Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME											
CENTRE NUMBER							CANDIDATE NUMBER				

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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.

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

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

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

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

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

mass of $NaCl$ = ... g [1]

(b) The student weighs the mass of $NaCl$(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 $NaCl$ transferred into the small beaker is known.

....

....

....

.... [1]

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

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

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

....

....

....

....

.... [2]

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

Step 1 Mix the NaCl(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} NaCl(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} $NaCl$(aq) and 0.200 mol dm^{-3} aqueous lead compound which produce the maximum mass of precipitate.

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

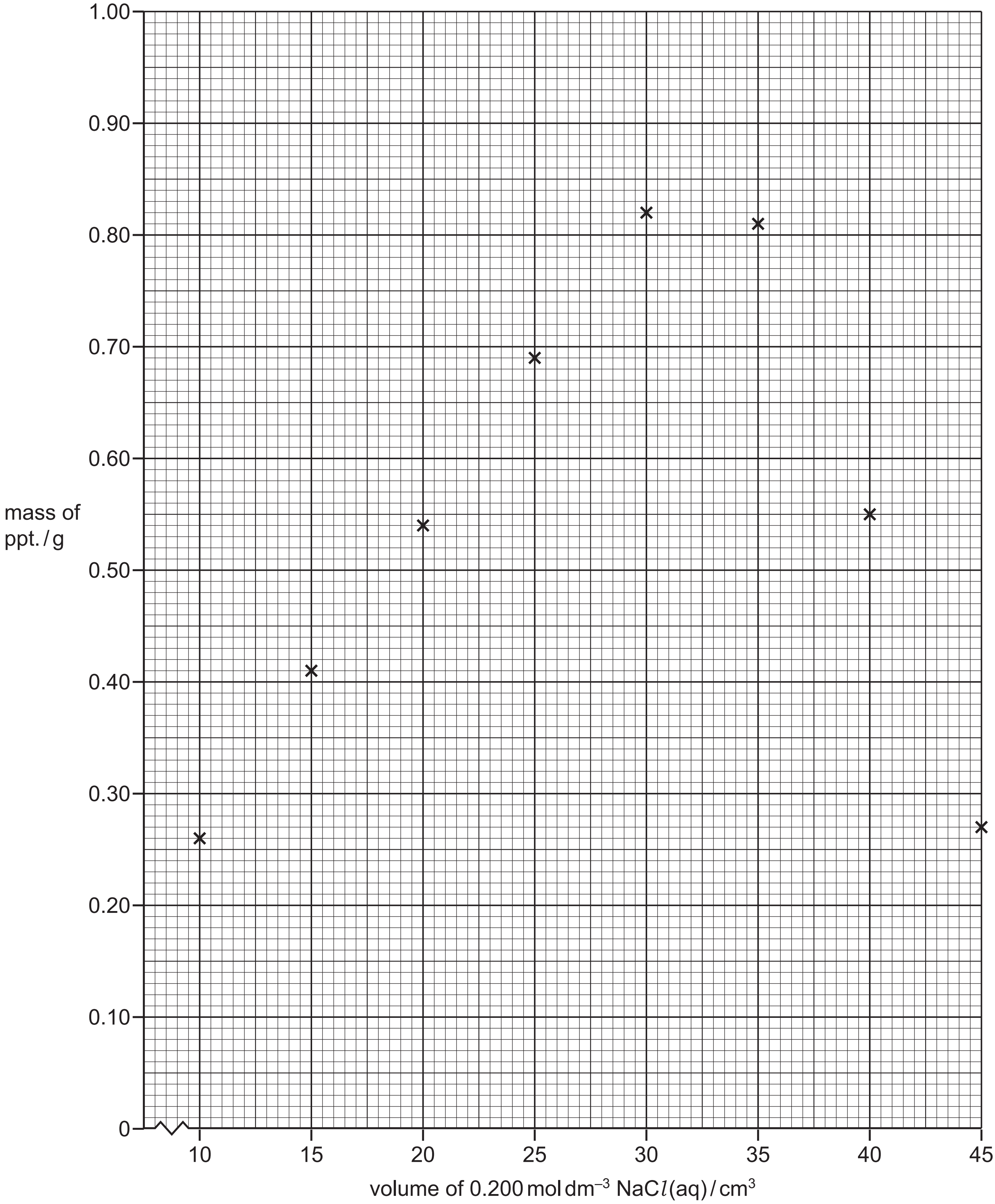
volume of 0.200 mol dm^{-3} $NaCl$(aq) = ... cm^3

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

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

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

formula = ... [1]



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

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} NaCl(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} NaCl(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

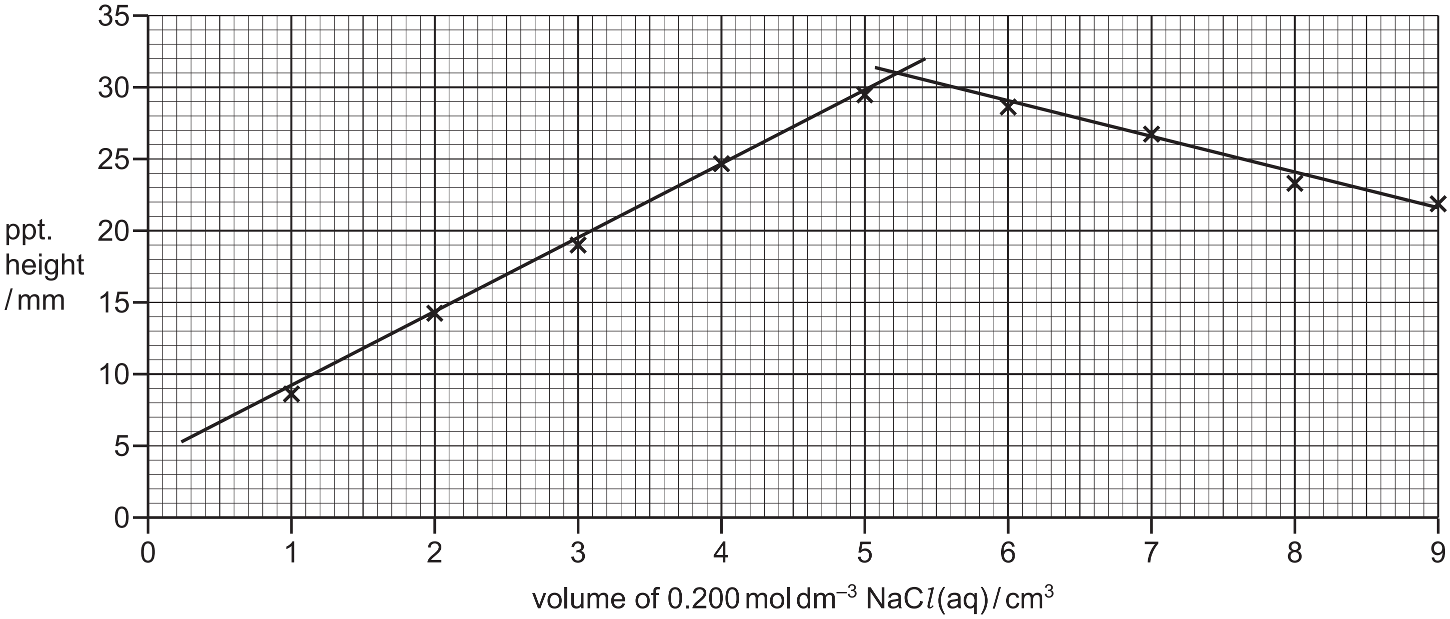


Fig. 1.2

Investigation 2

Precipitate heights are measured after 5 minutes.

Table 1.3

volume 0.200 $mol\,dm^{-3}$ $NaCl(aq)/cm^3$	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

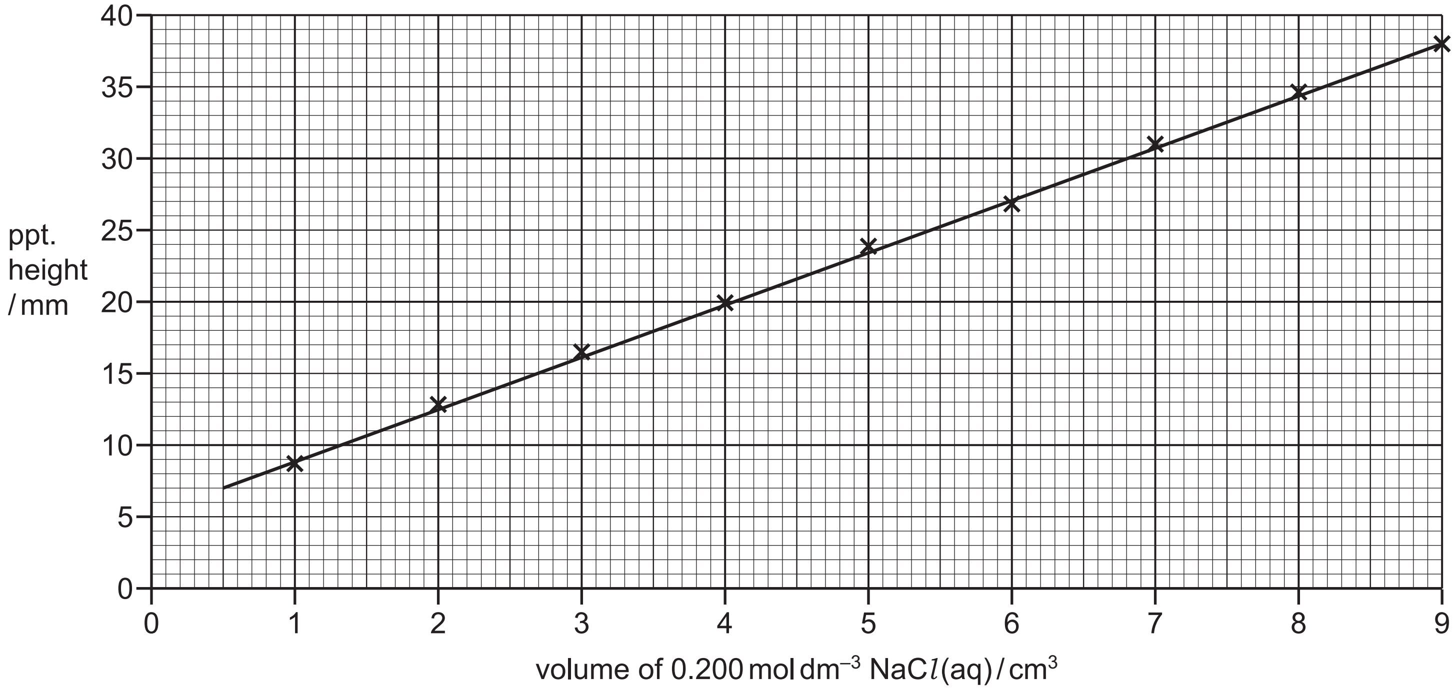


Fig. 1.3

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:

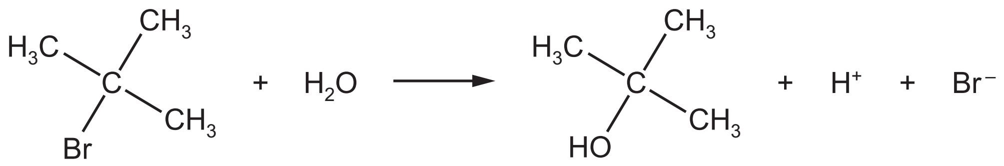
....

....

[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]

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]

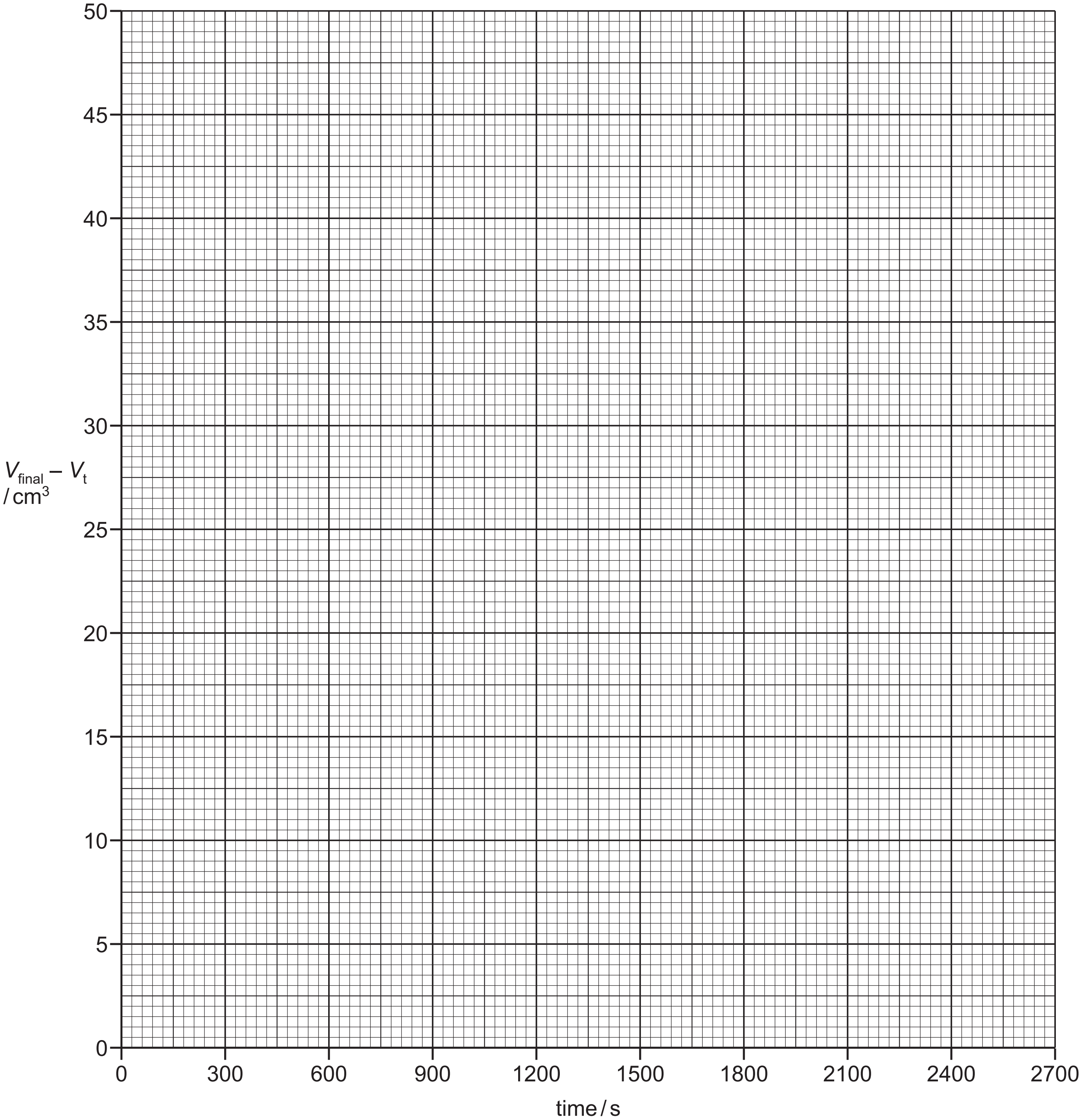
(ii) The titre, V_t, is proportional to the concentration of the hydrogen ions.

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]



(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	$R = 8.31\,J\,K^{-1}\,mol^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,C\,mol^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23}\,mol^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,C$
molar volume of gas	$V_m = 22.4\,dm^3\,mol^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,dm^3\,mol^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,mol^2\,dm^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ ($4.18\,J\,g^{-1}\,K^{-1}$)

The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							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 –

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 –