value for the  $\text{p}K_a$ .

$\text{p}K_a = \dots\dots\dots$  [1]



- (v) Use your answer to (c)(iv) to calculate the value of  $K_a$ . State the units of  $K_a$ . Give your answer to **three significant figures**.

$$pK_a = -\log K_a$$

$$K_a = \dots\dots\dots$$

$$\text{units} = \dots\dots\dots$$

[2]

- (d) The value of  $pK_a$  is lower when the experiment is repeated at a higher temperature.

What does this tell you about the enthalpy of dissociation of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ ?

Explain your answer.

.....

..... [1]

[Total: 16]



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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**October/November 2021**

**1 hour 15 minutes**

You must answer on the question paper.

No additional materials are needed.

### INSTRUCTIONS

- Answer **all** questions.
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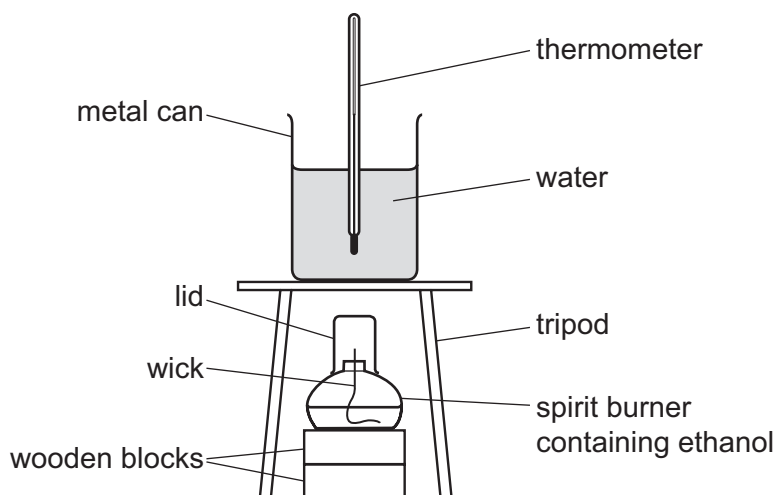
### INFORMATION

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- 1 It is possible to measure the enthalpy change of combustion,  $\Delta H_c$ , of ethanol,  $C_2H_5OH$ , using the following apparatus.



A student carries out an experiment to determine the value for  $\Delta H_c$  of ethanol using the following instructions:

- Weigh the spirit burner with ethanol and lid, record the starting mass to two decimal places.
- Measure  $100.00\text{ cm}^3$  of water and place it into the metal can.
- Place a thermometer, with  $0.1\text{ }^\circ\text{C}$  graduations, into the water and stir it, wait for 2 minutes.
- Record the temperature of the water.
- Light the wick and allow the flame to heat the water.
- Continue to stir the water using the thermometer.
- After the temperature has risen by approximately  $20\text{ }^\circ\text{C}$  place the lid on the flame to extinguish it.
- Record the maximum temperature of the water.
- Weigh the spirit burner and record the final mass.

The student obtained the following results.

initial temperature of water/ $^\circ\text{C}$	maximum temperature of water/ $^\circ\text{C}$	change in temperature of water, $\Delta T/^\circ\text{C}$	initial mass of spirit burner/g	final mass of spirit burner/g	mass of ethanol burned/g
18.1	38.2		153.29	152.76	

(a) Complete the table. Record your answers to the correct number of decimal places. [1]

(b) Calculate the number of moles of ethanol burned. Give your answer to **three** significant figures.

[ $A_r$ : C, 12.0; H, 1.0; O, 16.0]

moles of ethanol = ..... [1]



- (c) Use the formula  $q = mc\Delta T$  to determine the energy change,  $q$ , that took place during the experiment. Use  $q$  and your answer to (b) to calculate the enthalpy change of combustion of ethanol,  $\Delta H_c$ , in  $\text{kJ mol}^{-1}$ .

Include a sign in your answer.

1.00  $\text{cm}^3$  of water has a mass of 1.00 g  
 $c = 4.18 \text{ J g}^{-1} \text{ K}^{-1}$

$$\Delta H_c = \dots\dots\dots \text{ kJ mol}^{-1} \quad [2]$$

- (d) Calculate the percentage error of the temperature change recorded in the table in (a).

Show your working.

$$\text{percentage error} = \dots\dots\dots [1]$$

- (e) State the effect, if any at all, on the accuracy of the experiment if the spirit burner was allowed to burn for longer. Explain your answer.

.....  
 .....  
 .....  
 ..... [1]

- (f) The flame was extinguished, but the lid of the spirit burner was not replaced immediately.

Predict how this would affect the value of  $\Delta H_c$ . Explain your answer.

.....  
 .....  
 .....  
 ..... [2]

(g) The value for  $\Delta H_c$  of ethanol under standard conditions is  $-1367 \text{ kJ mol}^{-1}$ .

- (i) Other than the reaction not being carried out under standard conditions, suggest **two** reasons why the value the student obtained in (c) is different from the actual value.

1 .....

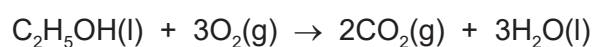
.....

2 .....

.....

[2]

- (ii) It is possible to calculate  $\Delta H_c$  of ethanol using average bond enthalpies and the chemical equation for the reaction.



Using average bond enthalpies,  $\Delta H_c$  of ethanol is  $-1297 \text{ kJ mol}^{-1}$ .

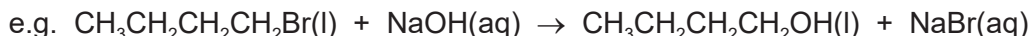
Explain why this value is different from the actual value for  $\Delta H_c$  of ethanol under standard conditions.

.....

..... [1]

[Total: 11]

2 Halogenoalkanes undergo hydrolysis with aqueous sodium hydroxide to form alcohols.



A student carried out an experiment to compare the rate at which three halogenoalkanes, 1-chlorobutane,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl}$ , 1-bromobutane,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$ , and 1-iodobutane,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{I}$ , undergo hydrolysis. The method used was as follows:

- Place a  $5\text{ cm}^3$  sample of each halogenoalkane into separate test-tubes.
- Add  $1\text{ cm}^3$  of organic solvent to each test-tube.
- Add  $2\text{ cm}^3$  aqueous sodium hydroxide to each test-tube.
- Add 3 drops of acid–base indicator to the mixture.
- Heat the test-tubes in a thermostatically controlled, electrically heated water bath.
- Record the time taken for the indicator to change colour.

(a) Give **two** reasons why the experiment was carried out using an electrically heated water bath.

1 .....

.....

2 .....

.....

[2]

(b) Sodium hydroxide is corrosive.

Apart from wearing safety glasses and a lab coat, state **one** safety precaution which must be taken when handling sodium hydroxide.

..... [1]

(c) Suggest why an organic solvent must be used in this experiment.

.....

..... [1]

(d) Why is acid–base indicator added to the reaction mixture?

.....

..... [1]

(e) The student obtained the following results.

halogenoalkane	time taken for indicator to change colour/s	$\frac{1}{\text{time}}/\text{s}^{-1}$
1-chlorobutane	417	
1-bromobutane	238	
1-iodobutane	135	

(i) Complete the table to show  $\frac{1}{\text{time}}$ . [1]

(ii)  $\frac{1}{\text{time}}$  can be used to represent rate of reaction.

Suggest what the  $\frac{1}{\text{time}}$  values tell you about the trend in carbon-halogen bond enthalpies.

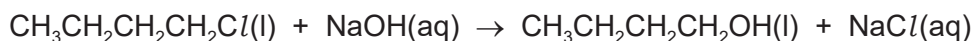
.....  
 ..... [1]

(f) Identify **one** additional variable that must be controlled in this experiment.

..... [1]

**Question 2 continues on the next page.**

- (g) The student decided to investigate the order of reaction with respect to aqueous sodium hydroxide.



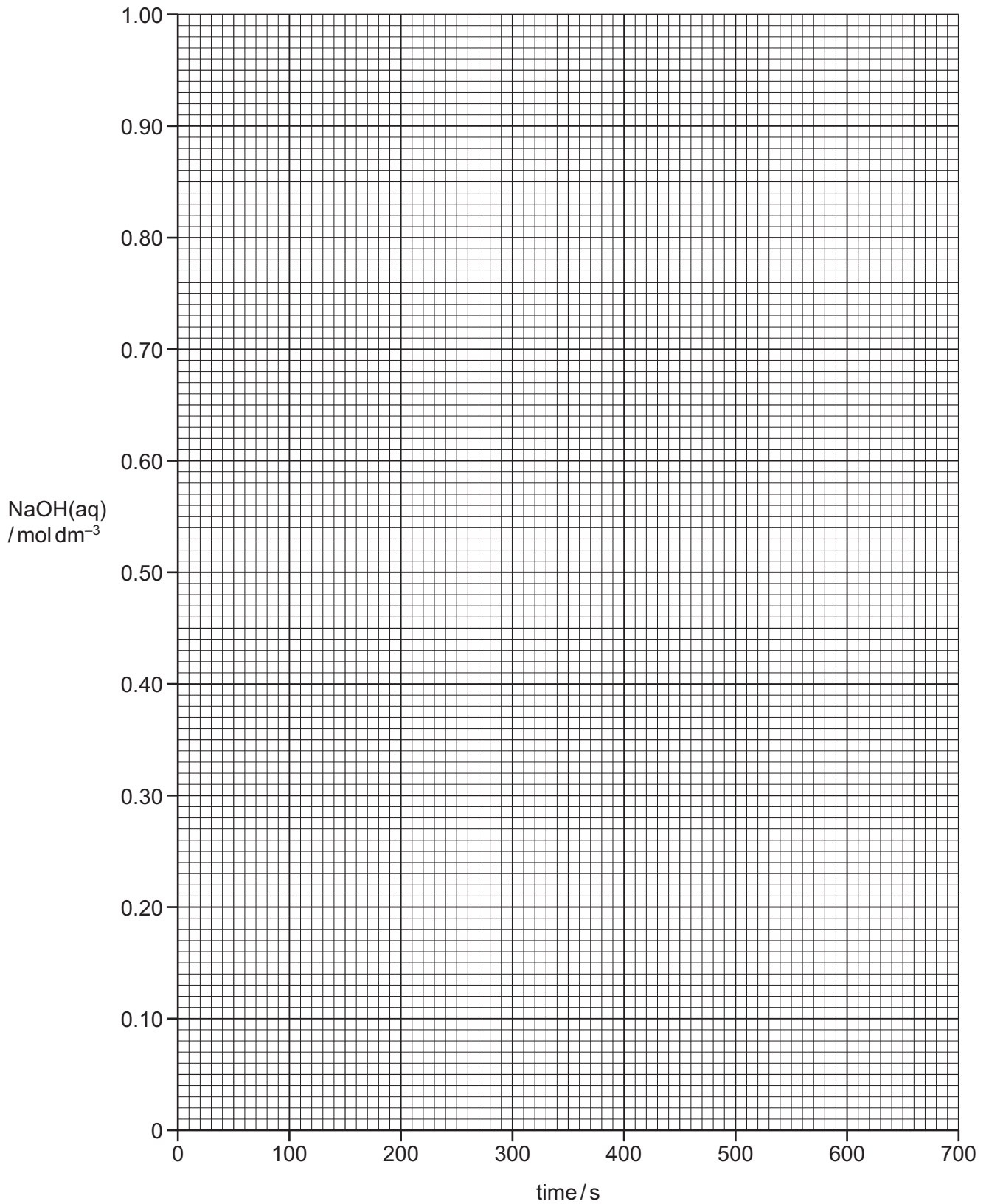
- step 1 An excess of 1-chlorobutane was mixed with  $1.00 \text{ mol dm}^{-3}$  NaOH(aq), at room temperature.
- step 2 A stop-clock was immediately started.
- step 3 At intervals of 60 seconds the student took  $10.00 \text{ cm}^3$  samples from the reaction mixture, for 11 minutes.
- step 4 Each  $10.00 \text{ cm}^3$  sample was immediately added to ice in a conical flask.
- step 5 The concentration of NaOH(aq) in each sample was determined by titration.

The results are shown.

time/s	concentration of NaOH(aq)/ $\text{mol dm}^{-3}$
0	1.00
60	0.75
120	0.62
180	0.51
240	0.39
300	0.31
360	0.24
420	0.19
480	0.12
540	0.13
600	0.11
660	0.09

(i) Plot a graph of concentration of NaOH(aq) ( $y$ -axis) against time ( $x$ -axis).

Use a cross ( $\times$ ) to plot each data point. Draw a curved line of best fit.



[2]

(ii) Circle the point which you consider to be most anomalous.

[1]

(iii) Suggest **one** reason for this anomalous point.

.....  
 ..... [1]

(iv) Draw construction lines on the graph to calculate two consecutive half-lives for this reaction.

first half-life = ..... s

second half-life = ..... s  
 [2]

(v) State whether you consider this to be a first-order reaction with respect to NaOH.  
 Explain your answer.

.....  
 ..... [1]

(h) The total volume of the reaction mixture at the start of the experiment was 250 cm<sup>3</sup>.

(i) Name a piece of apparatus that could be used to remove 10.00 cm<sup>3</sup> samples from the reaction mixture.

..... [1]

(ii) Suggest why the student did not remove 25.00 cm<sup>3</sup> samples for titration from the reaction mixture.

.....  
 ..... [1]

(iii) Explain why each sample is added to ice in step 4.

.....  
 ..... [1]

(i) Another method for following the rate of a reaction is to measure changes in electrical conductivity.

Explain why this would not be a suitable method for following this reaction.

.....  
 ..... [1]

[Total: 19]





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## Cambridge International AS & A Level

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### CHEMISTRY

9701/52

Paper 5 Planning, Analysis and Evaluation

May/June 2020

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

### INSTRUCTIONS

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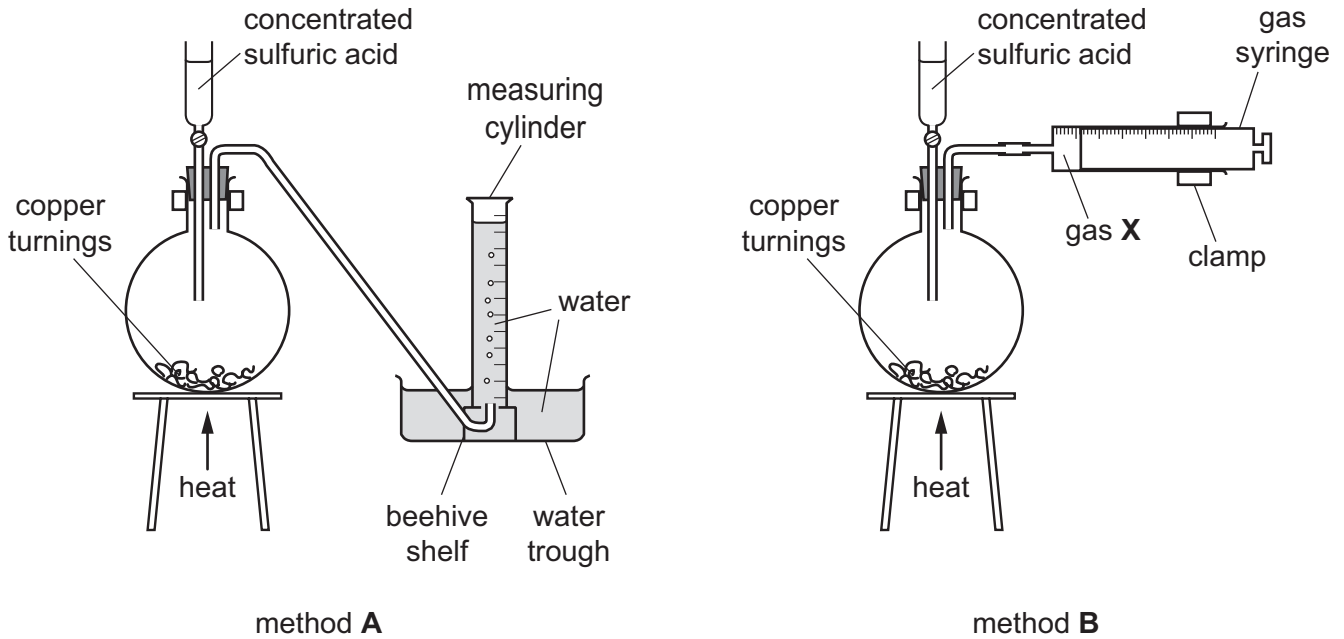
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- 1 A student plans to carry out an experiment to find the relative molecular mass,  $M_r$ , of a soluble acidic gas, **X**, by finding the mass of a measured volume of gas **X**. Gas **X** can be prepared by the reaction between concentrated sulfuric acid and copper.

Two methods of gas collection are available to the student, as shown.



- (a) (i) Explain why the first sample of gas collected from either apparatus should not be used for the  $M_r$  determination of gas **X**.

.....  
 ..... [1]

- (ii) Give **two** reasons, other than your answer to (a)(i), why, for this experiment, the apparatus in method **A** is less suitable than the apparatus in method **B** for collecting a sample of gas **X**.

reason 1 .....

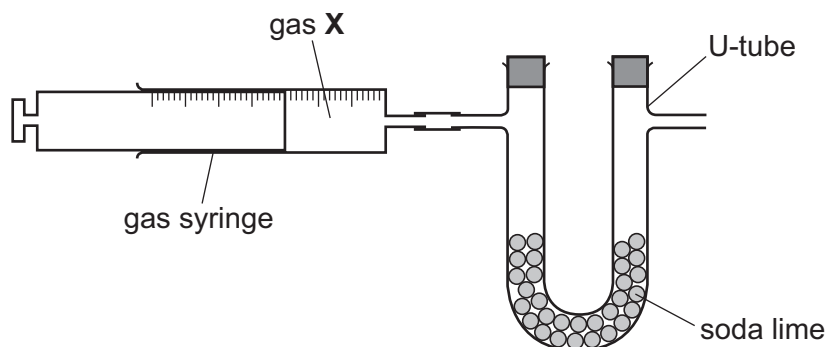
.....

reason 2 .....

.....

[2]

(b) The student is told to use the U-tube shown to find the mass of a sample of gas X.



A  $100.0\text{cm}^3$  sample of pure gas X is placed in a gas syringe. The gas syringe is attached to a U-tube containing small lumps of solid soda lime, a mixture of sodium hydroxide and calcium hydroxide. All of gas X is slowly passed into the U-tube and the mass of gas X absorbed determined.

The temperature and the pressure of the room are recorded.

(i) State the measurements that are needed to determine the mass of gas X absorbed.

.....  
 ..... [1]

(ii) Suggest why soda lime is used to absorb gas X.

.....  
 ..... [1]

(c) Gas X can cause respiratory distress.

State an appropriate precaution that should be taken when doing this experiment.

.....  
 ..... [1]

(d) Experiment 1 is carried out at a temperature of 21 °C, a pressure of  $9.8 \times 10^4$  Pa, and uses 100 cm<sup>3</sup> of pure gas X.

(i) Calculate the number of moles of gas X present in Experiment 1.

You should assume that gas X behaves like an ideal gas and so use  $PV = nRT$ .

$$R = 8.31 \text{ JK}^{-1} \text{ mol}^{-1}$$

moles of gas X = ..... mol [2]

(ii) The sample of gas X is found to have a mass of 0.251 g.

Explain how the student should use this information and their results to determine the  $M_r$  of X.

.....  
 .....  
 ..... [1]

(iii) Not all of gas X is absorbed by the soda lime.

State what effect, if any, this has on the student's calculated value of the  $M_r$  of gas X.

.....  
 ..... [1]

(iv) In Experiment 2, the same mass of gas X is used, but the student did not record the temperature and pressure.

The calculated  $M_r$  of X for Experiment 2 is higher than the value calculated by the student for Experiment 1.

State and explain how the value of  $\frac{P}{T}$  changes from Experiment 1 to Experiment 2.

.....  
 .....  
 ..... [1]

(e) State how the reliability of the results in Experiment 1 could be improved.

.....  
..... [1]

(f) A different gas, methylamine, is alkaline.

State a change that would have to be made to the apparatus so that the  $M_r$  of methylamine could be determined.

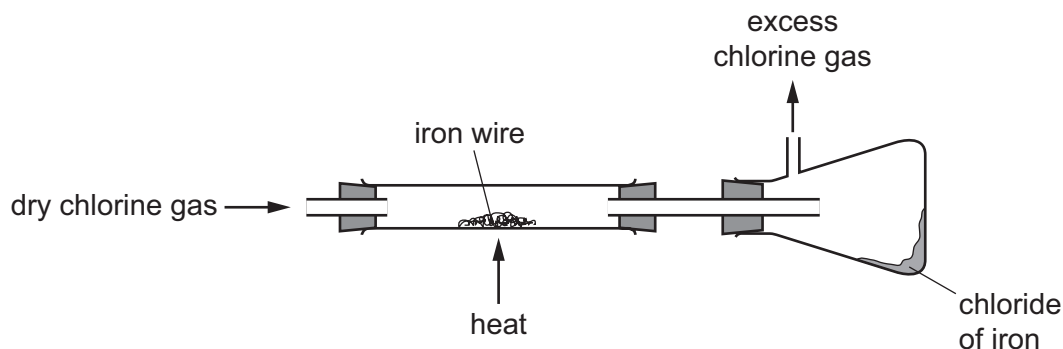
.....  
..... [1]

[Total: 13]





- 2 Each student in a class of nine students performs an experiment to find the formula of a chloride of iron. Each student prepares the chloride of iron by passing a stream of chlorine gas over a sample of iron wire as shown in the diagram.



- (a) Each student carries out the following steps in the order shown in the list. Some of the measurement steps are missing from the list.

- Weigh the reaction tube containing a quantity of iron wire.
- Set up the apparatus as shown in the diagram.
- Start the flow of dry chlorine gas.
- Heat the iron wire until it has completely reacted.
- Allow the apparatus to cool, with chlorine gas still flowing.
- Weigh the side-arm conical flask containing the chloride of iron.

- (i) State the **two** additional measurement steps that each student must perform in order to find the formula of the chloride of iron.

1 .....

2 .....

[1]

- (ii) The flow of dry chlorine gas must start before the iron wire is heated.

Explain why.

.....

..... [1]

- (iii) State an assumption that has to be made for the measurements made in this experiment to be valid.

.....

..... [1]

(b) (i) The class results are shown in the table.

student	mass of iron wire /g	mass of iron chloride /g	mass of chlorine /g	amount of iron /mol	amount of chlorine atoms /mol
1	0.57	1.64			
2	1.10	3.16			
3	1.40	4.03			
4	1.95	5.61			
5	2.18	5.89			
6	2.75	7.90			
7	3.05	8.77			
8	3.45	9.80			
9	3.90	11.18			

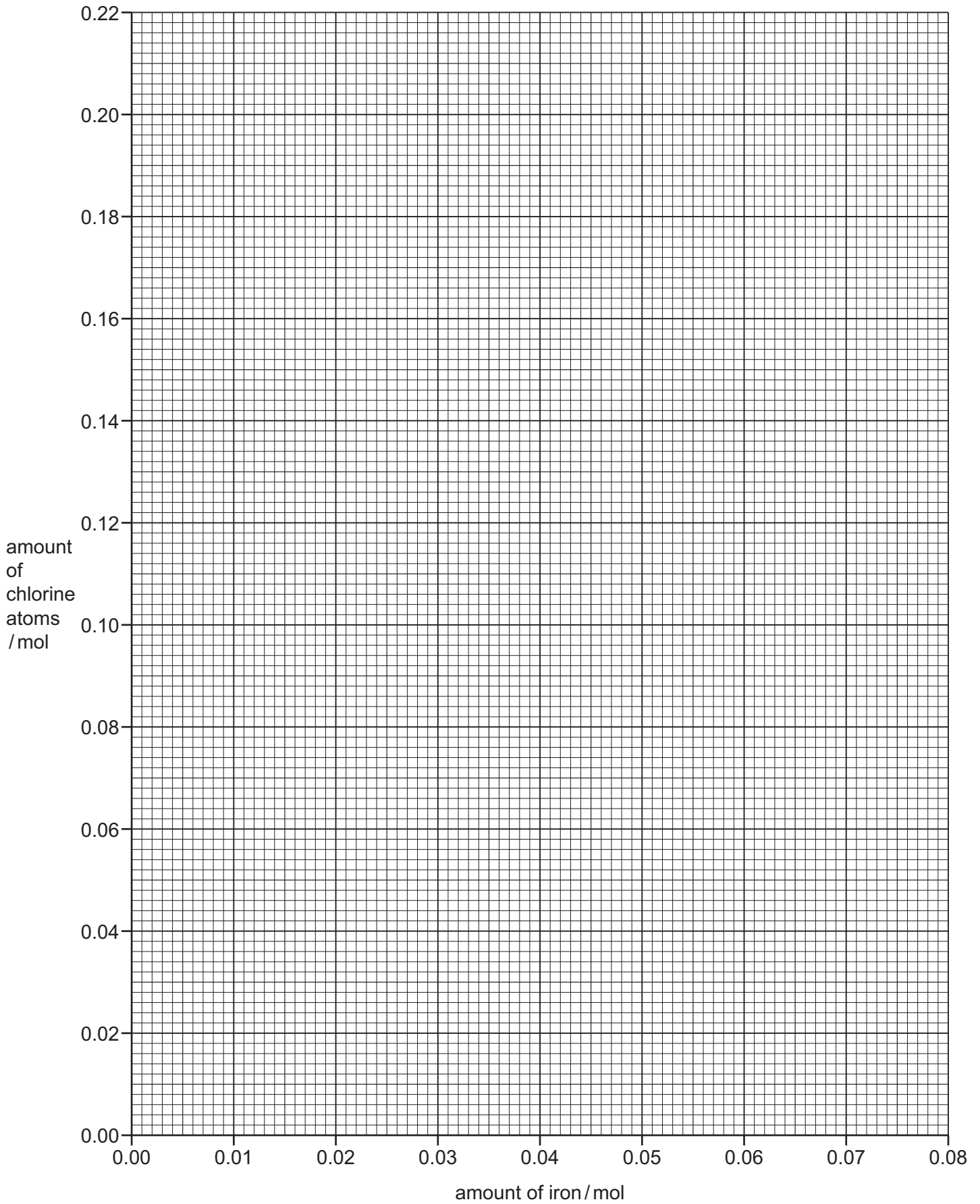
Calculate the mass of chlorine that reacts with the iron wire in each experiment. Record each mass to **two decimal places**.

Calculate the amount of iron, in mol, and amount of chlorine atoms, in mol, that reacts in each experiment. Record the number of moles to **three significant figures**.

[ $A_r$ : Fe, 55.8; Cl, 35.5]

[3]

- (ii) Plot a graph on the grid of the amount of chlorine atoms against the amount of iron. Use a cross (×) to plot each data point. Draw a line of best fit through the plotted points. You should consider whether (0,0) should be on the line of best fit. [2]



- (iii) Circle the point on the graph you consider to be most anomalous. Suggest **one** reason why this anomaly may have occurred during this experimental procedure.

.....  
 ..... [2]

- (c) Use the graph to determine the gradient of the line of best fit.

State the coordinates of both points you used in your calculation. These must be on your line of best fit.

Give your answer to **three significant figures**.

coordinates 1 ..... coordinates 2 .....

gradient = ..... [2]

- (d) The formula of the chloride of iron produced in this experiment is  $\text{FeCl}_3$ .

State how the results student 4 obtains could be used to determine this formula.

.....  
 .....  
 ..... [1]

- (e) (i) Student 3 weighs the conical flask using a balance accurate to two decimal places and records its mass. After the chloride of iron is produced the mass increases by 4.03 g.

Calculate the percentage error in measuring the mass of this chloride of iron.

percentage error = ..... % [1]

- (ii) Student 8 follows the same procedure as student 3.

State whether the results from student 8 will have more or less percentage error than those from student 3.

Explain your answer.

.....  
 ..... [1]

- (f) Another student suggested that the chloride of iron could also be prepared by the reaction between iron wire and hydrochloric acid.

- (i) A sample of a chloride of iron prepared in this way contains 44% iron by mass.

Show that the formula of this chloride of iron is  $\text{FeCl}_2$ .

[ $A_r$ : Fe, 55.8; Cl, 35.5]

[1]

- (ii) Explain, using the electrode potential values in the table, why the methods in (a) and (f) do not produce the same chlorides of iron.

reaction	electrode potential, $E^\ominus/\text{V}$
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Fe}(\text{s})$	-0.44
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+0.77

.....  
 .....  
 .....  
 ..... [1]

[Total: 17]

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## Cambridge International AS & A Level

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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**October/November 2020**

**1 hour 15 minutes**

You must answer on the question paper.

No additional materials are needed.

### INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working, use appropriate units and use an appropriate number of significant figures.

### INFORMATION

- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **12** pages. Blank pages are indicated.

- 1 Calcium hydroxide,  $\text{Ca}(\text{OH})_2$ , is slightly soluble in water. Aqueous calcium hydroxide is also known as limewater. A student measures the concentration of saturated aqueous calcium hydroxide using the following method.

**step 1** Add a spatula measure of solid calcium hydroxide to  $250\text{ cm}^3$  of distilled water in a conical flask. Stopper the flask and shake the flask thoroughly.

**step 2** Leave the flask stoppered for 24 hours.

**step 3** Filter the aqueous calcium hydroxide into a clean, dry beaker.

**step 4** Transfer  $25.00\text{ cm}^3$  of the aqueous calcium hydroxide to a clean conical flask.

**step 5** Carry out a titration with  $0.100\text{ mol dm}^{-3}$  hydrochloric acid.

**step 6** Record the volume of hydrochloric acid required to react with the aqueous calcium hydroxide.

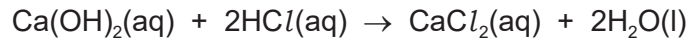
- (a) (i) Suggest why it is necessary for the flask to remain stoppered in **step 2**.

..... [1]

- (ii) Suggest why the student leaves the solution for 24 hours in **step 2**.

.....  
 ..... [1]

- (b) (i) The student finds that the mean titre is  $10.65\text{ cm}^3$ .  
 The equation for the reaction is shown.



Calculate the number of moles of calcium hydroxide that reacted.

moles of  $\text{Ca}(\text{OH})_2 = \dots\dots\dots\text{ mol}$  [1]

- (ii) Calculate the concentration of the aqueous calcium hydroxide in  $\text{g dm}^{-3}$ .  
 [ $A_r$ : Ca, 40.1; O, 16.0; H; 1.0]

concentration of  $\text{Ca}(\text{OH})_2(\text{aq}) = \dots\dots\dots\text{ g dm}^{-3}$  [2]



- (iii) In a chemistry data book, the student found the value for the concentration of a saturated solution of calcium hydroxide at 293 K to be higher than the value calculated in (b)(ii).

Give **two** reasons why the data book value is higher than the value calculated in (b)(ii). (Assume the student recorded all volumes correctly, carried out the titration accurately and recorded concordant titres.)

.....  
.....  
..... [2]

- (c) A second student carried out the experiment but did not filter their solution correctly in **step 3**, leaving some undissolved calcium hydroxide suspended in the solution.

Predict and explain how this would affect the titre obtained in their experiment.

.....  
..... [1]

- (d) Describe how to prepare exactly 250.0 cm<sup>3</sup> of 0.100 mol dm<sup>-3</sup> hydrochloric acid from 1.00 mol dm<sup>-3</sup> hydrochloric acid. Include the names and capacities of any suitable apparatus used.

.....  
.....  
.....  
..... [2]

[Total: 10]

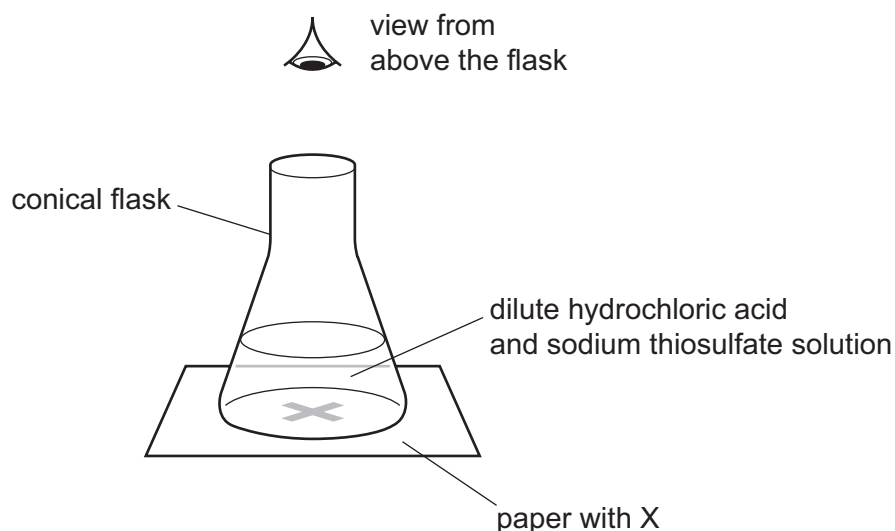
- 2 Sodium thiosulfate reacts with excess dilute hydrochloric acid according to the following equation.



The reaction produces sulfur dioxide which is corrosive and toxic by inhalation.

The effect of temperature on the rate of this reaction can be investigated by the 'disappearing cross experiment' as follows.

- step 1** Measure  $10.00 \text{ cm}^3$  of  $0.100 \text{ mol dm}^{-3}$   $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$  and transfer into a boiling tube.
- step 2** Into a second boiling tube, transfer  $10 \text{ cm}^3$  of  $0.500 \text{ mol dm}^{-3}$   $\text{HCl}(\text{aq})$ .
- step 3** Heat both tubes in the same water-bath.
- step 4** Place a conical flask on a piece of paper, on which is drawn a large X.
- step 5** When the solutions reach the required temperature, remove them from the water-bath, pour the contents of both tubes into the conical flask and immediately start a timer.
- step 6** The X on the paper should be viewed from above the flask as shown in the diagram.
- step 7** When the X can no longer be seen, due to formation of solid sulfur, stop the timer.
- step 8** Repeat the experiment using the same volumes and concentrations of solution at different temperatures.



- (a) State **one** precaution that should be taken to reduce a hazard caused by one of the products of this reaction.

.....  
..... [1]

- (b) Suggest appropriate equipment for measuring the required volumes of  $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$  and  $\text{HCl}(\text{aq})$  stated in the method.

$\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$  .....

$\text{HCl}(\text{aq})$  ..... [1]

The student recorded their data in the table.

A	B	C	D	E	F
temperature /°C	temperature, $T$ /K	time, $t$ , for cross to disappear/s	rate of reaction $\left(\frac{1}{t}\right)/\text{s}^{-1}$	$\frac{1}{T}/\text{K}^{-1}$	$2.303 \log\left(\frac{1}{t}\right)$
60	333	7.39	0.135		-2.00
50	323	13.46	0.0743		-2.60
41	314	21.12	0.0473		-3.05
36	309	40.45	0.0247		-3.70
27	300	49.40	0.0202		-3.90
21	294	70.11	0.0143		-4.25

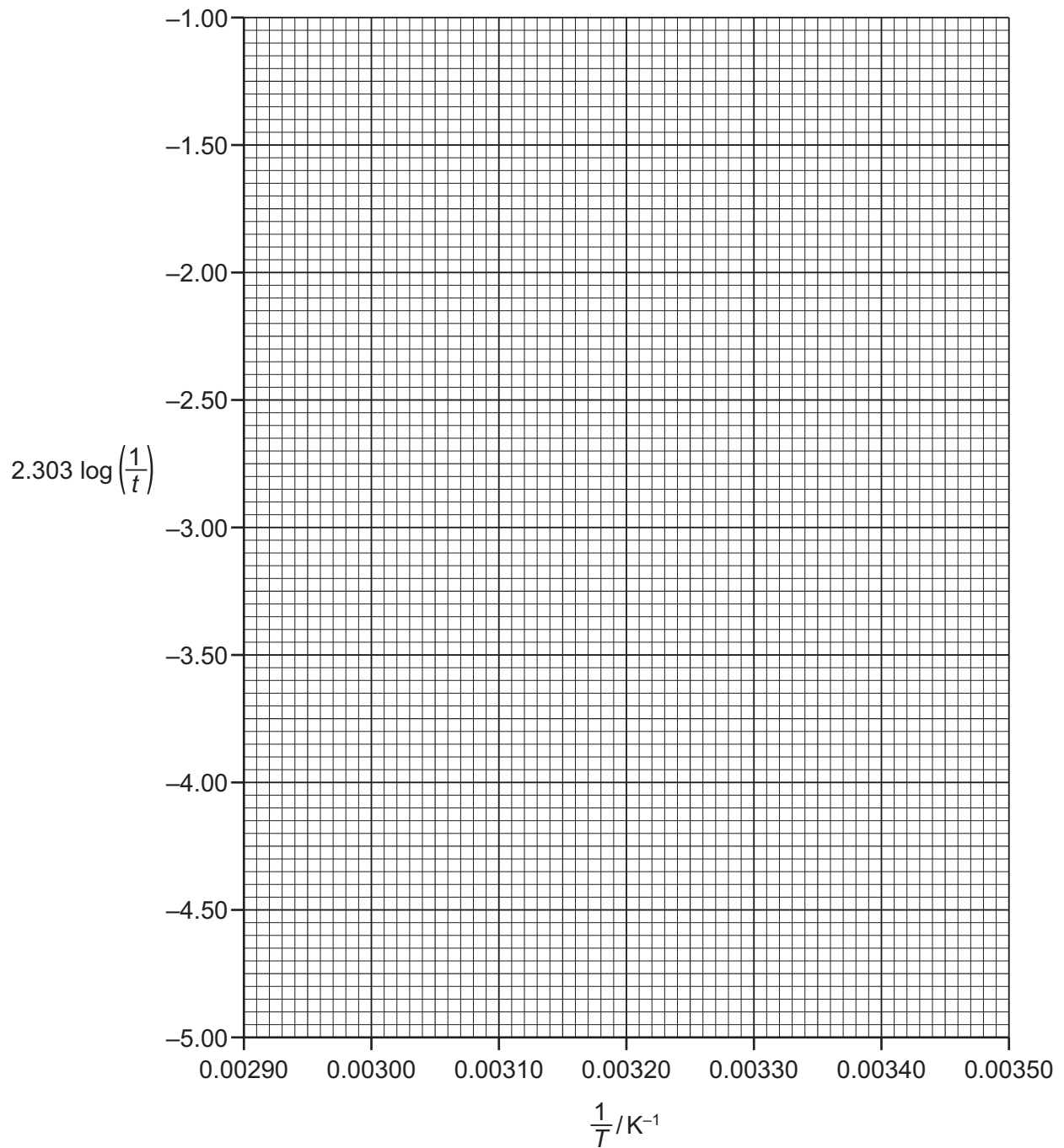
(c) Complete column E in the table, giving your values to **three significant figures**. [1]

- (d) The activation energy,  $E_a$ , of the reaction between sodium thiosulfate and hydrochloric acid can be calculated using the equation shown.

$$2.303 \log \left( \frac{1}{t} \right) = -E_a / RT$$

$$R = 8.31 \text{ JK}^{-1} \text{ mol}^{-1}$$

- (i) Plot a graph of  $2.303 \log \left( \frac{1}{t} \right)$  on the y-axis and  $\frac{1}{T}$  on the x-axis. Draw a line of best fit.



[2]

- (ii) Circle the point on the graph you consider to be most anomalous.

Suggest **two** possible errors in how the procedure was carried out which could have caused this anomalous point.

1 .....

.....

2 .....

.....

[2]

- (iii) Use the graph to determine the gradient of the line of best fit.

State the coordinates of both points you used in your calculation. These must be selected from your line of best fit.

Give the gradient to **three significant figures**.

coordinates 1 ..... coordinates 2 .....

gradient = ..... K  
[2]

- (iv) Use the gradient you have calculated and the equation to calculate  $E_a$ , in  $\text{kJ mol}^{-1}$ , for the reaction.

Give your answer to **two significant figures**. Include a sign.

$E_a = \dots\dots\dots \text{kJ mol}^{-1}$  [3]

- (e) A student repeats the experiment at 60 °C but with a different concentration of Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>(aq). The new solution is named solution **B**. The time taken until X can no longer be seen is 11.52 s.

Assume no error was made in the timing.

State whether the concentration of solution **B** is more or less than 0.10 mol dm<sup>-3</sup>.

Explain your answer.

.....  
.....  
..... [1]

- (f) It is more appropriate for the values in column C of the table on page 6 to be recorded to the nearest second.

Suggest **one** reason for this.

.....  
..... [1]

[Total: 14]

- 3 A student investigates the reaction between magnesium and hydrochloric acid to determine the order of reaction with respect to hydrochloric acid.

The student is supplied with  $2.00 \text{ mol dm}^{-3}$  hydrochloric acid and six identical, clean pieces of magnesium ribbon.

In experiment 1, the student places  $50 \text{ cm}^3$  of  $2.00 \text{ mol dm}^{-3}$  hydrochloric acid in a  $100 \text{ cm}^3$  beaker and adds a piece of magnesium ribbon to the acid in the beaker. The student records how long it takes for the magnesium ribbon to disappear.

The student carries out five further experiments, diluting the  $2.00 \text{ mol dm}^{-3}$  hydrochloric acid each time to provide results from five different concentrations of acid.

The student carries out each experiment in a  $100 \text{ cm}^3$  beaker.

- (a) (i) Complete the table so the student can use it to record the reaction time for each experiment. The table should include suggested volumes of acid and water for each experiment. Columns should be suitably labelled.

experiment number			
1			
2			
3			
4			
5			
6			

[2]

- (ii) Identify the dependent variable in this experiment.

..... [1]

- (iii) Apart from the magnesium ribbon, identify **one** variable that should be controlled in these experiments.

..... [1]



- (b) Explain why the student's proposed method of determining the reaction time may lead to inaccuracies in the recorded results.

.....  
..... [1]

- (c) Suggest **one** other variable that could be measured to determine the order of the reaction.

.....  
..... [1]

[Total: 6]

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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**May/June 2019**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**MODIFIED LANGUAGE**

**READ THESE INSTRUCTIONS FIRST**

Write your centre number, candidate number and name 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.

Do not use staples, paper clips, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

You may lose marks if you do not show your working or if you do not use appropriate units.

Use of a Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.

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

This document consists of **10** printed pages and **2** blank pages.

- 1 (a) A student is provided with samples of six metal carbonate ores, known to be ores of the metals barium, calcium, copper, iron, lead and zinc. All the ores contain carbonate ions and some might also contain hydroxide ions.

Each ore sample is ground up and a measured mass of the ore is reacted with an excess of dilute hydrochloric acid. The carbon dioxide produced by the reaction is collected over water. The volume of gas collected is recorded. Each ore is tested three times.

- (i) Name the independent variable.

.....

Name the dependent variable.

.....

[2]

- (ii) Apart from mass of ore, state a variable that should be controlled.

..... [1]

- (iii) The student plans to collect the carbon dioxide produced over water.

Draw a labelled diagram of the apparatus that could be used to do these experiments. The apparatus should allow the accurate recording of the carbon dioxide produced.

[3]

- (b) State **one** weakness in the procedure of collecting carbon dioxide over water. Suggest a change in apparatus that could be made to avoid this problem.

weakness in procedure

.....

change in apparatus

.....

[2]

- (c) Three experiments for each of the six ores are done and the final gas volumes are recorded in the table. All 18 experiments use exactly the same mass of ore.

metal	ore	volume of CO <sub>2</sub> collected/cm <sup>3</sup>			
		Expt 1	Expt 2	Expt 3	calculated average
barium	witherite	67	70	69	69
calcium	calcite	81	79	82	81
copper	malachite	47	45	46	46
iron	siderite	68	55	70	64
lead	cerussite	75	73	72	73
zinc	smithsonite	53	55	52	53

- (i) The student uses the results to obtain an average volume of CO<sub>2</sub> produced for each ore and records it in the table.

Suggest another reason why each ore is tested three times.

.....  
 ..... [1]

- (ii) The student made an error in processing the data to obtain the average volume of CO<sub>2</sub> produced for one of the ores.

State the error made by the student and calculate the correct value.

error .....

correct value = ..... cm<sup>3</sup>  
 [1]

- (d) A second student suggested that the percentage of carbonate ions could be obtained by titrating the ground-up ore samples with hydrochloric acid.

Explain why a titration would **not** be a suitable method to determine the percentage of carbonate ions in some of these ore samples.

.....  
 ..... [1]

Rhodochrosite is the carbonate ore of manganese and does not contain hydroxide ions.

- (e) (i) 2.00 g of rhodochrosite produced 148 cm<sup>3</sup> of carbon dioxide under room conditions in its reaction with excess hydrochloric acid.



Calculate the percentage of MnCO<sub>3</sub> in rhodochrosite. Give your answer to **three significant figures**.

The molar volume of a gas is 24.0 dm<sup>3</sup> under room conditions.

[A<sub>r</sub>: Mn, 54.9; C, 12.0; O, 16.0]

percentage of MnCO<sub>3</sub> in rhodochrosite = ..... %  
[3]

A teacher suggested that the mass change from the thermal decomposition of a ground-up sample of rhodochrosite could be used to determine the percentage of carbonate in the sample. The teacher told the students to strongly heat a ground-up sample of the ore in a crucible.

- (ii) State the measurements the students should make to determine the percentage of manganese carbonate in the sample of rhodochrosite.

.....  
.....  
..... [1]

- (iii) Explain how the students can ensure the results in (e)(ii) are as accurate as possible.

.....  
..... [1]

[Total: 16]

- 2 (a) An investigation is done to find the percentage of copper in a brass nail. The brass nail is dissolved in concentrated nitric acid and the resulting solution is diluted with distilled water.

$\text{Cu}^{2+}$  ions are formed in this reaction.

Use the electrode potentials shown to write a balanced ionic equation for the reaction between the copper in the brass nail and the concentrated nitric acid.

equation	electrode potential, $E^\ominus/\text{V}$
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{Cu}^{2+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Cu}^+(\text{aq})$	+0.15
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	+0.34
$\text{NO}_3^-(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{NO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$	+0.81

..... [2]

- (b) A balance accurate to two decimal places was used to weigh a small beaker and the mass of the beaker recorded.  
The brass nail was placed in the beaker and the mass increased by 3.76 g.

Calculate the percentage error in measuring the mass of this nail.

percentage error = ..... %  
[1]

- (c)  $50\text{cm}^3$  of concentrated nitric acid was added to the nail in the beaker. When the reaction finished and the nail had dissolved, the solution was completely transferred to a  $250.0\text{cm}^3$  volumetric flask along with the washings. The solution was made up to the mark with distilled water.

Concentrated nitric acid is corrosive.

State **one** precaution related to this hazard that must be taken when using concentrated nitric acid.

.....  
..... [1]

- (d) (i) A colorimeter can be used to determine concentrations of metal ions in solution. When light passes through solutions of metal ions some of the light may be absorbed.

The quantity of light absorbed is called the absorbance and is measured by a colorimeter. The absorbance of solutions of known concentration of copper(II) ions can be used to determine an unknown concentration of copper(II) ions.

A solution of copper(II) nitrate of concentration  $0.800\text{ mol dm}^{-3}$  is required for this investigation.

Calculate the mass of copper(II) nitrate,  $\text{Cu}(\text{NO}_3)_2$ , needed to prepare  $100.0\text{ cm}^3$  of  $0.800\text{ mol dm}^{-3}$  solution. Give your answer to **three significant figures**.

[ $A_r$ : Cu, 63.5; N, 14.0; O, 16.0]

mass of copper(II) nitrate,  $\text{Cu}(\text{NO}_3)_2 = \dots\dots\dots\text{ g}$   
[2]



**Question 2 continues on the next page.**

Volumes of  $0.800 \text{ mol dm}^{-3}$  copper(II) nitrate are diluted with distilled water to prepare a series of ten solutions of different concentrations of copper(II) ions.

(ii) The total volume needed of each solution is  $20.00 \text{ cm}^3$ .

The absorbance of each solution is recorded in a colorimeter at a wavelength of light of  $630 \text{ nm}$  and recorded in the table.

Complete the table to show the volumes of  $0.800 \text{ mol dm}^{-3}$  copper(II) nitrate and distilled water needed to prepare each solution. Give all volumes to **two decimal places**.

solution	volume of $0.800 \text{ mol dm}^{-3}$ copper(II) nitrate / $\text{cm}^3$	volume of distilled water / $\text{cm}^3$	concentration of $\text{Cu}^{2+}(\text{aq})$ / $\text{mol dm}^{-3}$	absorbance
1	0.00	20.00	0.00	0.00
2			0.04	0.12
3			0.12	0.36
4			0.16	0.48
5			0.22	0.66
6			0.30	0.89
7			0.36	1.06
8			0.42	1.25
9			0.48	1.41
10			0.60	1.76

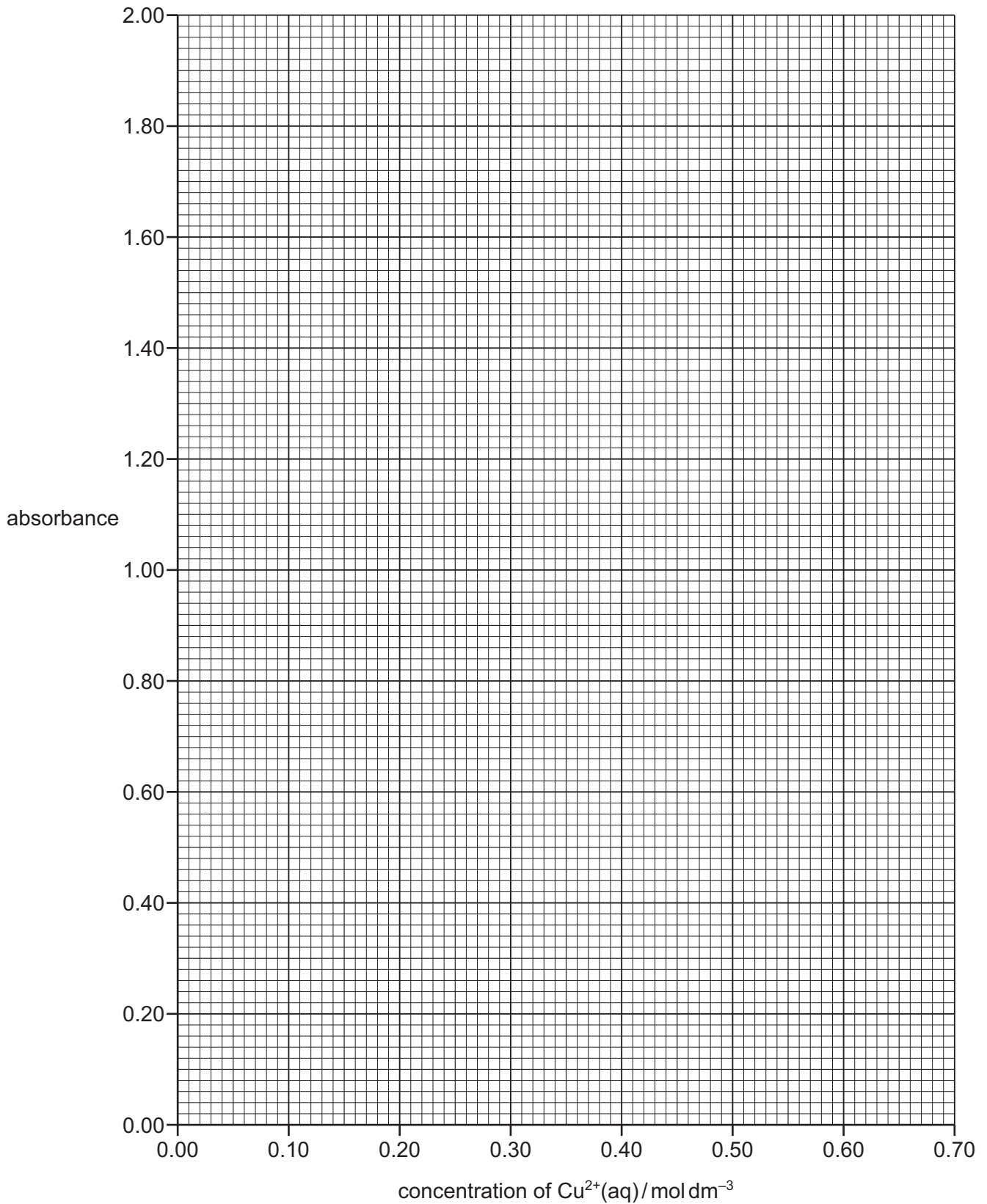
[1]

(iii) Name a suitable piece of apparatus for accurately measuring the volumes you have calculated in (d)(ii).

..... [1]

- (e) (i) The plot produced by comparing the absorbance of each solution with its concentration is referred to as a calibration graph.

Plot a calibration graph of absorbance ( $y$ -axis) against concentration of  $\text{Cu}^{2+}(\text{aq})$  ( $x$ -axis). Use a cross ( $\times$ ) to plot each data point. Draw a line of best fit.



[2]

- (ii) State the relationship between concentration of  $\text{Cu}^{2+}(\text{aq})$  and absorbance.

.....  
 ..... [1]

- (f) (i) The absorbance of the solution prepared in (c) from the brass nail was found to be 0.56.

Use your calibration graph to find the concentration of  $\text{Cu}^{2+}(\text{aq})$  in this solution.

concentration of  $\text{Cu}^{2+}(\text{aq}) = \dots\dots\dots \text{mol dm}^{-3}$  [1]

- (ii) Use your answer to (f)(i) and the information in (b) and (c) to calculate the percentage of copper, by mass, in the brass nail. Give your answer to **three significant figures**.

(If you were unable to obtain an answer to (f)(i) you may use the value  $0.22 \text{ mol dm}^{-3}$ . This is **not** the correct value.)

[A<sub>r</sub>: Cu, 63.5]

percentage of copper in the brass nail = .....%  
 [2]

[Total: 14]



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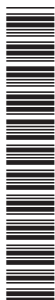
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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**October/November 2019**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your centre number, candidate number and name 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.

Do not use staples, paper clips, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

You may lose marks if you do not show your working or if you do not use appropriate units.

Use of a Data Booklet is unnecessary.

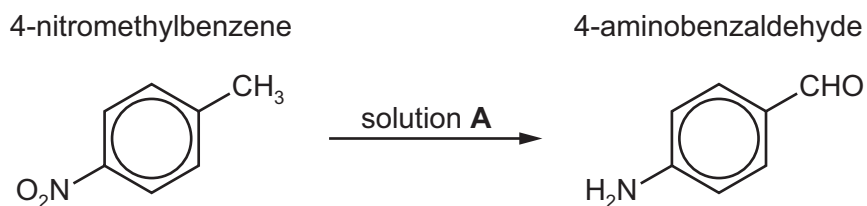
At the end of the examination, fasten all your work securely together.

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

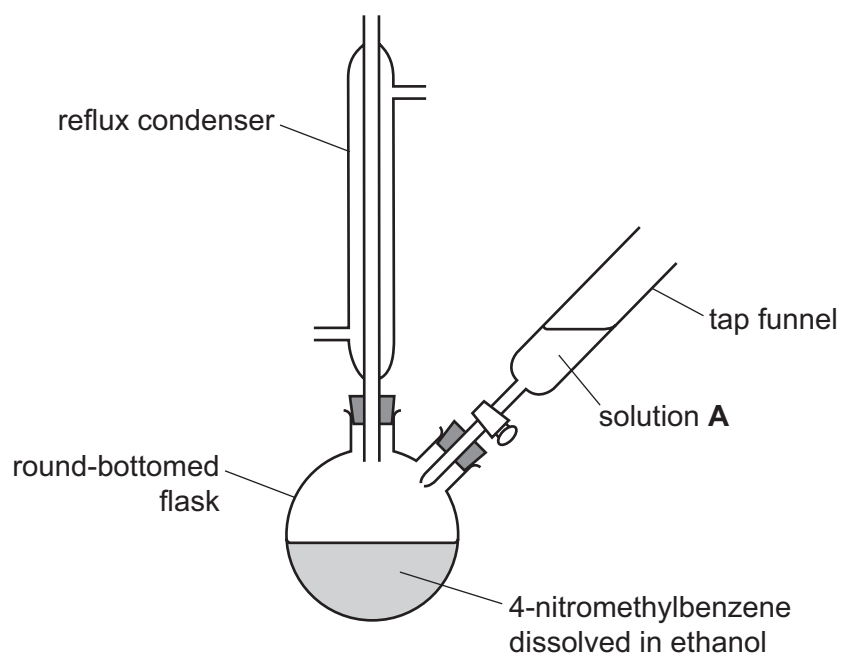
This document consists of **12** printed pages.

1 Many organic reactions performed in the laboratory require heating under reflux.

4-nitromethylbenzene can be converted directly to 4-aminobenzaldehyde by heating it under reflux with an excess of solution **A**. Solution **A** is an aqueous alkaline mixture of  $\text{Na}_2\text{S}\cdot 9\text{H}_2\text{O}$  and  $\text{S}_8$ . Ethanol is used as a solvent for the reaction.



The apparatus for this reaction is shown in the diagram.



(a) (i) Show, using a labelled arrow, where the cooling water enters the reflux condenser. [1]



- (ii) After the complete addition of solution **A** to the solution in the round-bottomed flask, a vigorous exothermic reaction takes place.

What should be done to control the vigorous exothermic reaction during the addition of solution **A**?

.....  
..... [1]

- (iii) The mixture is heated to increase the rate of reaction. This is carried out under reflux.

Other than to increase the rate of reaction, explain why a reflux process is used for heating the mixture.

.....  
..... [1]

- (iv) A student suggests that placing a bung in the top of the condenser would improve the experiment.

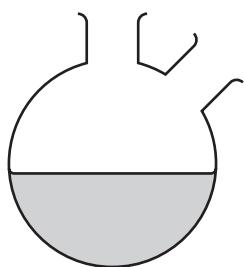
Comment on whether the student is correct. Explain your answer.

.....  
.....  
..... [1]

- (b) Once the reaction is complete, the round-bottomed flask is removed from the set-up on page 2 and included in a new set-up for distillation.

The distillation process separates the substances in the mixture in the flask.

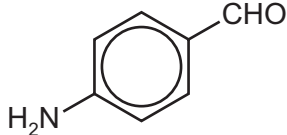
- (i) Complete and label the diagram to show how the apparatus could be set up for distillation.



[2]

- (ii) The mixture in the round-bottomed flask is heated until all of the first substance distils off. The heating is then stopped. After distillation a hot solution remains in the round-bottomed flask.

The table shows some data relevant to the experiment.

substance	melting point/°C	boiling point/°C
	72	138
H <sub>2</sub> O	0	100
CH <sub>3</sub> CH <sub>2</sub> OH	-114	78

Use the data to identify the liquid that is first distilled off.  
Explain your answer.

.....  
..... [1]

- (iii) 4-aminobenzaldehyde is soluble in hot water, but not in cold water.

Starting with the hot solution in the round-bottomed flask, suggest how pure crystals of 4-aminobenzaldehyde can be obtained.

.....  
 .....  
 ..... [2]

- (c) Under acidic conditions, 4-aminobenzaldehyde ( $C_7H_7NO$ ) forms a solid compound with molecular formula  $C_{14}H_{12}N_2O$ .



A student carries out two experiments according to the method on page 2 to make  $C_7H_7NO$ .

In Experiment 1, the student obtains 6.00 g of solid.

In Experiment 2, the student uses the same method as in Experiment 1 but adds acid to neutralise the alkali in the mixture in the flask after heating under reflux.

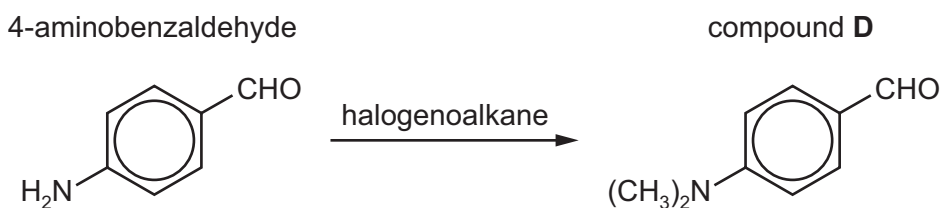
The same quantities of reagents are used in Experiment 1 and Experiment 2.

Suggest how the mass of solid obtained in Experiment 2 compares to that of Experiment 1.

Explain your answer.

.....  
 .....  
 ..... [2]

(d) 4-aminobenzaldehyde can be reacted with a halogenoalkane to form 4-(dimethylamino)benzaldehyde, compound **D**.



Some data is given that is relevant to this reaction.

halogenoalkane	boiling point /°C	carbon-halogen bond energy /kJ mol <sup>-1</sup>
CH <sub>3</sub> Cl	-97	340
CH <sub>3</sub> Br	4	280
CH <sub>3</sub> I	43	240

Give **two** reasons why CH<sub>3</sub>I is the preferred halogenoalkane in the conversion of 4-aminobenzaldehyde to compound **D**.

1 .....

.....

2 .....

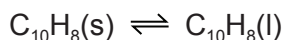
.....

[2]

[Total: 13]

- 2 Naphthalene,  $C_{10}H_8$ , is an aromatic organic compound that is a solid at room temperature and pressure.

The enthalpy change of fusion,  $\Delta H_{\text{fusion}}$ , of naphthalene is the enthalpy change that occurs when naphthalene melts. It cannot be directly measured.



The melting point of naphthalene depends on its purity. When other compounds dissolve in liquid naphthalene its melting point is lowered.

Diphenylamine,  $(C_6H_5)_2NH$ , dissolves in liquid naphthalene. By varying the amount of diphenylamine and measuring the melting points of the different mixtures, the enthalpy change of fusion of naphthalene can be calculated.

- (a) The equation that links the melting point of a naphthalene-diphenylamine mixture with its enthalpy change of fusion,  $\Delta H_{\text{fusion}}$ , is shown.

$$\log Y = A - \frac{\Delta H_{\text{fusion}}}{2.30 \times RT_m}$$

$Y$  = mole fraction of naphthalene

$R$  = molar gas constant,  $8.31 \text{ JK}^{-1} \text{ mol}^{-1}$

$T_m$  = melting point of naphthalene in K

$A$  is a constant

- (i) A series of experiments is performed using the same amount, 0.100 mol, of naphthalene each time.

Calculate the mass of naphthalene,  $C_{10}H_8$ , that should be used for each of these experiments.

[ $A_r$ : C, 12.0; H, 1.0]

mass of naphthalene = ..... g [1]

- (ii) The melting point and freezing point of a substance are the same. The melting point,  $T_m$ , of a substance can be found by recording the temperature at which the substance freezes, measured when crystals first start to appear on cooling.

The results of a series of experiments using 0.100 mol of naphthalene and different masses of diphenylamine are shown.

Process the results to complete the table.

Record all your data to **three** significant figures.

The mole fraction of naphthalene,  $Y$ , is calculated as shown.

$$Y = \frac{n_N}{n_N + n_D}$$

$n_N$  = amount in moles of naphthalene,  $C_{10}H_8$ , = 0.100

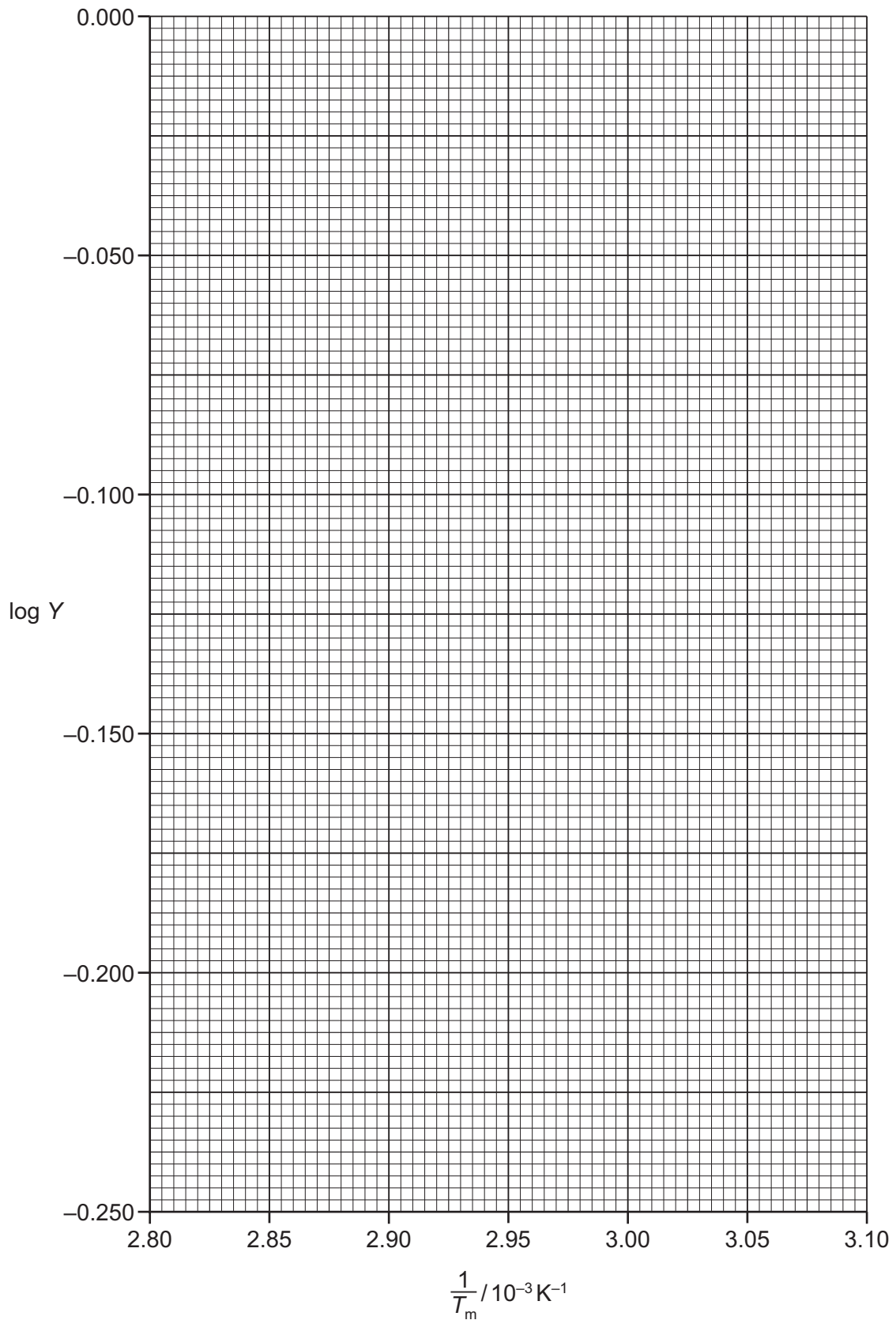
$n_D$  = amount in moles of diphenylamine,  $(C_6H_5)_2NH$

amount of $(C_6H_5)_2NH$ , $n_D$ / mol	mole fraction of $C_{10}H_8$ , $Y$	temperature at which crystals appear, $T_m$ / K	$\frac{1}{T_m}$ / $10^{-3} K^{-1}$	log $Y$
0.00	1.00	353	2.83	0.00
0.00888		349		
0.0178		345		
0.0266		341		
0.0355		338		
0.0444		334		
0.0533		331		
0.0621		329		
0.0769		325		

[3]

(b) Plot a graph on the grid to show the relationship between  $\frac{1}{T_m}$  and  $\log Y$ .

Use a cross (×) to plot each data point. Draw the straight line of best fit.



[2]

- (c) (i) Use the graph to determine the gradient of the line of best fit. State the co-ordinates of both points you used in your calculation.

co-ordinates 1 ..... co-ordinates 2 .....

gradient = ..... K  
[2]

- (ii) Use your answer to (c)(i) to determine the value of the enthalpy change of fusion of naphthalene,  $\Delta H_{\text{fusion}}$ , in  $\text{kJ mol}^{-1}$ .

$\Delta H_{\text{fusion}} = \dots\dots\dots \text{kJ mol}^{-1}$  [1]

- (d) (i) Do you consider the results obtained to be reliable? Explain your answer.

.....  
.....  
..... [1]



- (ii) Different literature values for the enthalpy change of fusion of naphthalene suggest that 10.00 g of naphthalene require between 1.45 kJ and 1.47 kJ to melt.

Use this information to calculate the range of  $\Delta H_{\text{fusion}}$  values of naphthalene,  $\text{C}_{10}\text{H}_8$ , given in literature.

Use your values to comment on the accuracy of the experimental procedure.

[ $A_r$ : C, 12.0; H, 1.0]

If you were not able to calculate  $\Delta H_{\text{fusion}}$  in (c)(ii), you may use  $18.4 \text{ kJ mol}^{-1}$ , but this may not be the correct answer.

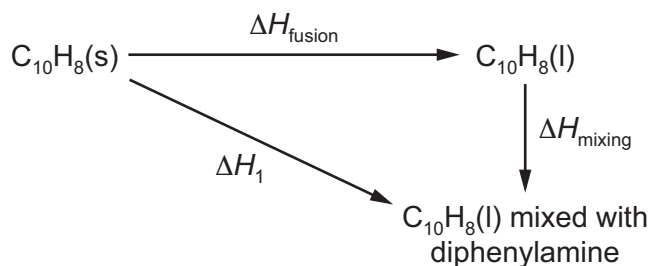
range .....  $\text{kJ mol}^{-1}$

comment .....

.....

[2]

- (e) The enthalpy change calculated in this reaction is actually  $\Delta H_1$ , shown in the Hess' cycle.



It is assumed that the enthalpy change when  $\text{C}_{10}\text{H}_8(\text{l})$  and diphenylamine are mixed,  $\Delta H_{\text{mixing}}$ , is zero, and therefore  $\Delta H_1 = \Delta H_{\text{fusion}}$ .

State how the value of  $\Delta H_1$  compares to the value of  $\Delta H_{\text{fusion}}$  if the mixing of naphthalene and diphenylamine is endothermic.

Explain your answer.

.....

.....

.....

..... [2]

- (f) A student incorrectly uses a value for the  $M_r$  of diphenylamine that is too low. This produces incorrect values for the mole fraction,  $Y$ .
- (i) Predict the effect this will have on the calculated values of  $Y$ .

Explain your answer.

$$Y = \frac{n_N}{n_N + n_D}$$

$n_N$  = amount in moles of naphthalene

$n_D$  = amount in moles of diphenylamine

.....  
 .....  
 ..... [1]

- (ii) The student uses the incorrectly calculated value of  $Y$  from (f)(i) in the determination of  $\Delta H_{\text{fusion}}$ .

$$\log Y = A - \frac{\Delta H_{\text{fusion}}}{2.30 \times RT_m}$$

Predict how the student's calculated value of  $\Delta H_{\text{fusion}}$  is different from the actual value.

Explain your answer.

.....  
 .....  
 ..... [2]

[Total: 17]

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NUMBER

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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**May/June 2018**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name 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.

Do not use staples, paper clips, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

You may lose marks if you do not show your working or if you do not use appropriate units.

Use of a Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.

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

This document consists of **11** printed pages and **1** blank page.

- 1 When concentrated iron(III) chloride is added to water at just below boiling point, a reaction occurs and produces  $\text{Fe}_2\text{O}_3$ , seen as a red colour in the water. This is a 'sol' of  $\text{Fe}_2\text{O}_3$ . A sol contains particles that are insoluble but do not form a precipitate.

A student prepared a concentrated solution of iron(III) chloride by dissolving  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}(\text{s})$  in distilled water.

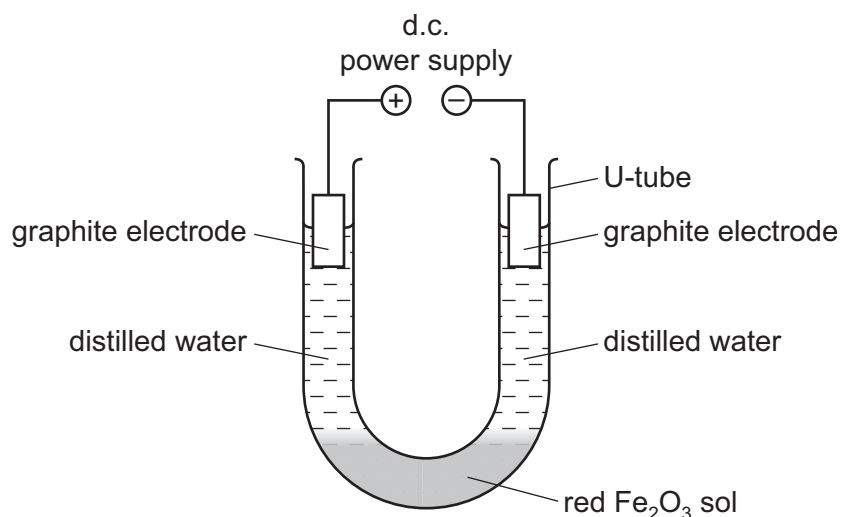
- (a) Hazard information for hydrated iron(III) chloride is given.

For this hazard, state a precaution, other than eye protection and a lab coat, that the student could take when preparing a solution of concentrated iron(III) chloride.

hazard: solid  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  is irritating to the skin

precaution ..... [1]

Particles of a sol can be positively or negatively charged. The student used the experimental set-up shown to confirm that the  $\text{Fe}_2\text{O}_3$  sol particle is positively charged.



- (b) The student placed a few  $\text{cm}^3$  of the sol at the bottom of the U-tube and poured  $10\text{cm}^3$  of distilled water into each side of the U-tube, without disturbing the sol. The two layers of distilled water were colourless at the beginning of the experiment. Graphite electrodes were inserted and a current was passed. After 30 minutes a difference was noted between the distilled water in the two sides of the U-tube.

Predict the colour of the distilled water in both sides of the U-tube after 30 minutes, if the  $\text{Fe}_2\text{O}_3$  sol particle is positively charged.

observation in side with positive electrode .....

.....

observation in side with negative electrode .....

.....

[1]

Salt solutions can be added to sols to cause them to precipitate. This method is used in water purification.

- (c) The student made up 100.0 cm<sup>3</sup> of standard solutions containing 0.100 mol dm<sup>-3</sup> of the following ions.



- (i) What mass of solid potassium sulfate, K<sub>2</sub>SO<sub>4</sub>, did the student use to make up exactly 100.0 cm<sup>3</sup> of 0.100 mol dm<sup>-3</sup> SO<sub>4</sub><sup>2-</sup>(aq)?  
[A<sub>r</sub>: K, 39.1; S, 32.1; O, 16.0]

mass of K<sub>2</sub>SO<sub>4</sub> = ..... g [1]

- (ii) Describe how the student should have accurately prepared this volume of standard solution from a sample of K<sub>2</sub>SO<sub>4</sub> of mass calculated in (c)(i).

.....

.....

.....

.....

.....

.....

..... [2]

- (d) The student carried out an experiment to precipitate the Fe<sub>2</sub>O<sub>3</sub> sol, using 0.100 mol dm<sup>-3</sup> K<sub>2</sub>SO<sub>4</sub>(aq). Only one drop of K<sub>2</sub>SO<sub>4</sub>(aq) was needed for the complete precipitation of 10.0 cm<sup>3</sup> Fe<sub>2</sub>O<sub>3</sub> sol.

Calculate how many moles of SO<sub>4</sub><sup>2-</sup> were added. Assume that one drop is 0.05 cm<sup>3</sup>.

moles of SO<sub>4</sub><sup>2-</sup> added = ..... mol [1]

- (e) The student decided to dilute the standard solution of  $0.100 \text{ mol dm}^{-3} \text{ K}_2\text{SO}_4$  to make  $50.0 \text{ cm}^3$  of  $0.0100 \text{ mol dm}^{-3} \text{ K}_2\text{SO}_4(\text{aq})$ .
- (i) Calculate the volume of standard solution required to make exactly  $50.0 \text{ cm}^3$  of  $0.0100 \text{ mol dm}^{-3} \text{ K}_2\text{SO}_4(\text{aq})$ .

volume of standard  $\text{K}_2\text{SO}_4(\text{aq}) = \dots\dots\dots \text{ cm}^3$  [1]

- (ii) Name a piece of apparatus that could be used to measure accurately the volume of solution calculated in (e)(i).

..... [1]

- (f) In an alternative method,  $50.0 \text{ cm}^3$  of  $0.0100 \text{ mol dm}^{-3} \text{ K}_2\text{SO}_4(\text{aq})$  could be prepared by using  $0.0872 \text{ g}$  of  $\text{K}_2\text{SO}_4$ .

Explain why the dilution method used by the student to prepare  $50.0 \text{ cm}^3$  of  $0.0100 \text{ mol dm}^{-3} \text{ K}_2\text{SO}_4(\text{aq})$  is the more accurate of the two methods.

.....  
 .....  
 ..... [1]

- (g) The student carried out experiments to investigate how much of a particular salt solution was required to fully precipitate all the  $\text{Fe}_2\text{O}_3$  sol in a  $1000\text{ cm}^3$  sample. The salt solutions used were all of concentration  $0.0100\text{ mol dm}^{-3}$  with respect to the ion being investigated.

### Experiment 1

identity of salt solution	charge on anion	minimum amount of anion required for complete precipitation of $1000\text{ cm}^3$ sol/mol
$\text{KCl}$	-1	$1.02 \times 10^{-1}$
$\text{K}_2\text{SO}_4$	-2	$3.25 \times 10^{-4}$
$\text{K}_3\text{PO}_4$	-3	$8.56 \times 10^{-5}$

### Experiment 2

identity of salt solution	charge on cation	minimum amount of cation required for complete precipitation of $1000\text{ cm}^3$ sol/mol
$\text{KCl}$	+1	$1.02 \times 10^{-1}$
$\text{MgCl}_2$	+2	$1.10 \times 10^{-1}$
$\text{AlCl}_3$	+3	$1.15 \times 10^{-1}$

- (i) Describe the effect of changing the charge on the anion from -1 to -2 to -3 on the precipitation of the  $\text{Fe}_2\text{O}_3$  sol in Experiment 1.

.....  
 ..... [1]

- (ii) Identify the independent variable in Experiment 2.

..... [1]

- (iii) Arsenic sulfide,  $\text{As}_2\text{S}_3$ , is highly toxic and should be removed from drinking water.

The  $\text{Fe}_2\text{O}_3$  sol particles are positively charged.

The  $\text{As}_2\text{S}_3$  sol particles are negatively charged.

Based on the student's results, which salt used in either Experiment 1 or Experiment 2 would be the most effective at removing  $\text{As}_2\text{S}_3$  from drinking water?  
 Explain your answer.

salt .....

explanation .....

..... [2]

[Total: 13]





- 2 Water boils when the pressure of its vapour above the liquid surface is equal to the atmospheric pressure. When substances are dissolved in water, the vapour pressure of the water is reduced and its boiling point is increased.

The increase in boiling point is known as the boiling point elevation,  $\Delta T$ , which is the difference between the boiling point of a solution and the boiling point of pure water.  $\Delta T$  is usually small, often less than  $1^\circ\text{C}$ .

When glucose is dissolved in 1 kg of water, the relationship between  $\Delta T$  and the number of moles of glucose dissolved is as shown.

$$\Delta T = K_b \times Z$$

$K_b$  is the boiling point constant of pure water

$$Z = \frac{\text{number of moles of glucose}}{\text{mass of water, in kg}} \text{ in mol kg}^{-1}$$

- (a) Use the information above to explain why lowering the vapour pressure of a liquid increases the temperature at which it boils.

.....

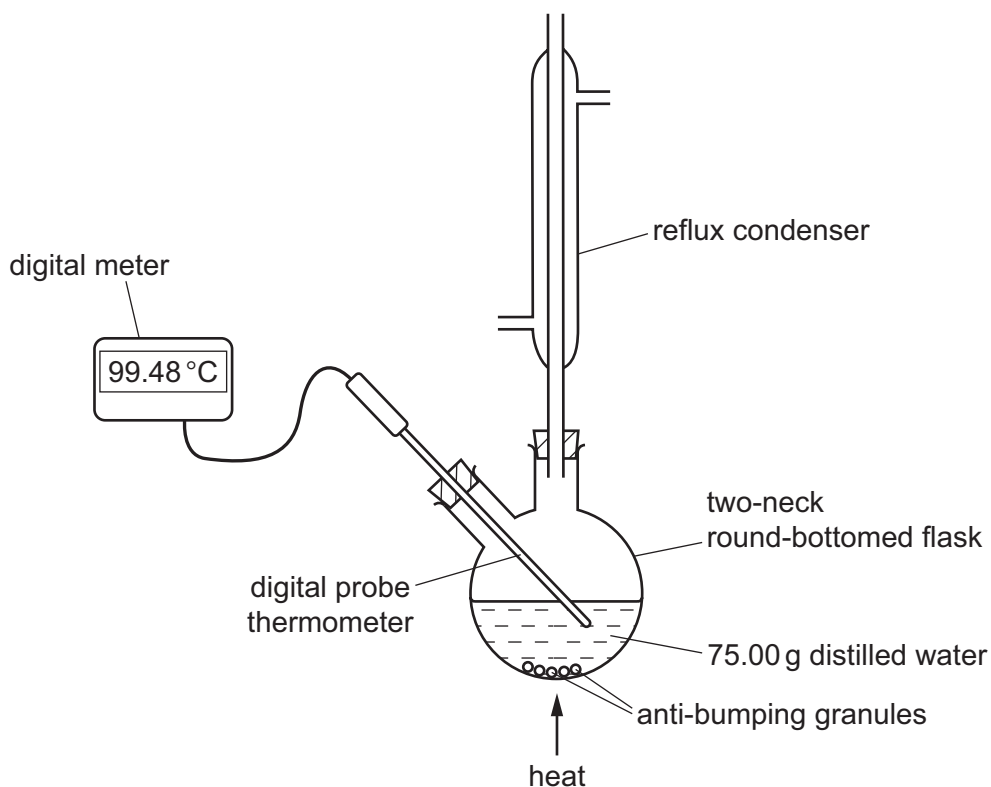
.....

.....

..... [1]

A student carries out an experiment to determine the boiling point constant,  $K_b$ , for water. The student uses anhydrous glucose,  $C_6H_{12}O_6$ , as the solute because it is non-volatile and very soluble in water.

The experimental set-up the student uses is shown.



(b) Show, using a labelled arrow, where the cooling water enters the reflux condenser. [1]

(c) A digital probe thermometer is used as shown in the diagram.

Explain why a normal laboratory glass thermometer would **not** be suitable.

.....  
 ..... [1]

The student follows this procedure.

- 1 Transfer 75.00 g of distilled water to the round-bottomed flask.
- 2 Add anti-bumping granules to the distilled water to prevent violent, uneven boiling.
- 3 Heat the distilled water until it boils and record the highest stable temperature.
- 4 Stop heating and allow the distilled water to cool to room temperature.
- 5 Remove the reflux condenser and add about 1 g of anhydrous glucose, measured accurately.
- 6 Replace the reflux condenser and heat the solution until it boils, noting the highest stable temperature.
- 7 Repeat steps 4 to 6, each time adding approximately 1 g more of anhydrous glucose, accurately weighed, until sufficient readings are taken.

- (d) In step 4, the heating is stopped and the distilled water allowed to cool from its boiling point, before removing the reflux condenser.

Apart from for safety reasons, explain why this is essential.

.....  
..... [1]

- (e) At 101 kPa (1 atm), distilled water is known to boil at 100.00 °C.

Suggest why the boiling point of distilled water in this experiment was found to be 99.48 °C.

Assume that the digital probe thermometer was reading correctly.

.....  
..... [1]

- (f) (i) The student constructed the table shown to record the results for this experiment.

Complete columns **C** and **D** to **three** significant figures and column **E** to **two** decimal places.

[The  $M_r$  of glucose is 180.]

$$Z = \frac{\text{moles of glucose}}{\text{mass of water, in kg}}$$

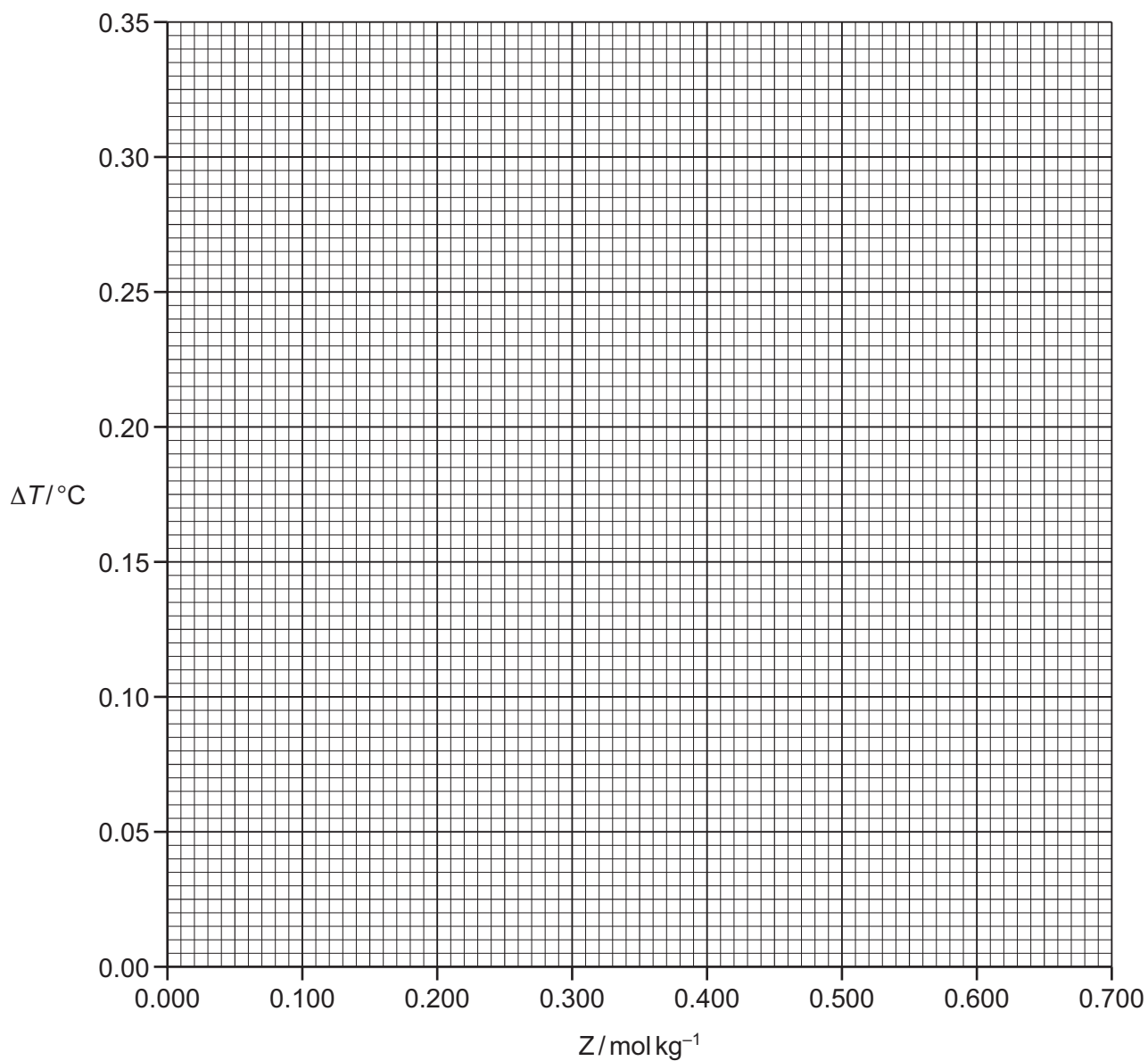
<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
mass of glucose /g	boiling point /°C	amount of glucose in 75.00 g of water /mol	Z /molkg <sup>-1</sup>	ΔT /°C
0.00	99.48	0	0	0.00
1.22	99.53	0.00678	$\frac{0.00678}{0.075} = 0.0904$	0.05
2.54	99.58			
3.46	99.61			
4.37	99.65			
5.01	99.67			
5.93	99.70			
7.01	99.72			
7.95	99.78			
8.78	99.81			

[3]

You may use the space below for any working.

- (ii) Plot a graph on the grid to show the relationship between  $\Delta T$  and the amount of glucose in 1 kg of water,  $Z$ .

Use a cross ( $\times$ ) to plot each data point. Draw a line of best fit.



[2]

- (iii) Circle the most anomalous point on your graph.

[1]

- (g) Use the graph and the equation to determine the boiling point constant,  $K_b$ , for water. Give this value to **three** significant figures and state the units.

$$\Delta T = K_b \times Z$$

State the co-ordinates of both points you used in your calculation.

co-ordinates 1 ..... co-ordinates 2 .....

$K_b =$  .....

units = .....

[3]

$\Delta T$  actually depends on the number of dissolved particles in solution.

- (h) (i) The experiment was repeated using solid from a bottle that was labelled glucose,  $C_6H_{12}O_6$ , but actually contained sucrose,  $C_{12}H_{22}O_{11}$ . Sucrose is non-volatile and very soluble in water.

What would be the effect of this on the value the student obtained for  $K_b$ ?

Explain your answer.

.....  
 ..... [1]

- (ii) The student used distilled water to dissolve the glucose.

Suggest why the student did not use tap water.

.....  
 ..... [1]

- (iii) The student repeated this experiment using sodium chloride as the solute. The student found their calculated value of  $K_b$  was **twice** the calculated value of that obtained with glucose.

Suggest a reason for this.

.....  
 ..... [1]

[Total: 17]

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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**October/November 2018**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name 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.

Do not use staples, paper clips, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

You may lose marks if you do not show your working or if you do not use appropriate units.

Use of a Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.

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

This document consists of **11** printed pages and **1** blank page.

- 1 A sample of waste water contains calcium ions, copper(II) ions and lead(II) ions.

You are to plan an experimental procedure to separate the metal ions in the waste water sample by forming precipitates of the metal ions.

The table shows the numerical values of the solubility products,  $K_{sp}$ , of some compounds. For example, the solubility product of calcium chloride,  $K_{sp} = [Ca^{2+}][Cl^-]^2 = 2 \times 10^1 \text{ mol}^3 \text{ dm}^{-9}$ . The smaller the solubility product, the easier it is for a precipitate to form.

	$K_{sp}$ values		
	$Cl^-$	$CO_3^{2-}$	$S^{2-}$
$Ca^{2+}$	$2 \times 10^1$	$5 \times 10^{-9}$	$3 \times 10^{-10}$
$Cu^{2+}$	$1 \times 10^1$	$3 \times 10^{-10}$	$6 \times 10^{-36}$
$Pb^{2+}$	$2 \times 10^{-5}$	$7 \times 10^{-14}$	$3 \times 10^{-28}$

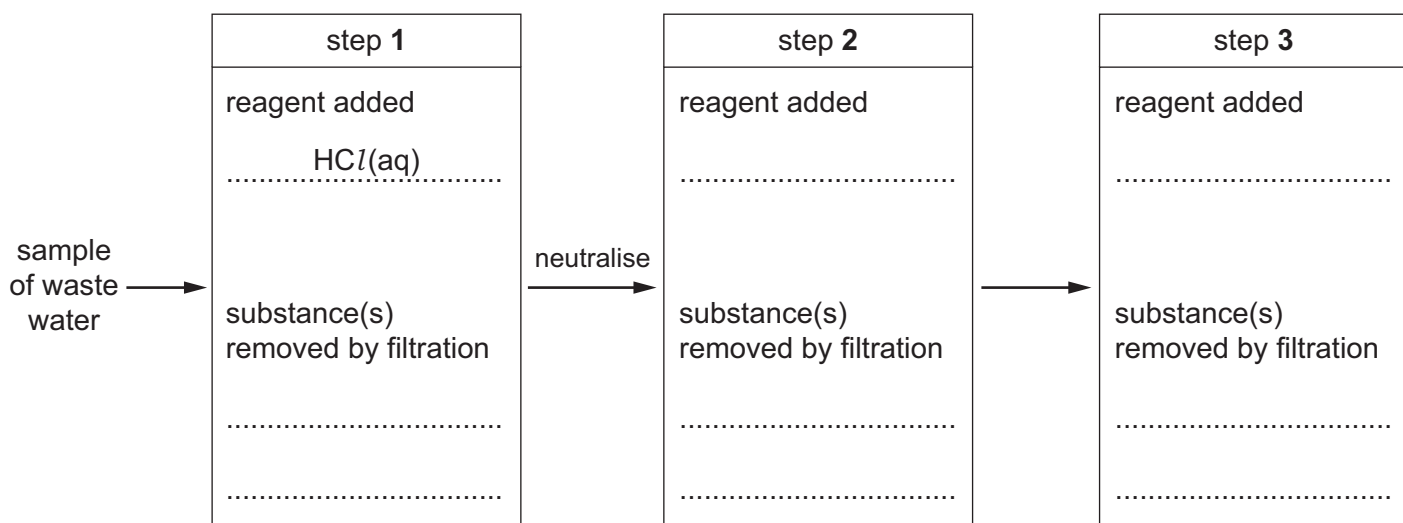
You are provided with

- a sample of waste water containing  $Ca^{2+}(aq)$ ,  $Cu^{2+}(aq)$  and  $Pb^{2+}(aq)$ ,
- $HCl(aq)$ ,
- $(NH_4)_2CO_3(aq)$ ,
- $(NH_4)_2S(aq)$ .

No other reagents should be used. Standard laboratory equipment is available.

- (a) The flowchart below is provided to plan the order of steps for the separation by filtration of the precipitates from the sample of waste water.

Complete the flowchart. For each step state the reagent added and the substance(s) removed by filtration.



[3]



- (b) After the substances formed in each step in (a) have been removed by filtration, a further drop of the reagent used for that step is added to the waste water sample.

Suggest why this is necessary.

.....  
 ..... [1]

- (c) Between steps 1 and 2, the waste water sample is neutralised. This is so that steps 2 and 3 will work.

Suggest a reagent that should be added to neutralise the waste water sample. State how you could test that the waste water sample had been neutralised.

reagent .....

test .....

.....  
 ..... [2]

A student completes the reactions in (a) with a sample of waste water and obtains one of the precipitates produced,  $XCO_3$ .

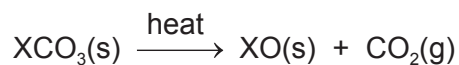
- (d) The student plans to calculate the concentration of  $X^{2+}$  ions present in this sample of waste water by measuring the mass loss on heating the freshly filtered sample of  $XCO_3(s)$ .

- (i) Draw and label a diagram of the experimental set-up the student should use.  
 Your diagram should show how loss of solid during heating would be prevented.

[2]

The student weighs the  $XCO_3$  precipitate and records its mass. The student then heats the precipitate strongly for five minutes and weighs it again. The student records the difference in mass and from this calculates  $[X^{2+}]$ .

The precipitate thermally decomposes according to the following equation.



- (ii) Identify **two** problems with this method. Explain the effect that each problem has on the calculated concentration of  $X^{2+}$ .

problem 1 .....

effect 1 .....

.....

problem 2 .....

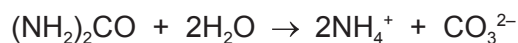
effect 2 .....

.....

[4]

[Total: 12]

- 2 The hydrolysis of urea,  $(\text{NH}_2)_2\text{CO}$ ,  $M_r = 60$ , is shown by the equation. The reaction is catalysed by the enzyme urease, when present in low concentrations.



The formation of the  $\text{NH}_4^+$  and  $\text{CO}_3^{2-}$  ions increases the conductivity of the solution. The increase in conductivity over time can be measured and the rate of hydrolysis can be determined from this.

A student plans to carry out this reaction using a  $50\text{ cm}^3$  sample of  $5.00 \times 10^{-3}\text{ mol dm}^{-3}$  urea solution.

- (a) The  $5.00 \times 10^{-3}\text{ mol dm}^{-3}$  urea solution cannot be accurately prepared by dissolving urea in  $50.0\text{ cm}^3$  of water. A more concentrated solution is first prepared. This is then diluted to make the solution of the required concentration.

- (i) Suggest why diluting a more concentrated solution is a more accurate method of preparing this solution than by dissolving urea in  $50.0\text{ cm}^3$  of water.

.....  
 .....  
 .....  
 ..... [1]

- (ii) Describe how you would accurately prepare exactly  $100\text{ cm}^3$  of  $5.00 \times 10^{-3}\text{ mol dm}^{-3}$  urea solution, starting with  $3.00\text{ g}$  of solid urea. Your method should use more than one volumetric flask, including one of capacity  $1000\text{ cm}^3$ , and other suitable equipment.

.....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....  
 ..... [3]

- (b) A student added a small amount of urease to a  $50.0\text{cm}^3$  sample of the solution made in (a)(ii). The conductivity of the solution was measured. The student obtained the results shown in the table. The student forgot to record the conductivity at 150 s. Conductivity is measured in  $\mu\text{S cm}^{-1}$ .

time, $t$ /s	conductivity / $\mu\text{S cm}^{-1}$
0	0
30	55
60	110
90	160
120	215
150	–
180	320
210	375
240	425
270	480
300	530

- (i) Plot a graph on the grid to show the relationship between time  $t$  and conductivity.

Use a cross ( $\times$ ) to plot each data point. Draw the straight line of best fit. [2]

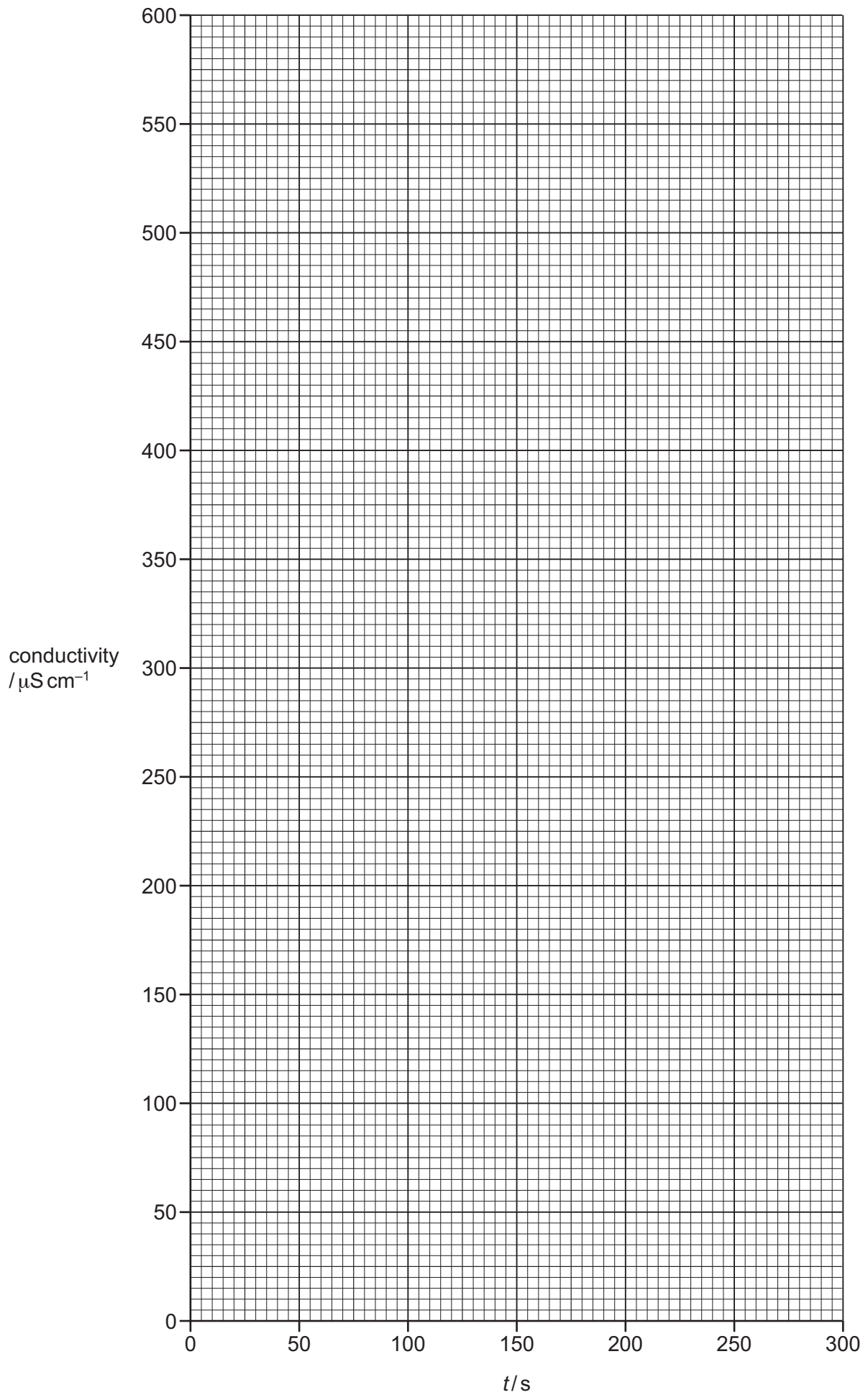
- (ii) Use the graph to determine the gradient of the best-fit line. State the co-ordinates of both points you used in your calculation.  
Give your answer to **three significant figures**.

co-ordinates 1 ..... co-ordinates 2 .....

gradient = .....  $\mu\text{S cm}^{-1} \text{ s}^{-1}$  [2]

- (iii) Use your graph to determine the conductivity of the solution at  $t = 150\text{ s}$ .

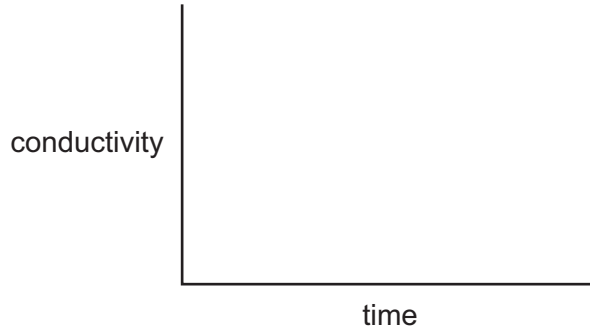
conductivity at 150 s = .....  $\mu\text{S cm}^{-1}$  [1]



(c) In another experiment, a student added a small amount of urease to 50.0 cm<sup>3</sup> samples of urea of various concentrations and measured their conductivity until hydrolysis was complete.

(i) Sketch a graph on the axes below to show the variation in conductivity in **one** such experiment.

Explain the shape of your graph as hydrolysis reaches completion.



.....

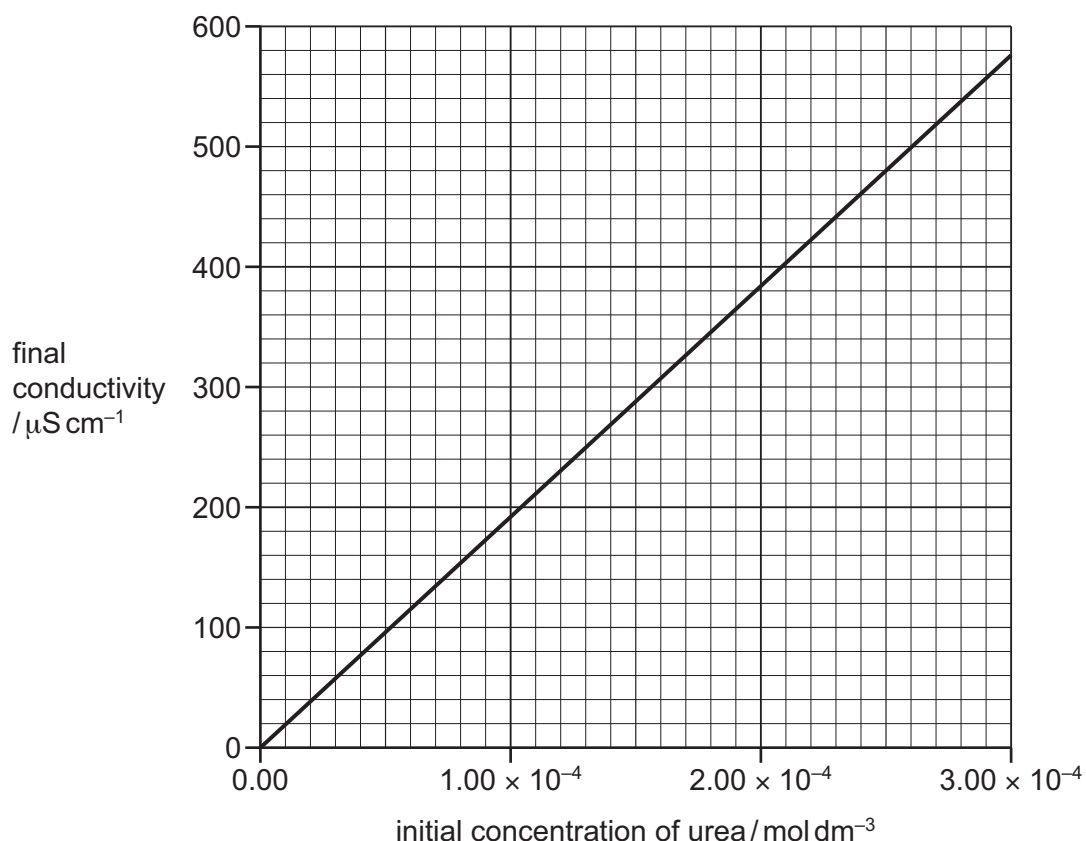
.....

.....

.....

[2]

From their results, the student plotted the calibration graph, shown below, of final conductivity of solution against initial concentration of urea.



You are going to determine the average rate of hydrolysis over the first 150 s of the experiment in **(b)**.

- (ii)** Use the calibration graph to determine the initial concentration of urea that would give the same final conductivity as your answer to **(b)(iii)**.  
(If you were unable to obtain an answer to **(b)(iii)** you should use the value of  $350 \mu\text{S cm}^{-1}$ . This is not the correct value.)

initial concentration of urea = ..... mol dm<sup>-3</sup> [1]

- (iii)** Use your answer to **(c)(ii)** to calculate the average rate of hydrolysis of urea during the first 150 s. Determine the units of the rate of hydrolysis.

rate of hydrolysis = ..... units = ..... [2]

(d) The student repeats the experiment in (b) using a different low concentration of urea solution.

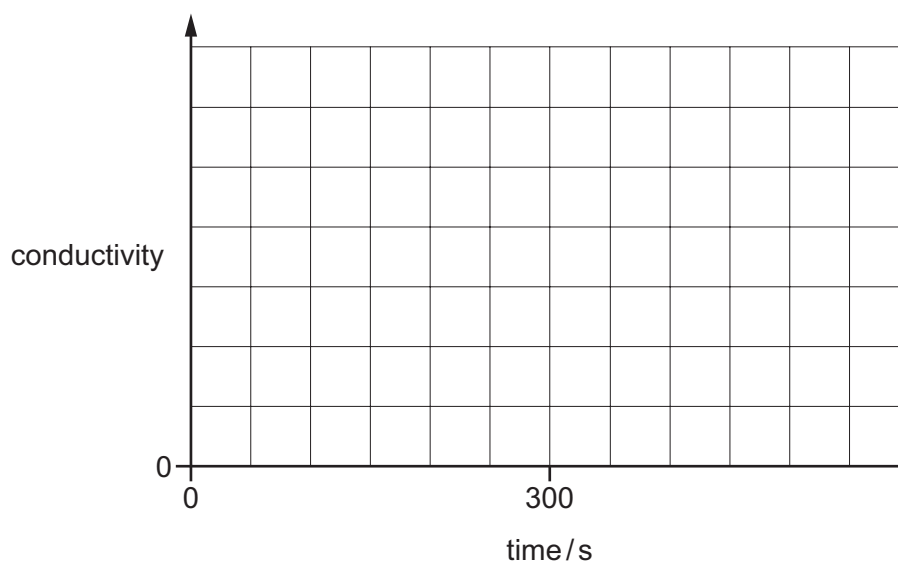
The student measures the conductivity of the solution for 300 s.

At 300 s, the student adds  $1.0 \text{ cm}^3$  of  $0.05 \text{ mol dm}^{-3}$  aqueous silver nitrate,  $\text{AgNO}_3(\text{aq})$ . The measured conductivity of the solution immediately increases.

$\text{AgNO}_3(\text{aq})$  is known to prevent the enzyme urease from hydrolysing urea.

Using the axes below, sketch a graph to show how the conductivity of the solution changes during this experiment.

Extend the graph beyond the point at which  $\text{AgNO}_3(\text{aq})$  is added at 300 s.



[3]



(e) The following information gives some of the hazards associated with the chemicals used in the procedure.

<b>silver nitrate</b>	Solutions equal to or more concentrated than $0.18 \text{ mol dm}^{-3}$ are classified as <b>corrosive</b> and <b>hazardous for the aquatic environment</b> ; solutions equal to or more concentrated than $0.06 \text{ mol dm}^{-3}$ but less concentrated than $0.18 \text{ mol dm}^{-3}$ are classified as <b>moderate hazard</b> and <b>hazardous for the aquatic environment</b> ; solutions less concentrated than $0.06 \text{ mol dm}^{-3}$ are classified as <b>hazardous for the aquatic environment</b> .
<b>urea</b>	All solutions are low hazard.
<b>urease</b>	Concentrated solutions may produce allergic reactions. They can cause asthma and irritate the eyes, nose and skin. Dilute solutions are low hazard.

Describe **one** relevant precaution, other than eye protection and a lab coat, that should be taken to keep the risk associated with the chemicals used to a minimum. Explain your answer.

precaution .....

.....

explanation .....

.....

[1]

[Total: 18]

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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**May/June 2017**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

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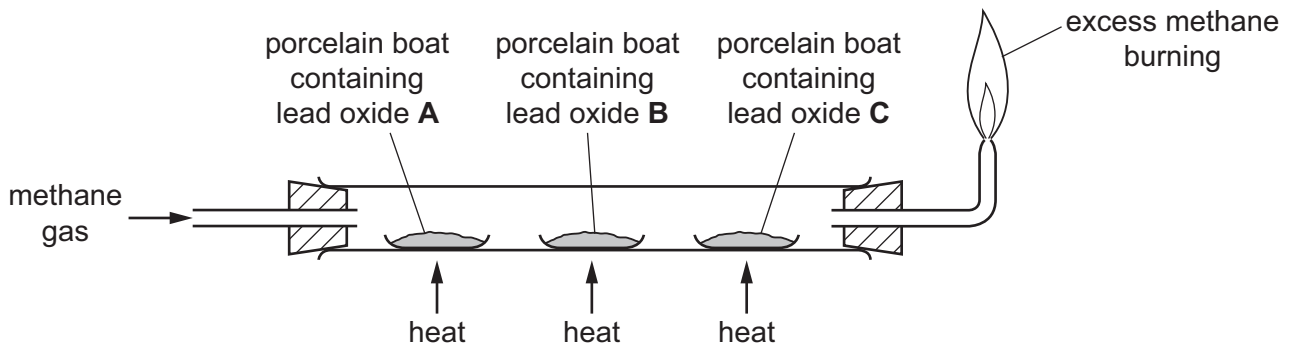
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **13** printed pages and **3** blank pages.

- 1 In 1804 the chemist John Dalton put forward the following idea. It is sometimes called 'Dalton's Law'.

'When two elements combine with each other to form **more than one compound**, the ratios of the masses of one element that combine with a fixed mass of the other element are simple whole numbers.'

A student used the apparatus shown to find out if Dalton's Law is true for three oxides of lead. Methane gas reduced the heated lead oxides to lead.



Lead and oxides of lead are harmful by inhalation and if swallowed. They are very toxic to aquatic organisms and may cause long-term damage in the aquatic environment.

- (a) State **two** hazards associated with experimenting with lead oxides.

For each hazard, state a precaution (other than eye protection) that the student could take to make sure that the experiment is carried out safely.

hazard 1 .....

precaution .....

hazard 2 .....

precaution .....

[2]

The student used the following procedure for the experiment.

- Three clean, dry porcelain boats were weighed when empty.
- Each boat was filled with a different lead oxide, labelled **A**, **B** or **C** and reweighed.
- The boats were placed in the apparatus and methane gas passed through.
- All three samples were heated strongly until they were reduced to lead.
- The boats were allowed to cool completely with the methane gas still passing over them before they were re-weighed.
- The results are shown in the table.

lead oxide	mass of porcelain boat/g	mass of boat + lead oxide/g	mass of boat + lead after heating/g	mass of lead/g	mass of oxygen/g	mass of lead that was combined with 1.0g oxygen in the lead oxide/g
<b>A</b>	5.26	9.31	9.04			
<b>B</b>	5.12	8.96	8.48			
<b>C</b>	5.23	10.52	10.06			

- (b) Complete the table. Record the mass of lead that was combined with 1.0g of oxygen in the lead oxide to **one decimal place**.  
Use the space below for any necessary calculations.

[2]

- (c) (i) Use the values of mass of lead that was combined with 1.0g oxygen in the lead oxide to calculate the ratio of mass of lead in each compound.

mass of lead in **A** : mass of lead in **B** : mass of lead in **C**  
 ..... : ..... : .....

[1]

- (ii) If Dalton's Law is true there should be a **simple whole number ratio** of the masses of lead in each compound combined with a fixed mass of oxygen.

Use your answer to (i) to state and explain whether the student's experimental results support Dalton's Law.

.....  
 ..... [1]

- (d) In this experiment, identify

the independent variable,

.....

the dependent variable.

.....

[2]

- (e) (i) Another sample of lead oxide **B** was found to contain 3.067g lead and 0.474g oxygen.

Calculate the empirical formula of **B**. Show your working.

[ $A_r$ : Pb, 207.2; O, 16.0]

empirical formula of **B** = ..... [1]

(ii) What additional piece of information is required to calculate the molecular formula of **B**?

..... [1]

(f) Before the porcelain boats containing the lead were weighed, they were allowed to cool completely with the methane gas still passing over them.

Apart from the hazards associated with handling hot apparatus, explain why this procedure is essential to ensure that the results are reliable.

.....  
..... [1]

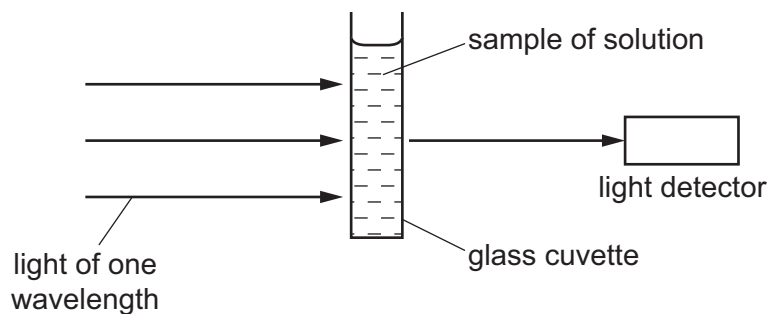
(g) The student thought that not all of the lead oxide **C** had been reduced.

What should the student do to make sure all the lead oxide **C** had been reduced?

.....  
.....  
..... [1]

[Total: 12]

- 2 When light passes through solutions of chemical compounds some of the light may be absorbed. The quantity of light absorbed is called the absorbance and it is measured by a spectrophotometer. A simplified diagram of a spectrophotometer is shown. A glass cuvette is a rectangular vessel.



- (a) (i) A chemist placed distilled water in the glass cuvette. This was then put into the spectrophotometer and a reading taken.

Explain why this reading was taken.

.....  
..... [1]

- (ii) Light passes through opposite sides of the cuvette. These two sides must be wiped with a cloth to ensure they are clean and dry.

Explain why this procedure makes the readings more accurate.

.....  
..... [1]



Manganese is added to steel to increase its strength. A spectrophotometer can be used to analyse the manganese content of steel. This is done by comparing the absorbance of a solution of  $\text{MnO}_4^-$ (aq) prepared from a sample of steel, with the absorbance of solutions of known concentrations of  $\text{MnO}_4^-$ (aq).

**(b)**  $1.0 \text{ dm}^3$  of a standard solution of  $0.0300 \text{ mol dm}^{-3} \text{ MnO}_4^-$  was prepared by a chemist using solid potassium manganate(VII),  $\text{KMnO}_4$ , measured using a two decimal place balance.

**(i)** Calculate the mass of  $\text{KMnO}_4$  required to prepare this standard solution.  
[ $A_r$ : K, 39.1; Mn, 54.9; O, 16.0]

mass of  $\text{KMnO}_4$  = ..... g [1]

**(ii)** Describe how the chemist should accurately prepare this standard solution using a sample of  $\text{KMnO}_4$  of mass calculated in **(i)**. There is a  $1.0 \text{ dm}^3$  volumetric flask available.

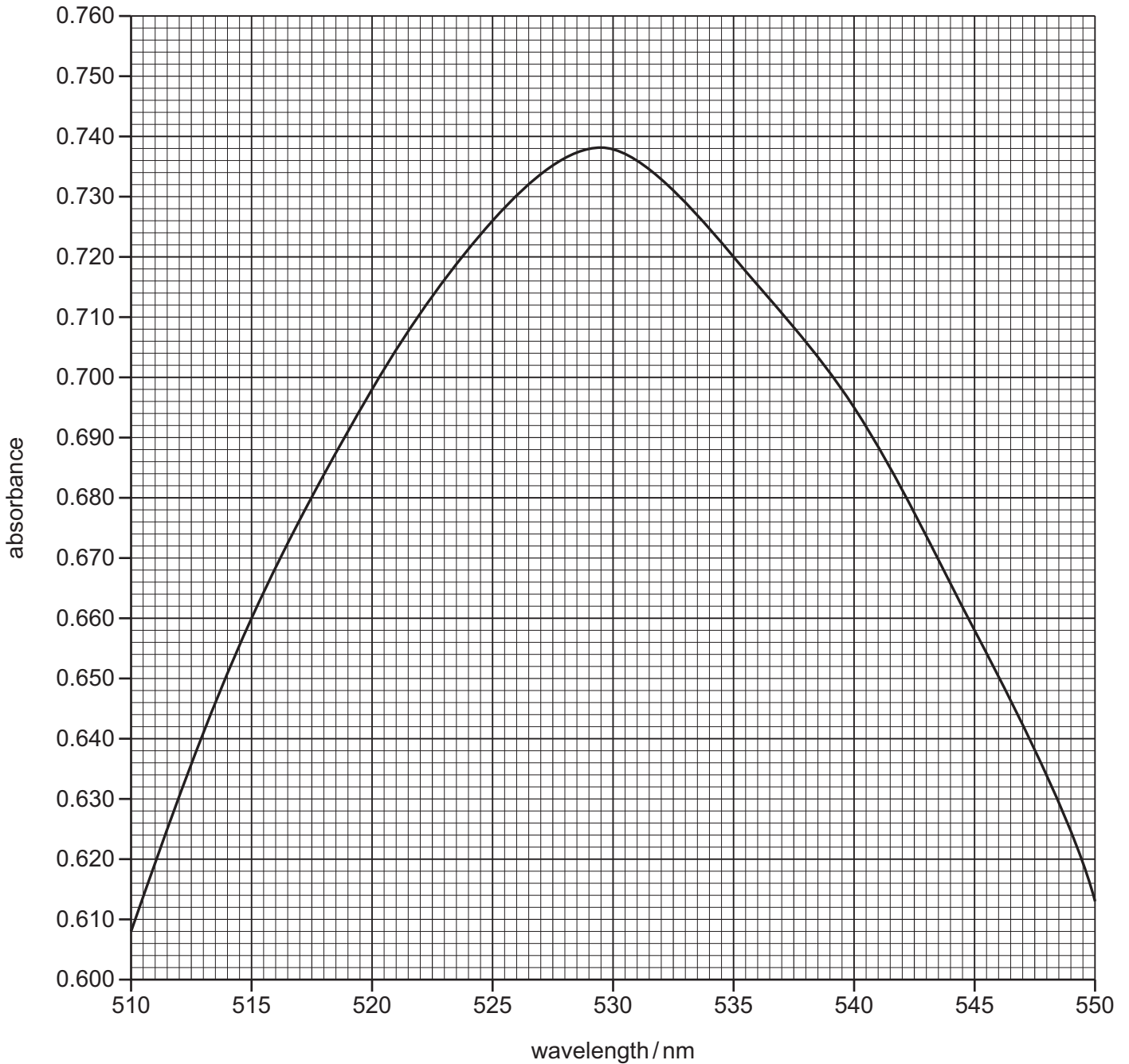
.....  
 .....  
 .....  
 .....  
 .....  
 ..... [2]

**(iii)** The chemist diluted this standard solution to  $3.0 \times 10^{-4} \text{ mol dm}^{-3}$  for use in the experiments.

Explain why the chemist did not prepare a solution of this concentration directly, by dissolving the required mass of  $\text{KMnO}_4$  in  $1.0 \text{ dm}^3$  of water.

.....  
 .....  
 ..... [1]

- (c) The chemist needed to determine which wavelength of light was most absorbed by a solution of  $\text{MnO}_4^-$ (aq). The clean, dry cuvette was filled with  $3.0 \times 10^{-4} \text{ mol dm}^{-3} \text{ MnO}_4^-$  and different wavelengths of light were passed through the solution. A graph of the results was plotted.



Use the graph to estimate the wavelength of light that is most absorbed by the  $\text{MnO}_4^-$  solution.

wavelength of light most absorbed = ..... nm [1]

**Question 2 continues on the next page.**

- (d) The spectrophotometer was then set to the wavelength that is most absorbed by the  $\text{MnO}_4^-$ (aq) solution.

The chemist measured the absorbance of solutions of known concentrations of  $\text{MnO}_4^-$ (aq). The results are shown in the table.

concentration of $\text{MnO}_4^-$ (aq)/mol dm <sup>-3</sup>	absorbance
$3.00 \times 10^{-4}$	0.748
$2.70 \times 10^{-4}$	0.680
$2.40 \times 10^{-4}$	0.610
$2.10 \times 10^{-4}$	0.530
$1.80 \times 10^{-4}$	0.440
$1.50 \times 10^{-4}$	0.378
$1.20 \times 10^{-4}$	0.315
$0.90 \times 10^{-4}$	0.230
$0.60 \times 10^{-4}$	0.150

- (i) Plot a graph on the grid on page 11 to show the relationship between the absorbance and the concentration of  $\text{MnO}_4^-$ (aq).

Use a cross (×) to plot each data point. Draw a line of best fit.

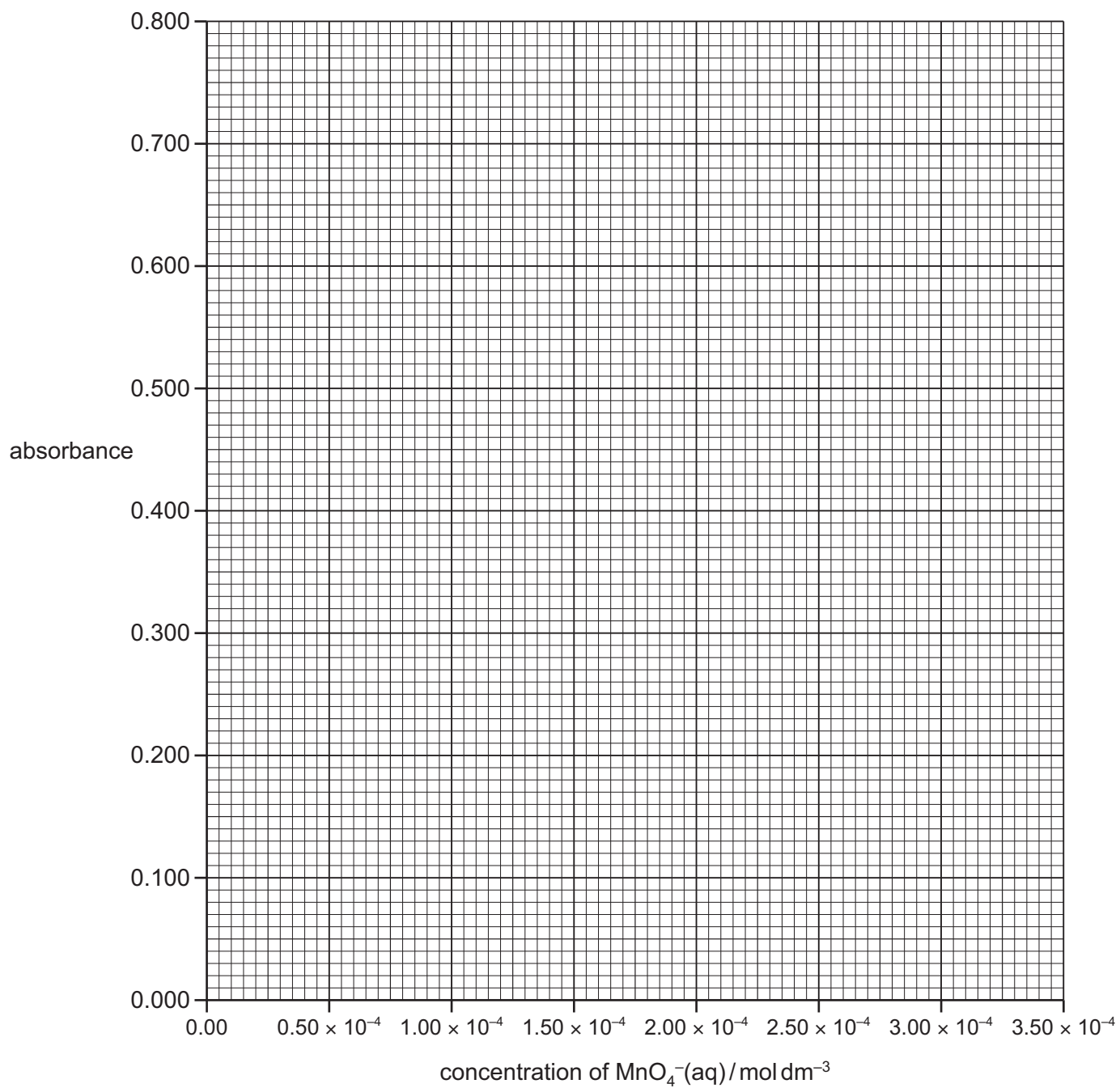
[2]

- (ii) State the relationship between absorbance and concentration of  $\text{MnO}_4^-$ (aq). Explain your answer with reference to particles.

.....  
 .....  
 ..... [2]

- (iii) Do you consider the results obtained to be reliable? Explain your answer.

.....  
 .....  
 ..... [1]



- (e) (i) The chemist used the  $\text{MnO}_4^-$ (aq) solution of concentration  $3.00 \times 10^{-4} \text{ mol dm}^{-3}$  to prepare the solutions in the table on page 10.

Calculate the volume of  $3.00 \times 10^{-4} \text{ mol dm}^{-3} \text{ MnO}_4^-$ (aq) solution and the volume of distilled water required to prepare a  $25.00 \text{ cm}^3$  solution of  $2.70 \times 10^{-4} \text{ mol dm}^{-3} \text{ MnO}_4^-$ (aq).  
Give your answers to **two decimal places**.

volume of  $3.00 \times 10^{-4} \text{ mol dm}^{-3} \text{ MnO}_4^-$ (aq) solution = .....  $\text{cm}^3$

volume of distilled water = .....  $\text{cm}^3$   
[1]

- (ii) The volumes of the two solutions given in (e)(i) could be measured using the same type of apparatus.

Name a suitable piece of apparatus which could be used to measure these volumes.

..... [1]

The chemist dissolved a known mass of steel, containing manganese, in acid. The manganese was then oxidised to manganate(VII) ions,  $\text{MnO}_4^-$ , using a very strong oxidising agent. The resulting solution was made up to  $100.0 \text{ cm}^3$  in a volumetric flask.

- (f) A small sample of the solution of  $\text{MnO}_4^-$ (aq) prepared from the steel sample was placed into a clean, dry cuvette and its absorbance measured using the spectrophotometer.

- (i) The absorbance of the  $\text{MnO}_4^-$ (aq) solution was 0.630.

Use the graph you have drawn in (d)(i) to determine the concentration of  $\text{MnO}_4^-$ (aq) in this solution.

Give your answer to **three significant figures**.

concentration of  $\text{MnO}_4^-$ (aq) = .....  $\text{mol dm}^{-3}$  [1]

- (ii) Calculate the mass of manganese present in the steel sample. Show your working.  
[ $A_r$ : Mn, 54.9]

mass of manganese = ..... g [1]

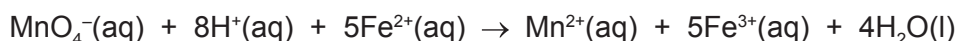
(g) The steel sample that the chemist used had a mass of 1.209g.

Use the mass of manganese you calculated in (f)(ii) to calculate the percentage of manganese by mass that was present in the steel sample.

(If you were unable to calculate an answer to (f)(ii) you may use 0.00143g as the mass of manganese. This is not the correct answer.)

percentage of manganese in the steel sample = ..... % [1]

(h) Another way of analysing the manganese content of the steel sample is by titration. The steel sample is prepared in the same way as previously. It is dissolved in acid and then oxidised using a very strong oxidising agent. The  $\text{MnO}_4^-$ (aq) ions produced are titrated with a solution of iron(II) ions. The equation for this reaction is shown.



Explain why it is essential to remove the strong oxidising agent used to prepare the solution of steel sample before carrying out the titration.

.....  
 ..... [1]

[Total: 18]







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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**October/November 2017**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

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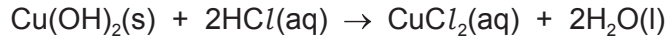
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The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **11** printed pages and **1** blank page.

- 1 Verdigris is a green pigment that contains both copper(II) carbonate,  $\text{CuCO}_3$ , and copper(II) hydroxide,  $\text{Cu(OH)}_2$ , in varying amounts.

Both copper compounds react with dilute hydrochloric acid.



- (a) You are to plan an experiment to determine the percentage of **copper(II) carbonate** in a sample of verdigris. Your method should involve the reaction of verdigris with excess dilute hydrochloric acid.

You are provided with the following materials.

- 0.5 g of verdigris
- $10.0 \text{ mol dm}^{-3}$  hydrochloric acid,  $\text{HCl}(\text{aq})$
- commonly available laboratory reagents and equipment

You may assume that any other material present in verdigris is unaffected by heating and is not acidic or basic.

- (i) Explain why a titration would **not** be a suitable method to determine the percentage of copper(II) carbonate in a sample of verdigris.

.....  
 .....  
 ..... [1]

- (ii) The  $10.0 \text{ mol dm}^{-3}$   $\text{HCl}(\text{aq})$  is corrosive and too concentrated for use in the experiment.

Describe how you would accurately prepare  $250 \text{ cm}^3$  of  $0.500 \text{ mol dm}^{-3}$  hydrochloric acid from the  $10.0 \text{ mol dm}^{-3}$   $\text{HCl}(\text{aq})$  provided.

Include details of any apparatus, including their capacities in  $\text{cm}^3$ , you would use.

.....  
 .....  
 .....  
 .....  
 ..... [2]

- (iii) Identify a dependent variable that you could measure to determine the percentage of copper(II) carbonate in verdigris.

Your answer should be based on a difference that you can identify between the reactions of copper(II) carbonate and copper(II) hydroxide with excess dilute hydrochloric acid.

.....  
.....  
..... [1]

- (iv) Draw a diagram to show how you would set up apparatus and chemicals to measure the dependent variable identified in (iii).

Label your diagram.

[2]

- (v) Using the axes below, sketch a graph to show how the dependent variable you identified in (iii) would change during your experiment.

Extend the graph beyond the point at which the reaction is complete.

Label both axes.



[2]

- (vi) A student carries out this experiment once.

Describe how this **one** experiment should be carried out to ensure that the results are as accurate as possible.

.....

.....

..... [1]

- (vii) A student suspected that their 0.5 g sample of verdigris only contained  $\text{CuCO}_3$ .

Calculate the minimum volume, in  $\text{cm}^3$ , of  $0.500 \text{ mol dm}^{-3} \text{ HCl(aq)}$  that would be needed for the complete reaction of the sample if the student was correct.

$[M_r: \text{CuCO}_3 = 123.5]$

volume of  $0.500 \text{ mol dm}^{-3} \text{ HCl(aq)} = \dots\dots\dots \text{ cm}^3$  [2]

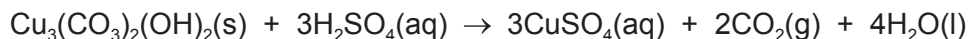
- (b) The following information gives some of the hazards associated with the chemicals used in the procedure.

<b>Copper(II) carbonate hydroxide</b>	The solid is classified as <b>health hazard</b> and is harmful if swallowed. Dispose of by reacting no more than 60 g in $1 \text{ dm}^3$ of warm $1 \text{ mol dm}^{-3}$ ethanoic acid before pouring down a foul-water drain.
<b>Hydrochloric acid</b>	Solutions equal to or more concentrated than $6.5 \text{ mol dm}^{-3}$ are classified as <b>corrosive</b> ; solutions equal to or more concentrated than $2.7 \text{ mol dm}^{-3}$ but less concentrated than $6.5 \text{ mol dm}^{-3}$ are classified as <b>moderate hazard</b> and are irritant.

Describe **one** relevant precaution, other than eye protection and a lab coat, that should be taken to keep the risk associated with the chemicals used to a minimum. Explain your answer.

.....  
 .....  
 ..... [1]

- (c) Azurite is a blue copper-containing mineral. The copper compound in azurite has the formula  $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$ . This copper compound reacts with sulfuric acid according to the reaction shown.



A student performed a series of titrations on 1.50 g samples of solid azurite using  $0.400 \text{ mol dm}^{-3}$  sulfuric acid.

It can be assumed that any other material present in azurite does not react with sulfuric acid.

The titration data is given in the table.

experiment	rough	1	2
final reading / $\text{cm}^3$	25.50	24.05	32.70
initial reading / $\text{cm}^3$	0.00	0.15	8.30
titre / $\text{cm}^3$	25.50	23.90	24.40

The indicator for the titration was bromophenol blue.

The student concluded that  $24.15 \text{ cm}^3$  of  $0.400 \text{ mol dm}^{-3}$  sulfuric acid completely neutralised 1.50 g of azurite.

- (i) Using the student's value of  $24.15 \text{ cm}^3$ , calculate the percentage by mass of  $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$  in the sample of azurite.

Write your answer to **three significant figures**.

[ $M_r$ :  $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2 = 344.5$ ]

percentage by mass of  $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$  in the sample of azurite = ..... % [3]



(ii) Identify **two** possible problems with the student's titration **and** suggest improvements to it.

Problem 1 .....

.....

Improvement 1 .....

.....

Problem 2 .....

.....

Improvement 2 .....

.....

[3]

[Total: 18]



- 2 Activated charcoal is a form of carbon with a very high surface area. It can be used to remove impurities from mixtures. It does this by a process called *adsorption*, where particles of the impurity bond (adsorb) to the activated charcoal surface.

A student wanted to determine the ability of activated charcoal to adsorb a blue dye (the impurity) from aqueous solution.

The equation that links the mass of activated charcoal with the amount of blue dye adsorbed is shown.

$$\log\left(\frac{D}{m}\right) = A + b \log [X]$$

$D$  = difference in concentration of dye (in  $\text{g dm}^{-3}$ ) before and after adsorption

$m$  = mass of activated charcoal (in g)

$[X]$  = final concentration of dye (in  $\text{g dm}^{-3}$ ) after adsorption

$A$  and  $b$  are constants

The student used the following procedure to investigate the ability of activated charcoal to adsorb a blue dye from an aqueous solution.

- Place a  $50.0 \text{ cm}^3$  sample of a  $25.00 \text{ g dm}^{-3}$  solution of blue dye in a conical flask.
- Add a weighed mass of activated charcoal to the flask.
- Stir the contents of the flask for three minutes and then leave for one hour.
- Filter the mixture.
- Determine the final concentration of the blue dye,  $[X]$ , by colorimetry.
- Repeat the procedure using different masses of activated charcoal.

(a) The final concentrations of blue dye after carrying out the procedure,  $[X]$ , are shown in the table.

(i) Process the results to complete the table.

Record your data to **two** decimal places.

mass of activated charcoal, $m$ /g	initial concentration of blue dye /g dm <sup>-3</sup>	final concentration of blue dye, $[X]$ /g dm <sup>-3</sup>	difference in concentration of blue dye, $D$ /g dm <sup>-3</sup>	$\frac{D}{m}$	$\log\left(\frac{D}{m}\right)$	$\log[X]$
0.20	25.00	0.96		120.20	2.08	
0.25	25.00	0.69		97.24	1.99	
0.30	25.00	0.60		81.33	1.91	
0.35	25.00	0.41		70.26	1.85	
0.40	25.00	0.33		61.68	1.79	
0.45	25.00	0.27		54.96	1.74	
0.50	25.00	0.23		49.54	1.69	
0.55	25.00	0.20		45.09	1.65	
0.60	25.00	0.17		41.38	1.62	

[3]

(ii) By considering the data in the first three columns, state the effect of increasing the mass of activated charcoal,  $m$ , on the amount of adsorption that occurs.

.....

.....

Explain this effect.

.....

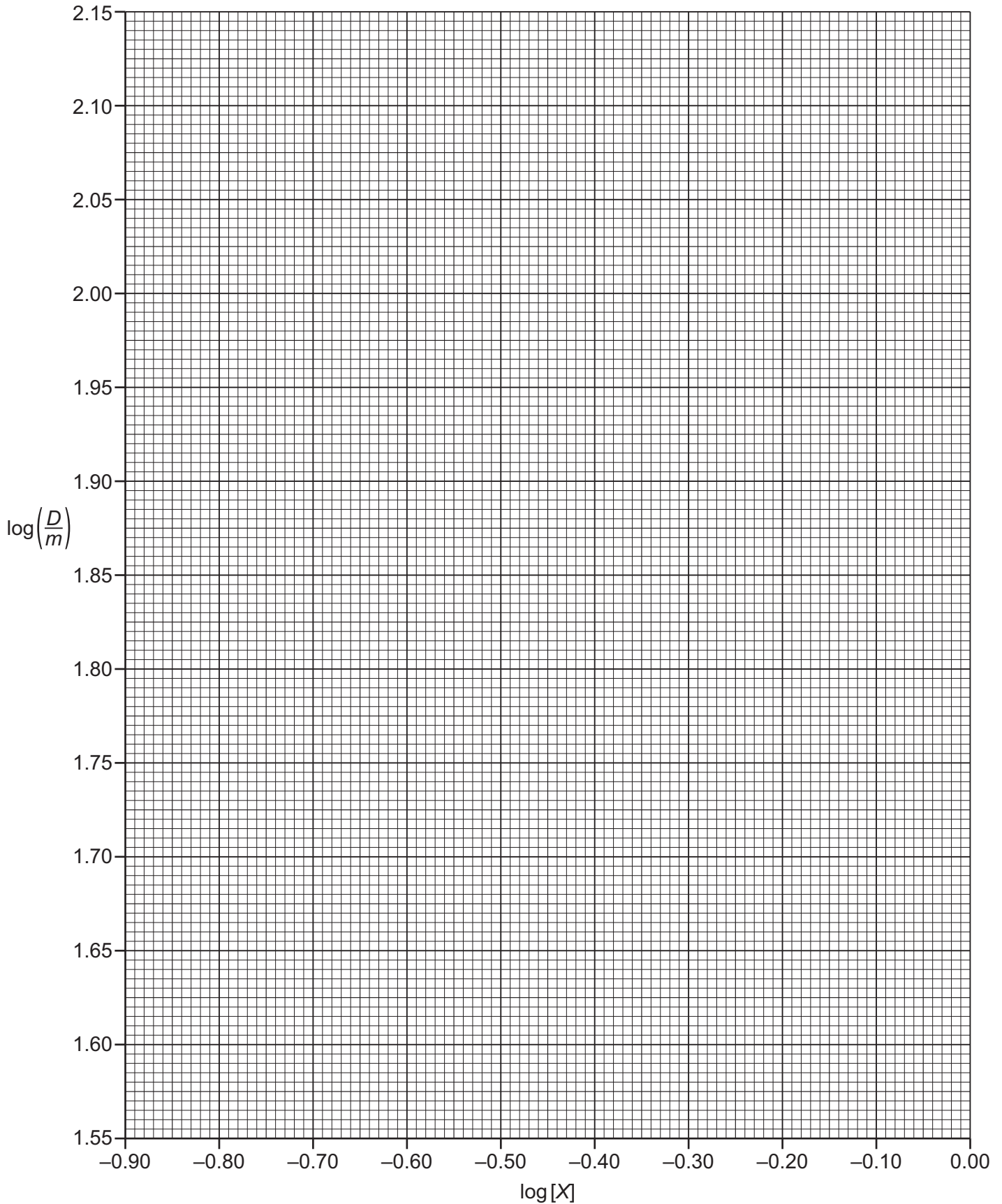
.....

.....

[2]

(b) Plot a graph on the grid to show the relationship between  $\log\left(\frac{D}{m}\right)$  and  $\log[X]$ .

Use a cross (×) to plot each data point. Draw the straight line of best fit.



[2]

(c) Circle the most anomalous point on the graph.

Suggest a reason why this anomaly may have occurred during the experimental procedure.

.....  
.....  
..... [2]

(d) (i) Use the graph to determine the gradient of the best-fit line. State the co-ordinates of both points you used in your calculation.

Determine the value of the constant  $b$ .

co-ordinates 1 ..... co-ordinates 2 .....

gradient = .....

$b$  = ..... [2]

(ii) Use the graph to determine a value for  $A$ .

$A$  = ..... [1]

[Total: 12]

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\* 6 6 \*  
\* 6 6 \*

**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**May/June 2016**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name 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.

Do not use staples, paper clips, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

You may lose marks if you do not show your working or if you do not use appropriate units.

Use of a Data Booklet is unnecessary.

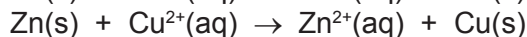
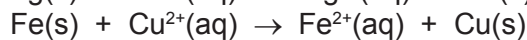
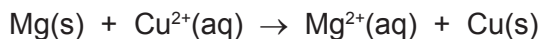
At the end of the examination, fasten all your work securely together.

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

This document consists of **11** printed pages and **1** blank page.

- 1 A more reactive metal will displace a less reactive metal from a solution of its salt. This reaction is exothermic. If the same reaction is set up in an electrochemical cell then, instead of an enthalpy change, electrical energy is produced and a cell voltage can be measured.

You are to plan an investigation of the reaction of three different metals (magnesium, iron and zinc) with aqueous copper(II) sulfate. You will plan to investigate whether there is a relationship between their cell potential values,  $E_{\text{cell}}^{\ominus}$ , and their enthalpy changes of reaction,  $\Delta H_r$ .



**Copper(II) sulfate solution** is classified as a **moderate hazard**.

**Zinc sulfate solution** is classified as **corrosive**.

**Iron(II) sulfate solution** is classified as a **health hazard**.

- (a) Predict how  $\Delta H_r$  may change as  $E_{\text{cell}}^{\ominus}$  increases. Give a reason for your prediction.

.....  
 .....  
 ..... [1]

- (b) The first part of the investigation is to determine the enthalpy change,  $\Delta H_r$ , for the reaction of the same number of moles of three powdered metals with  $0.500 \text{ mol dm}^{-3}$  copper(II) sulfate.

When determining the  $\Delta H_r$  for the reaction of the metals listed above with aqueous copper(II) sulfate,

the independent variable is, .....

.....

the dependent variable is. ....

..... [2]



You are provided with a sample of powdered metal and  $50.0\text{ cm}^3$  of  $0.500\text{ mol dm}^{-3}$  aqueous copper(II) sulfate.

- (c) (i) Draw a fully labelled diagram to show how the apparatus should be set up to allow you to determine the increase in temperature of aqueous copper(II) sulfate.  
You should use apparatus normally found in a school or college laboratory.

[1]

- (ii) State the measurements you would make in your experiment.

.....  
.....  
..... [2]

- (iii) Other than eye protection, state **one** precaution you would take to make sure that the experiment proceeds safely.

.....  
..... [1]

- (iv) For the reaction with magnesium, calculate the mass of magnesium, in g, you would use so that it is in a small excess. You must show your working.  
[A<sub>r</sub>: Mg, 24.3]

mass of Mg = ..... g [2]

- (v) Explain why the metal used should be in powdered form rather than in strips.

.....  
..... [1]

- (vi) The aqueous copper(II) sulfate and metal mixture should be stirred continuously. Explain why.

.....  
..... [1]

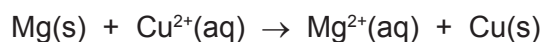
- (d) In one experiment, the increase in temperature when excess magnesium powder is added to 50.0 cm<sup>3</sup> of 0.500 mol dm<sup>-3</sup> aqueous copper(II) sulfate is 58.5 °C.

Calculate the enthalpy change for this reaction,  $\Delta H_r$ , in kJ mol<sup>-1</sup>.

Assume the specific heat capacity,  $c$ , of the reaction mixture is 4.18 J g<sup>-1</sup> K<sup>-1</sup>.

Assume 1.0 cm<sup>3</sup> of 0.500 mol dm<sup>-3</sup> aqueous copper(II) sulfate has a mass of 1.0 g.

Include a sign in your answer.



$\Delta H_r = \dots\dots\dots$  kJ mol<sup>-1</sup> [2]

- (e) The second part of the investigation involves determining the cell potential,  $E_{\text{cell}}^{\ominus}$ , for the three electrochemical cells.

cell reaction
$\text{Mg(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{Cu(s)}$
$\text{Zn(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Cu(s)}$
$\text{Fe(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Fe}^{2+}(\text{aq}) + \text{Cu(s)}$

Draw a diagram of the apparatus you would use to measure the  $E_{\text{cell}}^{\ominus}$  for the magnesium/copper cell. Your labels should include the **names** of the metals and the **names** and **concentrations** of the solutions you would use.

[3]

- (f) Explain why the enthalpy change determination and cell potential determination should be carried out at the same temperature as each other.

.....  
 .....  
 ..... [1]

(g) Accepted  $E_{\text{cell}}^{\ominus}$  values are shown for the cell reactions.

	cell reaction	$E_{\text{cell}}^{\ominus}/\text{V}$	$\Delta H_r$
1	$\text{Mg(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{Cu(s)}$	+2.72	
2	$\text{Zn(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Cu(s)}$	+1.10	
3	$\text{Fe(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Fe}^{2+}(\text{aq}) + \text{Cu(s)}$	+0.78	

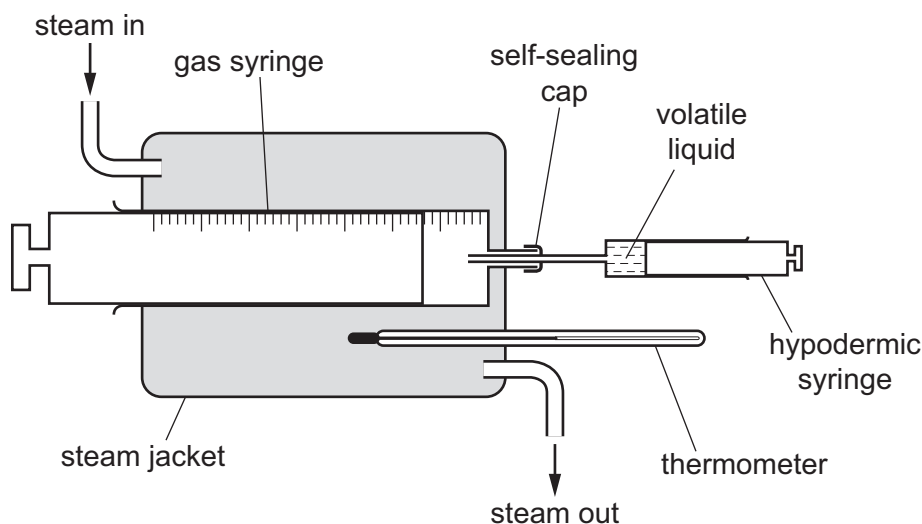
Use your prediction in (a), your answer to (d) and data from the table to predict  $\Delta H_r$  values for reactions 2 and 3.

Complete the table with these values.

[1]

[Total: 18]

- 2 The relative molecular mass,  $M_r$ , of volatile liquids can be determined using the apparatus below.



A known mass of volatile liquid is injected into the gas syringe using a hypodermic syringe. The injected volatile liquid vaporises and the volume of vapour is recorded.

The experiment can be repeated using different samples of the same volatile liquid. The following mathematical relationship can be used to calculate the relative molecular mass if the experiment is carried out at  $100\text{ }^\circ\text{C}$  and  $1.01 \times 10^5\text{ Pa}$ .

$$V = \left( \frac{3.07 \times 10^4}{M_r} \right) \times m$$

$m$  is the mass of the volatile liquid in g.

$V$  is the volume of the volatile liquid in  $\text{cm}^3$  when vaporised.

A graph of  $V$  against  $m$  can be plotted.

A group of students is given a volatile liquid hydrocarbon, **Y**, and asked to find its relative molecular mass in a series of experiments using this procedure.

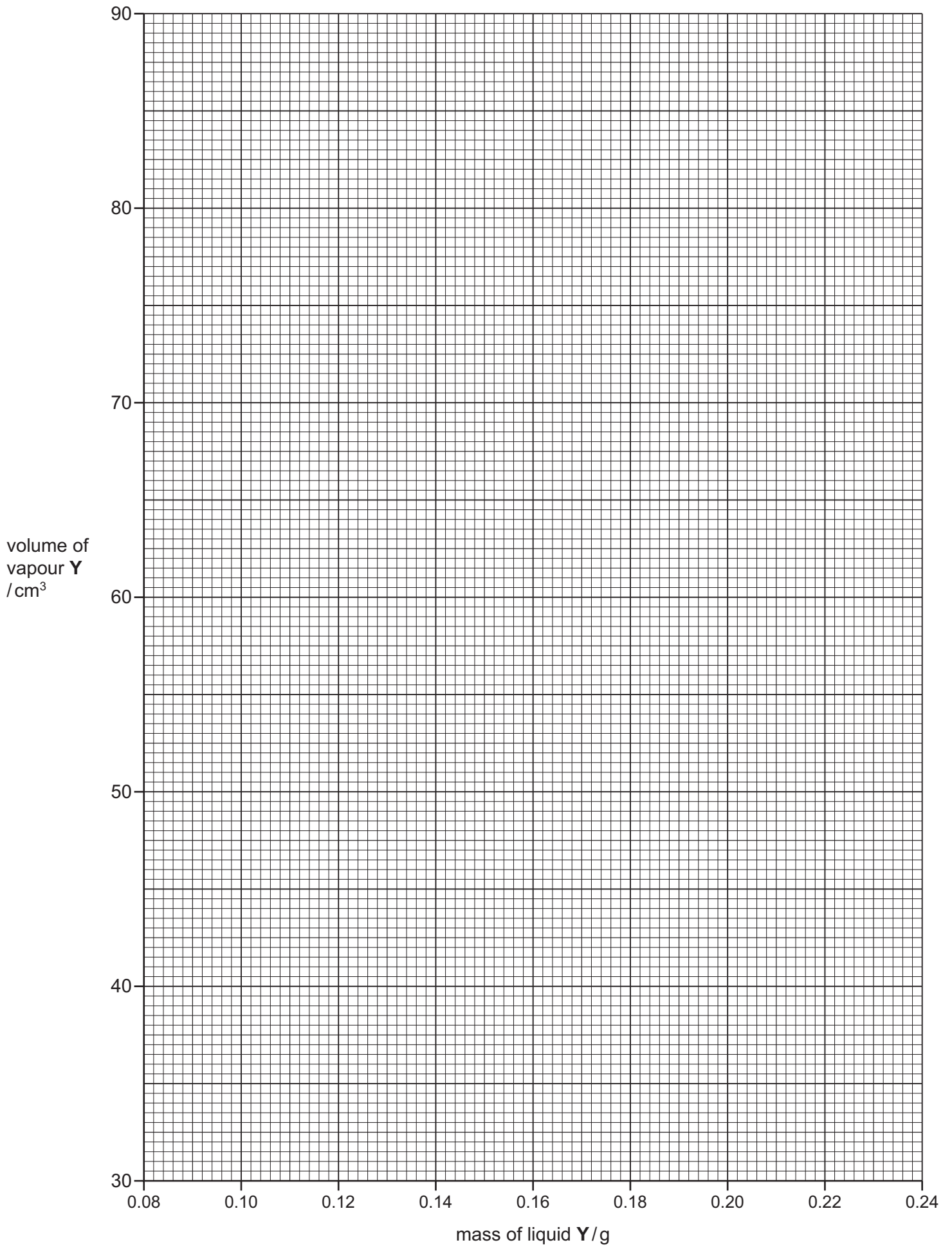
- A  $100\text{ cm}^3$  gas syringe is placed in a steam jacket.
- Approximately  $5\text{ cm}^3$  of air is pulled into the gas syringe.
- The temperature is allowed to reach a constant  $100\text{ }^\circ\text{C}$ .
- Once the air in the gas syringe has stopped expanding, its volume is recorded.
- The hypodermic syringe is filled with liquid **Y**.
- The total mass of the hypodermic syringe and liquid **Y** is recorded.
- A little liquid **Y** is injected into the hot gas syringe.
- The total mass of the hypodermic syringe is recorded again.
- The maximum volume of air and vapour in the gas syringe is recorded.
- The mass of liquid **Y** injected into the gas syringe is calculated and recorded.

The results from the group of students are given in the table.

mass of syringe + liquid Y before injection /g	mass of syringe + liquid Y after injection /g	volume of air in gas syringe before injection /cm <sup>3</sup>	volume of air + vapour Y in gas syringe after injection /cm <sup>3</sup>	mass of liquid Y used /g	volume of vapour Y /cm <sup>3</sup>
4.83	4.68	7	55		
5.33	5.23	9	44		
4.85	4.64	13	85		
5.09	4.92	11	69		
5.31	5.07	14	97		
5.57	5.48	8	39		
5.32	5.12	9	79		
5.17	4.94	12	91		
4.84	4.72	7	48		
5.05	4.83	11	84		

(a) Process the results in the table to calculate both the masses of volatile liquid Y used and the volumes of vaporised Y. [2]

(b) Plot a graph on the grid on page 9 to show the relationship between mass of liquid Y and volume of vapour Y.  
Use a cross (×) to plot each data point.  
Draw the line of best fit. [2]



(c) Liquid **Y** evaporates easily, even at room temperature. This can cause anomalous results giving points below the line of best fit.

(i) Explain how such anomalies occur.

.....  
 ..... [1]

(ii) With reference to the experimental procedure, explain how this source of error could be minimised.

.....  
 .....  
 ..... [1]

(d) (i) Determine the gradient of your graph. State the co-ordinates of both points you used for your calculation. Record the value of the gradient to **three** significant figures.

co-ordinates 1 .....

co-ordinates 2 .....

gradient = ..... [2]

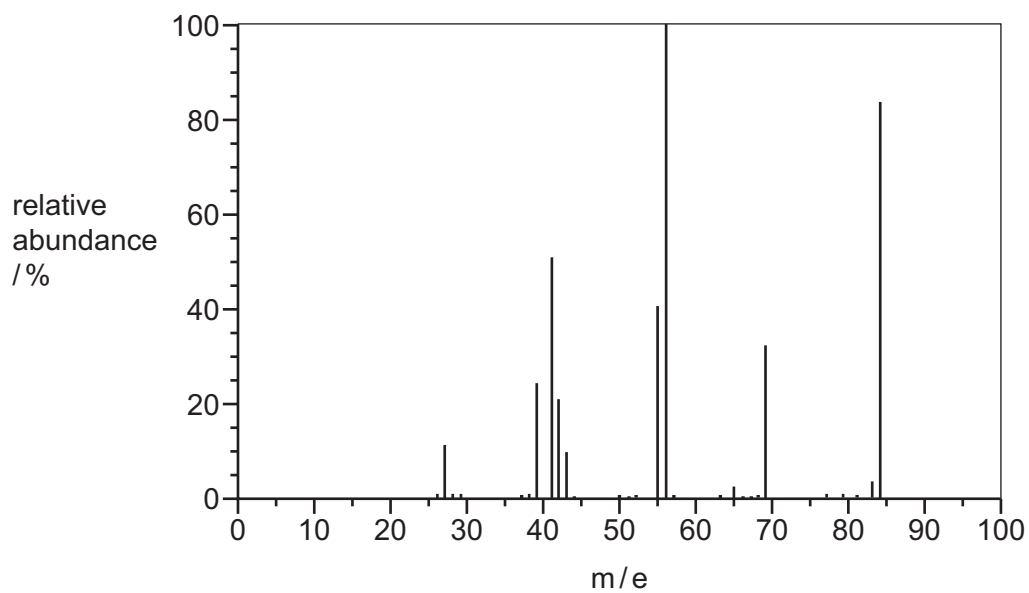
(ii) Use the gradient value in (i) and the mathematical relationship on page 7 to calculate the experimentally determined relative molecular mass of **Y**.

experimentally determined  $M_r$  of **Y** = ..... [2]



(e) Compound **Y** is a hydrocarbon that contains 85.7% carbon by mass.

The diagram shows the mass spectrum of compound **Y**.



Use all the information given to determine the molecular formula of **Y**.

molecular formula of **Y** ..... [2]

[Total: 12]

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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**October/November 2016**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name 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.

Do not use staples, paper clips, glue or correction fluid.

**DO NOT WRITE IN ANY BARCODES.**

Answer **all** questions.

Electronic calculators may be used.

You may lose marks if you do not show your working or if you do not use appropriate units.

Use of a Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.

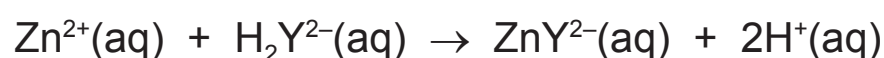
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **12** printed pages.

- 1 Titrations using ethylenediaminetetraacetic acid (EDTA) can be used to determine the concentration of metal ions in solution, such as  $\text{Zn}^{2+}(\text{aq})$ .

A solution of EDTA is usually prepared from the hydrated disodium salt,  $\text{Na}_2\text{H}_2\text{Y}\cdot 2\text{H}_2\text{O}$ . The anion of EDTA is  $\text{H}_2\text{Y}^{2-}$ , where Y represents the organic part of the ion.

The equation for the reaction between  $\text{Zn}^{2+}(\text{aq})$  and EDTA is shown.



The indicator for the reaction is Solochrome Black, which changes colour at the endpoint from purple to blue. The indicator only works at pH 10, so a buffer solution is added to the metal ion solution to maintain the pH.

- (a) Explain why the pH would change during the titration if the buffer were not present.

.....  
 .....  
 ..... [1]

- (b) You are to plan a titration experiment to determine the concentration of zinc ions in a solution of zinc sulfate of concentration approximately  $0.1 \text{ mol dm}^{-3}$ .

You are provided with the following materials.

20.0 g of hydrated disodium EDTA,  $\text{Na}_2\text{H}_2\text{Y}\cdot 2\text{H}_2\text{O}$  ( $M_r = 372.2$ )  
 aqueous zinc sulfate of approximate concentration  $0.1 \text{ mol dm}^{-3}$   
 buffer solution, pH 10  
 Solochrome Black indicator solution

- (i) Name **three** pieces of volumetric apparatus you would use, with their capacities in  $\text{cm}^3$ .

1 .....  
 2 .....  
 3 ..... [2]

- (ii) Calculate the mass of hydrated disodium EDTA that would be required for the preparation of a standard solution of concentration  $0.100\text{mol dm}^{-3}$ , using the apparatus you have specified in (i).

mass of hydrated disodium EDTA = ..... g [1]

- (iii) Describe how you would prepare this standard solution for use in your titration.

.....  
.....  
.....  
.....  
.....  
..... [2]

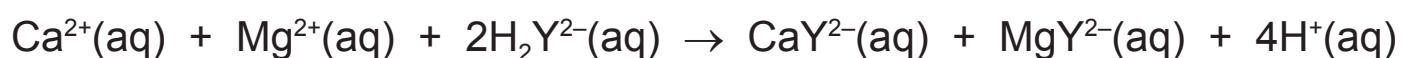
- (iv) After you have performed a rough titration, how would you ensure that your next titration is accurate?

.....  
..... [1]

- (v) How would you ensure that your titration result is reliable?

.....  
..... [1]

- (c) The term *hard water* is used to describe water containing the dissolved metal ions,  $\text{Ca}^{2+}(\text{aq})$  and  $\text{Mg}^{2+}(\text{aq})$ . Both of these metal ions react with EDTA anions,  $\text{H}_2\text{Y}^{2-}$ .



In an experiment to determine the concentration of each of these metal ions, two separate titrations with EDTA need to be performed.

For titration **1**, a  $25.0\text{ cm}^3$  sample of hard water is titrated with  $0.0100\text{ mol dm}^{-3}$  EDTA solution using Solochrome Black solution as indicator.

For titration **2**, another  $25.0\text{ cm}^3$  sample of the same hard water is first treated with excess  $2\text{ mol dm}^{-3}$   $\text{NaOH}(\text{aq})$  which precipitates **all** of the  $\text{Mg}^{2+}(\text{aq})$  ions as  $\text{Mg}(\text{OH})_2(\text{s})$ . After this treatment, no  $\text{Mg}^{2+}(\text{aq})$  ions remain in solution, leaving only dissolved  $\text{Ca}^{2+}(\text{aq})$  ions in solution. This solution is then titrated with  $0.0100\text{ mol dm}^{-3}$  EDTA solution using Solochrome Black solution as indicator.

The following information gives some of the hazards associated with the chemicals used in the procedure.

**Sodium hydroxide** Solutions equal to or more concentrated than  $0.5\text{ mol dm}^{-3}$  are classified as **corrosive**.

**Solochrome Black** Solid Solochrome Black is classified as **health hazard** and is irritating to eyes, respiratory system and skin. All solutions are made up in ethanol and so are classified as **flammable** and **health hazard**.

- (i) Identify **one** hazard that must be considered when planning the experiment and describe a precaution, other than eye protection, that should be taken to keep risks from this hazard to a minimum.

hazard: .....

precaution: .....

.....

[1]

(ii) Results obtained from this experiment are shown.

titre 1, 22.70 cm<sup>3</sup>      titre 2, 16.60 cm<sup>3</sup>

Use the results of the titrations to determine the concentrations of Ca<sup>2+</sup>(aq) and Mg<sup>2+</sup>(aq) in the hard water.

concentration of Ca<sup>2+</sup>(aq) ..... mol dm<sup>-3</sup>

concentration of Mg<sup>2+</sup>(aq) ..... mol dm<sup>-3</sup>  
[4]

[Total: 13]

- 2 Benzenediazonium chloride,  $C_6H_5N_2Cl$ , is readily hydrolysed at temperatures above  $5^\circ C$ , forming phenol, nitrogen gas and hydrochloric acid.



The progress of the reaction can be monitored by measuring the volume of gas produced over time. The volume of gas produced,  $V$ , after time,  $t$ , is proportional to the amount of benzenediazonium chloride that has been hydrolysed. The final volume of gas produced,  $V_{\text{final}}$ , is proportional to the original concentration of benzenediazonium chloride.

The order of reaction can be determined from these results.

- (a) (i) The experimentally determined volumes of gas produced during the hydrolysis of benzenediazonium chloride at  $50^\circ C$  are recorded below.

Process the results to allow you to plot a graph of  $(V_{\text{final}} - V)$  against time,  $t$ .

$$V_{\text{final}} = 252 \text{ cm}^3$$

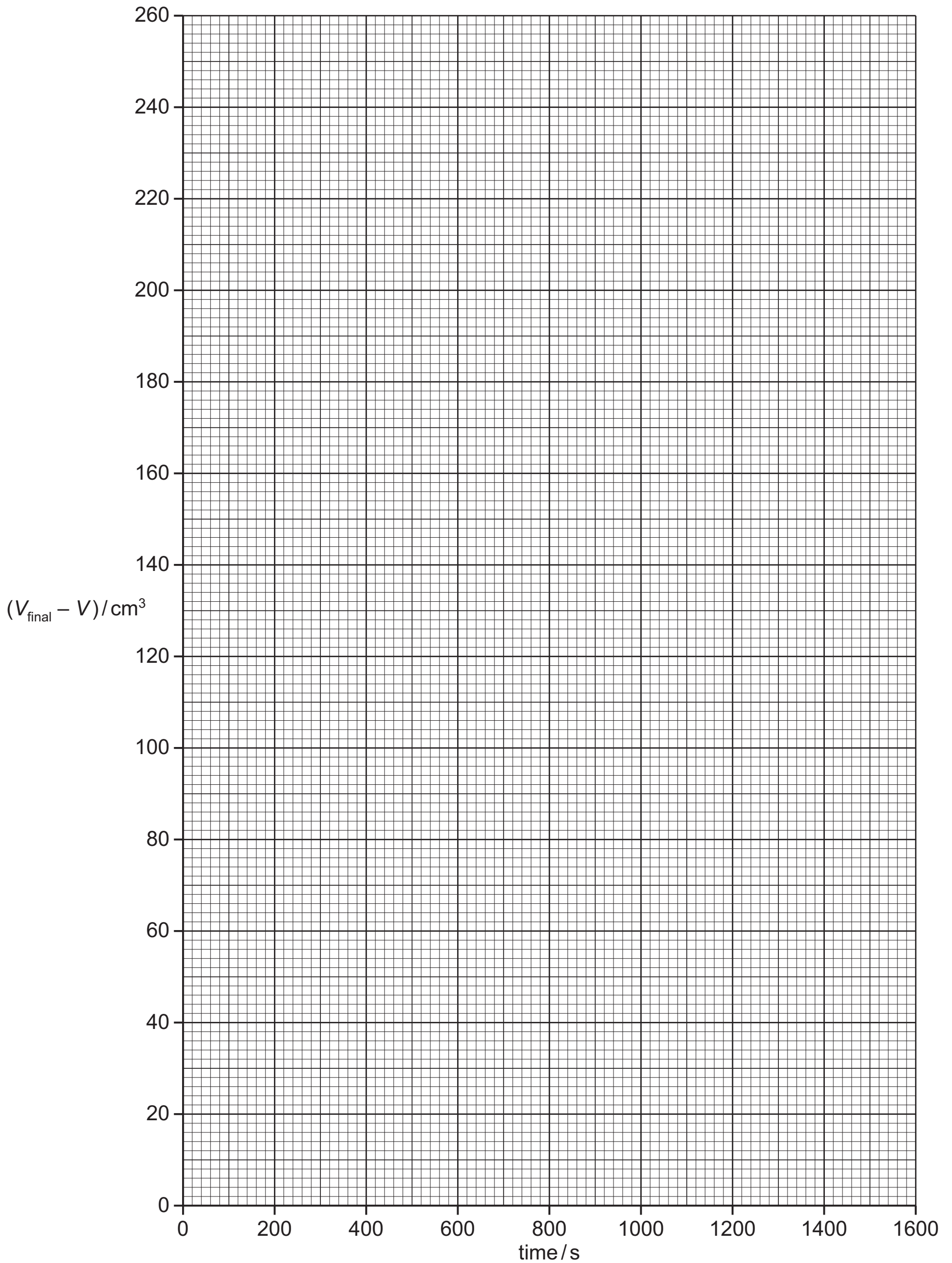
time/s	volume, $V/\text{cm}^3$	$(V_{\text{final}} - V)/\text{cm}^3$
0	0	
150	32	
300	62	
450	87	
600	110	
750	129	
900	146	
1050	160	
1200	173	
1350	184	
1500	193	

[1]



(ii) Plot a graph to show how  $(V_{\text{final}} - V)/\text{cm}^3$  varies with time/s.

Use a cross (x) to plot each data point. Draw the curve of best fit.



[2]

(iii) Do you think the results obtained in (i) are reliable? Explain your answer.

.....  
.....  
..... [1]

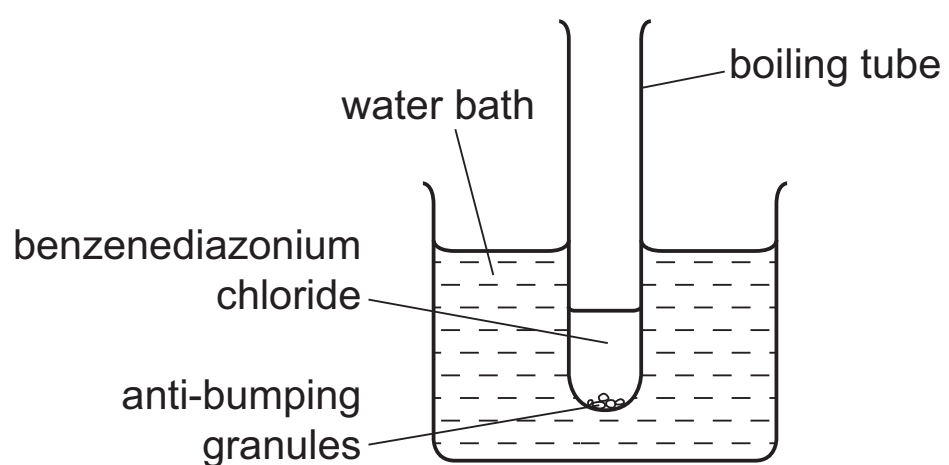
(iv) Use the graph to determine the half-life,  $t_{1/2}$ , of this reaction.

State the co-ordinates of both points you used in your calculation.

co-ordinates 1 ..... co-ordinates 2 .....

half-life = ..... s  
[2]

- (b) A student set up an experiment to determine the order of the reaction in (a). Part of the experimental set-up is shown below.



- (i) Complete the diagram above to show the experimental set-up the student could have used to collect and measure the volume of gas evolved by the reaction. [2]
- (ii) The water bath was set at 60 °C.

At a reaction temperature of 60 °C, the measurements made would be less accurate than measurements made at room temperature.

State why the measurements made at a higher temperature are less accurate.

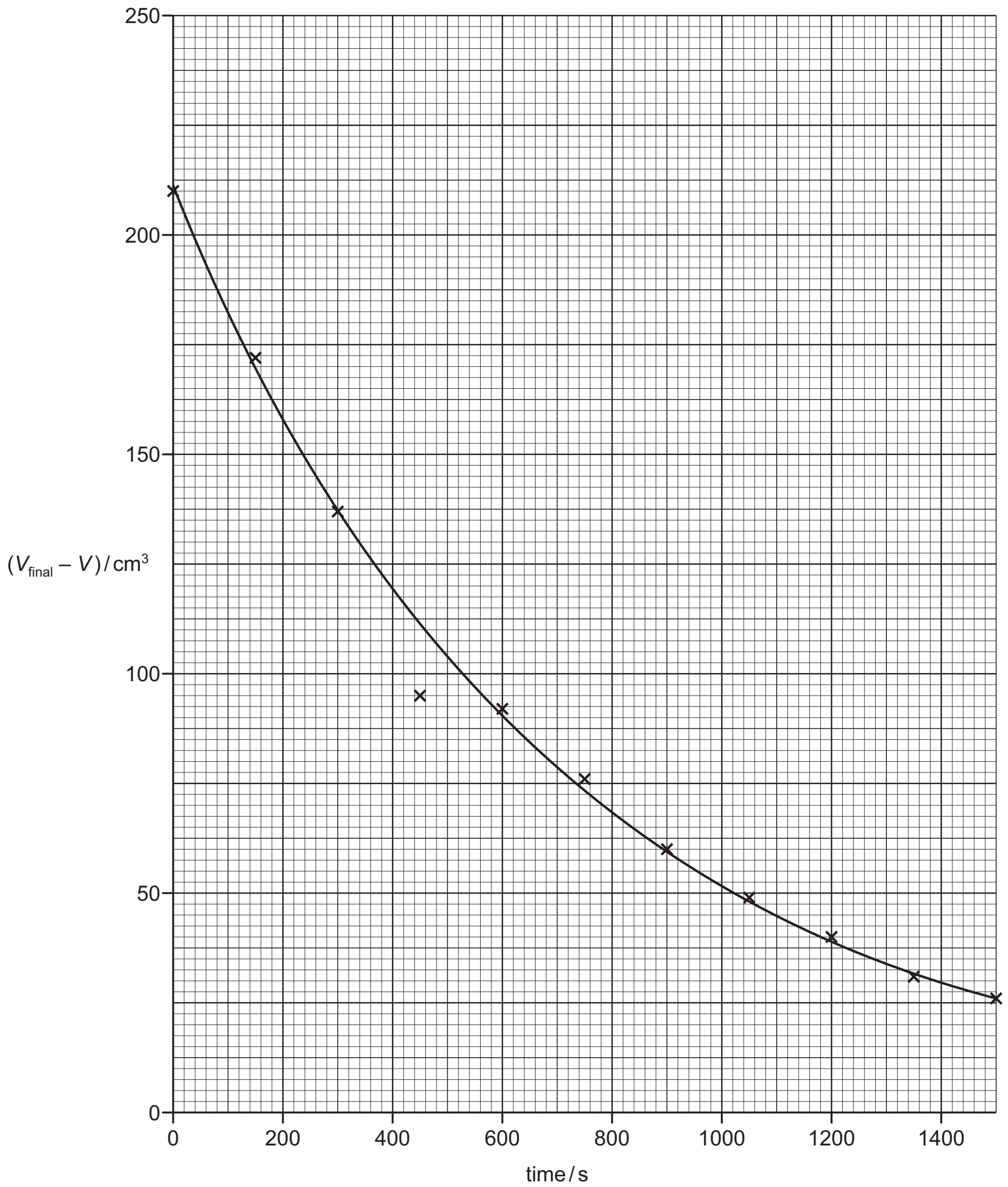
.....  
 .....

State the effect this will have on the values of  $V_{\text{final}} - V$ .

.....  
 .....

[2]

(c) The graph below shows the results obtained from another benzenediazonium chloride hydrolysis reaction performed at a different temperature.



- (i) The point at time = 450 s is considered to be anomalous.

Suggest what caused the anomaly.

.....

.....

..... [1]

**Question 2 continues on page 12.**

- (ii) The rate of reaction at different times can be calculated by drawing tangents to the best-fit line. The gradient of the tangent is equal to the rate of reaction, in  $\text{cm}^3 \text{s}^{-1}$ .

Use the graph in (c) to read the value of  $(V_{\text{final}} - V)$  at time  $t = 200 \text{ s}$  and write this value in the table below.

Draw a tangent to the curve at time  $t = 200 \text{ s}$ . Use the tangent to determine the gradient at time  $t = 200 \text{ s}$ .

State the co-ordinates of both points you used in your calculation.

co-ordinates 1 ..... co-ordinates 2 .....

gradient at 200 s = .....  $\text{cm}^3 \text{s}^{-1}$

Use your gradient to complete the table.

time/s	$(V_{\text{final}} - V)/\text{cm}^3$	rate of reaction/ $\text{cm}^3 \text{s}^{-1}$
200		
500	104	-0.143
600	91	-0.127
900	59	-0.0867
1000	52	-0.0720
1400	30	-0.0417

[4]

- (iii) The concentration of benzenediazonium chloride is directly proportional to  $(V_{\text{final}} - V)$ .

Use the data in the table in (ii) to calculate the order of reaction with respect to benzenediazonium chloride.

You must show your working.

[2]

[Total: 17]

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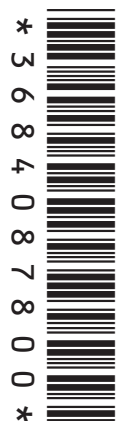
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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**May/June 2015**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

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Answer **all** questions.

Electronic calculators may be used.

You may lose marks if you do not show your working or if you do not use appropriate units.

Use of a Data Booklet is unnecessary.

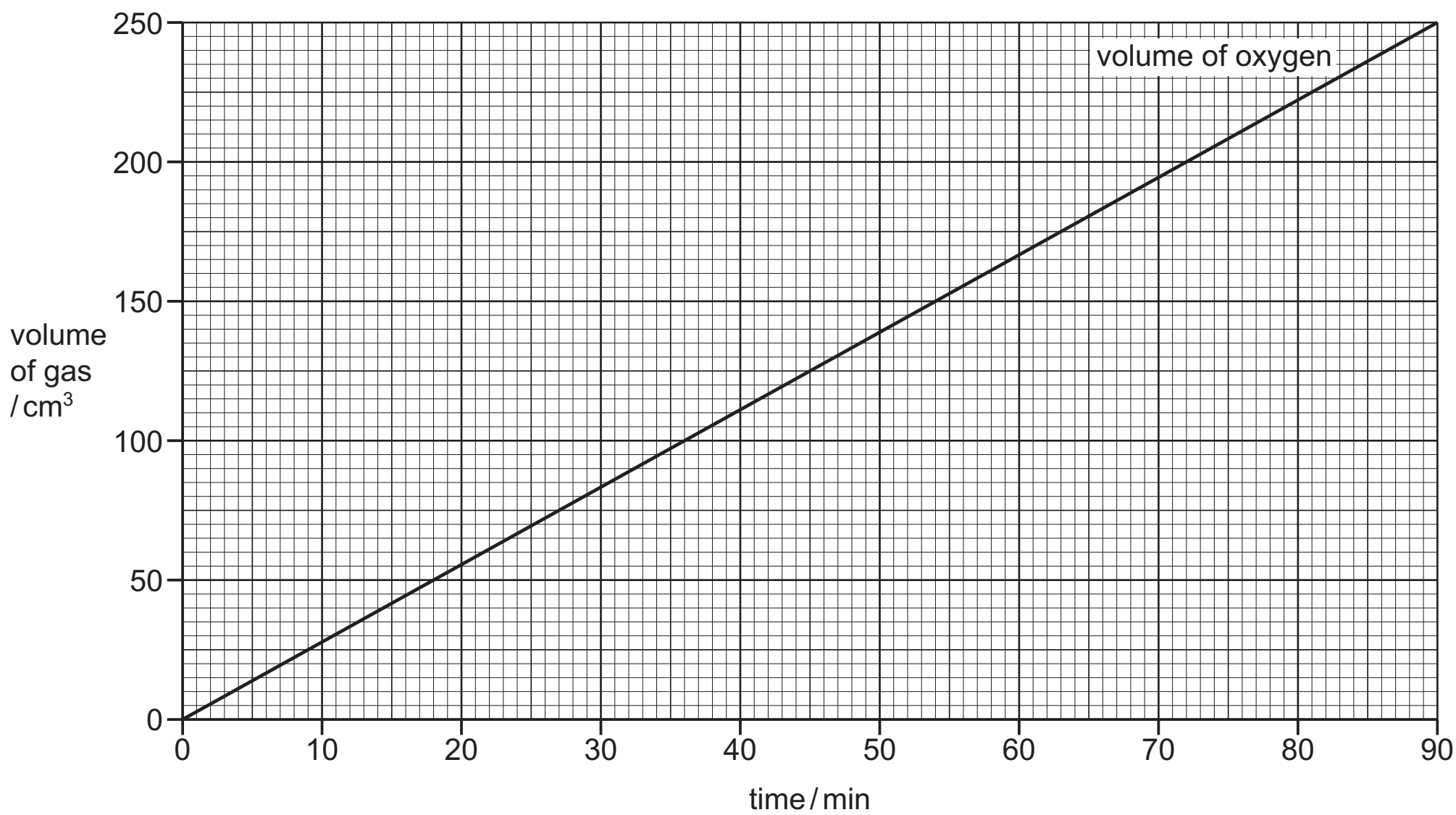
At the end of the examination, fasten all your work securely together.

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

This document consists of **8** printed pages.

1 This question concerns electrolysis of different compounds.

(a) During the electrolysis of dilute sulfuric acid using a current of 0.75A for 90 minutes, the volume of oxygen gas collected was recorded and is shown in the graph below.



(i) Give equations for the reactions that occur at each electrode in the electrolysis of sulfuric acid.

.....

.....

.....

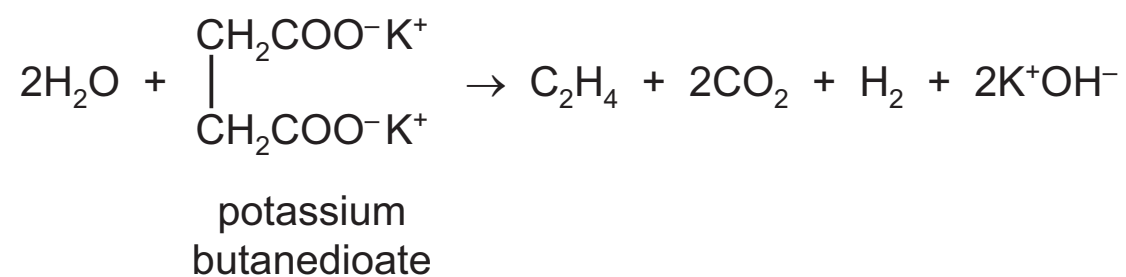
..... [2]

(ii) On the graph above, use a ruler to draw and label a line (hydrogen) to predict the volume of hydrogen that would be given off during the same experiment. [1]

(iii) On the graph above, use a ruler to draw and label a line (oxygen) to predict the volume of oxygen that would be produced if a current of 0.45A was used instead of the 0.75A used in the original experiment. [1]



(b) During the electrolysis of potassium butanedioate, the following reaction occurs.

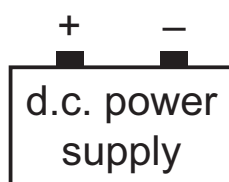


An experiment can be carried out to confirm the above equation. In order to do this, the amounts of hydrogen, ethene and carbon dioxide produced need to be measured.

Hydrogen is produced at one electrode, ethene and carbon dioxide are produced at the other. The carbon dioxide can be separated from the ethene by absorbing it in an alkali before the volume of ethene is measured.

(i) Using the power supply drawn below, draw a fully labelled circuit diagram and apparatus which shows how:

- the current could be measured,
- the hydrogen produced could be collected and its volume measured,
- the carbon dioxide could be removed using a named alkali,
- the volume of ethene could be measured.



[5]

- (ii) State what measurements should be taken when carrying out the experiment.

.....  
 .....  
 ..... [2]

- (iii) **C** coulombs of electricity resulted in **V** cm<sup>3</sup> of hydrogen gas being produced during the electrolysis.

In terms of **C** and **V**, state the number of coulombs, **N**, that would be required to produce 24 dm<sup>3</sup> of hydrogen.

[1]

- (iv) In terms of **N**, state the number of faradays of electricity that would be required to produce 1 mol of hydrogen at room temperature and pressure.  
 (1 faraday of electricity = 96 500 coulombs)

[1]

- (v) Give the equation for the reaction that takes place when the carbon dioxide is absorbed by the alkali.  
 Include state symbols.

..... [1]

- (vi) Predict the organic product that would be obtained at the anode when a solution of potassium *hexanedioate* is electrolysed.

[1]

[Total: 15]

- 2 In order to identify a monoprotic (monobasic) hydroxycarboxylic acid, HX, the following experiments are carried out.

25.0 cm<sup>3</sup> of an aqueous solution of HX is titrated against 0.0500 mol dm<sup>-3</sup> aqueous sodium carbonate. The end-point of the titration is reached when 25.0 cm<sup>3</sup> of the aqueous sodium carbonate has been added.

- (a) (i) Write the equation for the complete neutralisation of HX with sodium carbonate.

..... [1]

- (ii) How does the equation show that the concentration of HX is 0.100 mol dm<sup>-3</sup>?

.....  
 ..... [1]

- (b) (i) State the acid dissociation constant,  $K_a$ , for the above reaction **in terms of H<sup>+</sup> and HX only**.

$$K_a =$$

[1]

- (ii) The pH of the aqueous solution of HX is 2.43.

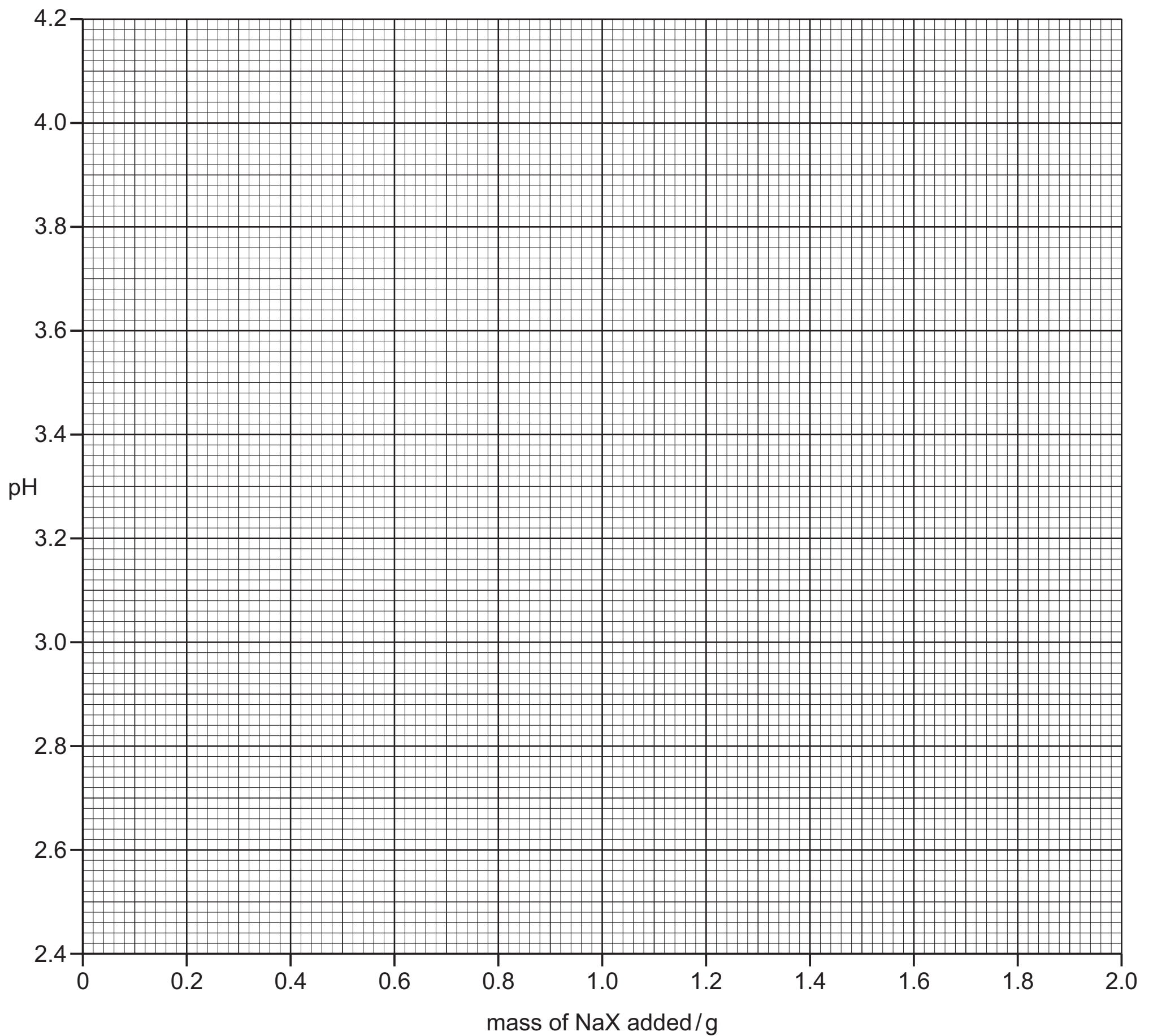
Use the pH and the concentration of HX to show that the  $pK_a$  of the acid is 3.86. **All your working must be shown.**

[2]

- (c) In an experiment various masses of the sodium salt of the acid, NaX, are added to separate portions of  $100\text{ cm}^3$  of HX with stirring. After each addition the pH of the solution obtained is measured. The results of the experiment are recorded in the table below.

mass of NaX added/g	pH
0.00	2.43
0.10	2.81
0.20	3.11
0.30	3.19
0.40	3.41
0.60	3.59
0.80	3.71
1.00	3.81
1.20	3.89
1.50	3.99
2.00	4.11

- (i) Plot a graph to show how the pH of the solution varies with the mass of NaX added. Draw the curve of best fit.



[2]

- (ii) Circle **one** anomalous point on your graph and give a reason for how this could have occurred using the experimental procedure described.

.....

.....

.....

..... [2]

- (d) (i) The graph shows that a pH of 3.86 is obtained when 1.12 g of NaX is added to 100 cm<sup>3</sup> of HX.

Remember that  $pK_a$  of HX is also 3.86.

Use this information to calculate the relative molecular mass,  $M_r$ , of HX.

Show your working.

[ $A_r$ : H, 1.0; C, 12.0; O, 16.0; Na, 23.0]

[3]

- (ii) The calculated  $M_r$  is subject to small experimental error. Suggest a structure for the organic hydroxycarboxylic acid, HX, that best fits your  $M_r$  data.

If you have not calculated a value for the  $M_r$ , use the value of 104. This is not the correct value.

[1]

- (e) Another method for determining the concentration of the acid HX could be to evaporate a sample of the solution and weigh the solid that remains.

Suggest **two** reasons why this might not be a very good method of finding the mass of solid HX in a sample of the solution.

.....

.....

.....

..... [2]

[Total: 15]

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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**October/November 2015**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

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Answer **all** questions.

Electronic calculators may be used.

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Use of a Data Booklet is unnecessary.

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This document consists of **9** printed pages and **3** blank pages.

1 It is possible to determine the relative molecular mass,  $M_r$ , of a small sample of a volatile liquid by measuring its mass and then heating to vaporise it to obtain its volume as a gas.

(a) Explain how the relative molecular mass can be determined in this way.

.....  
.....  
.....  
..... [2]

(b) (i) The volume of the vaporised sample depends on its temperature and pressure.

In an experiment, a sample of volatile liquid of known mass was vaporised and its volume recorded. The pressure was correctly recorded as 101 kPa but the temperature was incorrectly recorded as 50 °C. The correct temperature was 60 °C.

By considering the effect of these different temperatures on the gas volume, explain how the value of the calculated  $M_r$  would be affected.

.....  
.....  
.....  
.....  
.....  
..... [3]

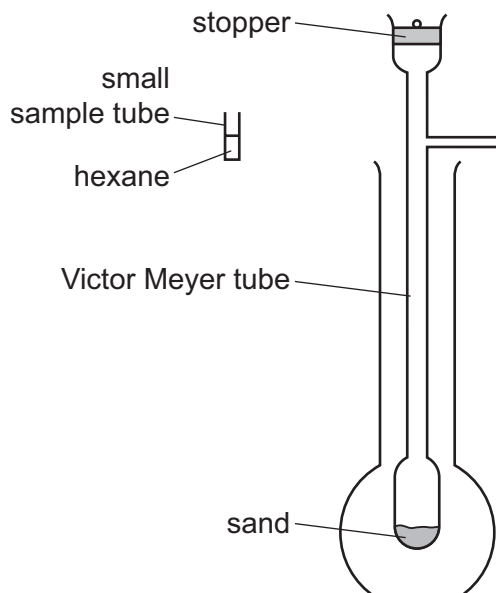
(ii) The temperature was maintained at 60 °C but the pressure was increased to 110 kPa. Would this have given an answer that was nearer to the true value of the relative molecular mass? Explain your answer.

.....  
.....  
..... [1]



In an experiment to determine the relative molecular mass of hexane, boiling point  $69^{\circ}\text{C}$ , a specialist piece of apparatus called a Victor Meyer tube can be used. This consists of a long tube with a bulb at the base in which a sample can be vaporised. The tube has a side arm to allow the escape of gas from within the tube. The tube is surrounded by another which can be used to heat the contents of the first tube.

A diagram of the apparatus is shown below.



A small sample tube containing the hexane is inserted at the top of the Victor Meyer tube. The sample tube is small enough to fit inside the Victor Meyer tube and falls freely onto the hot sand below. The sand will cushion its fall so that the sample tube does not break. The stopper is then quickly replaced at the top of the Victor Meyer tube. The hot sand causes the hexane to vaporise and expel air contained in the Victor Meyer tube.

(c) Complete the diagram above to show:

- how the apparatus should be heated,
- a connection to further apparatus which would allow the air expelled from the Victor Meyer tube when the sample of hexane is vaporised to be collected and measured.

[2]

(d) Suggest **one** hazard associated with the use of hexane.

.....  
 ..... [1]

(e) (i) With the gas collection apparatus connected to the heated Victor Meyer tube, expelled air will be collected before the hexane is introduced. Explain why.

.....  
.....  
.....  
..... [2]

(ii) At which stage of the experimental procedure should the sample tube be dropped into the Victor Meyer tube?

.....  
..... [1]

(f) State what measurements you would need to make in order to determine the relative molecular mass of hexane.

.....  
.....  
.....  
.....  
..... [3]

[Total: 15]

**QUESTION 2 STARTS ON THE NEXT PAGE.**

- 2 In an experiment, various masses of solid barium hydroxide are added to 60.0 cm<sup>3</sup> of a solution of hydrochloric acid contained in a polystyrene cup.

In each experiment a fresh sample of the acid is taken and its initial temperature is measured. After the barium hydroxide has been added, the acid is stirred and the maximum temperature reached is noted.

The results of each experiment are recorded in the table below.

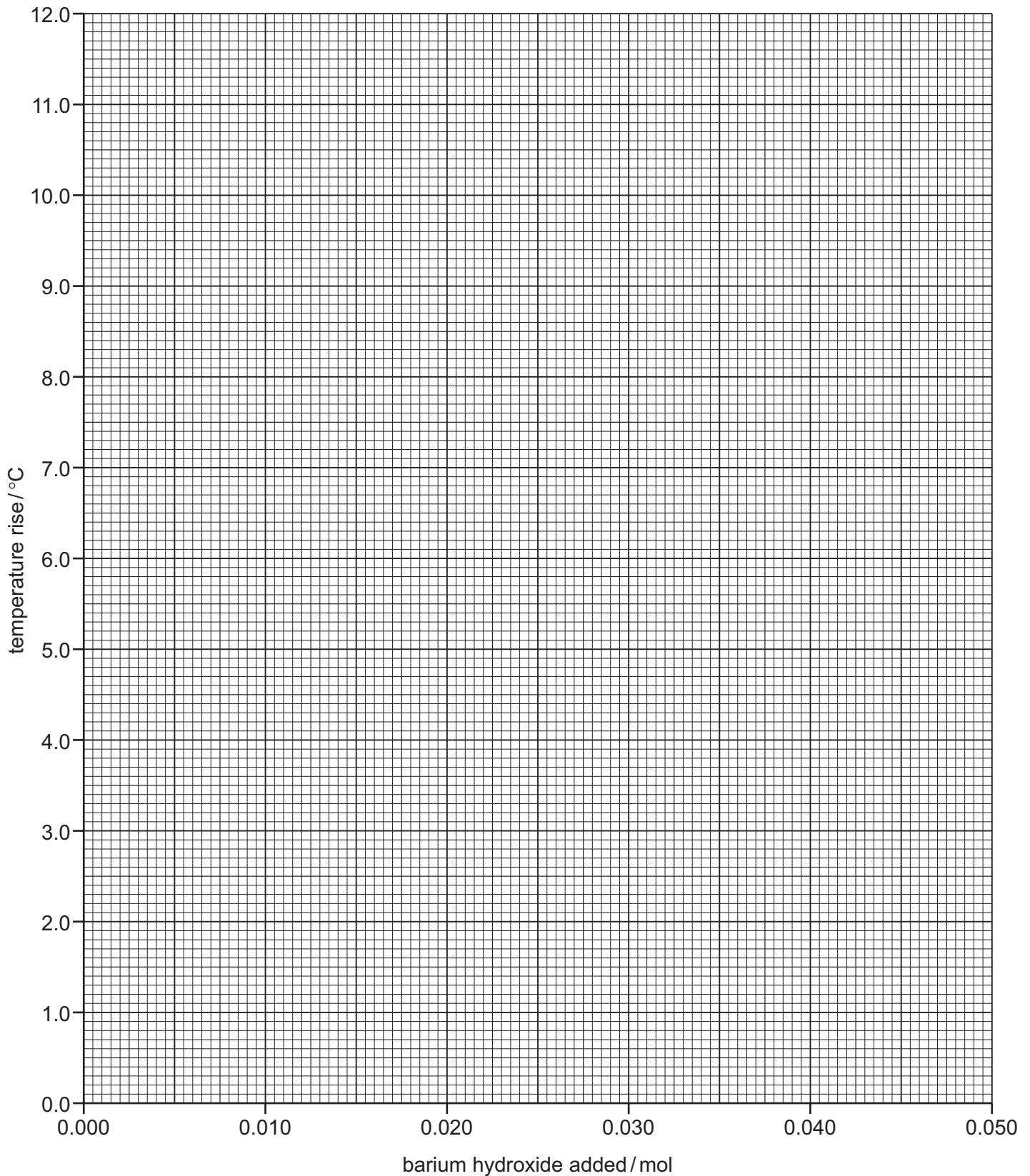
- (a) Complete the table below to give the temperature rise obtained from each experiment to **one decimal place** and the amount of barium hydroxide used in mol to **three significant figures** in each case.

The mass of 1 mol of barium hydroxide is 171 g.

initial temperature of HCl/°C	mass of barium hydroxide added /g	maximum temperature reached/°C	temperature rise/°C	barium hydroxide added/mol
21.0	0.500	22.2		
20.6	1.00	23.0		
21.2	1.50	24.9		
21.8	2.00	26.5		
20.5	3.00	27.8		
21.4	4.00	31.1		
21.2	5.00	31.6		
21.0	6.00	31.4		
20.8	8.00	31.2		

[2]

- (b) (i) Using the grid on page 7, plot a graph to show how the temperature rise varies with the moles of barium hydroxide added. [1]



- (ii) Draw **two** lines of best fit on your graph and state the value on the x-axis at the point of intersection of the two lines.

value on the x-axis at the point of intersection is .....

[2]

(c) Use the value on the *x*-axis at the point of intersection to calculate the concentration of the hydrochloric acid in mol dm<sup>-3</sup>.

[2]

(d) Explain the variation in temperature that takes place when barium hydroxide is added to the hydrochloric acid.

.....  
.....  
.....  
.....  
.....  
..... [2]

(e) (i) When the experiment is done in the way described, the results are not very accurate.

Apart from limitations due to the accuracy of the measuring equipment, suggest why:

- all the temperature rises measured are less than theoretically should be expected,

.....  
.....

- the temperature rises are more inaccurate as they approach their maximum value.

.....  
.....

[2]

(ii) What improvement would you make to achieve greater accuracy?

.....  
.....  
.....  
..... [1]

- (f) In another experiment, 60.0 cm<sup>3</sup> of ethanoic acid is used instead of the 60.0 cm<sup>3</sup> of hydrochloric acid.

If the ethanoic acid has the same concentration as the hydrochloric acid, draw on your graph another pair of lines to show the results you would expect to obtain.

Explain your answer.

.....

.....

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.....

.....

.....

..... [3]

[Total: 15]







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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**May/June 2014**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

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Answer **all** questions.

Electronic calculators may be used.

You may lose marks if you do not show your working or if you do not use appropriate units.

Use of a Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.

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

This document consists of **9** printed pages and **3** blank pages.



- 1 The liquids trichloromethane and water separate into two immiscible layers when shaken together and allowed to stand.  
Ammonia can dissolve in both of these layers. The distribution of ammonia between these two solvents is called partition, where the concentration of ammonia in each solvent will be different. The partition coefficient represents the ratio of the distribution.

You are to plan an experiment, using a titration with sulfuric acid, to determine the value of the partition coefficient of ammonia between water and trichloromethane at room temperature.

The following information gives some of the hazards associated with trichloromethane and ammonia.

**Trichloromethane:**

Anaesthetic if inhaled. Dangerously irritating to the respiratory system.

**Ammonia:**

An aqueous solution with a concentration of less than  $3 \text{ mol dm}^{-3}$  may cause harm to eyes or in a cut. At greater concentrations aqueous ammonia should not be inhaled and it causes irritation to the eyes and skin.

You are provided with the following.

- trichloromethane
- aqueous ammonia of concentration  $5.00 \text{ mol dm}^{-3}$
- sulfuric acid, of concentration  $0.500 \text{ mol dm}^{-3}$
- distilled water for dilution of aqueous ammonia

- (a) Explain why ammonia is likely to be more soluble in water than in trichloromethane.

.....  
.....  
.....  
..... [2]

- (b) Define the partition coefficient,  $K_{\text{partition}}$ , for ammonia between water and trichloromethane. State whether the partition coefficient you have defined will be greater or less than 1.

[1]



(c) In the experiment, explain whether it is important that the volumes of water and trichloromethane are the same.

.....  
.....  
.....  
..... [1]

(d) Write an equation for the reaction of aqueous ammonia and sulfuric acid.

..... [1]

(e) (i) The partition coefficient for ammonia distributed between water and trichloromethane is approximately 25.  
Calculate the concentration of aqueous ammonia that should be used so that a 25.0 cm<sup>3</sup> sample of the aqueous ammonia layer would require approximately 24.0–26.0 cm<sup>3</sup> of 0.500 mol dm<sup>-3</sup> sulfuric acid for complete neutralisation.  
Then state the factor by which the 5.00 mol dm<sup>-3</sup> aqueous ammonia should be diluted to give that concentration.

[2]

(ii) Describe, in detail, how you would dilute 5.00 mol dm<sup>-3</sup> aqueous ammonia to make 250 cm<sup>3</sup> of aqueous ammonia ready for use in the experiment.

.....  
.....  
.....  
.....  
.....  
.....  
.....  
..... [2]



(f) Other than the use of eye protection and gloves, state one safety precaution you would take while setting up the experiment.

.....  
.....  
..... [1]

(g) State a suitable indicator for use in the titration of a sample taken from the experiment. Explain your answer.

.....  
.....  
.....  
..... [2]

(h) It is unnecessary to titrate both layers of the partition. Explain why it would be better to titrate a sample of the aqueous layer rather than the trichloromethane layer.

.....  
.....  
.....  
..... [1]

(i) Once a mean titre has been calculated, outline the steps you would take to calculate the partition coefficient.

.....  
.....  
.....  
.....  
.....  
..... [2]

[Total: 15]



**QUESTION 2 STARTS ON THE NEXT PAGE.**



- 2 Nitrogen(II) oxide, NO, can be oxidised by ozone, O<sub>3</sub>, in the atmosphere to form nitrogen(IV) oxide, NO<sub>2</sub>.

It is possible to simulate this process in the laboratory to measure the rate at which this reaction takes place.

In this experiment, nitrogen(II) oxide is reacted with ozone. Since the concentration of nitrogen(II) oxide, [NO], in the air is very low, specialist equipment is required and [NO] oxide is measured as the number of molecules present in a volume of 1 cm<sup>3</sup>.

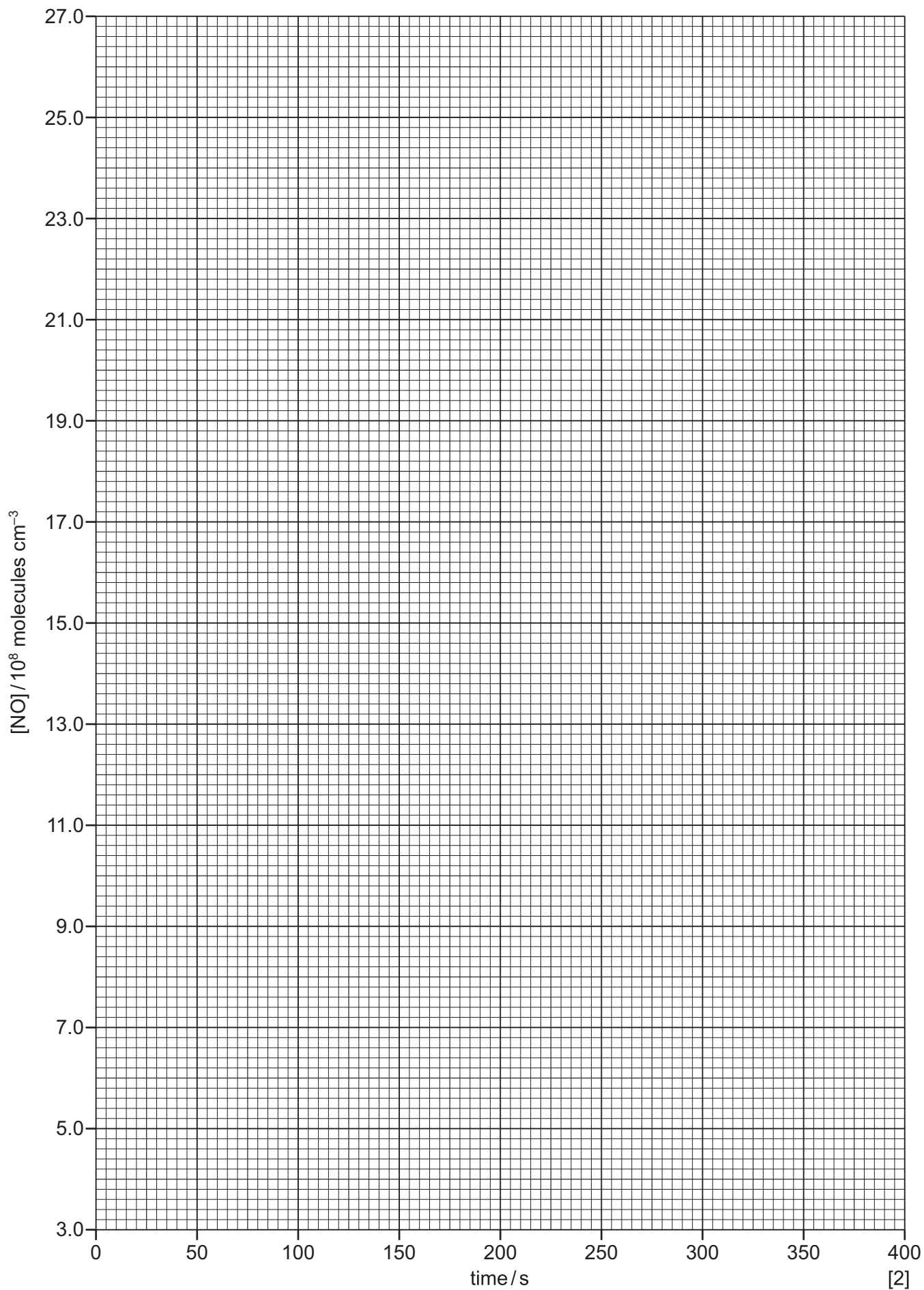
The results obtained from the experiment are shown below.

time/s	concentration of NO / 10 <sup>8</sup> molecules cm <sup>-3</sup>
0	27.0
30	21.9
60	17.7
90	14.4
120	13.2
150	9.45
180	7.66
210	6.21
240	5.03
270	4.08
300	3.31





(a) Use the results obtained to plot a graph to show the relationship between [NO] and time.





- (b) On your graph circle the **single** result that you consider to be the most anomalous. Suggest a reason why anomalous results may occur during an experiment to measure the rate of a reaction.

.....  
.....  
..... [2]

- (c) Use construction lines at concentrations of nitrogen(II) oxide equal to  $13.5 \times 10^8$  molecules  $\text{cm}^{-3}$  and  $6.75 \times 10^8$  molecules  $\text{cm}^{-3}$  to determine the order of reaction with respect to nitrogen(II) oxide.

Show the construction lines on your graph and your working.

[3]

- (d) (i) Use your graph to calculate the initial rate of the reaction.

[2]

- (ii) In the reaction between ozone and nitrogen(II) oxide the order of reaction with respect to ozone is 1.

In the experiment the initial concentration of ozone used was  $4 \times 10^{11}$  molecules  $\text{cm}^{-3}$ .

Calculate the value of the rate constant for the reaction and give its units.

[2]



- (e) 1 mole contains  $6.02 \times 10^{23}$  particles.  
Convert the initial rate in (d)(i) to a value with units of  $\text{mol dm}^{-3} \text{s}^{-1}$ .  
(If you have no answer to (d)(i) you may use  $3.0 \times 10^5$  as the value of the initial rate.)

[2]

- (f) The concentration of ozone used in the experiment is considerably greater than the concentration of nitrogen(II) oxide.  
Explain why this is necessary for the experiment, in order to determine the order with respect to nitrogen(II) oxide.

.....  
.....  
.....  
.....  
..... [2]

[Total: 15]



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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**October/November 2014**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

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Do not use staples, paper clips, glue or correction fluid.

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Answer **all** questions.

Electronic calculators may be used.

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Use of a Data Booklet is unnecessary.

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

This document consists of **10** printed pages and **2** blank pages.

- 1 A solder is an alloy of metals which is used to join other metal pieces together. A specialist solder that can be used to join together pieces of aluminium is made from a mixture by mass of 65% zinc, 20% aluminium and 15% copper.

You are to plan an experimental procedure to confirm the composition of a powdered sample of this solder, by adding reagents and then extracting from the mixture each of the following in sequence;

- (i) the copper metal,
- (ii) the aluminium as aluminium hydroxide,
- (iii) the zinc as zinc hydroxide.

You are provided with

- a sample of this solder, with approximate mass 4 g,
- $1.00 \text{ mol dm}^{-3}$  sulfuric acid,
- $1.00 \text{ mol dm}^{-3}$  ammonia.

No other reagents should be used. Standard laboratory equipment is available including a balance, accurate to two decimal places.

- (a) Complete the flowchart below to show the order in which the reagents would be added to the solder to allow you to extract and separate the components as copper metal, **(Step 1)**, aluminium hydroxide, **(Step 2)**, and zinc hydroxide, **(Step 3)**. You are reminded that aqueous ammonia contains both the base  $\text{OH}^-$  and the complex-forming molecule  $\text{NH}_3$ .

	Step 1	Step 2	Step 3
	reagent(s) added	reagent(s) added	reagent(s) added
	.....	.....	.....
	.....	.....	.....
	substance(s) present at the end of the reaction	substance(s) present at the end of the reaction	substance(s) present at the end of the reaction
	.....	.....	.....
	.....	.....	.....
	substance(s) removed by filtration (if any)	substance(s) removed by filtration (if any)	substance(s) removed by filtration (if any)
	.....	.....	.....
	.....	.....	.....

solder →

[5]



- (b) For some of the steps in the procedure you would need to be careful to add an appropriate quantity of a reagent.  
For each step of your procedure explain why particular quantities of reagent should be chosen.

**Step 1** .....

.....  
.....

**Step 2** .....

.....  
.....

**Step 3** .....

.....  
.....

[4]

- (c) The aluminium hydroxide and zinc hydroxide that have been extracted are difficult to dry so it is better to convert them to their oxides.  
Describe how this could be done and how you would make sure that each hydroxide had been completely converted into its oxide.

.....  
.....  
.....  
.....

[2]

(d) The purpose of the experiment is to confirm the composition of the solder.  
When the experiment is carried out state

- the measurements that would be taken,
- what you would do to the copper to make sure that the correct value is obtained.

.....  
.....  
.....  
.....  
.....  
..... [2]

(e) If the mass of aluminium oxide obtained was 1.50 g, calculate the mass of aluminium that was present in the solder.  
(A<sub>r</sub>: Al, 27.0; O, 16.0)

[1]

(f) Even if the experimental difficulties of extracting all of the copper from the mixture were overcome, it would be difficult to obtain an accurate mass of copper from this experiment. Suggest why.

.....  
.....  
.....  
..... [1]

[Total: 15]

**QUESTION 2 STARTS ON THE NEXT PAGE.**

- 2 The acid dissociation constant,  $K_a$ , of a weak monoprotic acid, **HA**, is to be determined from the measurement of the pH change that occurs when it is titrated with an aqueous solution of sodium hydroxide.

2.70 g of **HA** was dissolved in distilled water to make exactly 250.0 cm<sup>3</sup> of solution.

25.00 cm<sup>3</sup> of the solution was pipetted into a beaker.

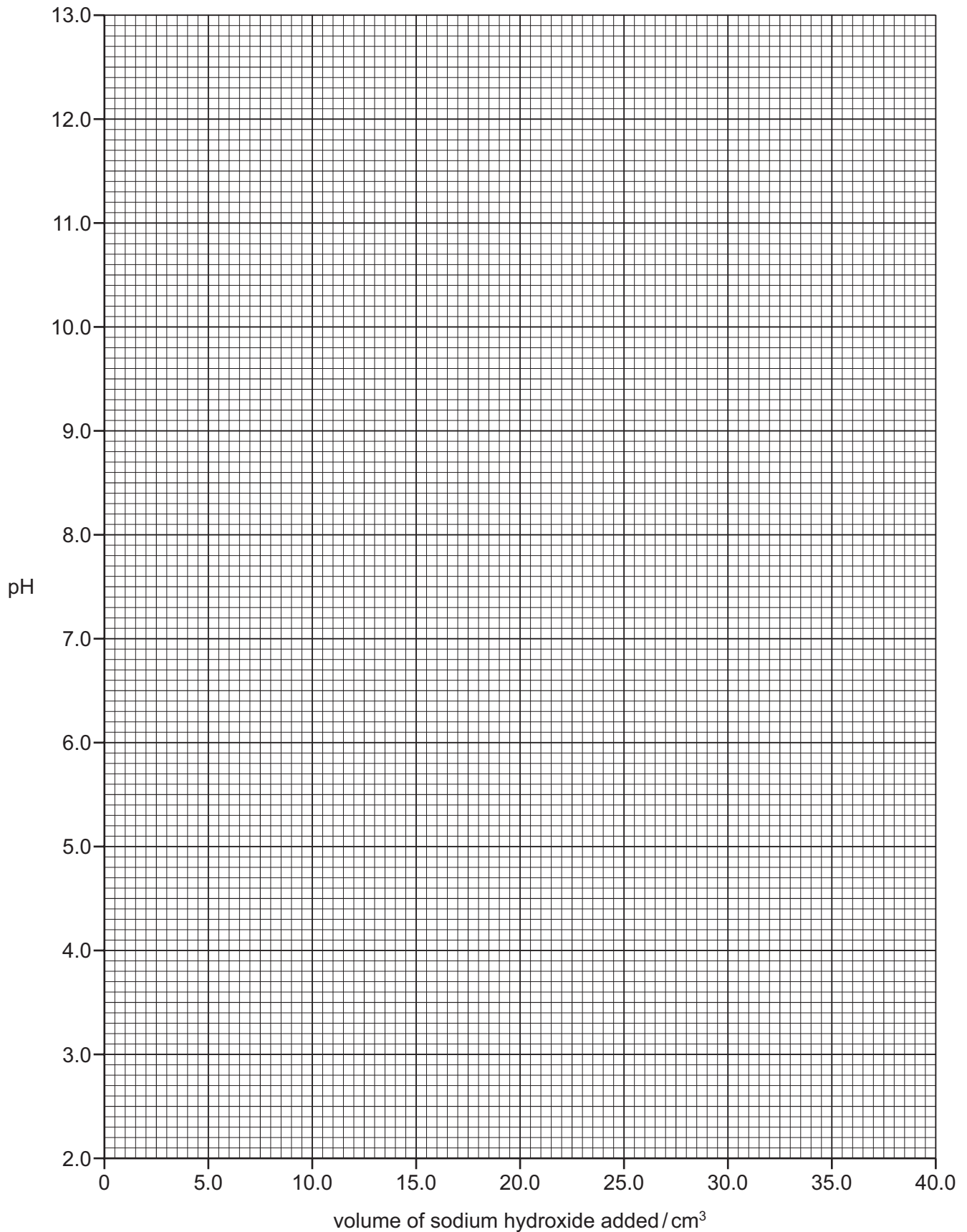
The pH of the acid in the beaker was measured and recorded in the table below.

A burette was then filled with aqueous sodium hydroxide and the 25.00 cm<sup>3</sup> of **HA** was titrated by adding volumes of the aqueous sodium hydroxide to the beaker as indicated in the table below. After each addition the pH was measured and the value recorded.

volume of sodium hydroxide added / cm <sup>3</sup>	pH measured
0.00	2.41
2.00	2.75
4.00	3.09
8.00	3.46
12.00	3.52
16.00	3.96
20.00	4.20
24.00	4.50
28.00	5.05
30.00	7.00
32.00	11.55
36.00	12.00

(a) Plot a graph to show how the pH of the mixture changes with the volume of added aqueous sodium hydroxide as shown in the table.

Draw a smooth curve, using the plotted points on your graph, to produce a titration curve for the addition of aqueous sodium hydroxide to the acid **HA**.



[2]

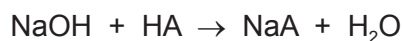
- (b) Circle any points on the graph that are anomalous and suggest a reason why this might occur.

.....  
.....  
.....  
..... [2]

- (c) What would be a suitable range of pH values in which an indicator would change colour to identify the end point of this neutralisation?

.....  
..... [1]

- (d) 30.00 cm<sup>3</sup> of aqueous sodium hydroxide is required to neutralise 25.00 cm<sup>3</sup> of **HA** and the equation for the neutralisation is shown.



- (i) Excluding water, state the three ions or molecules that will be present in the highest concentration when 15.00 cm<sup>3</sup> of aqueous sodium hydroxide has been added to 25.00 cm<sup>3</sup> of **HA**.

.....  
..... [1]

- (ii) State and explain how the concentrations of these ions or molecules compare.

.....  
.....  
.....  
..... [2]

- (e) Use your graph to determine the pH obtained when  $15.00 \text{ cm}^3$  of aqueous sodium hydroxide is added to  $25.00 \text{ cm}^3$  of **HA**. Use this pH to determine the value of  $K_a$  for **HA**.

[3]

- (f) (i) Use your answer to (e) and the initial pH of **HA** from the table to calculate the concentration of **HA** in  $\text{mol dm}^{-3}$ .

[2]

- (ii) Calculate the initial concentration of **HA**, in  $\text{g dm}^{-3}$ , and use this together with your answer to (f)(i) to calculate the relative molecular mass,  $M_r$ , of **HA**.  
(Remember that  $2.70 \text{ g}$  of **HA** was dissolved in distilled water to make exactly  $250.0 \text{ cm}^3$  of solution.)

[1]

(g) Even if the experiment is done very carefully with very accurate apparatus, the answer obtained for the molecular mass of **HA** is likely to be subject to error. Suggest why.

.....

.....

.....

..... [1]

[Total: 15]





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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**May/June 2013**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

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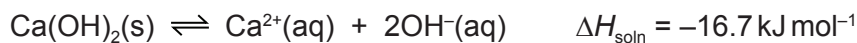
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- 1 Calcium hydroxide,  $\text{Ca}(\text{OH})_2$ , is slightly soluble in water, approximately  $1 \text{ g dm}^{-3}$  at  $25^\circ\text{C}$ . The molar enthalpy of solution of a solid is defined as the enthalpy change when one mole of the solid dissolves in water.

- (a) (i) Predict how the solubility of calcium hydroxide in water changes as the temperature is increased. Explain this prediction using Le Chatelier's Principle in terms of the equilibrium between the solid calcium hydroxide and the aqueous solution, as shown in the equation below.



Predict how the solubility will change as the temperature is increased. ....

.....

.....

Explanation .....

.....

.....

.....

- (ii) Display your prediction in the form of a sketch graph between  $0^\circ\text{C}$  and  $100^\circ\text{C}$ . Label the axes with units and give numerical values to ensure that the line clearly shows the solubility at  $25^\circ\text{C}$ .



[4]

- (b) If you were to carry out an experiment to investigate how the **solubility** of calcium hydroxide varies as the **temperature increases** name,

- (i) the independent variable,

.....

- (ii) the dependent variable. ....

[1]

- (c) You are to plan an experiment to determine as accurately as possible the concentration of a saturated aqueous solution of calcium hydroxide by titration with hydrochloric acid. You are reminded that the approximate solubility of calcium hydroxide is  $1 \text{ g dm}^{-3}$  at  $25^\circ\text{C}$ .

The following information gives some of the hazards associated with calcium hydroxide and hydrochloric acid.

**Hydrochloric acid,  $\text{HCl}(\text{aq})$**

**Corrosive;** Causes burns: Irritating to respiratory system.

Solutions equal to or more concentrated than  $6.5 \text{ mol dm}^{-3}$  are **corrosive**.

Solutions equal to or more concentrated than  $2 \text{ mol dm}^{-3}$  but more dilute than  $6.5 \text{ mol dm}^{-3}$  are said to be **irritant**.

**Calcium hydroxide,  $\text{Ca}(\text{OH})_2(\text{s})$**

**Irritant;** risk of serious damage to eyes.

You are provided with the following materials:

250  $\text{cm}^3$  of saturated calcium hydroxide,  
50  $\text{cm}^3$  of  $2.00 \text{ mol dm}^{-3}$  hydrochloric acid.

Give a step-by-step description of how you would carry out the experiment by including:

- (i) a balanced equation for the reaction between aqueous calcium hydroxide and hydrochloric acid,
- (ii) a list of apparatus with volumes where appropriate,
- (iii) a suitable indicator with relevant colours,
- (iv) a calculation of the approximate concentration of a saturated aqueous solution of calcium hydroxide in  $\text{mol dm}^{-3}$  at  $25^\circ\text{C}$ ,  
[A<sub>r</sub>: H, 1.0; O, 16.0; Ca, 40.1]
- (v) a detailed method for the dilution of the hydrochloric acid such that when a titration is carried out the two reacting volumes are approximately equal at the end-point. The relevant calculations and reasoning must be shown in full.
- (vi) a detailed method for carrying out sufficient titrations to allow an accurate end-point to be obtained,
- (vii) an outline calculation to show how the results are to be used to determine the accurate concentration of the aqueous calcium hydroxide.  
[A<sub>r</sub>: Cl, 35.5]







**QUESTION 2 STARTS ON THE NEXT PAGE.**

- 2 Hydrated copper(II) sulfate can be represented as  $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$  where  $x$  is the number of molecules of  $\text{H}_2\text{O}$  for each  $\text{CuSO}_4$ . When the compound is heated, it loses the molecules of water leaving anhydrous copper(II) sulfate.

A suggested equation is:



An experiment is carried out to attempt to determine the value of  $x$ .

- An open crucible is weighed and the mass recorded.
- A sample of hydrated copper(II) sulfate is added to the crucible and the new mass recorded.
- The crucible with hydrated copper(II) sulfate is heated strongly for five minutes and allowed to cool back to room temperature.
- The crucible with the contents is then reweighed and the mass recorded.

- (a) Calculate the relative formula masses,  $M_r$ , of  $\text{CuSO}_4$  and  $\text{H}_2\text{O}$ .  
[ $A_r$ : H, 1.0; O, 16.0; S, 32.1; Cu, 63.5]

[1]

- (b) The results of several of these experiments are recorded below.

Process the results in the table to calculate both the number of moles of anhydrous copper(II) sulfate and the number of moles of water.

Record these values in the additional columns of the table.

You may use some or all of the columns.

Masses should be recorded to **two decimal places**, while the numbers of moles should be recorded to **three significant figures**.

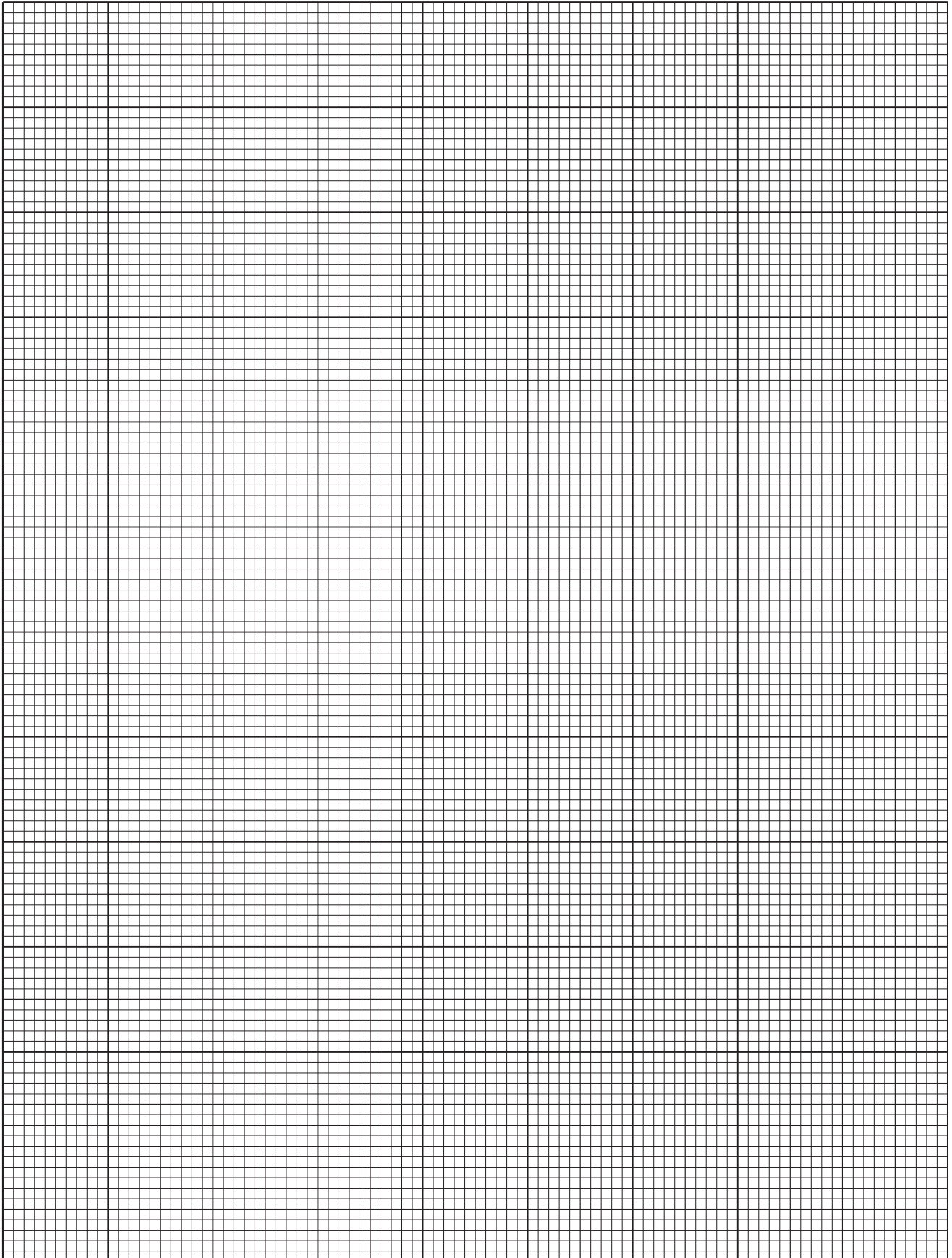
Label the columns you use. For each column you use include units where appropriate and an expression to show how your values are calculated.

You may use the column headings A to G for these expressions (e.g. A–B).

A	B	C	D	E	F	G
mass of crucible /g	mass of crucible + $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ /g	mass of crucible + $\text{CuSO}_4$ /g				
15.20	16.76	16.20				
15.10	16.90	16.25				
14.95	16.95	16.23				
15.15	17.25	16.49				
15.05	17.32	16.47				
14.90	17.24	16.43				
14.92	17.42	16.52				
15.30	17.99	17.02				
15.07	17.96	16.92				
15.01	18.09	16.98				

[2]

- (c) Plot a graph to show the relationship between the number of moles of anhydrous copper(II) sulfate,  $\text{CuSO}_4$  ( $x$ -axis), and the number of moles of water ( $y$ -axis). Draw the line of best fit. It is recommended that you do not include the origin in your choice of scaling.



[3]





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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**October/November 2013**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

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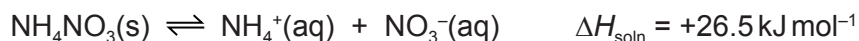
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2	
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- 1 Ammonium nitrate,  $\text{NH}_4\text{NO}_3$ , is soluble in water (approximately 2.5 mol / 100 g at 25 °C). The molar enthalpy of solution of a solid is defined as the enthalpy change when one mole of the solid is dissolved in water.



- (a) (i) Predict how the temperature of water, initially at 25 °C, would change as ammonium nitrate is dissolved. Explain this prediction in terms of lattice energy and the enthalpy of hydration of ions.

Prediction of the temperature change .....

.....

.....

Explanation .....

.....

.....

.....

- (ii) In the space below, sketch a graph to show your prediction of temperature change with concentration. Use two labelled axes and include an origin.

[4]

- (b) If you were to carry out an experiment to investigate how the **temperature change** of the solution varies as the **concentration changes** name,

(i) the independent variable, .....

(ii) the dependent variable. ....

[1]



- (c) You are to plan an experiment to determine as accurately as possible how the temperature change varies when different solutions are made, each with different concentrations of ammonium nitrate. You are reminded that the approximate solubility of ammonium nitrate is 2.5 mol / 100 g at 25 °C.

The following information gives some of the hazards associated with ammonium nitrate.

**Ammonium nitrate**  $\text{NH}_4\text{NO}_3$ . Contact with combustible material may cause fire. Explosive when mixed with combustible material.

**Do not allow the salt to become contaminated with organic matter and do not grind it.**

Solutions should be diluted to less than  $0.5 \text{ mol dm}^{-3}$  for disposal.

You should use only standard apparatus found in a school or college laboratory. Draw a diagram of the apparatus and experimental set up you would use showing clearly the following:

- (i) the apparatus used, such as the reaction vessel, and how the thermometer will be positioned in order to measure the temperature of the solution as accurately as possible,
- (ii) how the apparatus will be insulated.

Label each piece of apparatus used, indicating its size or capacity and both the temperature range and the precision of the thermometer.

[3]

- (d) Using the apparatus shown in (c) design an experiment to test your prediction in (a)(ii) of how the temperature change of the solution varies with solutions of different concentration.

In addition to the apparatus normally found in a laboratory you are provided with the following materials;

a supply of solid ammonium nitrate,  
distilled (deionised) water.

Give a step-by-step description of how you would carry out the experiment to include;

- (i) the number of experiments you would do,
- (ii) the temperature measurements you would take,
- (iii) the volume of water you would use,
- (iv) a calculation to show the maximum mass of ammonium nitrate you could use for your volume of water in (iii) and a range of masses for the other experiments.

[A<sub>r</sub>: H, 1.0; N, 14.0; O, 16.0]

[4]

- (e) State one hazard that must be considered when planning the experiment and describe a precaution that should be taken to keep risks from this hazard to a minimum. You may use the information in (c) if you wish.

.....

.....

.....

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.....

.....

..... [1]

- (f) In order to test your prediction in (a)(ii), you would need to plot a graph. In the space below, draw a table with appropriate headings, in which you would record all your experimental data and calculated values necessary for the construction of the graph. The headings **must** include the appropriate units.

[2]

[Total: 15]

- 2 The solubility of hydrated sodium sulfate,  $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ , in water increases with temperature. At a temperature between  $25^\circ\text{C}$  and  $70^\circ\text{C}$  there is a transition and the solubility becomes that of  $\text{Na}_2\text{SO}_4$ . The units of solubility are grams per one hundred grams of water, g/100 g water.

An experiment was carried out to investigate this solubility and determine the transition temperature between the two forms of sodium sulfate.

- An empty boiling tube was weighed and the mass recorded.
- Some distilled water was added to the boiling tube and the new mass recorded.
- A small sample of hydrated sodium sulfate was added and this new mass recorded.
- The boiling tube was carefully heated with stirring until all the solid had dissolved.
- The apparatus was cooled slowly while constantly stirring and the temperature recorded when the first crystals appeared in the tube.

(a) The results of several of these experiments are recorded below.

Process the results in the table to calculate the solubility, in g/100 g water, of the sodium sulfate for each of the temperatures listed.

Record these values to **two decimal places** in the additional columns of the table. You may use some or all of the columns.

Label the columns you use.

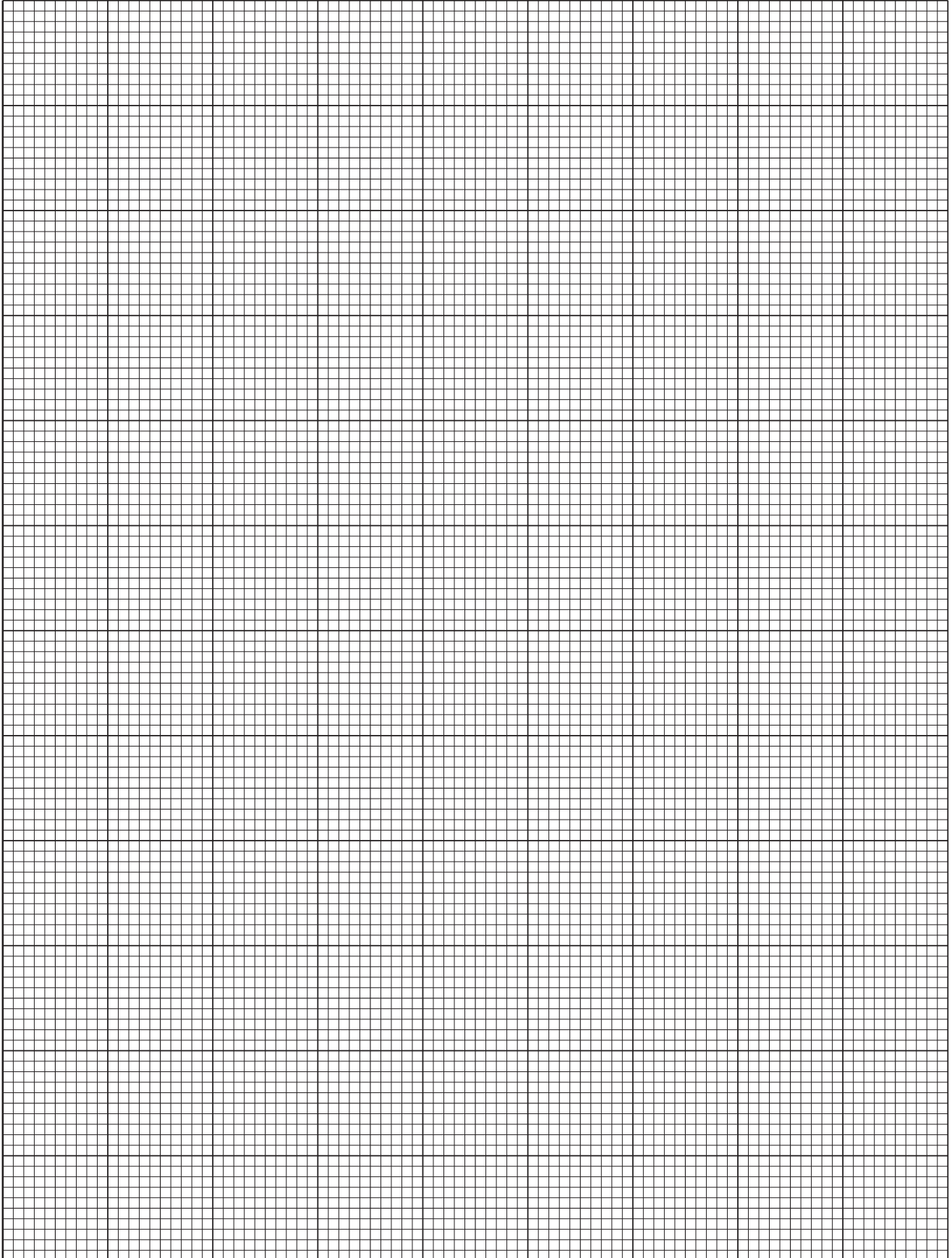
For each column you use include units where appropriate and an expression to show how your values are calculated.

Use the column headings **A** to **H** for these expressions (e.g. **A–B**).

<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	<b>F</b>	<b>G</b>	<b>H</b>
experiment number	mass of boiling tube  /g	mass of boiling tube + water /g	mass of boiling tube + water + solid /g	crystallising temperature  °C			
1	10.20	35.20	36.45	0.0			
2	10.35	30.35	31.60	10.0			
3	10.10	35.10	40.10	20.0			
4	9.80	29.20	36.96	30.0			
5	9.95	32.95	44.06	40.0			
6	9.90	34.90	46.65	50.0			
7	9.70	30.70	40.32	60.0			
8	10.45	30.45	39.55	70.0			
9	10.05	35.05	46.30	80.0			
10	10.10	40.10	53.45	90.0			

[3]

- (b) Plot a graph to show the variation of solubility ( $y$ -axis) with temperature ( $x$ -axis). Draw **two curves** of best fit and extrapolate to locate their intersection at the transition temperature.



[4]

(c) From your graph, state the transition temperature and the solubility at which it occurs.

[2]

(d) (i) In an attempt to repeat the 4th experiment using the same masses of water and solid, the temperature was mistakenly read and recorded before crystals appeared. Place a cross on your graph to represent the point that would have been obtained.

(ii) If this was a valid point, what effect would this have on your transition temperature? Explain your answer.

.....  
.....  
.....

[2]

(e) It was found that all the mass recordings in columns **C** and **D** had been made with a balance that had been zeroed incorrectly and they should all have been 0.3g smaller. The masses recorded in column **B** can be considered to be accurate. Using the corrected masses from experiment 6 calculate the new value of the solubility. By comparing this with the original solubility value for experiment 6 calculate the percentage error difference.

[2]

- (f) From the pattern of solubility demonstrated by your graph, predict and explain whether the dissolving of the two forms of sodium sulfate in water are exothermic or endothermic reactions.

prediction for  $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$  .....

.....

explanation .....

.....

.....

.....

prediction for  $\text{Na}_2\text{SO}_4$  .....

.....

explanation .....

.....

.....

.....

[2]

[Total: 15]







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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**May/June 2012**

**1 hour 15 minutes**

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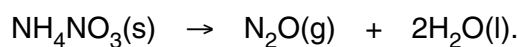
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- 1 When ammonium nitrate(V),  $\text{NH}_4\text{NO}_3$ , is heated it decomposes completely into nitrogen(I) oxide,  $\text{N}_2\text{O}$ , and water vapour,  $\text{H}_2\text{O}$ , which if allowed to cool will condense to liquid water.

For  
Examiner's  
Use

The stoichiometric equation for this decomposition is



The following information gives some of the hazards associated with ammonium nitrate(V).

**Ammonium nitrate(V)**  $\text{NH}_4\text{NO}_3$

**Oxidising:** Contact with combustible material may cause fire. Explosive when mixed with combustible material.

**Do not allow the salt to become contaminated with organic matter and do not grind it.**

You are to plan an experiment to investigate the molar ratio of nitrogen(I) oxide and ammonium nitrate(V) at  $25^\circ\text{C}$ , and confirm that it remains unchanged as the mass of ammonium nitrate(V) changes.

- (a) (i) Predict quantitatively how the number of moles of nitrogen(I) oxide varies as the number of moles of ammonium nitrate(V) increases, if the products are measured at room temperature  $25^\circ\text{C}$ .

.....

.....

.....

.....

- (ii) Predict quantitatively how the sum of the number of moles of water vapour and nitrogen(I) oxide varies as the number of moles of ammonium nitrate(V) increases, if the products are measured at  $110^\circ\text{C}$ .

.....

.....

.....

.....

(iii) Display both your predictions in the form of sketch graphs on the axes below. Label clearly each axis and each graph line.

*For  
Examiner's  
Use*



[3]

(b) In the experiment you are about to plan to test your prediction in (a)(i) at 25 °C, identify the following.

(i) the independent variable .....

(ii) the dependent variable .....

[2]

(c) Draw a diagram of the apparatus and the experimental set up you would use to carry out this experiment. Your apparatus should use only standard items found in a school or college laboratory and show clearly

(i) how the solid will be heated,

(ii) how the water vapour will be condensed into a liquid and collected. Ice is available,

(iii) how the nitrogen(I) oxide will be collected.

Label each piece of apparatus used, indicating its size or capacity.

[3]

For  
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- (d) Using the apparatus shown in (c) design a laboratory experiment to test your prediction in (a)(i) for an experiment at 25 °C.

For  
Examiner's  
Use

In addition to the standard apparatus present in a laboratory you are provided with the following materials.

a sample of solid ammonium nitrate(V)  
crushed ice

Give a step-by-step description of how you would carry out the experiment,

- (i) to produce enough results to give sufficient data to plot a graph as in (a)(iii),
  - (ii) by stating the volumes of nitrogen(I) oxide you would collect,
  - (iii) by calculating the mass of ammonium nitrate(V) needed to produce one of the volumes of nitrogen(I) oxide suggested in (ii),
  - (iv) by stating how you would ensure that decomposition was complete.
- [ $A_r$ : H, 1.0; N, 14.0; O, 16.0; the molar volume of a gas at 25 °C, 24.0 dm<sup>3</sup>]

[4]

- (e) State one hazard that must be considered when planning the experiment and describe a precaution that should be taken to minimise the risk from this hazard.

*For  
Examiner's  
Use*

.....  
.....  
.....  
..... [1]

- (f) Draw a table with appropriate headings to show the data you would record when carrying out your experiments and the values you would calculate in order to construct a graph to support or reject your prediction in (a)(i). The headings should include the appropriate units.

[2]

[Total: 15]



- 2 The variation of the volume with pressure of a fixed mass of any ideal gas at constant temperature may be represented by a relationship known as Boyle's law,

$$PV = \text{constant}$$

where P is the pressure of the gas, V is the volume of the gas.

A gas such as carbon dioxide, under certain conditions of temperature and pressure, does not always behave as an ideal gas.

An experiment was carried out on carbon dioxide to investigate its behaviour.

- A calibrated glass tube was filled with a sample of carbon dioxide.
- The tube was attached to a calibrated pressure pump.
- The pressure and the volume of the gas sample were recorded.
- The measured pressure on the gas was increased and the new volume recorded.

- (a) The results of the experiment are recorded in the table below.

A graph of V against P has been plotted for you.

Process the results in the table to enable you to plot two further graphs:

- PV against P
- 1/V against P

Record these values to **three significant figures** in the additional columns of the table.

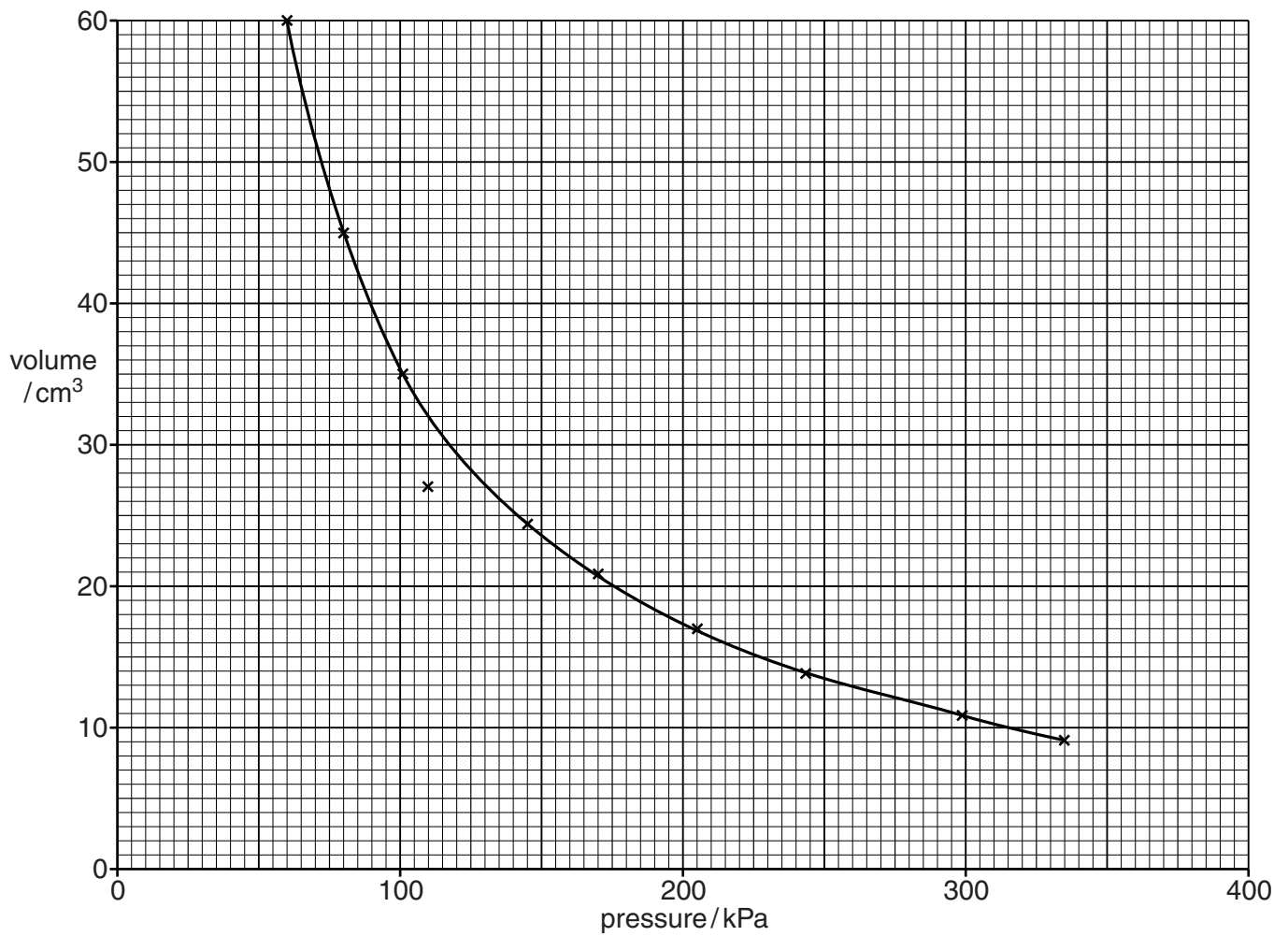
Label the columns you use. For each column you use include units where appropriate and an expression to show how your values are calculated.

You may use the column headings A to D for these expressions (e.g. A–B).

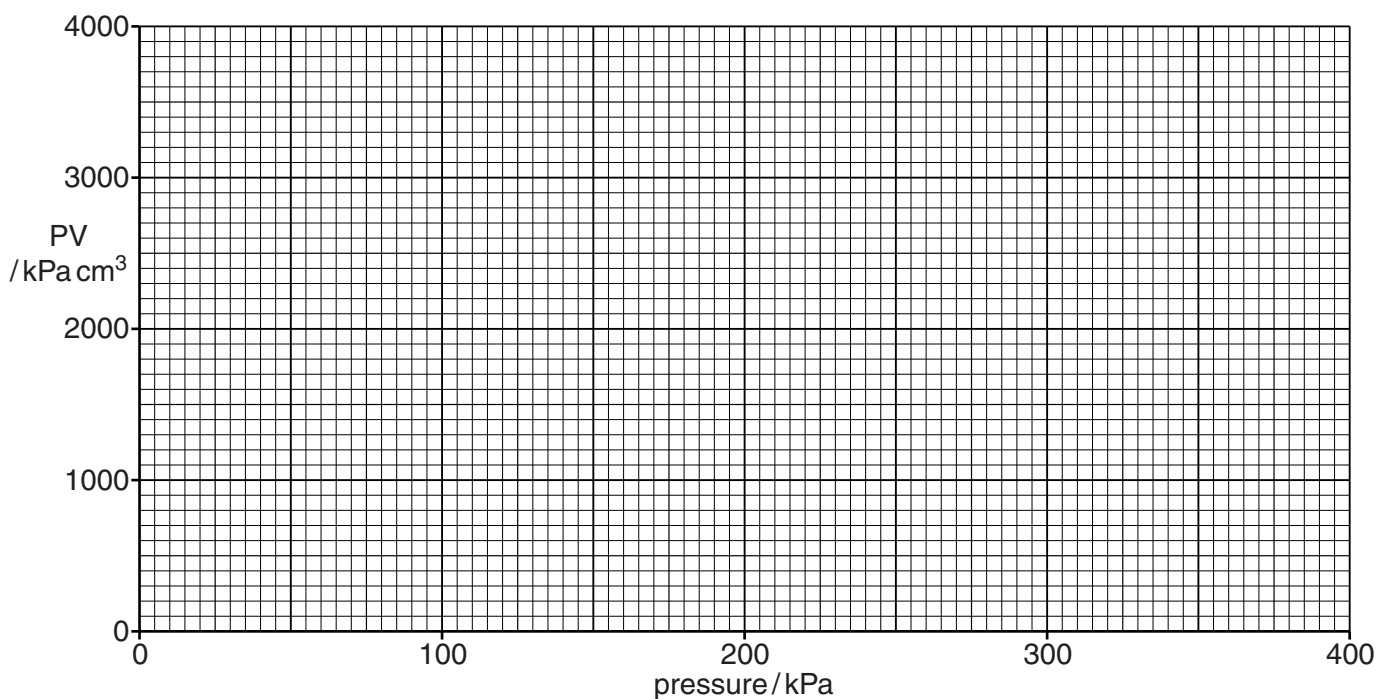
A	B	C	D
pressure of the gas/kPa	volume of the gas/cm <sup>3</sup>		
335	9.09		
298	10.9		
243	13.9		
205	17.0		
170	20.8		
145	24.4		
110	27.0		
101	35.0		
80.0	45.5		
60.0	60.0		

[2]

This graph shows the relationship between the volume of the gas and the pressure of the gas.

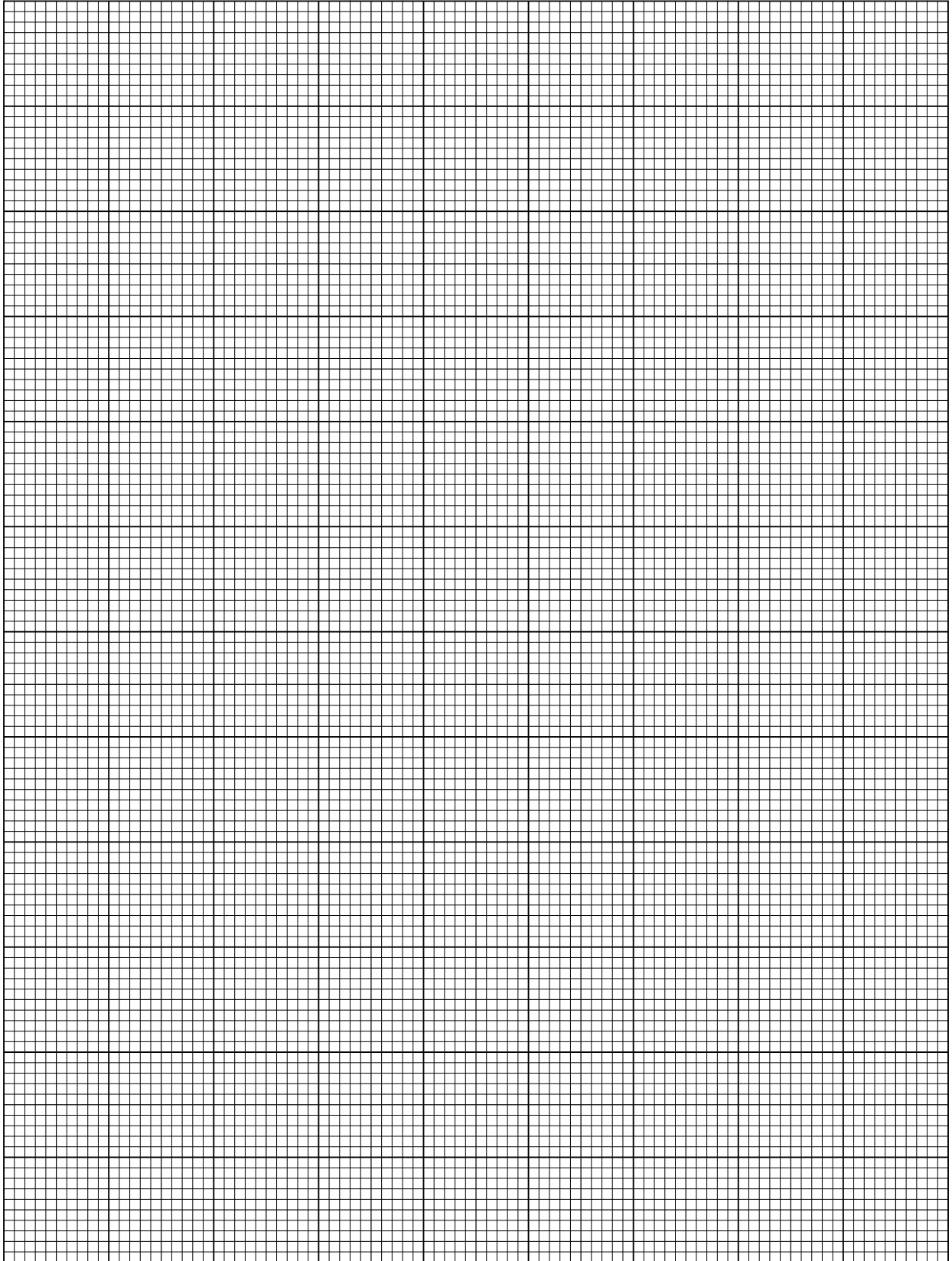


**(b)** Plot a graph to show the relationship between the product of the pressure and volume,  $PV$ , of the gas and the pressure,  $P$ , of the gas. Draw the line of best fit.



[1]

- (c) Plot a graph to show the relationship between the reciprocal of the volume of the gas and the pressure ( $1/V$  against  $P$ ) of the gas. Begin the scales on both axes at 0. Draw the line or curve of best fit.



[3]

**(d)** Circle and label on the graph in **(c)** any point(s) you consider to be anomalous. For each anomalous point give a different reason why it is anomalous, clearly indicating which point(s) you are describing.

.....  
.....  
.....  
.....  
..... [2]

**(e)** Determine the initial slope of the graph in **(c)**. Mark clearly on the graph any construction lines and show in your calculation how the intercepts were used in the calculation of the slope.

[2]

**(f) (i)** Does the initial shape of your graph in **(c)** confirm the equation  $PV = \text{constant}$ ?

.....

**(ii)** Explain your answer in **(i)** above.

.....  
.....  
.....  
.....

**(iii)** Why is the graph of volume against pressure provided inappropriate for the verification of Boyle's law?

[3]

(g) (i) Explain why it was important to measure the initial slope of the graph in (e).

.....  
.....  
.....

(ii) What is the significance of the value of the initial slope?

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.....  
..... [2]

[Total: 15]

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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**October/November 2012**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

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You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

You may lose marks if you do not show your working or if you do not use appropriate units.

Use of a Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.

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

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- 1 There are three oxides of lead,  $\text{PbO}$ ,  $\text{PbO}_2$  and  $\text{Pb}_3\text{O}_4$ , all of which can be reduced to metallic lead by hydrogen.

The following information gives some of the hazards associated with these compounds.

**Lead oxides**

**Lead(II) oxide** ( $\text{PbO}$ ) **Lead(IV) oxide** ( $\text{PbO}_2$ ) **Dilead(II) lead(IV) oxide** ( $\text{Pb}_3\text{O}_4$ )

**Toxic Dangerous for the environment**

Harmful by inhalation and if swallowed. Danger of cumulative effects.

**Hydrogen** Extremely flammable. Readily forms an explosive mixture with air. Mixtures between 4 and 74 % by volume are explosive.

An unknown sample of an oxide of lead can be identified by investigating the molar ratio of oxygen atoms to lead atoms.

You are to plan an experiment to investigate the molar ratio of oxygen atoms to lead atoms in the oxide sample. Your plan should result in a correct identification of the oxide.

- (a) Calculate the number of moles of oxygen atoms that combine with one mole of lead atoms in each of the three oxides.

[2]

- (b) Draw a sketch graph to show how the number of moles of oxygen atoms varies with the number of moles of lead for lead(II) oxide,  $\text{PbO}$ . Draw two more sketch graphs to show this relationship for the other two oxides. Label clearly each axis and each graph.



[2]



(c) In the experiment you are about to plan, identify the following.

(i) the independent variable .....

(ii) the dependent variable ..... [1]

(d) Draw a diagram of the apparatus and experimental set up you would use to determine the chemical formula of the oxide. Your apparatus should use only standard items found in a school or college laboratory and should show clearly

(i) how the hydrogen gas needed for the reduction is prepared, naming the chemicals (reagents) to be used,

(ii) how the oxide of lead will be heated,

(iii) how any excess hydrogen is dealt with safely.

Label each piece of apparatus used.

[3]

- (e) Using the apparatus shown in (d), design a laboratory experiment which will enable you to determine the chemical formula of the oxide.

Give a step-by-step description of how you would carry out the experiment by

- (i) stating a suitable mass of the oxide of lead,
- (ii) stating how you would ensure that the decomposition is complete,
- (iii) showing by calculation the minimum volume of hydrogen, measured at 25 °C, that would be needed to reduce the mass of oxide of lead stated in (i) above. For calculation purposes, you may assume that the oxide of lead is PbO,
- (iv) stating how you would use your results to reach a conclusion.

[A<sub>r</sub>: H, 1.0; O, 16.0; Pb, 207.0; the molar volume of a gas at 25 °C is 24.0 dm<sup>3</sup>]

[4]

- (f) State one hazard that must be considered when planning the experiment and describe a precaution that should be taken to minimise the risk from this hazard.

.....  
.....  
.....  
..... [1]

- (g) Draw up a table with appropriate headings to show the data you would record when carrying out your experiments and the values you would calculate in order to determine graphically the formula of the oxide. The headings should include appropriate units.

[2]

[Total: 15]

- 2 In aqueous solution, glucose can be slowly hydrolysed. The reaction appears to be first-order with respect to the glucose. As the hydrolysis proceeds, samples of the glucose solution can be analysed at regular intervals and the concentrations recorded. If the reaction is first-order, the following equation can be used to verify this.

$$\log_{10} a - \log_{10}(a-x) = kt$$

where  $a$  is the initial concentration of glucose,  $x$  is the decrease in the concentration of the glucose,  $a-x$  is the glucose concentration at any time  $t$  and  $k$  is a constant.

A plot of  $\log_{10}(a-x)$  against time will be linear for a first-order reaction and the slope will be equal to  $-k$ .

- (a) The experimentally determined values of such a hydrolysis experiment carried out at 298 K are recorded below.

You should use a value of  $1.000 \text{ mol dm}^{-3}$  for  $a$ .

Process the results in the table to enable you to plot a graph of  $\log_{10}(a-x)$  against time  $t$ .

Record these values to **three significant figures** in the additional columns of the table.

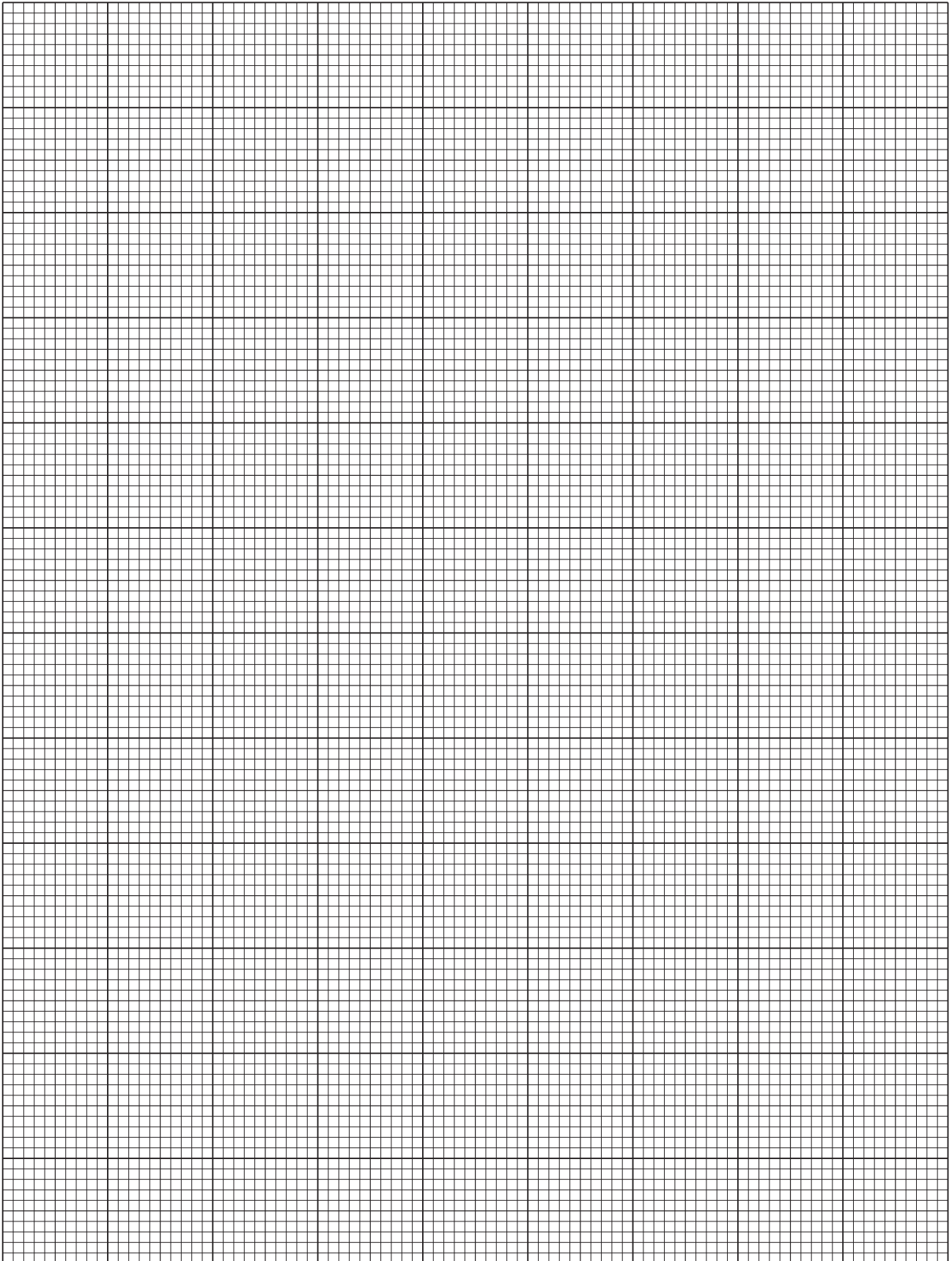
Label the columns you use. For each column you use, include units where appropriate and an expression to show how your values are calculated.

You may use the column headings A to D in these expressions (e.g. A-B).

A	B	C	D
time / min	decrease in the glucose concentration / $\text{mol dm}^{-3}$		
0	0.000		
30	0.101		
60	0.193		
100	0.259		
130	0.370		
180	0.469		
210	0.551		
240	0.573		
270	0.617		
300	0.655		

[2]

- (b) Present the data calculated in (a) in graphical form. Draw the line of best fit.  
In plotting this graph, it is necessary to show an origin for both axes.  
Remember that the values of  $\log_{10}(a-x)$  are negative.



[3]

- (c) Circle and label on the graph in (b) any point(s) you consider to be anomalous. For each anomalous point give a different reason why it is anomalous clearly indicating which point(s) you are describing.

.....

.....

.....

..... [3]

- (d) Comment on the reliability of the data provided in (a).

.....

.....

..... [1]

- (e) Determine the slope of the graph. Mark clearly on the graph any construction lines and show clearly in your calculation how the intercepts were used in the calculation of the slope. Record the value of the slope to **three significant figures** with appropriate units.

[3]

- (f) Do the results and your graph confirm the relationship  $\log_{10} a - \log_{10} (a-x) = kt$ ? Explain your answer.

[1]

- (g) On your graph, draw another line to show how an increase in temperature would affect your results.

[2]

[Total: 15]

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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**May/June 2011**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

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Use of a Data Booklet is unnecessary.

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- 1 Reactions involving two aqueous solutions are dependent on collisions occurring between the particles of the two reagents.

For  
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Use

As the temperature of the system is raised, the average kinetic energy of the particles increases.

You are to plan an experiment to investigate how the rate of the reaction between hydrochloric acid and sodium thiosulfate,  $\text{Na}_2\text{S}_2\text{O}_3$ , depends on the temperature of the reaction. When these two reagents react, after a short period they slowly produce a white or yellow precipitate of sulfur. As more sulfur is produced, the reaction mixture becomes more cloudy until it cannot be seen through (i.e. it is opaque). The time taken for the mixture to become opaque can be dependent on the relative concentrations of the reagents or the temperature of the reaction mixture.

- (a) (i) Predict how the rate of reaction will change if the temperature of the reagents is **increased**. Using the idea of how the kinetic energy of the particles changes as the temperature of the reagents **increases**, explain your prediction in terms of particle collisions.

prediction.....

.....

.....

explanation .....

.....

.....

.....

- (ii) Display your prediction in the form of a sketch graph, clearly labelling the axes.



[3]



(b) In the experiment you are about to plan, identify the following.

(i) the independent variable .....

(ii) the dependent variable .....

[2]

(c) Draw a diagram of the apparatus and experimental set up you would use to carry out this experiment. Your apparatus should use only standard items found in a school or college laboratory and show clearly the following.

(i) the apparatus used as the reaction vessel and how the thermometer will be positioned in order to measure the temperature of the solution as accurately as possible

(ii) how the solution will be heated

Label each piece of apparatus used, indicating its size or capacity and the temperature range that the thermometer should cover.

[2]

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Use



- (e) State a hazard that must be considered when planning the experiment and describe precautions that should be taken to keep risks to a minimum.

*For  
Examiner's  
Use*

.....  
..... [1]

- (f) Draw a table with appropriate headings to show the data you would record when carrying out your experiments and the values you would calculate in order to construct a graph to support or reject your prediction in section (a). The headings **must** include the appropriate units.

[2]

[Total: 15]

- 2 The solubility of potassium chlorate(V) in water increases with temperature. The units of solubility are grams per one hundred grams of water (g/100g water).

An experiment is carried out to investigate this solubility.

- An empty boiling tube was weighed and the mass recorded.
- Some distilled water was added to the boiling tube and the new mass recorded.
- A small sample of potassium chlorate(V) was added and this new mass recorded.
- The boiling tube was carefully heated with stirring until all the solid had dissolved.
- The apparatus was allowed to cool slowly while constantly stirring and the temperature recorded when the first crystals appeared in the tube.

(a) The results of several such experiments are recorded below.

A	B	C	D	E	F	G
crystallising temperature / °C	mass of boiling tube /g	mass of boiling tube and water /g	mass of boiling tube, water and solid /g			
20.0	10.10	35.10	36.85			
25.0	10.20	35.20	37.45			
30.0	9.80	29.20	31.20			
40.0	9.95	32.95	36.55			
45.0	10.35	30.35	33.45			
50.0	9.90	34.90	39.40			
60.0	9.70	30.70	35.53			
65.0	9.95	33.95	40.07			
70.0	10.45	30.45	36.15			
75.0	10.35	35.35	42.75			
80.0	10.05	35.05	44.05			
90.0	10.10	40.10	53.90			

Process the results in the table to calculate the solubility in g/100g of the potassium chlorate(V) for each of the temperatures listed.

Record these values to **two decimal places** in the additional columns of the table. You may use some or all of the columns.

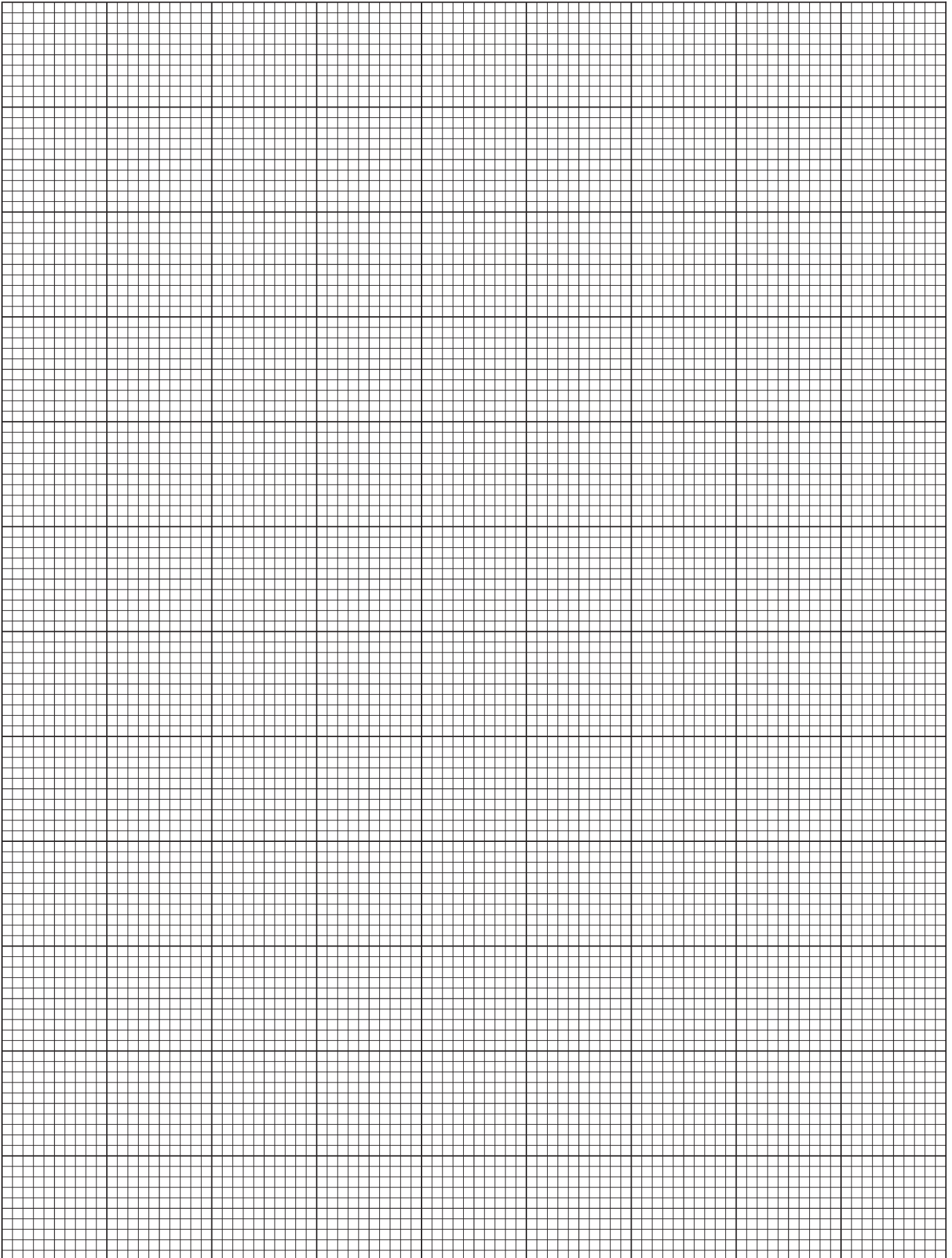
Label the columns you use.

For each column you use include units where appropriate and an expression to show how your values are calculated.

Use the column headings A to G for these expressions (e.g. A–B).

[3]

- (b) Plot a graph to show the variation of solubility with temperature.  
Draw the line of best fit.



[4]

- (c) Circle and label on the graph any point(s) you consider anomalous. For each anomalous point give a different reason why it is anomalous clearly indicating which point you are describing.

For  
Examiner's  
Use

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..... [4]

- (d) A solution of potassium chlorate(V) is made up using 50g of water. This is found to be saturated at 85 °C. The solution is then cooled to 35 °C. Using your graph calculate the mass of solid deposited as a result of this temperature change.

[2]

(e) From the pattern of solubility demonstrated by your graph predict and explain whether the dissolving of potassium chlorate(V) in water is an exothermic or an endothermic reaction.

*For  
Examiner's  
Use*

prediction

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explanation

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..... [2]

[Total: 15]







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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**October/November 2011**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

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Answer **all** questions.

You are advised to show all working in calculations.

Use of Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.

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- 1 When potassium nitrate dissolves in water, the temperature of the solution goes down because the enthalpy of solution is endothermic.

You are to plan an experiment to investigate how the solubility of potassium nitrate varies with temperature. The units of solubility are grams per one hundred grams of water (g/100g water).

- (a) (i) Predict how the solubility of potassium nitrate will change if the solution temperature is **increased**.

Explain your prediction using the fact that dissolving potassium nitrate is endothermic.

prediction .....

.....

explanation .....

.....

.....

.....

- (ii) Display your prediction in the form of a sketch graph, labelling clearly the axes.



[3]

- (b) In the experiment you are about to plan, identify the following.

(i) the independent variable .....

(ii) the dependent variable .....

[2]



- (d) State a hazard that must be considered when planning the experiment and describe precautions that should be taken to keep risks to a minimum.

*For  
Examiner's  
Use*

.....  
..... [1]

- (e) Draw a table with appropriate headings to show the data you would record when carrying out your experiments and the values you would calculate in order to construct a graph to support or reject your prediction in (a). The headings **must** include the appropriate units.

[2]

[Total: 15]

- 2 Chemical reactions occur more rapidly as the temperature of the reaction mixture increases. The mathematical relationship that summarises this is

For  
Examiner's  
Use

$$\log_{10} (\text{rate of reaction}) = \frac{-E_A}{19T}$$

where  $E_A$  is the **activation energy** of the reaction and  $T$  is the **absolute temperature** in Kelvin and the **rate of reaction** can be taken as the reciprocal of the time taken in seconds (**1/time**).

An experiment was carried out to investigate this relationship using dilute hydrochloric acid and aqueous sodium thiosulfate.

- 20 cm<sup>3</sup> of dilute hydrochloric acid was placed in a boiling tube contained in a water bath.
- 20 cm<sup>3</sup> of aqueous sodium thiosulfate was added to the dilute hydrochloric acid, while stirring and a stopwatch started.
- The temperature of the water bath was recorded.
- After a period of time the liquid became cloudy (opaque) due to the formation of a precipitate of sulfur.
- As soon as this cloudiness (opacity) appeared the time was recorded.
- The temperature of the water bath was raised and the whole experiment repeated.

- (a) The results of several such experiments are recorded below.

Process the results in the table to calculate **log<sub>10</sub> (rate of reaction)**, the reciprocal of the absolute temperature (**1/T**) and the 'rate of reaction' (**1/time**). You should expect the values of **log<sub>10</sub> (rate of reaction)** to be negative.

Record these values to **three significant figures** in the additional columns of the table.

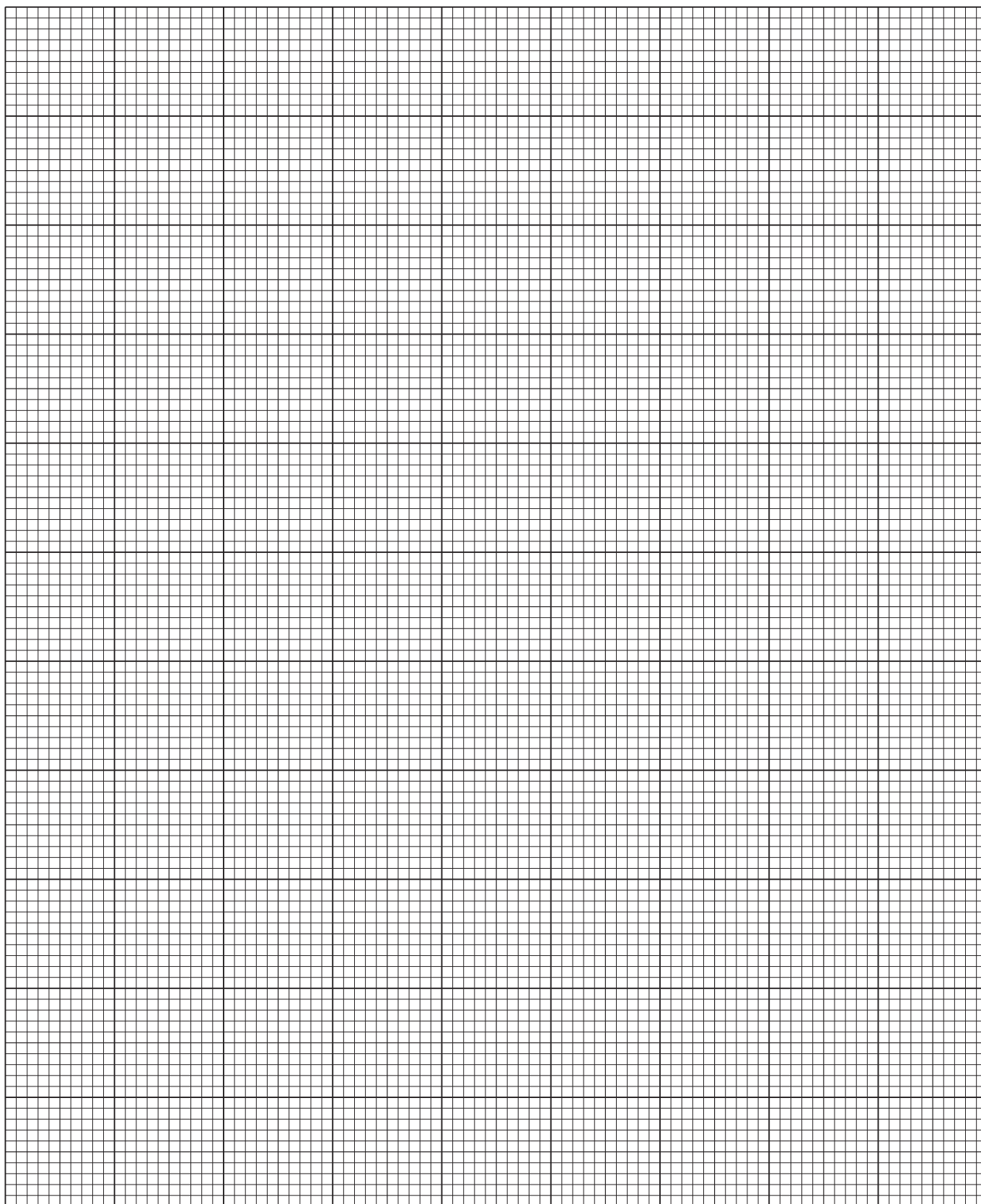
Label the columns you use. For each column you use include units where appropriate and an expression to show how your values are calculated.

You may use the column headings A to F for these expressions (e.g. A–B). [3]

A	B	C	D	E	F
temperature /°C	absolute temperature /K	time /s			
20.0	293	60.3			
30.0	303	46.8			
40.0	313	41.6			
45.0	318	31.6			
50.0	323	28.8			
55.0	328	25.1			
60.0	333	21.0			
65.0	338	20.4			
70.0	343	18.1			
80.0	353	15.1			



- (b) Plot a graph to show the relationship between  $\log_{10}$  (rate of reaction) and the reciprocal of the absolute temperature. You are reminded that the values for  $\log_{10}$  (rate of reaction) are negative.  
Draw the line of best fit.



[3]



- (g) By considering the movement of particles in the reaction explain why the rate of reaction increases with increasing temperature.

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[2]

[Total: 15]





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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS  
General Certificate of Education Advanced Level

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NAME

CENTRE  
NUMBER

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NUMBER

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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**May/June 2010**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

You may lose marks if you do not show your working or if you do not use appropriate units.

Use of a Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.

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

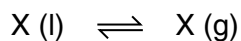
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- 1 At any temperature, equilibrium can be established between a liquid X and the vapour given off by that liquid.

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As the temperature of the system is raised, so the pressure exerted by the vapour increases. When the vapour pressure becomes equal to the surrounding (ambient) air pressure, the liquid boils.

When the liquid contains a dissolved solid (solute), the vapour pressure above the liquid is reduced.

You are to plan an experiment to investigate how the boiling point of an aqueous solution of potassium chloride depends on the concentration of the solution.

- (a) (i) By considering how the vapour pressure changes as the concentration of the aqueous potassium chloride increases, predict and explain how the boiling point of the solution will be affected by the concentration of the solution.

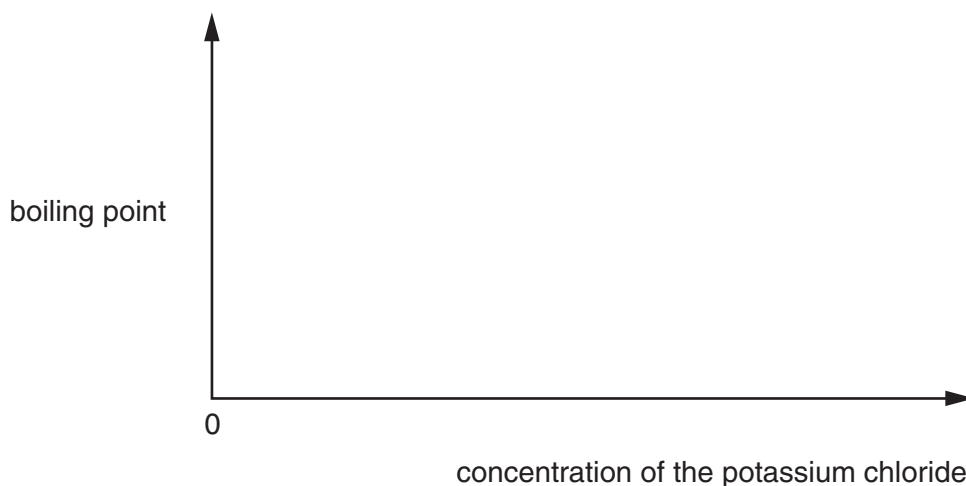
Predict how the boiling point will change .....

.....  
.....

Explanation .....

.....  
.....

- (ii) Display your prediction in the form of a sketch graph, labelling clearly the point representing the boiling point of pure water and its value.



[3]



(b) In the experiment you are about to plan, identify the following.

(i) the independent variable .....

(ii) the dependent variable .....

[2]

(c) Draw a diagram of the apparatus you would use in the experiment. Your apparatus should use only standard items found in a school or college laboratory and should show clearly

(i) how the solution will be heated and over-heating of the solution prevented,

(ii) how the thermometer will be positioned. Remember you are investigating an equilibrium.

Label each piece of apparatus used, indicating its size or capacity and the temperature range that the thermometer should cover.

[3]

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(e) State a hazard that must be considered when planning the experiment.

.....  
.....[1]

(f) State a limiting factor that must be taken into account when increasing the concentration of the aqueous potassium chloride.

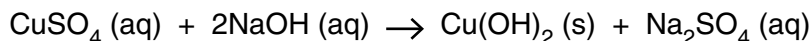
.....  
.....  
.....[1]

(g) Draw up a table with appropriate headings to show the data you would record when carrying out your experiments and the values you would calculate in order to construct a graph to support or reject your prediction in (a). The headings should include the appropriate units.

[2]

[Total: 15]

- 2 When aqueous sodium hydroxide, NaOH, is added to aqueous copper(II) sulfate, CuSO<sub>4</sub>, a precipitate of copper(II) hydroxide, Cu(OH)<sub>2</sub>, is produced. The stoichiometric equation for this reaction is



An experiment was carried out to investigate this stoichiometry.

- A weighed sample of copper(II) sulfate-5-water, CuSO<sub>4</sub>·5H<sub>2</sub>O, was completely dissolved in distilled water.
- An **excess** of aqueous sodium hydroxide was added.
- The resultant precipitate was filtered off.
- The precipitate was washed thoroughly and completely dried.
- The mass of the precipitate was recorded.

- (a) Calculate the relative formula mass,  $M_r$ , of each of the following. [ $A_r$ : Cu, 63.5; S, 32.1; O, 16.0; H, 1.0]

CuSO <sub>4</sub> ·5H <sub>2</sub> O	Cu(OH) <sub>2</sub>
$M_r$	$M_r$

[1]

- (b) The results of the experiment are recorded below.

A	B	C	D	E
mass of CuSO <sub>4</sub> ·5H <sub>2</sub> O /g	mass of Cu(OH) <sub>2</sub> /g			
2.50	0.78			
6.24	1.95			
9.99	3.12			
14.98	4.20			
19.97	6.24			
24.96	7.80			
29.95	9.36			
34.94	11.81			
42.43	13.26			

Process the results in the table to calculate the number of moles of CuSO<sub>4</sub>·5H<sub>2</sub>O used and the number of moles of Cu(OH)<sub>2</sub> produced, to enable you to plot a graph to show the relative number of moles of the CuSO<sub>4</sub>·5H<sub>2</sub>O and Cu(OH)<sub>2</sub>.

Record these values to **three** decimal places in the additional columns of the table. You may use some or all of the columns.

Label the columns you use.

For each column you use, include units where appropriate and an expression to show how your values are calculated.

You may use the column headings A to E in your expressions. [2]

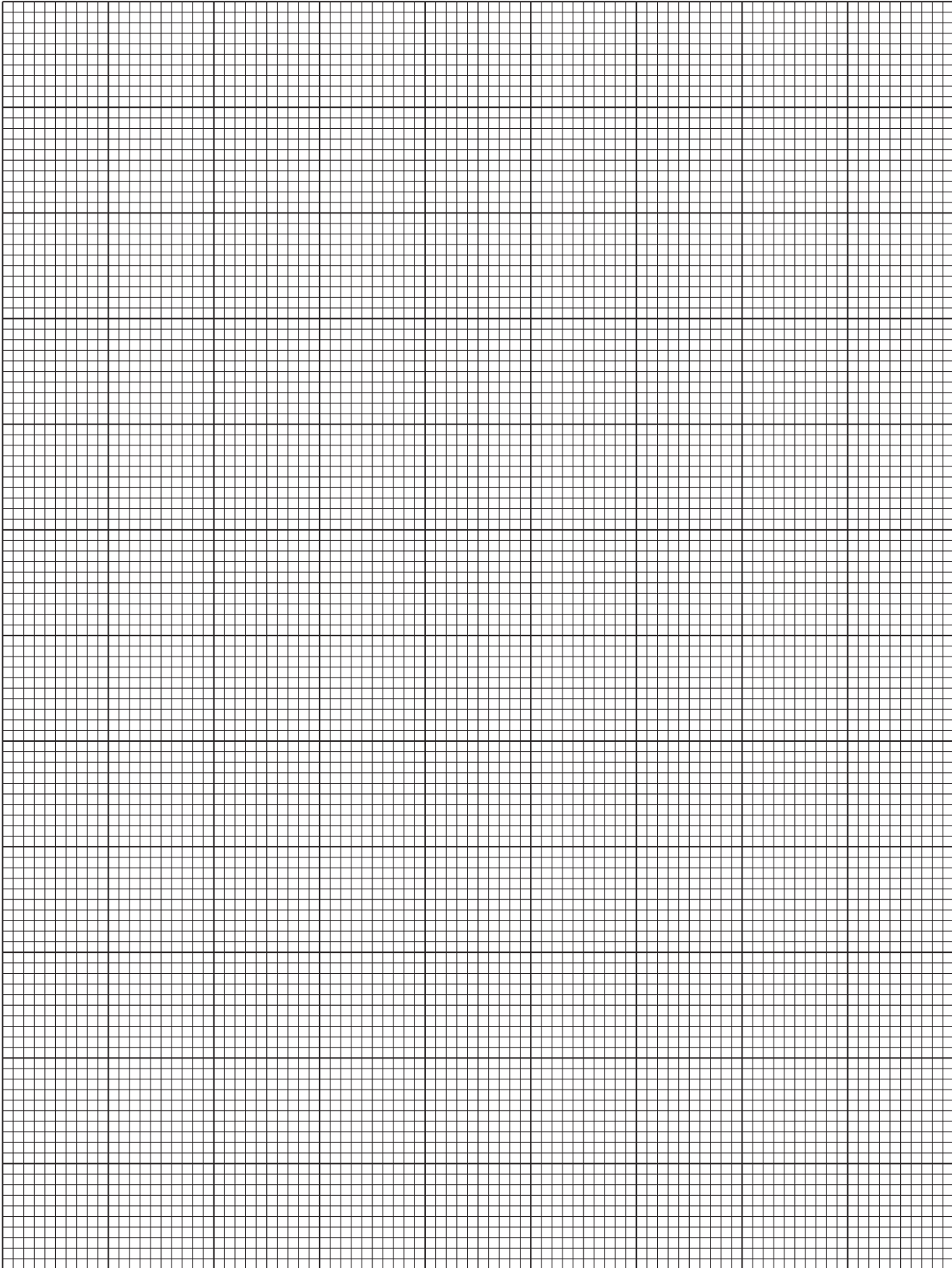
- (c) Why was it **not** necessary to know the concentration of the aqueous sodium hydroxide?

.....

.....[1]

(d) Present the data calculated in (b) in graphical form. Draw the line of best fit.

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Use*



[3]



(g) State whether the result in (f) confirms or not the stoichiometry of the equation for the reaction between aqueous copper(II) sulfate and aqueous sodium hydroxide.

*For  
Examiner's  
Use*

.....  
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.....

Comment on your conclusion.

.....  
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.....  
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.....  
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.....

[2]

[Total: 15]







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**CHEMISTRY**

**9701/52**

Paper 5 Planning, Analysis and Evaluation

**October/November 2010**

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs, or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

**DO NOT WRITE IN ANY BARCODES.**

Answer **all** questions.

You are advised to show all working in calculations.

Use of Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.

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

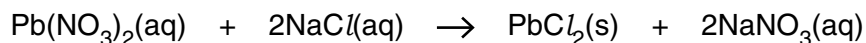
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- 1 When aqueous sodium chloride,  $\text{NaCl}$ , is added to aqueous lead nitrate,  $\text{Pb}(\text{NO}_3)_2$ , a white precipitate of lead chloride,  $\text{PbCl}_2$ , is produced. A suggested stoichiometric equation is



In separate experiments, different volumes of  $0.20 \text{ mol dm}^{-3}$  aqueous sodium chloride are added to a fixed volume of  $0.10 \text{ mol dm}^{-3}$  aqueous lead nitrate. In each case, the precipitate is filtered, washed with distilled water and thoroughly dried. The mass of the precipitate is recorded.

You are to plan an experiment to investigate this reaction in order to confirm or reject the stoichiometry of the equation.

- (a) By considering the suggested stoichiometric equation, predict and explain how the number of moles of the precipitate,  $\text{PbCl}_2$ , will change as the number of moles of  $\text{NaCl}$  added increases.

Prediction .....

.....  
 .....

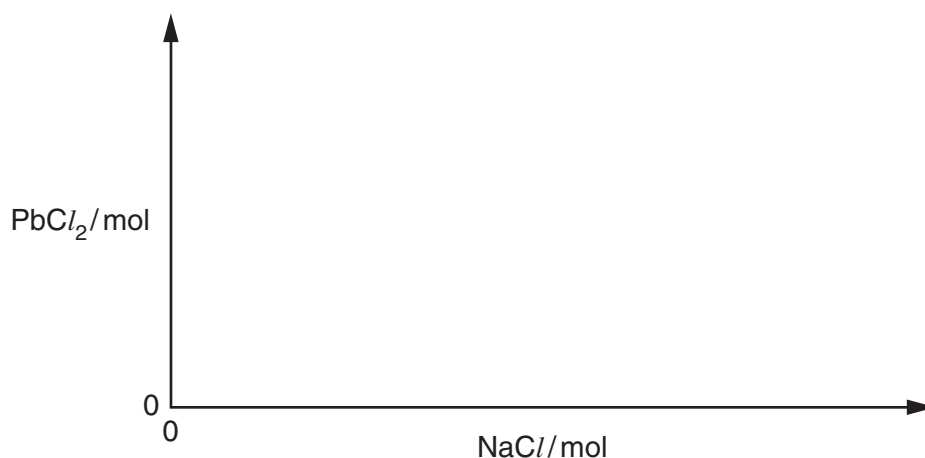
Explanation .....

.....  
 ..... [2]

- (b) State a limiting factor that must be taken into account when increasing the volume of the aqueous sodium chloride added.

.....

Sketch the graph which would result if, after some of the experiments, the  $\text{NaCl}$  is in excess. Start your graph with no  $\text{NaCl}$  added.



[3]



.....

.....

.....

..... [6]

(e) In the table below

- enter appropriate headings to show additional data you would record when carrying out your experiments and the values you would calculate in order to construct a graph to support or reject your prediction in (a). The headings should include the appropriate units,
- enter the volumes from your plan in (d),
- enter suitable volumes for four further experiments.


[2]

(f) How would you ensure that at the end of each experiment the precipitate was thoroughly dried?

.....

..... [1]

[Total: 16]





- 2 The melting point of solid water is 0°C. This is the same as the freezing point of water. This freezing point can be lowered (depressed) by the addition of a solute, such as glucose. The extent of the freezing point depression depends on the **number of particles of solute dissolved** in the solution.

For  
Examiner's  
Use

The freezing point depression,  $\Delta T_f$ , is proportional to the molal concentration,  $c_m$ , of the solution.

$$\Delta T_f = K_f c_m$$

where  $K_f$  is the freezing point depression constant.

***The molal concentration (molality) of a solution is defined as the number of moles of a solute dissolved in one kilogram of water e.g. a one molal solution has one mole of solute dissolved in one kilogram of water.***

An experiment was carried out to investigate the relationship between  $\Delta T_f$  and  $c_m$ .

- A weighed sample of distilled water was placed in a boiling tube.
- A weighed sample of glucose was added.
- The mixture was stirred until a solution was obtained.
- The tube was placed in a freezing apparatus to lower the temperature.
- The freezing point of the solution was measured precisely and the freezing point depression calculated.

(a) Calculate the  $M_r$  of glucose  $C_6H_{12}O_6$ .

[ $A_r$ : H, 1.0; C, 12.0; O, 16.0]

For  
Examiner's  
Use  
[1]

(b) The results of the experiment are recorded below.

A	B	C	D	E	F
mass of water /g	mass of glucose /g	freezing point depression $\Delta T_f$ /°C			
100	10.0	1.03			
100	12.2	1.26			
100	18.0	2.09			
100	23.3	2.40			
100	27.7	2.86			
100	30.9	3.22			
100	33.1	3.31			
100	38.6	3.98			
100	42.3	4.37			

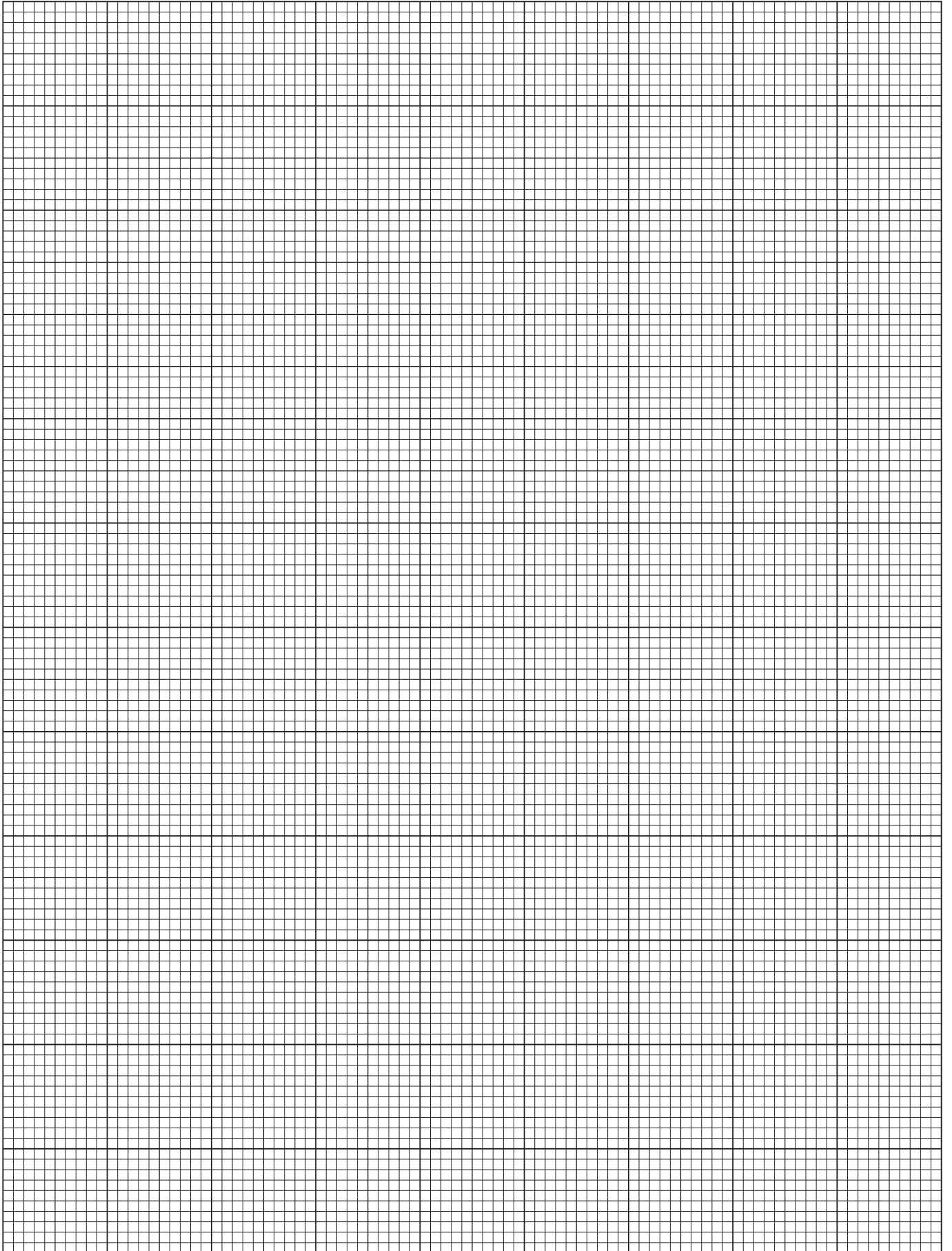
Process the results in the table to calculate the molality of the glucose solution. This will enable you to plot a graph to show how the freezing point depression,  $\Delta T_f$ , varies with the molality of the solution.

Record these values to **three significant figures** in the additional columns of the table. You may use some or all of the columns.

Label the columns you use.

For each column you use include units where appropriate and an expression to show how your values are calculated. You may use the column headings A to F for this purpose. [2]

(c) Present the data calculated in (b) in graphical form. Draw the line of best fit.



[3]



- (f) When the experiment was repeated using sodium chloride instead of glucose as the solute, the freezing point depressions were found to be twice the value obtained in the glucose experiment for each molality.  
Using the information given at the start of the question suggest a reason for this.

.....  
.....  
..... [1]

- (g) Using your suggestion from (f) predict the effect on the freezing point depression if a weak acid such as ethanoic acid was used instead of glucose or sodium chloride as the solute.

.....  
..... [1]

[Total: 14]

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