



Cambridge International AS & A Level

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CHEMISTRY

9701/51

Paper 5 Planning, Analysis and Evaluation

October/November 2025

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 and use appropriate units.

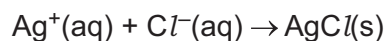
INFORMATION

- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

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



- 1 The concentration of aqueous chloride ions can be found by titration with aqueous silver nitrate, $\text{AgNO}_3(\text{aq})$.



The indicator used is aqueous potassium chromate(VI), $\text{K}_2\text{CrO}_4(\text{aq})$.

As $\text{AgNO}_3(\text{aq})$ is added to aqueous chloride ions, a white precipitate of $\text{AgCl}(\text{s})$ is formed.

When all the chloride ions have reacted, further addition of $\text{AgNO}_3(\text{aq})$ leads to the formation of a red precipitate of silver chromate(VI), $\text{Ag}_2\text{CrO}_4(\text{s})$. The first appearance of the red precipitate shows the end-point of the titration.

A student carries out an experiment to determine the number of molecules of water of crystallisation, x , in hydrated barium chloride, $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$.

(a) The student makes 250.0 cm^3 of $0.0500\text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$ to use for the titration.

- (i) Calculate the mass of solid silver nitrate, $\text{AgNO}_3(\text{s})$, needed to make 250.0 cm^3 of $0.0500\text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$.

Give your answer to **two** decimal places.

mass of $\text{AgNO}_3(\text{s}) = \dots\dots\dots\text{g}$ [1]

- (ii) Describe how the student should make 250.0 cm^3 of $0.0500\text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$ starting from the mass of $\text{AgNO}_3(\text{s})$ calculated in (a)(i) in a 50 cm^3 beaker.

Give the name and size of any key apparatus used.

Write your answer using a series of numbered steps.

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.....

.....

..... [3]



(b) The student uses the following method.

- step 1 Dissolve 1.58 g of $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$ to form 250 cm^3 of aqueous solution. Label this solution **A**.
- step 2 Transfer 20.0 cm^3 of solution **A** into a conical flask.
- step 3 Add aqueous sodium sulfate, $\text{Na}_2\text{SO}_4(\text{aq})$, to the flask and swirl the mixture to remove barium ions from the solution.
- step 4 Add 2–3 drops of $\text{K}_2\text{CrO}_4(\text{aq})$ indicator to the flask.
- step 5 Titrate the contents of the flask against $0.0500\text{ mol dm}^{-3}\text{ AgNO}_3(\text{aq})$.
- step 6 Repeat steps 2 to 5 to collect sufficient data for analysis.

(i) Suggest a suitable piece of apparatus for transferring 20.0 cm^3 of solution **A** in step 2.

..... [1]

(ii) Suggest why barium ions are removed in step 3 before performing the titration.

..... [1]

(iii) Suggest why chemically resistant gloves should be worn to carry out step 4.

..... [1]

(c) The student's results are shown in Table 1.1.

Table 1.1

	rough titration	titration 1	titration 2	titration 3
burette reading (final)/ cm^3	20.10	40.55	20.75	20.90
burette reading (initial)/ cm^3	0.00	20.25	0.05	0.30
titre/ cm^3	20.10	20.30	20.70	20.60

The student uses the titres from titrations 2 and 3 shown in Table 1.1 to calculate a mean titre value of 20.65 cm^3 .

(i) Explain why only these two values are used.

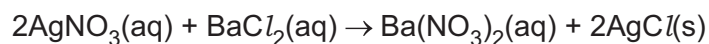
..... [1]



- (ii) Calculate the percentage error in the titre volume for titration 3.
Show your working.

percentage error = ... [1]

- (d) The equation for the reaction of silver nitrate with barium chloride is shown.



- (i) Calculate the amount, in mol, of $\text{AgNO}_3(\text{aq})$ in the mean titre of 20.65 cm^3 .

amount of $\text{AgNO}_3 = \dots\dots\dots \text{mol}$ [1]

- (ii) Calculate the amount, in mol, of $\text{BaCl}_2(\text{aq})$ in 250 cm^3 of solution **A**.

amount of $\text{BaCl}_2 = \dots\dots\dots \text{mol}$ [1]

- (iii) Calculate the value of x in the formula $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$.

$x = \dots\dots\dots$ [2]



- (e) Another student uses a different experimental method to check the value of x obtained by the method described in (b).

Give a **brief** description of another method, not involving titration, that could be used to determine the value of x in the formula $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$. Write your answer using a series of numbered steps.

Your plan should include details of the following:

- the apparatus and method you would use
- the measurements you would make.

You are provided with standard laboratory apparatus.

.....

.....

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.....

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.....

.....

..... [3]

[Total: 16]



- 2 Effusion is the process in which a gas escapes through a small hole.

A student investigates the relationship between rate of effusion and relative molar mass of a gas using the apparatus shown in Fig. 2.1.

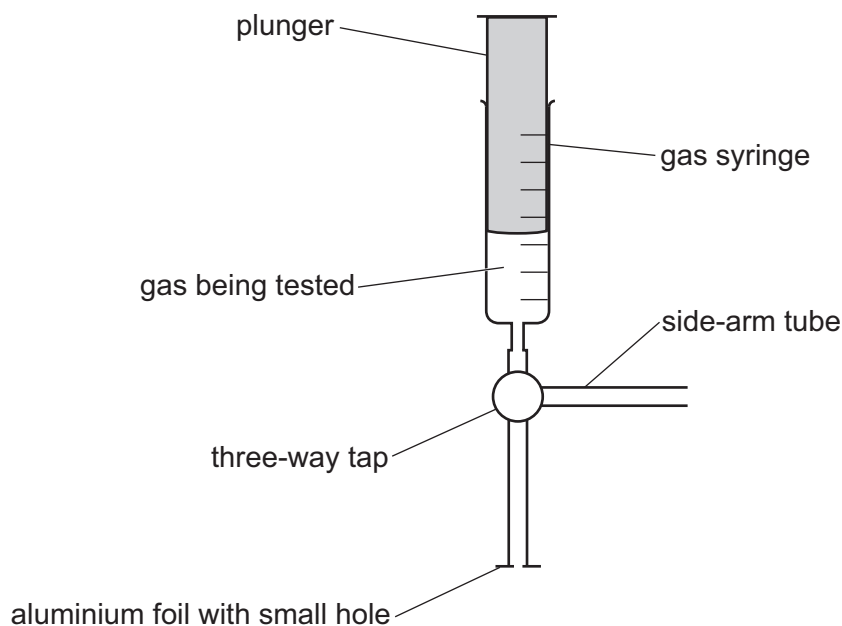


Fig. 2.1

The following method is used:

- step 1 Turn the tap and remove any gas from the syringe through the side-arm tube, by pushing in the plunger.
- step 2 Add 50 cm^3 of the gas being tested to the syringe through the side-arm tube.
- step 3 Remove the gas from the syringe, through the side-arm tube, by pushing in the plunger.
- step 4 Add 70 cm^3 of the gas being tested to the syringe through the side-arm tube.
- step 5 Turn the tap to connect the syringe to the tube with the aluminium foil and small hole.
- step 6 Allow the syringe plunger to fall and start a timer when the volume of gas in the syringe reaches 60 cm^3 .
- step 7 Stop the timer when the volume of gas in the syringe reaches 10 cm^3 . Record the time taken.
- step 8 Repeat steps 1 to 7 with different gases.



- (a) Suggest why the student adds 50 cm^3 of the gas being tested to the syringe in step 2 and then removes this gas in step 3.

.....
 [1]

- (b) The student's results are shown in Table 2.1.

Table 2.1

gas	hydrogen, H_2	helium, He	neon, Ne	argon, Ar	krypton, Kr
relative molar mass, M	2.0	4.0	20.2	39.9	83.8
$\sqrt{\frac{1}{M}}$					
time taken /s	10.8	15.3	34.5	39.7	70.4
rate of effusion / $\text{cm}^3\text{ s}^{-1}$					

$$\text{rate of effusion} = \frac{\text{volume of gas}}{\text{time taken}}$$

- (i) Complete Table 2.1.

Give the values for $\sqrt{\frac{1}{M}}$ to **three** significant figures.

Give the values for rate of effusion to **two** decimal places. [2]

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

..... [1]

- (iii) Identify a variable, other than temperature, that is controlled when carrying out this experiment.

..... [1]



- (c) Plot a graph on the grid in Fig. 2.2 to show the relationship between rate of effusion and $\sqrt{\frac{1}{M}}$.
Use a cross (×) to plot each data point. Draw a suitable line of best fit.

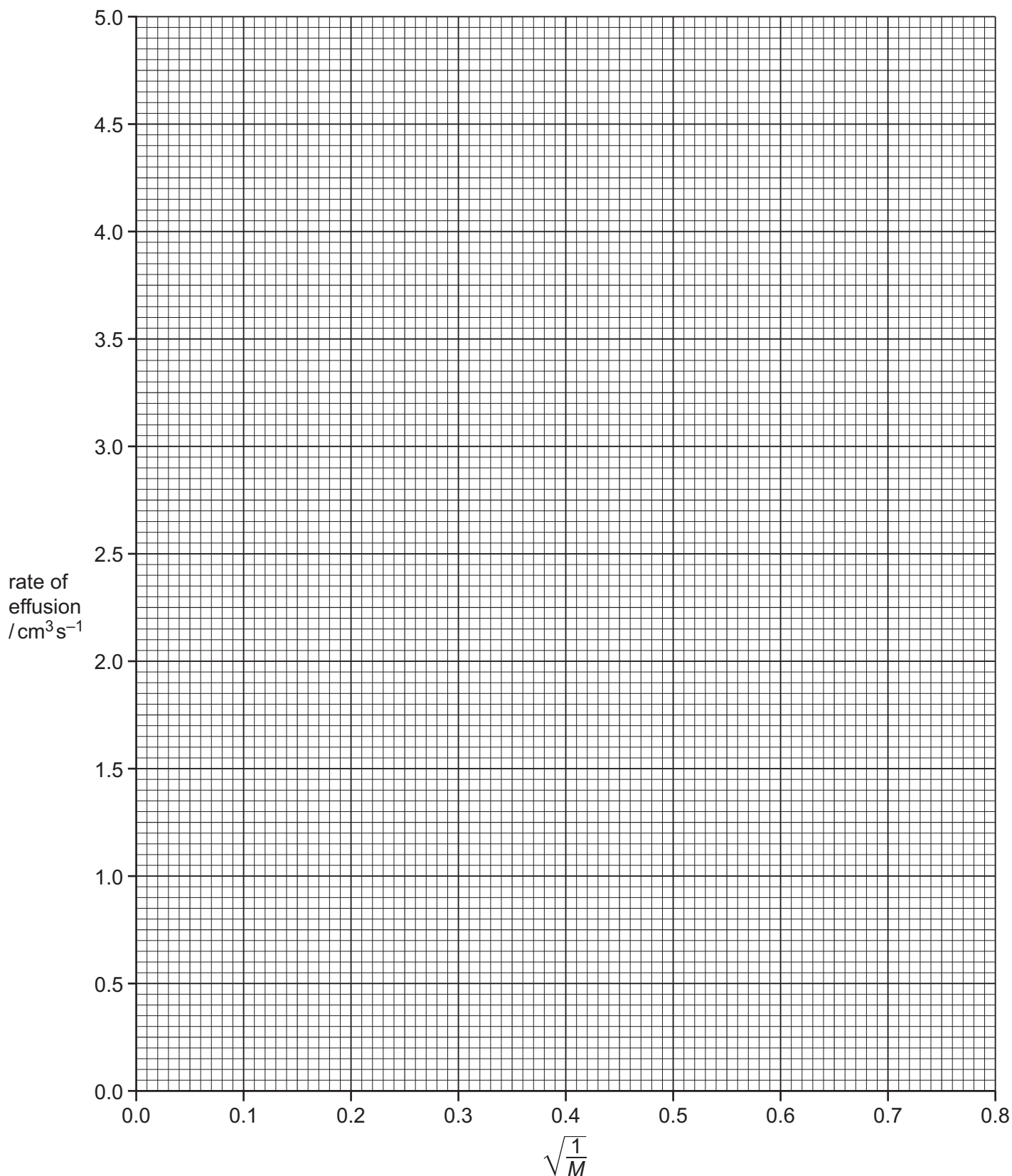


Fig. 2.2

[2]



- (d) Circle **one** point on the graph in Fig. 2.2 which you consider to be most anomalous.

Suggest **one** reason for this anomaly. Assume there is no error in $\sqrt{\frac{1}{M}}$.

.....
 [1]

- (e) Graham's law of effusion can be expressed as:

the rate of effusion of a gas is proportional to $\sqrt{\frac{1}{M}}$.

State whether or not the student's results support Graham's law of effusion.

Explain your answer, using the graph in Fig. 2.2.

.....
 [1]

- (f) Suggest how the position of the plotted points relative to the line of best fit in Fig. 2.2 is related to the reliability of the results.

.....
 [1]

- (g) The student then repeats this method to determine the value of M of a sample of natural gas.

The time recorded in step 7 is 31.6 s.

- (i) Use the graph in Fig. 2.2 and the student's result to calculate the value of M for this sample.

$M =$ [2]

- (ii) Natural gas is a mixture of mainly methane, CH_4 , with small amounts of other gases.

Suggest what your calculated value of the M of natural gas in (g)(i) tells you about the other gases in the mixture.

.....
 [1]



(h) The experiment described in (g) is repeated at a higher temperature.

Suggest how the rate of effusion for this sample of natural gas would change, if at all.

Explain your answer.

effect on the rate of effusion

explanation

[1]

[Total: 14]

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)



The Periodic Table of Elements

Group																			
1	2	1 H hydrogen 1.0												13	14	15	16	17	18
		Key atomic number atomic symbol name relative atomic mass																	
3 Li lithium 6.9	4 Be beryllium 9.0																		
11 Na sodium 23.0	12 Mg magnesium 24.3																		
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8		
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3		
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids		72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —	
87 Fr francium —	88 Ra radium —	89–103 actinoids		104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganesson —	

lanthanoids

57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium —	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
89 Ac actinium —	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium —	94 Pu plutonium —	95 Am americium —	96 Cm curium —	97 Bk berkelium —	98 Cf californium —	99 Es einsteinium —	100 Fm fermium —	101 Md mendelevium —	102 No nobelium —	103 Lr lawrencium —

actinoids





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CHEMISTRY

9701/52

Paper 5 Planning, Analysis and Evaluation

October/November 2025

1 hour 15 minutes

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INSTRUCTIONS

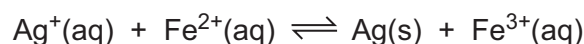
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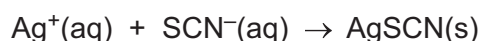
This document has **16** pages. Any blank pages are indicated.

- 1 Aqueous silver ions, $\text{Ag}^+(\text{aq})$, react slowly with aqueous iron(II) ions, $\text{Fe}^{2+}(\text{aq})$. An equilibrium is established.



The concentration of $\text{Ag}^+(\text{aq})$ at equilibrium can be determined by titration with a standard solution of aqueous potassium thiocyanate, $\text{KSCN}(\text{aq})$.

During the titration, the remaining $\text{Ag}^+(\text{aq})$ ions react with $\text{SCN}^-(\text{aq})$ ions to form a precipitate of $\text{AgSCN}(\text{s})$.



When all $\text{Ag}^+(\text{aq})$ ions have been removed from solution, excess $\text{SCN}^-(\text{aq})$ ions react with $\text{Fe}^{3+}(\text{aq})$ to form a complex ion, $\text{FeSCN}^{2+}(\text{aq})$, which has a red colour.



The appearance of the red colour indicates the end-point.

A student carries out an experiment to determine the equilibrium constant, K_c .

$$K_c = \frac{[\text{Fe}^{3+}(\text{aq})]_{\text{eqm}}}{[\text{Fe}^{2+}(\text{aq})]_{\text{eqm}} [\text{Ag}^+(\text{aq})]_{\text{eqm}}}$$

The student makes 250.0 cm^3 of $0.0200 \text{ mol dm}^{-3}$ $\text{KSCN}(\text{aq})$ to use in the titration.

- (a) Calculate the mass of solid potassium thiocyanate, $\text{KSCN}(\text{s})$, needed to make 250.0 cm^3 of $0.0200 \text{ mol dm}^{-3}$ $\text{KSCN}(\text{aq})$.

mass of $\text{KSCN}(\text{s}) = \dots\dots\dots \text{g}$ [1]



- (b) Describe how the student should make 250.0 cm^3 of $0.0200\text{ mol dm}^{-3}$ KSCN(aq) starting from the mass of KSCN(s) calculated in (a) in a 50 cm^3 beaker.

Give the name and size of any key apparatus used.

Write your answer using a series of numbered steps.

.....

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.....

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.....

.....

..... [3]

- (c) The student uses the following method to determine K_c .

step 1 Add 25.0 cm^3 of 0.100 mol dm^{-3} aqueous silver nitrate, $\text{AgNO}_3(\text{aq})$, into a dry conical flask. Label this flask **A**.

step 2 Add 25.0 cm^3 of 0.100 mol dm^{-3} aqueous iron(II) sulfate, $\text{FeSO}_4(\text{aq})$, into flask **A**.

step 3 Seal flask **A**, using a bung.

step 4 Allow flask **A** to stand for twelve hours.

step 5 Transfer 10.0 cm^3 of the mixture from flask **A** into another conical flask, flask **B**, without disturbing the precipitate in flask **A**.

step 6 Titrate the sample in flask **B** with $0.0200\text{ mol dm}^{-3}$ aqueous potassium thiocyanate, KSCN(aq).

step 7 Repeat steps 5 and 6 until concordant values are obtained.

- (i) Suggest why flask **A** is sealed with a bung in step 3.

.....

..... [1]

- (ii) Suggest why flask **A** is left to stand for twelve hours in step 4.

.....

..... [1]

- (iii) Identify the precipitate in flask **A** in step 5.

..... [1]



(d) The student's results are shown in Table 1.1

Table 1.1

	rough titration	titration 1	titration 2	titration 3
final burette reading/cm ³	22.50	21.75	31.65	32.20
initial burette reading/cm ³	0.00	0.00	9.75	10.20
titre/cm ³	22.50	21.75	21.90	22.00

(i) State if concordant titres have been achieved.

Explain your answer.

.....
 [1]

(ii) Calculate the percentage error in the titre volume in titration 2.

Show your working.

percentage error = ... [1]

(iii) The student repeats the experiment using KSCN(aq) at a **higher** concentration. The student obtains **smaller** titres.

Suggest **one** reason why a larger titre is better than a smaller titre.

..... [1]



(e) Another student calculates a mean titre of 21.85 cm^3 . Use this value to complete the following calculation.

(i) Calculate $[\text{Ag}^+(\text{aq})]$ in the equilibrium mixture in flask **A**.

$$[\text{Ag}^+(\text{aq})]_{\text{eqm}} = \dots\dots\dots \text{mol dm}^{-3} \quad [1]$$

(ii) Calculate $[\text{Fe}^{3+}(\text{aq})]$ in the equilibrium mixture in flask **A**.

$$[\text{Fe}^{3+}(\text{aq})]_{\text{eqm}} = \dots\dots\dots \text{mol dm}^{-3} \quad [1]$$

(iii) The formula for the equilibrium constant, K_c , is shown.

$$K_c = \frac{[\text{Fe}^{3+}(\text{aq})]_{\text{eqm}}}{[\text{Fe}^{2+}(\text{aq})]_{\text{eqm}} [\text{Ag}^+(\text{aq})]_{\text{eqm}}}$$

Determine the value of K_c .

Give the units of K_c .

$$K_c = \dots\dots\dots$$

$$\text{units} \dots\dots\dots [2]$$



- (f) Several other students perform the same experiment at different temperatures. The K_c values that they obtain are used to produce the graph in Fig. 1.1.

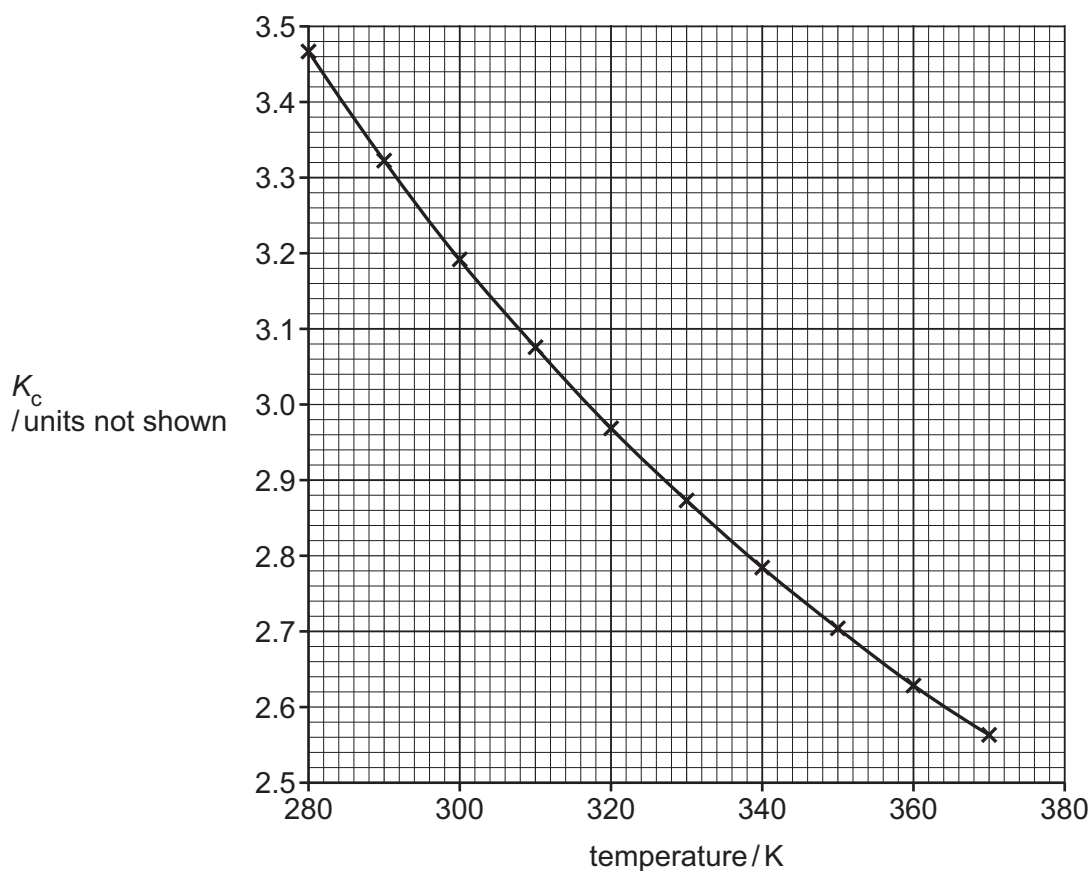


Fig. 1.1

- (i) One student suggests that K_c is directly proportional to temperature.

State and explain if the results displayed in Fig. 1.1 support this suggestion.

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

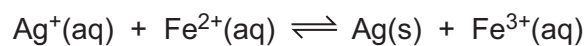
- (ii) Another student suggests that the data represented in the graph in Fig. 1.1 is reliable.

Explain how the graph supports this suggestion.

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



- (iii) Use the data displayed in Fig. 1.1 to state if the forward reaction is exothermic or endothermic.



Explain your answer.

forward reaction

explanation

.....

.....

[1]

[Total: 17]





- 2 A student carries out an experiment to determine the concentration of aqueous sulfate ions, $\text{SO}_4^{2-}(\text{aq})$, in a sample of lake water.

(a) The student uses the following method.

- step 1** Transfer 25.00 cm^3 of the lake water sample to a beaker and record its conductivity as shown in Fig. 2.1.
- step 2** Add 5.00 cm^3 of 0.100 mol dm^{-3} aqueous barium hydroxide, $\text{Ba}(\text{OH})_2(\text{aq})$, to the beaker.
- step 3** Stir the mixture and record the conductivity of the contents of the beaker as shown in Fig. 2.1.
- step 4** Repeat steps 2 and 3 until a total of 40.00 cm^3 of 0.100 mol dm^{-3} $\text{Ba}(\text{OH})_2(\text{aq})$ has been added to the beaker.

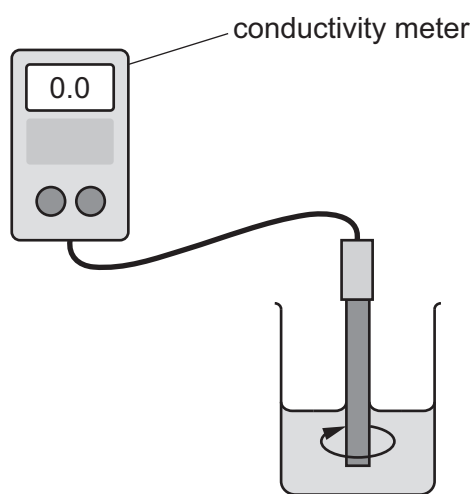


Fig. 2.1

- (i) Suggest a suitable piece of apparatus to transfer 25.00 cm^3 of the lake water sample to the beaker in step 1.
- [1]
- (ii) 0.100 mol dm^{-3} $\text{Ba}(\text{OH})_2(\text{aq})$ is an irritant to skin and eyes. Other than wearing safety goggles, state **one** safety precaution that the student should take when conducting this experiment.
- [1]





(b) The student's results are given in Table 2.1.

A correction can be applied to the conductivity values to take into account dilution of the solution as its volume increases using the following equation.

$$\text{corrected conductivity} = \text{measured conductivity} \times \frac{(\text{total volume in beaker})}{25.00}$$

Table 2.1

reading number	volume of $0.100 \text{ mol dm}^{-3}$ $\text{Ba(OH)}_2(\text{aq})$ added to beaker / cm^3	total volume in beaker / cm^3	measured conductivity / $\mu\text{S cm}^{-1}$	corrected conductivity / $\mu\text{S cm}^{-1}$
1	0.00	25.00	37 000	37 000
2	5.00		23 000	27 600
3	10.00		12 000	16 800
4	15.00		2 300	3 680
5	20.00		5 000	
6	25.00		12 000	
7	30.00		18 000	
8	35.00		21 000	
9	40.00		24 500	

(i) Complete Table 2.1.

[2]

(ii) Identify the independent variable in this experiment.

..... [1]



- (c) Plot a graph on the grid in Fig. 2.2 to show the relationship between corrected conductivity and volume of $0.100 \text{ mol dm}^{-3} \text{ Ba(OH)}_2$ added to beaker.

Use a cross (x) to plot each data point.

Draw a line of best fit using readings 1 to 4 and another line of best fit using readings 5 to 9. Extend the lines so that they intersect.

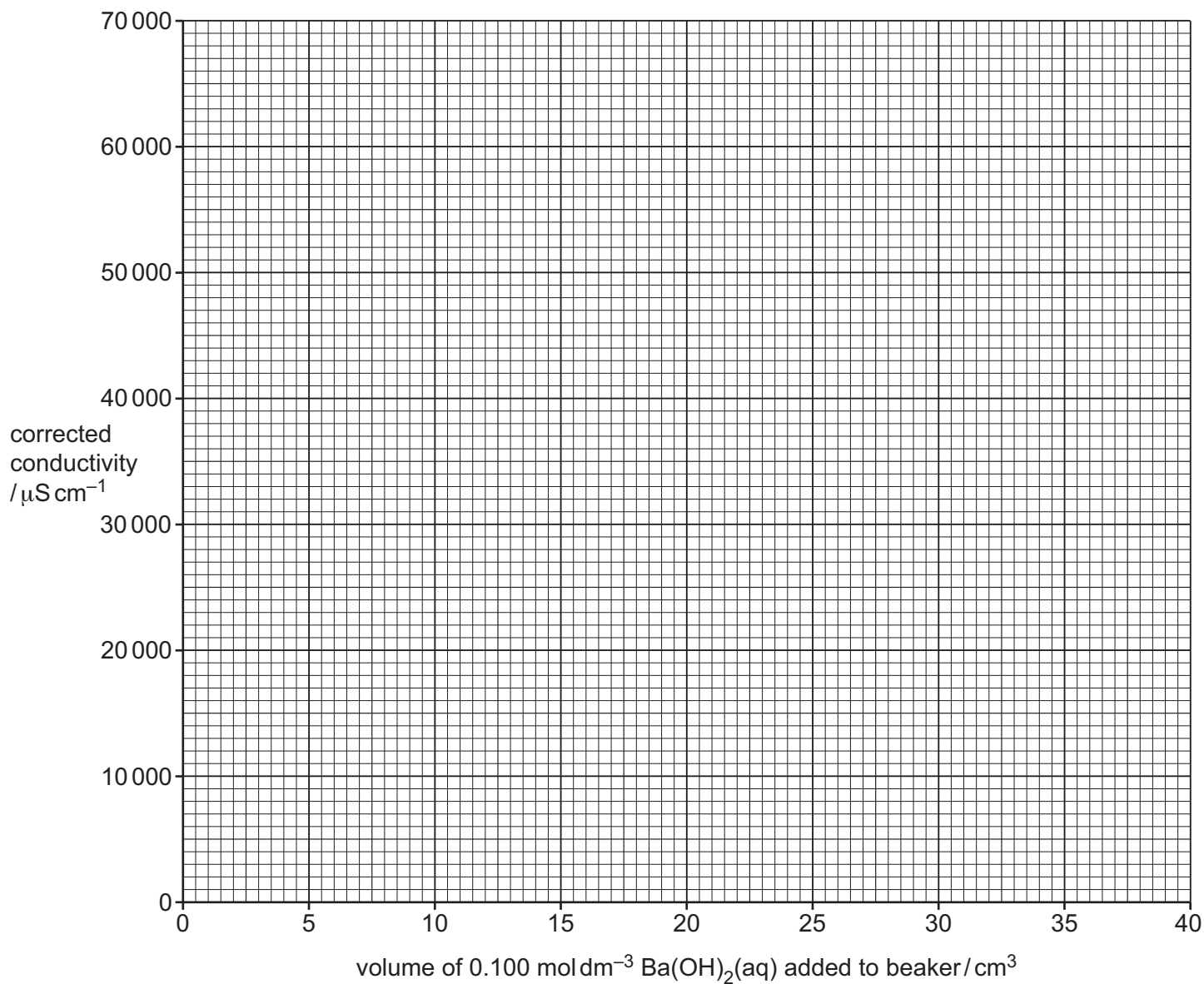


Fig. 2.2

[2]



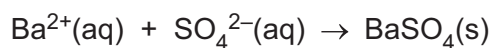


(d) The point on the graph where the two lines intersect indicates the volume of $0.100 \text{ mol dm}^{-3}$ $\text{Ba(OH)}_2(\text{aq})$ required to react exactly with the $\text{SO}_4^{2-}(\text{aq})$ present in 25.00 cm^3 of lake water being tested.

(i) Use the graph in Fig. 2.2 to determine the volume of $0.100 \text{ mol dm}^{-3}$ $\text{Ba(OH)}_2(\text{aq})$ required to react exactly with $\text{SO}_4^{2-}(\text{aq})$ in the lake water sample.

volume required = ... cm^3 [1]

(ii) The equation for the reaction taking place in the beaker is shown.



Use your answer in (d)(i) to calculate the concentration of $\text{SO}_4^{2-}(\text{aq})$ in the lake water sample.

concentration of $\text{SO}_4^{2-}(\text{aq})$ = ... mol dm^{-3} [1]



- (e) The concentration of $\text{SO}_4^{2-}(\text{aq})$ in a sample of water can also be determined by measuring the mass of precipitate produced when excess $\text{Ba}(\text{OH})_2(\text{aq})$ is added to the sample.

The student suggests the following method.

step 1 Place 25.0 cm^3 of the water sample in a conical flask.

step 2 Add excess 0.100 mol dm^{-3} $\text{Ba}(\text{OH})_2(\text{aq})$ to the flask.

step 3 Filter the contents of the flask.

step 4 Dry the residue in a warm oven.

step 5 Measure the mass of residue.

- (i) Draw a labelled diagram to describe the arrangement of apparatus that would be needed to complete step 3.

[1]

- (ii) Suggest a step that the student should add between steps 3 and 4 to improve this method.

..... [1]

- (iii) Describe what the student can do to ensure that the residue weighed in step 5 is completely dry.

.....
 [1]

- (iv) The mass of residue is used to calculate the concentration of $\text{SO}_4^{2-}(\text{aq})$.

Suggest the effect, if any, on the concentration of $\text{SO}_4^{2-}(\text{aq})$ that is calculated if the residue is **not** completely dried in step 4.

Explain your answer.

effect on concentration of $\text{SO}_4^{2-}(\text{aq})$ calculated

explanation

..... [1]

[Total: 13]





Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)





The Periodic Table of Elements

Group																		
1	2	Key										13	14	15	16	17	18	
		atomic number atomic symbol name relative atomic mass										1 H hydrogen 1.0						
3 Li lithium 6.9	4 Be beryllium 9.0																	
11 Na sodium 23.0	12 Mg magnesium 24.3	3 Sc scandium 45.0	4 Ti titanium 47.9	5 V vanadium 50.9	6 Cr chromium 52.0	7 Mn manganese 54.9	8 Fe iron 55.8	9 Co cobalt 58.9	10 Ni nickel 58.7	11 Cu copper 63.5	12 Zn zinc 65.4	5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2	
19 K potassium 39.1	20 Ca calcium 40.1	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3	
37 Rb rubidium 85.5	38 Sr strontium 87.6	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —	
87 Fr francium —	88 Ra radium —	89–103 actinoids	104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganeson —	

lanthanoids

actinoids

57	La	lanthanum	138.9
58	Ce	cerium	140.1
59	Pr	praseodymium	140.9
60	Nd	neodymium	144.2
61	Pm	promethium	—
62	Sm	samarium	150.4
63	Eu	europlum	152.0
64	Gd	gadolinium	157.3
65	Tb	terbium	158.9
66	Dy	dysprosium	162.5
67	Ho	holmium	164.9
68	Er	erbium	167.3
69	Tm	thulium	168.9
70	Yb	ytterbium	173.1
71	Lu	lutetium	175.0

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CHEMISTRY**9701/53**

Paper 5 Planning, Analysis and Evaluation

October/November 2025**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 and use appropriate units.

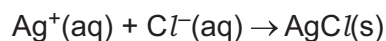
INFORMATION

- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

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



- 1 The concentration of aqueous chloride ions can be found by titration with aqueous silver nitrate, $\text{AgNO}_3(\text{aq})$.



The indicator used is aqueous potassium chromate(VI), $\text{K}_2\text{CrO}_4(\text{aq})$.

As $\text{AgNO}_3(\text{aq})$ is added to aqueous chloride ions, a white precipitate of $\text{AgCl}(\text{s})$ is formed.

When all the chloride ions have reacted, further addition of $\text{AgNO}_3(\text{aq})$ leads to the formation of a red precipitate of silver chromate(VI), $\text{Ag}_2\text{CrO}_4(\text{s})$. The first appearance of the red precipitate shows the end-point of the titration.

A student carries out an experiment to determine the number of molecules of water of crystallisation, x , in hydrated barium chloride, $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$.

(a) The student makes 250.0 cm^3 of $0.0500\text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$ to use for the titration.

- (i) Calculate the mass of solid silver nitrate, $\text{AgNO}_3(\text{s})$, needed to make 250.0 cm^3 of $0.0500\text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$.

Give your answer to **two** decimal places.

mass of $\text{AgNO}_3(\text{s}) = \dots\dots\dots\text{g}$ [1]

- (ii) Describe how the student should make 250.0 cm^3 of $0.0500\text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$ starting from the mass of $\text{AgNO}_3(\text{s})$ calculated in (a)(i) in a 50 cm^3 beaker.

Give the name and size of any key apparatus used.

Write your answer using a series of numbered steps.

.....

.....

.....

.....

.....

.....

.....

..... [3]



(b) The student uses the following method.

- step 1 Dissolve 1.58 g of $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$ to form 250 cm^3 of aqueous solution. Label this solution **A**.
- step 2 Transfer 20.0 cm^3 of solution **A** into a conical flask.
- step 3 Add aqueous sodium sulfate, $\text{Na}_2\text{SO}_4(\text{aq})$, to the flask and swirl the mixture to remove barium ions from the solution.
- step 4 Add 2–3 drops of $\text{K}_2\text{CrO}_4(\text{aq})$ indicator to the flask.
- step 5 Titrate the contents of the flask against $0.0500\text{ mol dm}^{-3}\text{ AgNO}_3(\text{aq})$.
- step 6 Repeat steps 2 to 5 to collect sufficient data for analysis.

(i) Suggest a suitable piece of apparatus for transferring 20.0 cm^3 of solution **A** in step 2.

..... [1]

(ii) Suggest why barium ions are removed in step 3 before performing the titration.

..... [1]

(iii) Suggest why chemically resistant gloves should be worn to carry out step 4.

..... [1]

(c) The student's results are shown in Table 1.1.

Table 1.1

	rough titration	titration 1	titration 2	titration 3
burette reading (final)/ cm^3	20.10	40.55	20.75	20.90
burette reading (initial)/ cm^3	0.00	20.25	0.05	0.30
titre/ cm^3	20.10	20.30	20.70	20.60

The student uses the titres from titrations 2 and 3 shown in Table 1.1 to calculate a mean titre value of 20.65 cm^3 .

(i) Explain why only these two values are used.

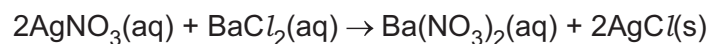
..... [1]



- (ii) Calculate the percentage error in the titre volume for titration 3.
Show your working.

percentage error = ... [1]

- (d) The equation for the reaction of silver nitrate with barium chloride is shown.



- (i) Calculate the amount, in mol, of $\text{AgNO}_3(\text{aq})$ in the mean titre of 20.65 cm^3 .

amount of $\text{AgNO}_3 = \dots\dots\dots \text{mol}$ [1]

- (ii) Calculate the amount, in mol, of $\text{BaCl}_2(\text{aq})$ in 250 cm^3 of solution **A**.

amount of $\text{BaCl}_2 = \dots\dots\dots \text{mol}$ [1]

- (iii) Calculate the value of x in the formula $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$.

$x = \dots\dots\dots$ [2]



- (e) Another student uses a different experimental method to check the value of x obtained by the method described in (b).

Give a **brief** description of another method, not involving titration, that could be used to determine the value of x in the formula $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$. Write your answer using a series of numbered steps.

Your plan should include details of the following:

- the apparatus and method you would use
- the measurements you would make.

You are provided with standard laboratory apparatus.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [3]

[Total: 16]



- 2 Effusion is the process in which a gas escapes through a small hole.

A student investigates the relationship between rate of effusion and relative molar mass of a gas using the apparatus shown in Fig. 2.1.

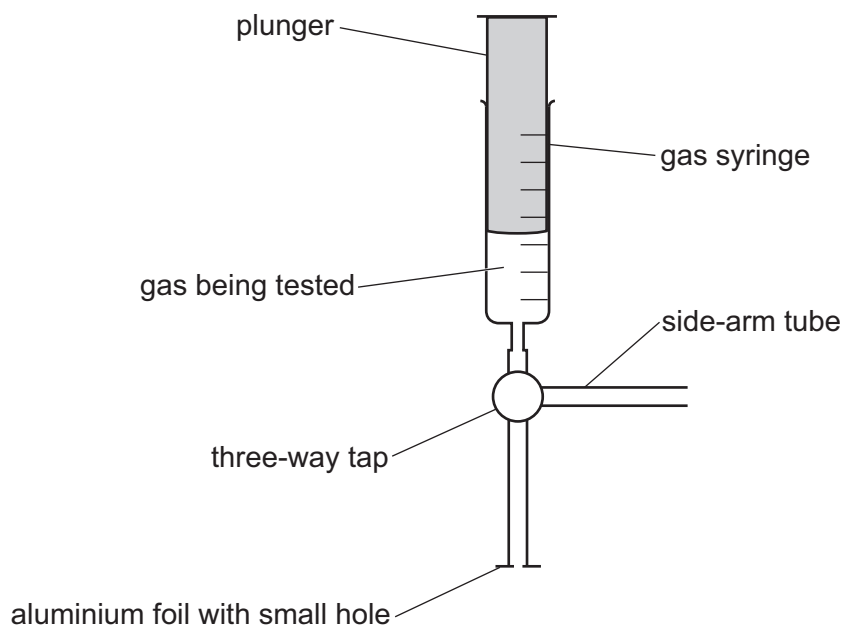


Fig. 2.1

The following method is used:

- step 1 Turn the tap and remove any gas from the syringe through the side-arm tube, by pushing in the plunger.
- step 2 Add 50 cm^3 of the gas being tested to the syringe through the side-arm tube.
- step 3 Remove the gas from the syringe, through the side-arm tube, by pushing in the plunger.
- step 4 Add 70 cm^3 of the gas being tested to the syringe through the side-arm tube.
- step 5 Turn the tap to connect the syringe to the tube with the aluminium foil and small hole.
- step 6 Allow the syringe plunger to fall and start a timer when the volume of gas in the syringe reaches 60 cm^3 .
- step 7 Stop the timer when the volume of gas in the syringe reaches 10 cm^3 . Record the time taken.
- step 8 Repeat steps 1 to 7 with different gases.



- (a) Suggest why the student adds 50 cm^3 of the gas being tested to the syringe in step 2 and then removes this gas in step 3.

.....
 [1]

- (b) The student's results are shown in Table 2.1.

Table 2.1

gas	hydrogen, H_2	helium, He	neon, Ne	argon, Ar	krypton, Kr
relative molar mass, M	2.0	4.0	20.2	39.9	83.8
$\sqrt{\frac{1}{M}}$					
time taken /s	10.8	15.3	34.5	39.7	70.4
rate of effusion / $\text{cm}^3\text{ s}^{-1}$					

$$\text{rate of effusion} = \frac{\text{volume of gas}}{\text{time taken}}$$

- (i) Complete Table 2.1.

Give the values for $\sqrt{\frac{1}{M}}$ to **three** significant figures.

Give the values for rate of effusion to **two** decimal places. [2]

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

..... [1]

- (iii) Identify a variable, other than temperature, that is controlled when carrying out this experiment.

..... [1]



- (c) Plot a graph on the grid in Fig. 2.2 to show the relationship between rate of effusion and $\sqrt{\frac{1}{M}}$.
Use a cross (×) to plot each data point. Draw a suitable line of best fit.

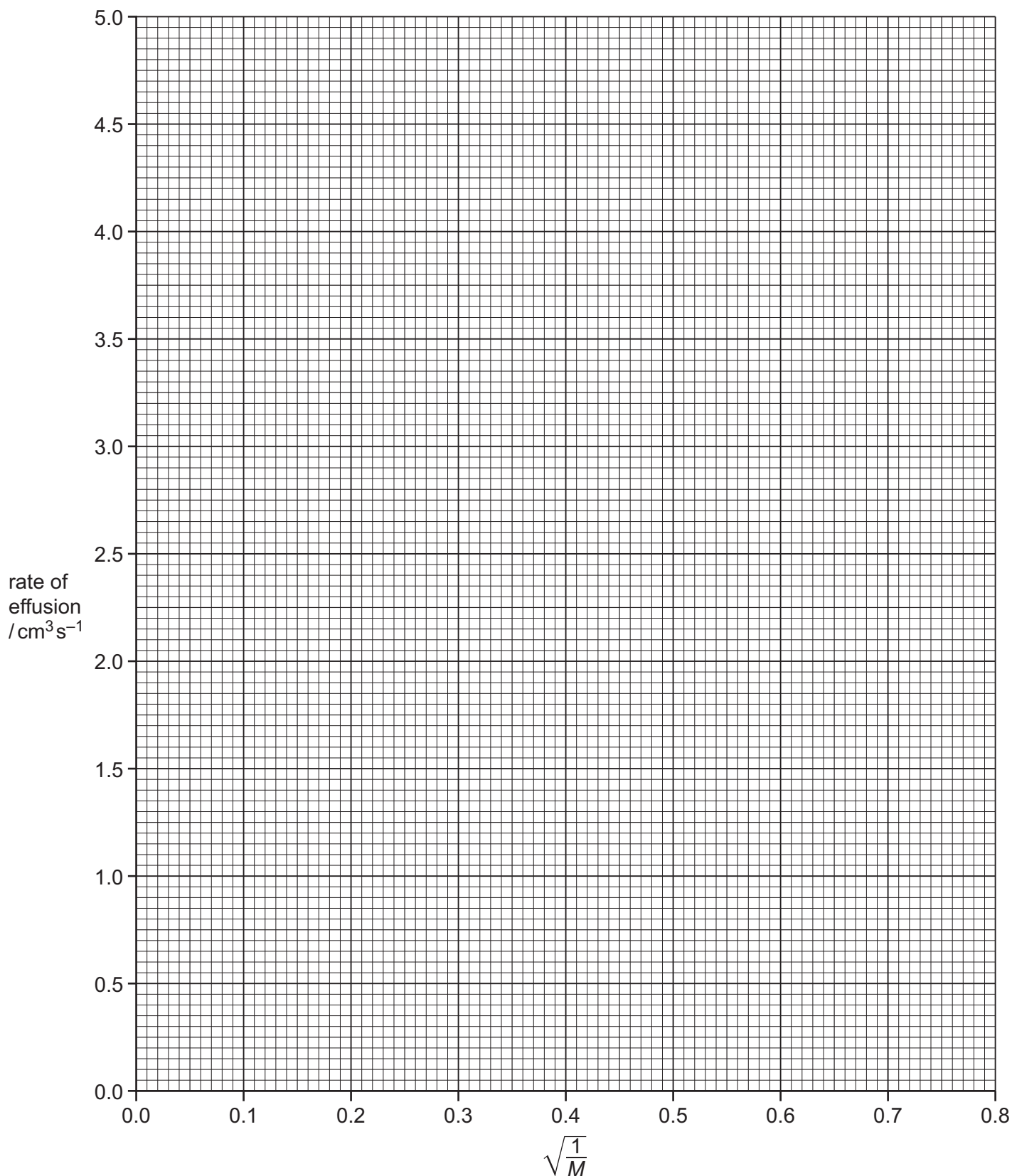


Fig. 2.2

[2]





- (d) Circle **one** point on the graph in Fig. 2.2 which you consider to be most anomalous.

Suggest **one** reason for this anomaly. Assume there is no error in $\sqrt{\frac{1}{M}}$.

.....
 [1]

- (e) Graham's law of effusion can be expressed as:

the rate of effusion of a gas is proportional to $\sqrt{\frac{1}{M}}$.

State whether or not the student's results support Graham's law of effusion.

Explain your answer, using the graph in Fig. 2.2.

.....
 [1]

- (f) Suggest how the position of the plotted points relative to the line of best fit in Fig. 2.2 is related to the reliability of the results.

.....
 [1]

- (g) The student then repeats this method to determine the value of M of a sample of natural gas.

The time recorded in step 7 is 31.6 s.

- (i) Use the graph in Fig. 2.2 and the student's result to calculate the value of M for this sample.

$M =$ [2]

- (ii) Natural gas is a mixture of mainly methane, CH_4 , with small amounts of other gases.

Suggest what your calculated value of the M of natural gas in (g)(i) tells you about the other gases in the mixture.

.....
 [1]



(h) The experiment described in (g) is repeated at a higher temperature.

Suggest how the rate of effusion for this sample of natural gas would change, if at all.

Explain your answer.

effect on the rate of effusion

explanation

[1]

[Total: 14]

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)



The Periodic Table of Elements

Group																					
1	2	1												13	14	15	16	17	18		
		Key atomic number atomic symbol name relative atomic mass																			
		1 H hydrogen 1.0																			
3	4													5	6	7	8	9	10	11	12
Li lithium 6.9	Be beryllium 9.0													B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0	Ne neon 20.2		
11	12													13	14	15	16	17	18		
Na sodium 23.0	Mg magnesium 24.3													Al aluminium 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5	Ar argon 39.9		
19	20													31	32	33	34	35	36		
K potassium 39.1	Ca calcium 40.1													Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9	Kr krypton 83.8		
37	38													49	50	51	52	53	54		
Rb rubidium 85.5	Sr strontium 87.6													In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9	Xe xenon 131.3		
55	56													81	82	83	84	85	86		
Cs caesium 132.9	Ba barium 137.3													Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	At astatine —	Rn radon —		
87	88													113	114	115	116	117	118		
Fr francium —	Ra radium —													Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganesson —		

Key

atomic number	atomic symbol	name	relative atomic mass
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lanthanoids

actinoids

57	La	lanthanum	138.9	58	Ce	cerium	140.1	59	Pr	praseodymium	140.9	60	Nd	neodymium	144.2	61	Pm	promethium	—	62	Sm	samarium	150.4	63	Eu	euroium	152.0	64	Gd	gadolinium	157.3	65	Tb	terbium	158.9	66	Dy	dysprosium	162.5	67	Ho	holmium	164.9	68	Er	erbium	167.3	69	Tm	thulium	168.9	70	Yb	ytterbium	173.1	71	Lu	lutetium	175.0
89	Ac	actinium	—	90	Th	thorium	232.0	91	Pa	protactinium	231.0	92	U	uranium	238.0	93	Np	neptunium	—	94	Pu	plutonium	—	95	Am	americium	—	96	Cm	curium	—	97	Bk	berkelium	—	98	Cf	californium	—	99	Es	einsteinium	—	100	Fm	fermium	—	101	Md	mendelevium	—	102	No	nobelium	—	103	Lr	lawrencium	—

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CHEMISTRY

9701/54

Paper 5 Planning, Analysis and Evaluation

October/November 2025

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 and use appropriate units.

INFORMATION

- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

This document has **12** pages.

- 1 A student uses a technique called the Winkler method to determine the mass of oxygen dissolved in a sample of water from a lake.

Two solutions, **X** and **Y**, are prepared.

Solution **X** is 2.30 mol dm^{-3} aqueous manganese(II) sulfate, $\text{MnSO}_4(\text{aq})$.

Solution **Y** is alkaline aqueous potassium iodide, $\text{KI}(\text{aq})$.

- (a) Calculate the mass of solid hydrated manganese(II) sulfate, $\text{MnSO}_4 \cdot \text{H}_2\text{O}(\text{s})$, needed to make 100.0 cm^3 of solution **X**.

Give your answer to **two** decimal places.

mass of $\text{MnSO}_4 \cdot \text{H}_2\text{O}(\text{s}) = \dots\dots\dots \text{ g [1]}$

- (b) The student is given a small beaker containing the mass of $\text{MnSO}_4 \cdot \text{H}_2\text{O}(\text{s})$ calculated in (a). Describe how the student should prepare exactly 100.0 cm^3 of solution **X**.

Include the names and capacities of each piece of key apparatus used.

Write your answer using a series of numbered steps.

.....

.....

.....

.....

.....

.....

.....

..... [3]



(c) Solution **Y** is prepared as follows.

- step 1** Place 100 cm³ of distilled water in a 250 cm³ beaker.
- step 2** Add about 8 g of solid sodium hydroxide, NaOH(s), and stir to dissolve.
- step 3** Cool the solution to room temperature using an ice-bath.
- step 4** Repeat steps 2 and 3 until a total of 32 g of NaOH(s) has been dissolved.
- step 5** Dissolve about 14 g of potassium iodide, KI(s), into the solution formed in step 4.

(i) Solution **Y** is corrosive.

Other than wearing safety goggles, state **one** safety precaution that the student should take when preparing solution **Y**.

..... [1]

(ii) Suggest why the solution is cooled in step 3.

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



- (d) The student uses the following procedure to determine the mass of oxygen dissolved in a sample of water from the lake.

- step 1** Collect a 250 cm^3 sample of lake water in a bottle.
- step 2** Add 1 cm^3 of solution **X** and 1 cm^3 of solution **Y** to the bottle.
- step 3** Immediately stopper the bottle, ensuring as little air as possible is trapped.
- step 4** Shake the bottle to mix its contents.
A brown precipitate, manganese(III) hydroxide, $\text{Mn}(\text{OH})_3(\text{s})$, is formed.
- step 5** Add 1.5 cm^3 of concentrated sulfuric acid to the contents of the bottle.
The precipitate dissolves, and iodine is formed.
- step 6** Dilute this solution to exactly 500.0 cm^3 using distilled water to form solution **Z**.
- step 7** Transfer 25.0 cm^3 of solution **Z** into a conical flask, and titrate with $1.00 \times 10^{-3}\text{ mol dm}^{-3}$ aqueous sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$. Add 1 cm^3 of starch solution near to the end-point.
- step 8** Repeat step 7 as many times as necessary.

- (i) Suggest why it is important to avoid trapping air inside the bottle in step 3.

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

- (ii) Identify the piece of apparatus that the student should use to transfer the 25.0 cm^3 of solution **Z** in step 7.

..... [1]

- (iii) Suggest why starch solution is added in step 7.

..... [1]



(e) The student records the results shown in Table 1.1.

Table 1.1

	rough titration	titration 1	titration 2	titration 3
final burette reading / cm ³	13.60	12.75	26.20	14.50
initial burette reading / cm ³	0.00	0.05	13.15	1.35
titre / cm ³	13.60			

(i) Complete Table 1.1 and calculate the mean titre.

mean titre = ... cm³ [2]

(ii) Explain why the student does **not** need to carry out any further titrations.

.....
 [1]

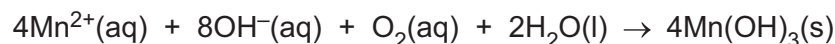
(iii) Calculate the percentage error in the measurement of the titre for titration 3.
 Show your working.

percentage error = ... % [1]

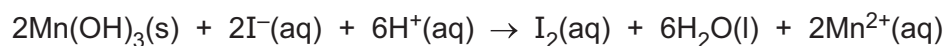


(f) The following equations show the reactions that take place during the procedure in (d).

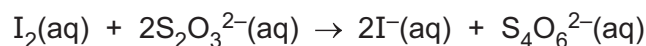
steps 2, 3 and 4



step 5



step 7



(i) Calculate the amount, in mol, of iodine, $\text{I}_2(\text{aq})$, in 25.0 cm^3 of solution **Z**.

amount of $\text{I}_2(\text{aq})$ = ... mol [1]

(ii) Use your answer to (f)(i) and the equations given to calculate the amount, in mol, of dissolved oxygen, $\text{O}_2(\text{aq})$, in 500.0 cm^3 of solution **Z**.

amount of $\text{O}_2(\text{aq})$ in 500.0 cm^3 of solution **Z** = ... mol [1]

(iii) Dissolved oxygen content, mg dm^{-3} , is the mass of oxygen dissolved in water.

Use your answer to (f)(ii) to calculate the dissolved oxygen content in the lake water collected in step 1.

[If you were unable to obtain an answer to (f)(ii), then use amount of $\text{O}_2(\text{aq})$ in 500.0 cm^3 of solution **Z** = $7.12 \times 10^{-5}\text{ mol}$. This is **not** the correct answer.]

dissolved oxygen content = ... mg dm^{-3} [1]

[Total: 16]



- 2 A student uses the following method to investigate the kinetics of the reaction between iodine and tin to produce tin(IV) iodide, SnI_4 .

- step 1** Rinse a block of tin with distilled water and then rinse it with propanone.
- step 2** Place 50 cm^3 of a $0.400 \text{ mol dm}^{-3}$ solution of iodine dissolved in methylbenzene in a 100 cm^3 beaker.
- step 3** Suspend the block of tin from a three decimal place balance as shown in Fig. 2.1. Start a timer.
- step 4** Record the balance reading every 100 seconds.

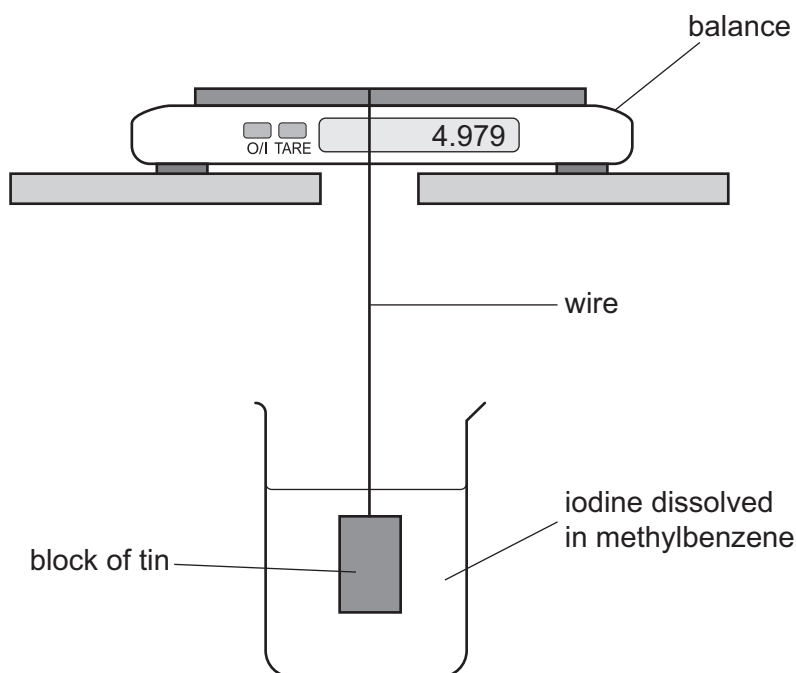


Fig. 2.1

- (a) (i) Suggest why the student rinses the block of tin with propanone after rinsing it with distilled water in step 1.

.....
 [1]

- (ii) Suggest why water is **not** used as the solvent for iodine.

.....
 [1]



- (iii) Suggest why a three decimal place balance is more suitable than a two decimal place balance for this experiment.

..... [1]

- (iv) Suggest a control experiment that could be used to verify that the loss in mass of tin is caused by reaction with iodine and **not** any other factor.

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

- (b) The student's results are shown in Table 2.1.

Complete Table 2.1.

Table 2.1

time/s	balance reading/g	total mass of tin reacted/g
0	4.979	0.000
100	4.910	
200	4.859	
300	4.761	
400	4.688	
500	4.620	

[1]

- (c) (i) Use the results from Table 2.1 to plot a graph on the grid in Fig. 2.2 to show the relationship between total mass of tin reacted and time.

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



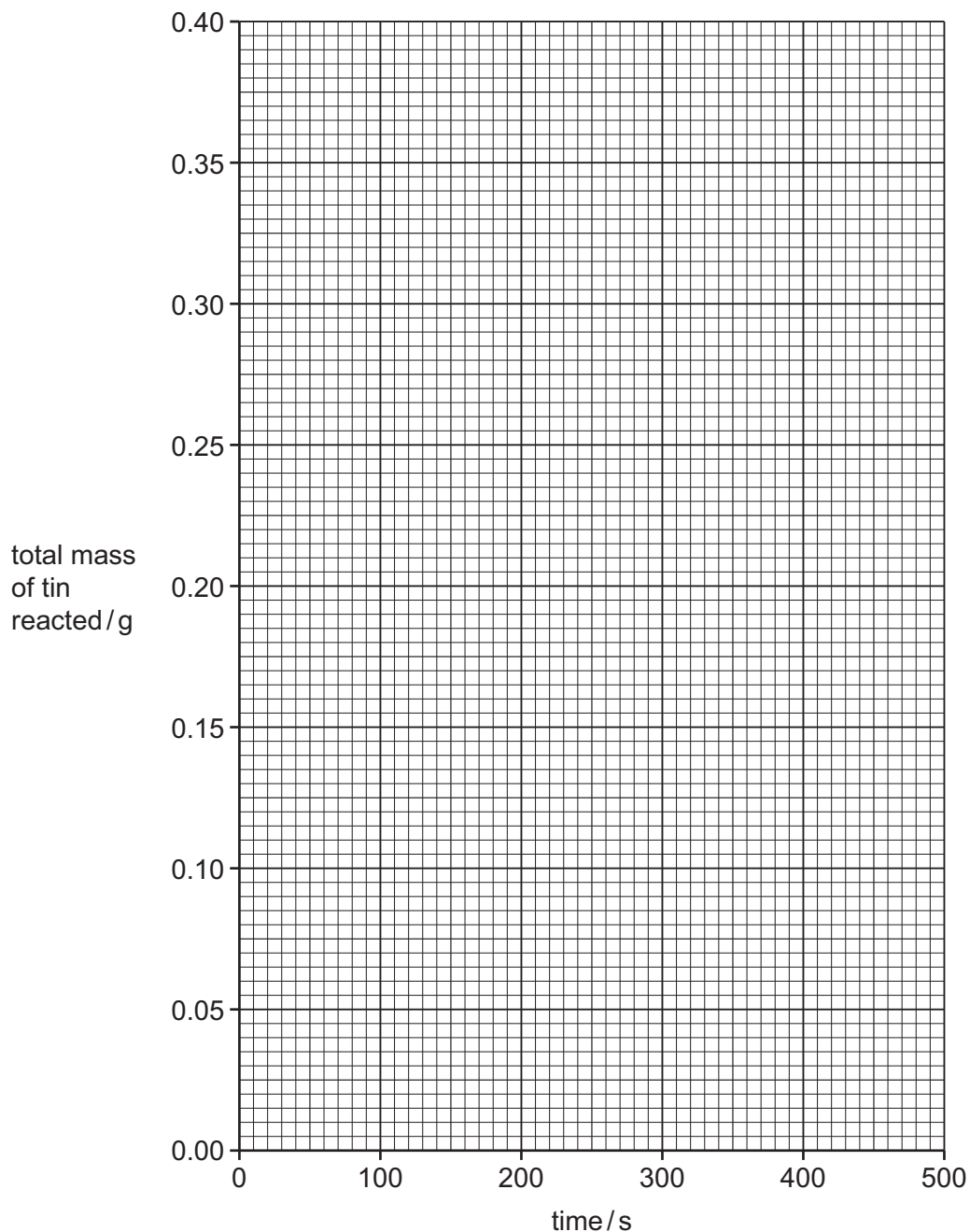


Fig. 2.2

[2]

- (ii) Circle the point on the graph in Fig. 2.2 that you consider to be most anomalous.

Suggest **one** reason why this anomaly may have occurred during this experimental procedure.

Assume all measurements of mass are accurate.

.....

..... [1]



(d) Use your graph in Fig. 2.2 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 your gradient to **three** significant figures.

coordinates 1

coordinates 2

gradient = ... [2]

(e) Another student makes various concentrations of solutions of iodine dissolved in methylbenzene by dilution of the $0.400 \text{ mol dm}^{-3}$ I_2 solution.

The student repeats the experiment at a different temperature using these solutions.

Table 2.2

volume of $0.400 \text{ mol dm}^{-3}$ I_2 solution used / cm^3	volume of methylbenzene used / cm^3	$[\text{I}_2]$ / mol dm^{-3}	relative rate of reaction
100.0	0.0	0.400	4.76
		0.300	3.57
		0.200	2.35
		0.100	1.15

(i) Complete Table 2.2 by adding the volumes of solutions that are mixed to make 100.0 cm^3 of a solution of iodine dissolved in methylbenzene for each required concentration. [1]

(ii) Identify the independent variable in this experiment.

..... [1]



- (iii) The student concludes that the rate equation for the reaction between iodine and tin is as follows.

$$\text{rate} = k [\text{I}_2]^2$$

State whether the results support the student's conclusion.

Explain your answer using values from Table 2.2.

.....

.....

.....

.....

.....

..... [2]

[Total: 14]

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ ($4.18 \text{ J g}^{-1} \text{ K}^{-1}$)



The Periodic Table of Elements

Group																						
1	2	Key												13	14	15	16	17	18			
		atomic number atomic symbol name relative atomic mass												1 H hydrogen 1.0							2 He helium 4.0	
3 Li lithium 6.9	4 Be beryllium 9.0													5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2			
11 Na sodium 23.0	12 Mg magnesium 24.3													13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9			
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8					
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3					
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids		72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —				
87 Fr francium —	88 Ra radium —	89–103 actinoids		104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganesson —				

Key

atomic number
atomic symbol
name
relative atomic mass

lanthanoids		57	La	lanthanum	138.9	58	Ce	cerium	140.1	59	Pr	praseodymium	140.9	60	Nd	neodymium	144.2	61	Pm	promethium	—	62	Sm	samarium	150.4	63	Eu	euporium	152.0	64	Gd	gadolinum	157.3	65	Tb	terbium	158.9	66	Dy	dysprosium	162.5	67	Ho	holmium	164.9	68	Er	erbium	167.3	69	Tm	thulium	168.9	70	Yb	ytterbium	173.1	71	Lu	lutetium	175.0
actinoids		89	Ac	actinium	—	90	Th	thorium	232.0	91	Pa	protactinium	231.0	92	U	uranium	238.0	93	Np	neptunium	—	94	Pu	plutonium	—	95	Am	americium	—	96	Cm	curium	—	97	Bk	berkelium	—	98	Cf	californium	—	99	Es	einsteinium	—	100	Fm	fermium	—	101	Md	mendelevium	—	102	No	nobelium	—	103	Lr	lawrencium	—

