Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER | | | | | |

CANDIDATE NUMBER | | | | |

*9754737583*

**CHEMISTRY** **9701/51**

Paper 5 Planning, Analysis and Evaluation **May/June 2022**

**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 **16** pages. Any blank pages are indicated.


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**1** A student plans an investigation to find the molar ratio of the reaction between sodium chloride, NaC$l$, and a lead compound.

The student is provided with solid NaC$l$ and 0.200 mol dm$^{-3}$ aqueous lead compound.

The reaction between NaC$l$(aq) and the aqueous lead compound produces an insoluble compound as a precipitate.

**(a)** The student prepares 0.200 mol dm$^{-3}$ NaC$l$(aq).

Calculate the mass of NaC$l$(s) needed to make 250.0 cm$^3$ of 0.200 mol dm$^{-3}$ NaC$l$(aq).

mass of NaC$l$ = ..... g [1]

**(b)** The student weighs the mass of NaC$l$(s) calculated in **(a)** in a weighing boat. The solid mass is then transferred into a small beaker.

Describe how the student should accurately weigh by difference so the exact mass of NaC$l$ transferred into the small beaker is known.

.....

.....

.....

..... [1]

**(c)** The student is given a small beaker containing the mass of NaC$l$ calculated in **(a)**.

Describe how the student should prepare 250.0 cm$^3$ of 0.200 mol dm$^{-3}$ NaC$l$(aq).

Include the names and capacities of each piece of apparatus used in the preparation of the solution.

.....

.....

.....

.....

..... [2]

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**(d)** The student plans the following method using the 0.200 mol dm$^{-3}$ aqueous lead compound and the 0.200 mol dm$^{-3}$ NaC$l$(aq) prepared in **(c)**.

**Step 1** Mix the NaC$l$(aq) and the aqueous lead compound in eight separate beakers in the proportions by volume shown in Table 1.1.

**Table 1.1**

| beaker | volume of 0.200 mol dm$^{-3}$ NaC$l$(aq) / cm$^3$ | volume of 0.200 mol dm$^{-3}$ aqueous lead compound / cm$^3$ |
|---|---|---|
| 1 | 10.00 | 40.00 |
| 2 | 15.00 | 35.00 |
| 3 | 20.00 | 30.00 |
| 4 | 25.00 | 25.00 |
| 5 | 30.00 | 20.00 |
| 6 | 35.00 | 15.00 |
| 7 | 40.00 | 10.00 |
| 8 | 45.00 | 5.00 |

**Step 2** Filter the contents of each beaker to collect the precipitate.

**Step 3** Dry the precipitate for 3 minutes in an oven and allow to cool.

**Step 4** Weigh and record the mass of precipitate produced in each beaker.

**(i)** State **one** extra step that would improve this method. Explain why this step is necessary.

extra step:

.....

.....

explanation:

.....

.....

.....

[2]

**(ii)** The volumes of solutions are measured using a burette.

Calculate the percentage error when measuring 10.00 $cm^3$ of solution.
Show your working.

percentage error = ..... [1]

**(iii)** Explain how you would ensure that the results of the investigation are reliable.

.....

.....

..... [1]

**(e)** The results of the investigation are shown on the graph in Fig. 1.1.

**(i)** Draw **two** straight lines of best fit through the points. Extrapolate both lines so they intersect. [1]

**(ii)** Using Fig. 1.1 and Table 1.1, state the volumes of 0.200 mol $dm^{-3}$ NaC$l$(aq) and 0.200 mol $dm^{-3}$ aqueous lead compound which produce the maximum mass of precipitate.

Calculate the molar ratio in which the NaC$l$ and the lead compound react.

volume of 0.200 mol $dm^{-3}$ NaC$l$(aq) = ..... $cm^3$

volume of 0.200 mol $dm^{-3}$ aqueous lead compound = ..... $cm^3$

molar ratio of NaC$l$: lead compound = ..... : .....
[2]

**(f)** Use the molar ratio in **(e)(ii)** to deduce the formula of the precipitate.

formula = ..... [1]

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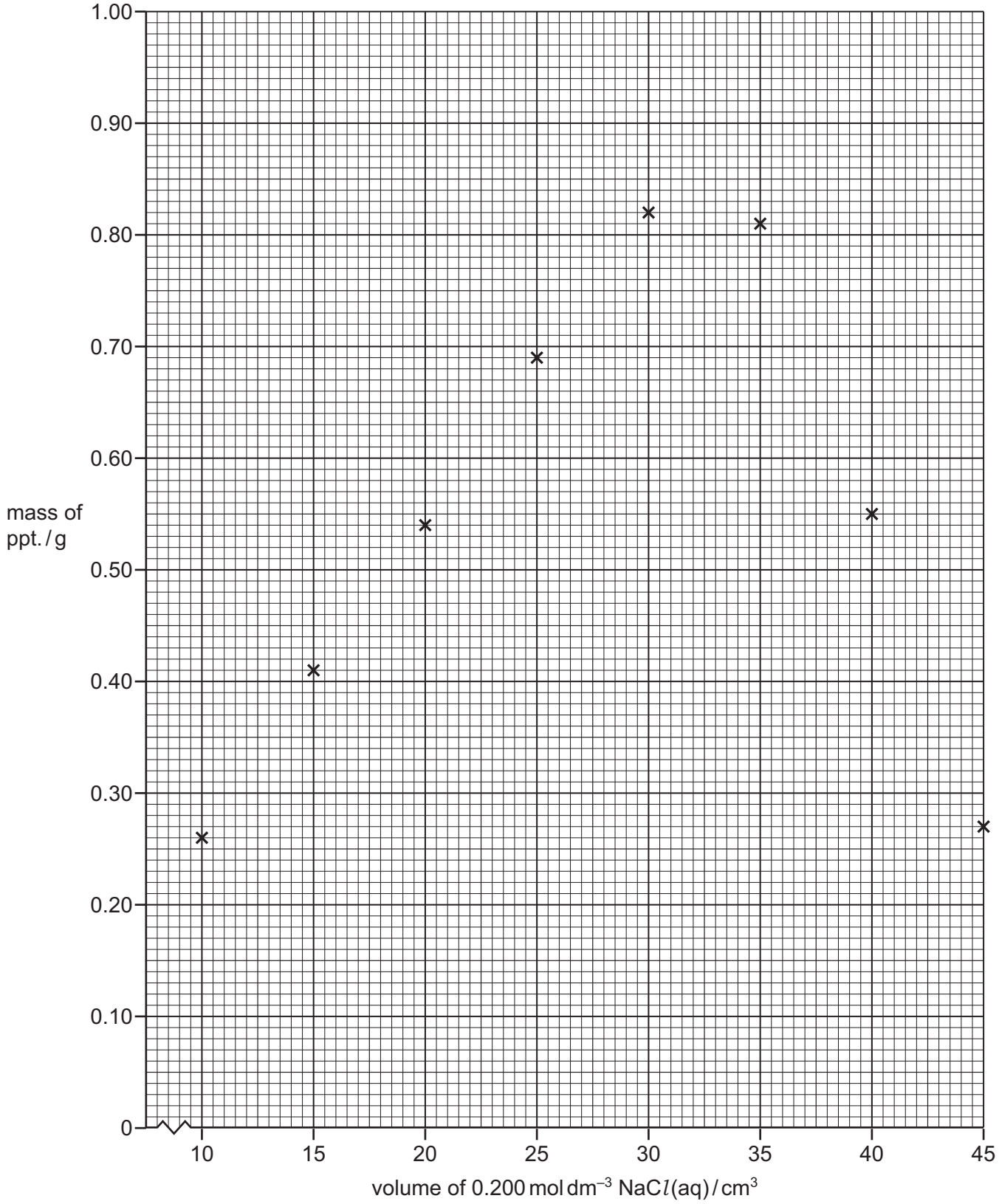

1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0
mass of ppt. / g
10
15
20
25
30
35
40
45
volume of 0.200 mol dm–3 NaCl(aq) / cm3

**Fig. 1.1**

**(g)** A student suggests that a simpler method can be used to find the molar ratio.

Different volumes of 0.200 mol dm$^{-3}$ NaC$l$(aq) and 0.200 mol dm$^{-3}$ aqueous lead compound are mixed in test-tubes. The resulting precipitates are allowed to settle. The height of each precipitate is then measured.

A further two investigations are carried out. The volumes used and the results of the two investigations are shown.

**Investigation 1**

Precipitate heights are measured after 1 minute.

**Table 1.2**

| volume 0.200 mol dm$^{-3}$ NaC$l$(aq) / cm$^3$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| volume 0.200 mol dm$^{-3}$ aqueous lead compound / cm$^3$ | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

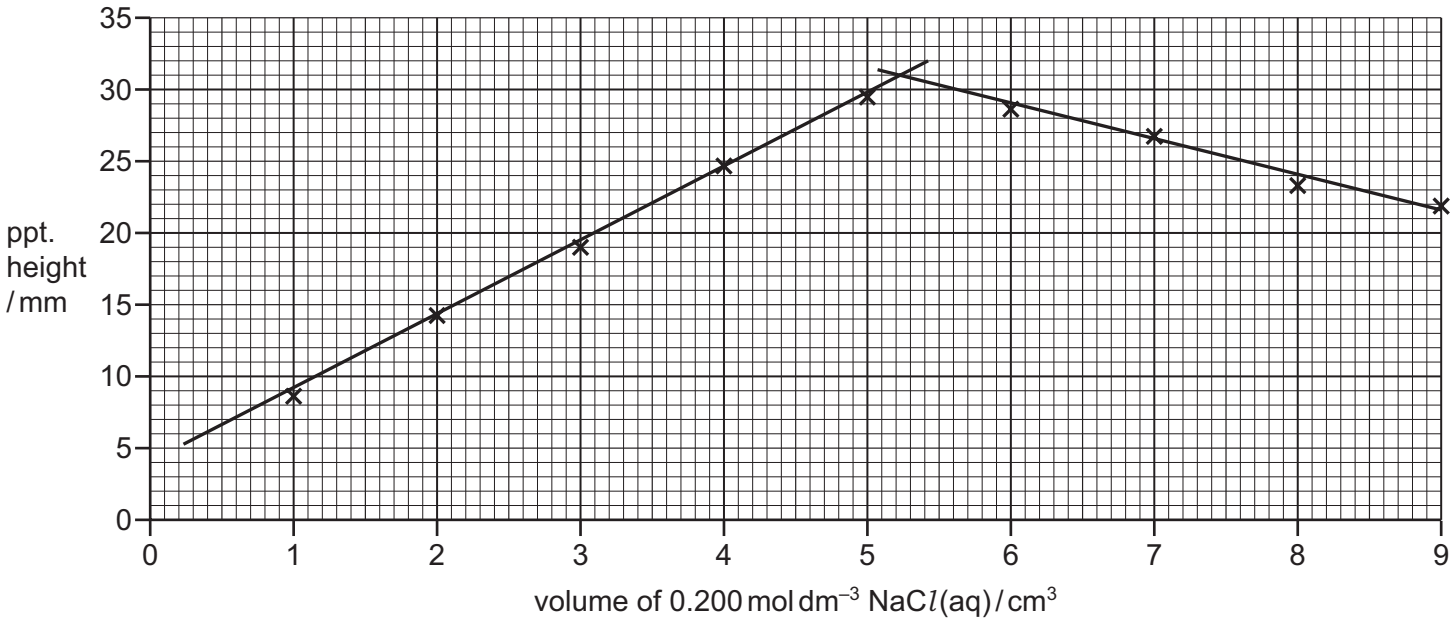



**Fig. 1.2**

**Investigation 2**

Precipitate heights are measured after 5 minutes.

**Table 1.3**

| volume 0.200 mol dm$^{-3}$ NaC$l$(aq) / cm$^3$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| volume 0.200 mol dm$^{-3}$ aqueous lead compound / cm$^3$ | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

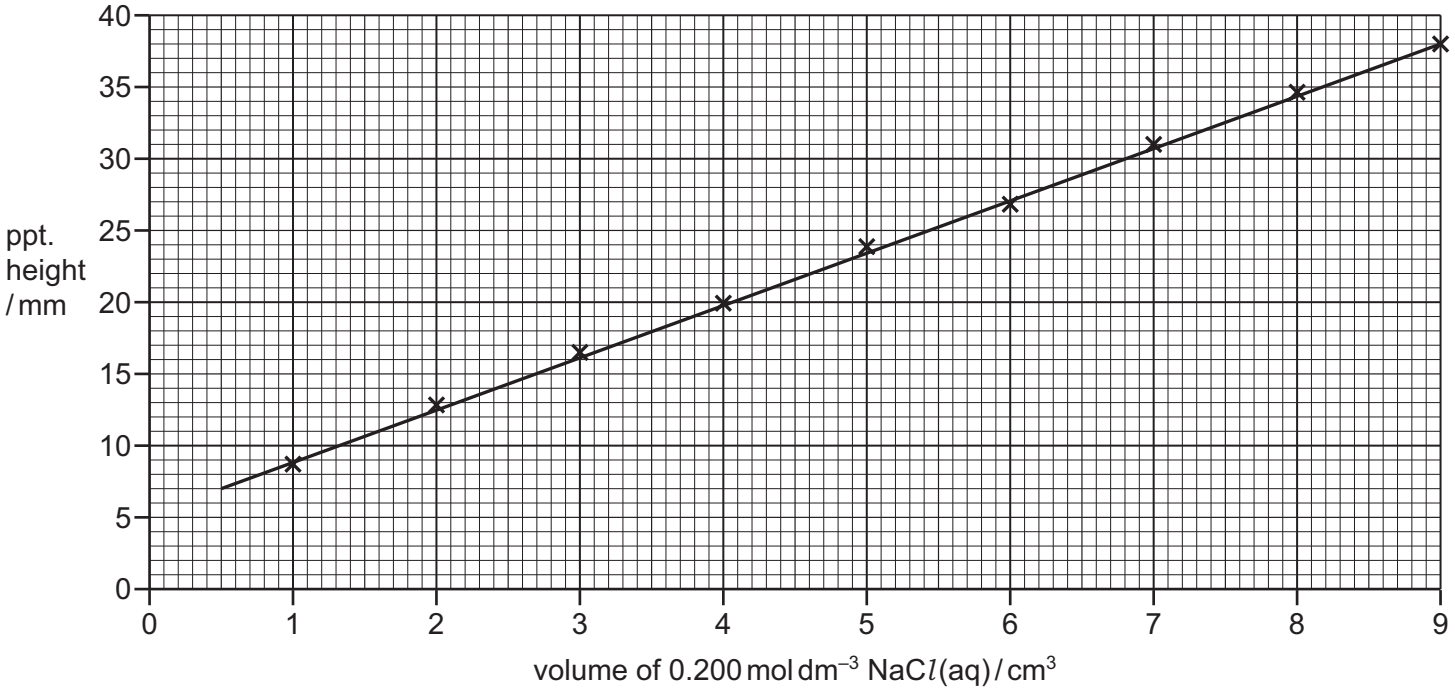



**Fig. 1.3**

Neither investigation produced the expected results. Both investigations, 1 and 2, contain weaknesses in the experimental procedure.

State how you would modify the experimental procedure in each case so that the expected results are obtained.

modification for investigation 1:

.....

.....

modification for investigation 2:

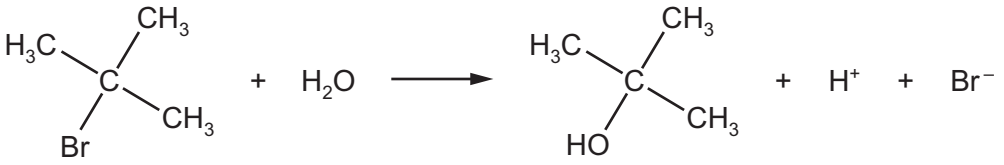
.....

.....

[2]

[Total: 14]

**2** A student plans to study the rate of hydrolysis of 2-bromo-2-methylpropane.




As the concentration of 2-bromo-2-methylpropane decreases during the reaction, the concentration of hydrogen ions increases.

The student plans the following method.

**Step 1** Place 100 $cm^3$ of a mixture of propanone and water into a conical flask.

**Step 2** Heat the mixture to 35 °C and maintain this temperature.

**Step 3** Add 1.00 $cm^3$ of 2-bromo-2-methylpropane to the mixture and start timing.

**Step 4** After 1 minute, transfer a 10.00 $cm^3$ sample of the reaction mixture into a conical flask containing ice and 4 drops of methyl orange indicator.

**Step 5** Immediately titrate the 10.00 $cm^3$ of the reaction mixture with 0.0200 mol $dm^{-3}$ sodium hydroxide.

**Step 6** Repeat sampling and titrating at regular time intervals over a total time of 45 minutes.

**Step 7** Heat the reaction mixture to 50 °C, remove the final sample, and titrate this.

**(a) (i)** State the apparatus you would use to maintain the temperature of the reaction mixture.

..... [1]

**(ii)** Suggest why the experiment is carried out away from naked flames.

.....

..... [1]

**(b)** State the pieces of equipment and their capacities that you would use to:

**(i)** measure 1.00 $cm^3$ of 2-bromo-2-methylpropane in step 3

..... [1]

**(ii)** transfer a 10.00 $cm^3$ sample of the mixture in step 4.

..... [1]

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

**(c)** Explain why the reaction mixture is transferred into a conical flask containing ice.

.....

..... [1]

**(d)** State the measured dependent variable for this experiment.

..... [1]

**(e) (i)** The student recorded the results. $V_{final}$ is the final titre volume, 47.25 $cm^3$ in step 7.

Complete Table 2.1 by calculating the value of $V_{final} - V_t$.

Record the values to **2 decimal places**.

**Table 2.1**

| time / s | titre, $V_t$ / $cm^3$ | $V_{final} - V_t$ / $cm^3$ |
|---|---|---|
| 60 | 1.25 | |
| 300 | 7.75 | |
| 600 | 17.75 | |
| 900 | 20.00 | |
| 1200 | 24.25 | |
| 1500 | 28.40 | |
| 1800 | 31.15 | |
| 2700 | 38.00 | |
| final | 47.25 | |

[1]

**(ii)** The titre, $V_t$, is proportional to the concentration of the hydrogen ions.

State what $V_{final} - V_t$ is proportional to.

..... [1]

**(iii)** Plot a graph on the grid to show the relationship between $V_{final} - V_t$ and time.

Use a cross (×) to plot each data point. Draw a curved line of best fit. [2]

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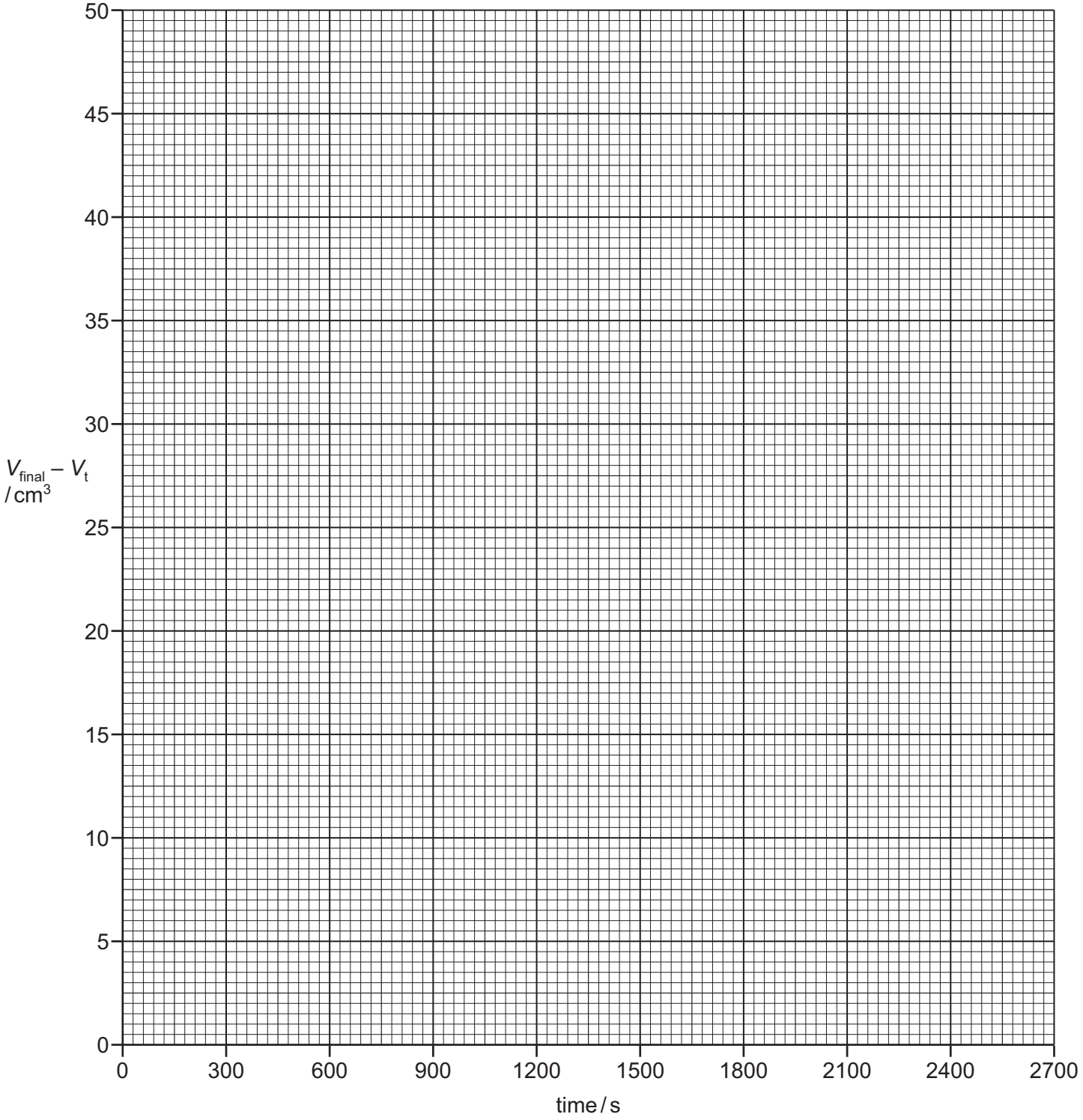


**(iv)** Circle the point on the graph you consider to be most anomalous.

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

.....

..... [2]

**(v)** Use the graph to find two half-lives, $t_{\frac{1}{2}}$, for this reaction.

State the coordinates of both points you used in your calculations.

first $t_{\frac{1}{2}}$: coordinates ..... and .....

half-life = ..... s

second $t_{\frac{1}{2}}$: coordinates ..... and .....

half-life = ..... s

[3]

**(vi)** Use your answer to **(e)(v)** to state the order of the reaction with respect to 2-bromo-2-methylpropane. Explain your answer.

(If you were unable to obtain an answer to **(e)(v)** you may use the values 1050 s and 1045 s for the half-lives. These are **not** the correct values.)

order = .....

explanation .....

[1]

[Total: 16]

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## 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 | $L = 6.022 \times 10^{23}\,\text{mol}^{-1}$ |
| 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)<br>$V_m = 24.0\,\text{dm}^3\,\text{mol}^{-1}$ 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 | $c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$) |

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## The Periodic Table of Elements

Group

| 1 | 2 | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 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 144.4 | 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 |
| 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 – |

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