



Cambridge International AS & A Level

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NAME



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CHEMISTRY

9701/51

Paper 5 Planning, Analysis and Evaluation

October/November 2024

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 uses the following method to determine the percentage by mass of the painkiller aspirin, $C_9H_8O_4(s)$, in some tablets.

step 1 Grind five tablets into a powder.

step 2 Use a weighing boat to accurately weigh by difference approximately 0.4 g of powdered tablets into a pear-shaped flask containing anti-bumping granules.

step 3 Add 25 cm^3 of aqueous 1 mol dm^{-3} sodium hydroxide, NaOH(aq) , to the pear-shaped flask, forming mixture **A**.

step 4 Reflux mixture **A** for 20 minutes.

step 5 Allow mixture **A** to cool and then filter into a small beaker. Label the filtrate solution **B**.

step 6 Add 30 cm^3 of alkaline aqueous iodine to solution **B** and leave to stand for 1 hour. A precipitate, **C**, $(C_6H_2I_2O)_2(s)$, will form.

step 7 Filter the resulting mixture under reduced pressure. Wash the residue, **C**, with a small volume of cold distilled water.

step 8 Allow solid **C** to dry.

step 9 Weigh solid **C** and record its mass.

Alkaline aqueous iodine is irritating to the skin and eyes.

- (a) Identify an appropriate precaution, other than eye protection and a lab coat, that the student should take when using alkaline aqueous iodine.

.....
 [1]

- (b) Describe how the student should carry out **step 2**. Include a results table, with appropriate headings, for the student to fill in.

.....



(c) Complete Fig. 1.1 to show how **step 4** is carried out in the laboratory.

Label your diagram fully.

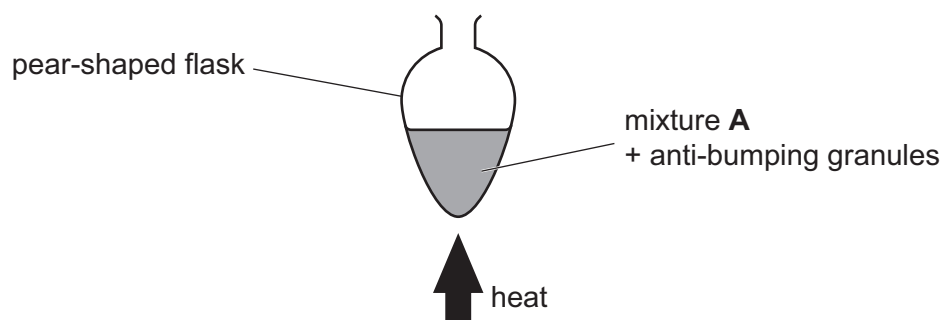


Fig. 1.1

[2]

(d) (i) The student uses a measuring cylinder to measure the volume of alkaline aqueous iodine in **step 6**. Suggest why this is a suitable piece of apparatus to use.

.....
 [1]

(ii) Suggest why the student leaves the mixture to stand for 1 hour in **step 6**.

.....
 [1]

(iii) Explain why the residue is washed in **step 7**.

.....
 [1]

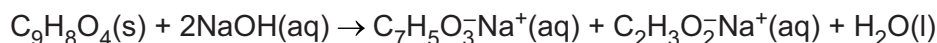
(iv) Explain why hot distilled water is **not** used in **step 7**.

.....
 [1]

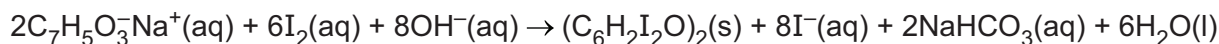




- (e) The equation for the reaction between aspirin, $\text{C}_9\text{H}_8\text{O}_4(\text{s})$, and $\text{NaOH}(\text{aq})$, which takes place in **step 4**, is shown.



The equation for the reaction in which solid **C**, $(\text{C}_6\text{H}_2\text{I}_2\text{O})_2(\text{s})$, is formed in **step 6** is shown.



The student's results are shown in Table 1.1.

Table 1.1

mass of powdered tablets added to the pear-shaped flask in step 2	0.409 g
mass of dry $(\text{C}_6\text{H}_2\text{I}_2\text{O})_2(\text{s})$ recorded in step 9	0.764 g

- (i) Calculate the amount, in mol, of $(\text{C}_6\text{H}_2\text{I}_2\text{O})_2(\text{s})$ collected in **step 9**.

$[M_r: (\text{C}_6\text{H}_2\text{I}_2\text{O})_2, 687.6]$

amount of $(\text{C}_6\text{H}_2\text{I}_2\text{O})_2$ mol [1]

- (ii) Use your answer to (i) to calculate the mass, in g, of $\text{C}_9\text{H}_8\text{O}_4(\text{s})$ in the powdered tablets added to the flask in **step 2**.

mass of $\text{C}_9\text{H}_8\text{O}_4(\text{s})$ g [1]

- (iii) Use your answer to (ii) to calculate the percentage by mass of aspirin, $\text{C}_9\text{H}_8\text{O}_4(\text{s})$, in the tablets.

If you were unable to obtain an answer to (ii) you may use 0.374 g for the mass of $\text{C}_9\text{H}_8\text{O}_4(\text{s})$. This is **not** the correct value.

percentage by mass $\text{C}_9\text{H}_8\text{O}_4(\text{s})$ in the tablets [1]





- (f) Another student follows the same method but does not allow solid **C** to dry completely in **step 8**.

State and explain the effect that this has on the calculated percentage by mass of aspirin, $C_9H_8O_4(s)$, in the tablets.

.....

.....

..... [1]

[Total: 13]





- 2 Crystal violet, $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{s})$, is a purple dye.

Some light is absorbed when it passes through $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$.

Absorbance is the proportion of light absorbed at a particular wavelength. This is measured using a colorimeter.

A graph of absorbance against wavelength for $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$ is shown in Fig. 2.1.

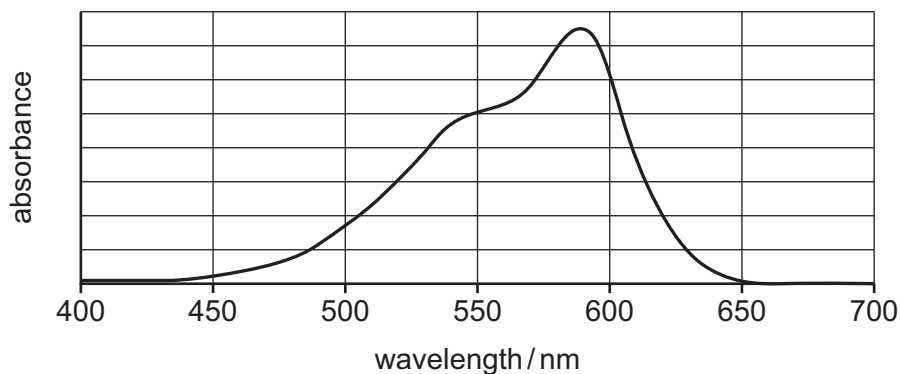


Fig. 2.1

A student investigates how to determine the concentration of aqueous crystal violet, $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$, using colorimetry.

- (a) Suggest the best wavelength of light to use in the colorimeter when measuring the concentration of $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$.

wavelength = ...nm [1]





(b) Solution **D** is 500.0 cm^3 of $2.50 \times 10^{-2}\text{ mol dm}^{-3}$ $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$.

(i) Calculate the mass of $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{s})$ needed to prepare solution **D**.

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

$[M_r: \text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{s}), 407.5]$

mass of $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{s}) = \dots\dots\dots\text{g}$ [1]

(ii) The student is given a small beaker containing the mass of $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{s})$ calculated in (i).

Describe how the student should prepare 500.0 cm^3 of solution **D**.

Include the name and capacity of the key apparatus which should be used and describe how the student should ensure the volume is exactly 500.0 cm^3 .

.....

.....

.....

.....

.....

.....

..... [3]





- (c) A small sample of solution **D** was diluted to form solution **E**, $2.50 \times 10^{-4} \text{ mol dm}^{-3}$ $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl(aq)}$.

The student prepares solutions 2 to 6 as shown in Table 2.1.

The total volume needed for each of solutions 2 to 6 is 20.00 cm^3 .

Each solution is placed into a colorimeter and the absorbance is measured.

- (i) Complete Table 2.1 to show the volumes of solution **E** and distilled water needed to prepare each of the solutions from 2 to 6. Give all volumes to **two** decimal places.

Table 2.1

solution	volume of $2.50 \times 10^{-4} \text{ mol dm}^{-3}$ $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl(aq)}$ (solution E) $/\text{cm}^3$	volume of distilled water $/\text{cm}^3$	$[\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl(aq)}]$ $/\text{mol dm}^{-3}$	absorbance
1	0.00	20.00	0.00	0.000
2			0.50×10^{-4}	0.191
3			1.00×10^{-4}	0.270
4			1.50×10^{-4}	0.545
5			2.00×10^{-4}	0.711
6			2.50×10^{-4}	0.860

[1]

- (ii) Identify the dependent variable.

..... [1]



(d) (i) Plot a graph of absorbance against $[\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})]$ on the grid in Fig. 2.2.

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

Draw a straight line of best fit.

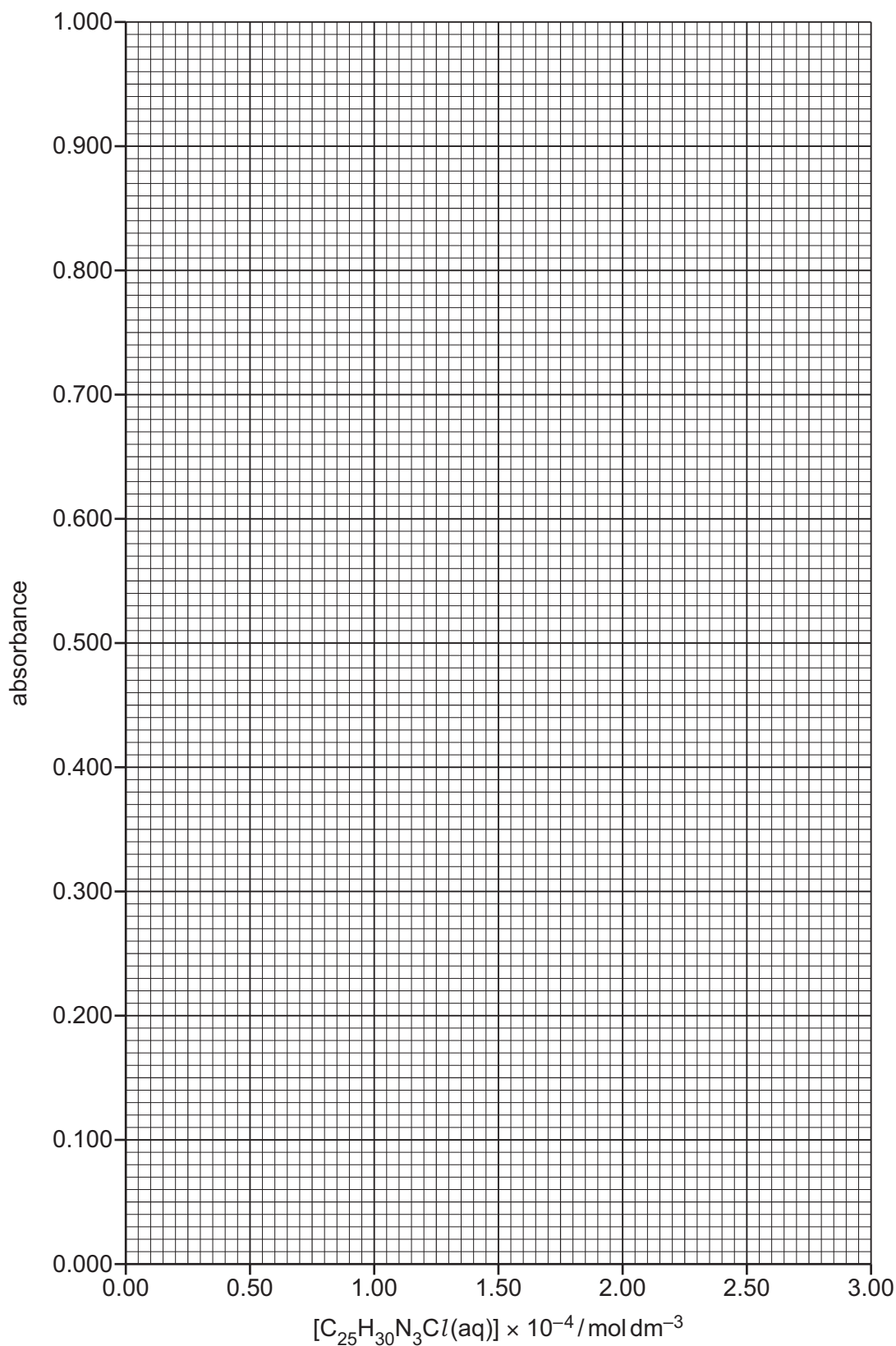


Fig. 2.2



- (ii) 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 the measurement of absorbance.

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

- (iii) State the relationship between $[C_{25}H_{30}N_3Cl(aq)]$ and absorbance.

..... [1]

- (iv) Suggest how the student could improve the reliability of the data obtained in the experiment in (c).

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



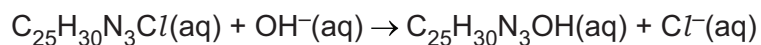


Question 2 continues on the next page.





- (e) The student carries out a further experiment to examine the kinetics of the reaction between crystal violet, $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$, and aqueous sodium hydroxide, $\text{NaOH}(\text{aq})$.



The disappearance of the purple colour as the reaction proceeds can be monitored by measuring how the absorbance of light by the mixture changes using a colorimeter.

The student mixes 5 cm^3 of solution 6 with 5 cm^3 of $\text{NaOH}(\text{aq})$, a large excess, and immediately starts the stopwatch.

The resulting mixture is then placed in a colorimeter. The absorbance of this mixture is measured every 100 seconds after starting the stop-watch.

Fig. 2.3 shows a graph of the student's results.

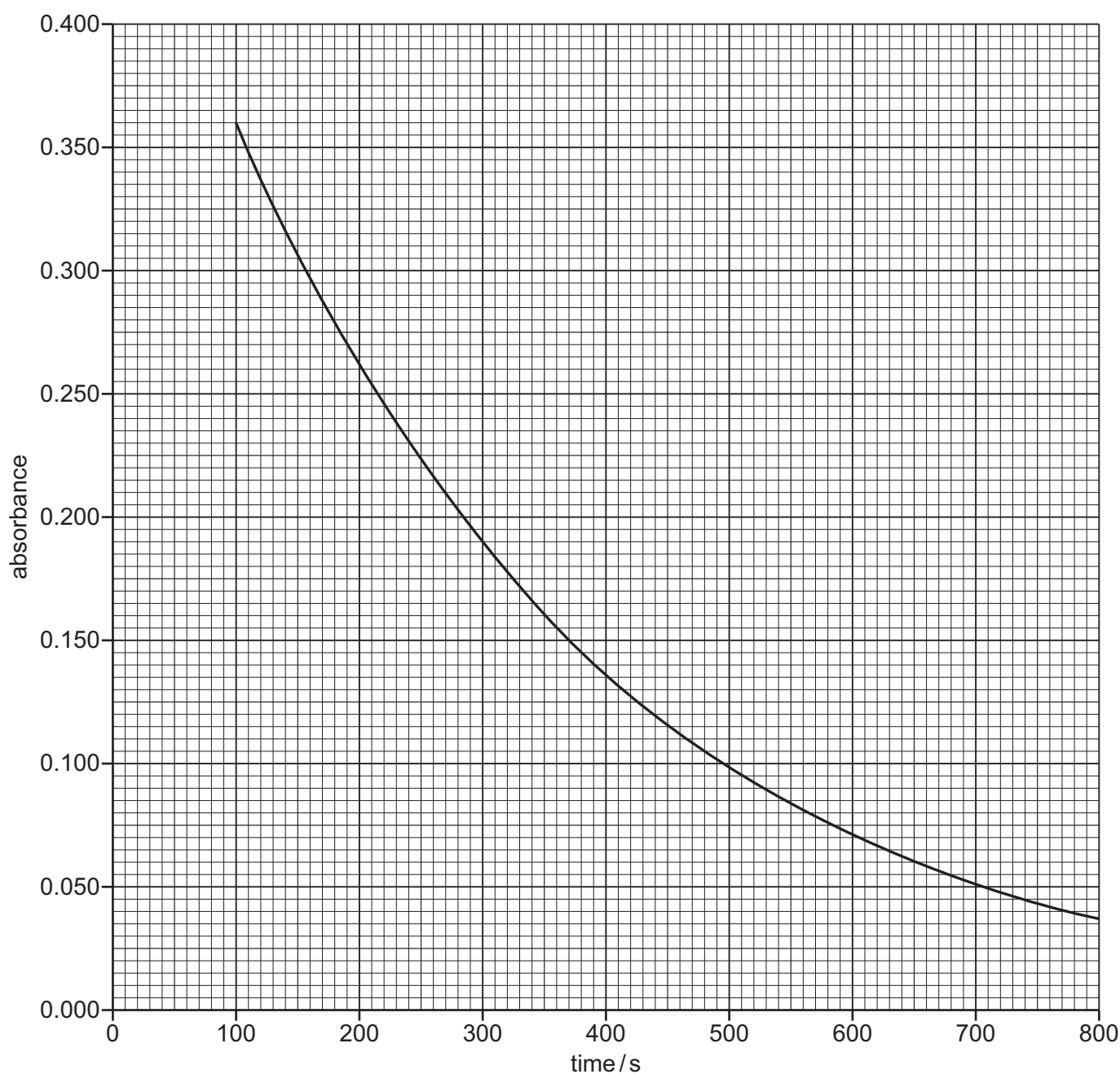


Fig. 2.3





- (i) Suggest why it is **not** possible for the student to measure the absorbance of the mixture at $t = 0$ s.

.....
 [1]

- (ii) Use the graph in Fig. 2.3 to find the half-life, $t_{1/2}$, starting at 100 s.

State the coordinates of both points on the line of best fit used in your calculation.

coordinates 1 coordinates 2

half-life s
 [2]

- (iii) Another student repeats the experiment at a different temperature and measures two half-life values. The values obtained are 420 s and 425 s.

Use these values to deduce the order of the reaction with respect to $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$.
 Explain your answer.

order = ...

explanation
 [1]

[Total: 17]







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) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ 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						2 He helium 4.0					
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 oganeson —							

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	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
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	merendelevium	—	102	No	nobelium	—	103	Lr	lawrencium	—

actinoids

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CHEMISTRY

9701/52

Paper 5 Planning, Analysis and Evaluation

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1 hour 15 minutes

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- 1 Solution **X** is dilute hydrochloric acid of unknown concentration. A student uses titration with aqueous sodium carbonate, $\text{Na}_2\text{CO}_3(\text{aq})$, to determine the concentration of solution **X**.

The student plans to prepare 250.0 cm^3 of 0.500 mol dm^{-3} aqueous sodium carbonate, $\text{Na}_2\text{CO}_3(\text{aq})$.

- (a) (i) Calculate the mass of $\text{Na}_2\text{CO}_3(\text{s})$ needed to make 250.0 cm^3 of 0.500 mol dm^{-3} $\text{Na}_2\text{CO}_3(\text{aq})$, using a **two** decimal place balance.

mass of $\text{Na}_2\text{CO}_3(\text{s}) = \dots\dots\dots \text{ g}$ [1]

- (ii) Describe how the student should make 250.0 cm^3 of 0.500 mol dm^{-3} $\text{Na}_2\text{CO}_3(\text{aq})$ starting from the mass of $\text{Na}_2\text{CO}_3(\text{s})$ calculated in (i) supplied in a 50 cm^3 beaker.

Give the name and size of any key apparatus to be used.

Write your answer using a series of numbered steps.

.....

.....

.....

.....

.....

.....

..... [3]





- (b) The student incorrectly makes up the 250.0 cm^3 of $\text{Na}_2\text{CO}_3(\text{aq})$ and the concentration is **not** 0.500 mol dm^{-3} . The student calls this solution **Y**.

The student uses the following method to determine both the concentration of solution **X** and the concentration of solution **Y**.

step 1 Transfer 25.0 cm^3 of solution **Y** into a conical flask using a volumetric pipette. Add a few drops of methyl orange.

step 2 Titrate the sample in the conical flask with solution **X**.

step 3 Transfer a fresh 25.0 cm^3 portion of solution **Y** into a second conical flask, but do **not** add methyl orange.

step 4 Use the burette to add the volume of solution **X** used in **step 2** to the second conical flask.

step 5 Measure and record the mass of a dry evaporating basin.

step 6 Transfer the contents of the second conical flask into the evaporating basin.

step 7 Use a water bath to heat the solution in the evaporating basin until all the water is evaporated and only solid remains.

step 8 Measure and record the mass of the evaporating basin and solid residue.

- (i) In **step 1**, 25.0 cm^3 of solution **Y** is transferred using a volumetric pipette.

State what the volumetric pipette should be rinsed with before carrying out **step 1**.

..... [1]

- (ii) Describe how the student detects the end-point of the titration in **step 2**.

..... [1]

- (iii) Explain why the evaporating basin is not heated directly with a Bunsen burner in **step 7**.

..... [1]

- (iv) Suggest what the student should do to ensure all of the water has evaporated from the residue before completing **step 8**.

..... [1]





(c) The student's burette readings taken in **step 2** are shown in Fig. 1.1.

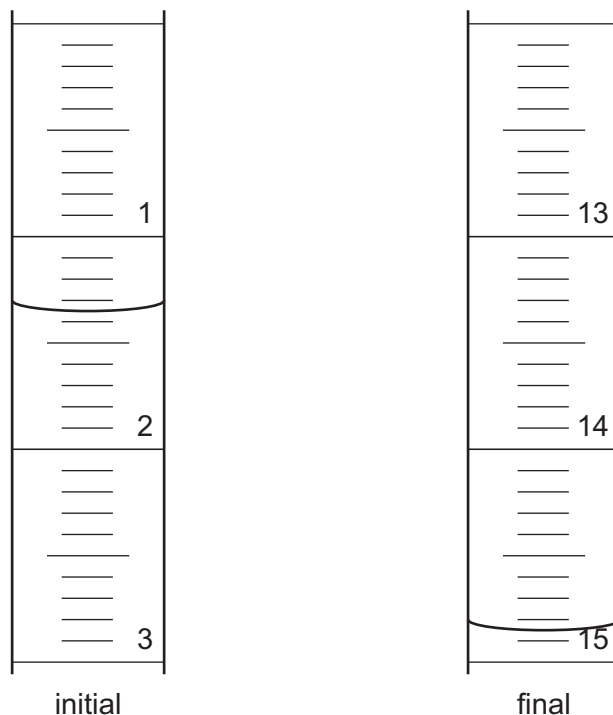


Fig. 1.1

(i) Use Fig. 1.1 to complete Table 1.1.

Table 1.1

burette reading (final)/cm ³	
burette reading (initial)/cm ³	
volume of solution X added/cm ³	

[2]

(ii) Calculate the percentage error in the volume of solution **X** calculated in (i).

Show your working.

percentage error = ... [1]

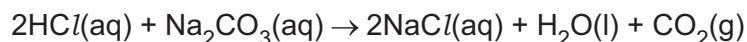


- (d) A second student repeats the experiment in (b) using solution **X** and 25.0 cm³ of solution **Y**. The results are shown in Table 1.2.

Table 1.2

volume of solution X added in titration / cm ³	13.35
mass of dry evaporating basin / g	44.52
mass of evaporating basin and solid residue / g	45.69

The reaction that takes place in the titration is:



Using the results in Table 1.2, calculate the following:

- the amount, in mol, of sodium chloride

amount of sodium chloride = ... mol

- the concentration of solution **X** and the concentration of solution **Y**.

concentration of solution **X** = ... mol dm⁻³

concentration of solution **Y** = ... mol dm⁻³
[3]

- (e) State what happens to the value obtained for the concentration of solution **Y** if not all the water is evaporated in **step 7**.

Explain your answer.

.....

 [2]

[Total: 16]





- 2 A group of students uses the following method to investigate the change in mass that takes place when metal **M** combines with sulfur to form a metal sulfide.

step 1 Weigh a clean crucible and lid using a balance. Record the mass.

step 2 Place a coiled length of metal wire into the crucible and weigh the crucible, lid and wire.

step 3 Cover the metal wire in the crucible with a large quantity of powdered sulfur and replace the lid.

step 4 Heat the crucible in a fume hood until the crucible glows red. Continue heating strongly until no more sulfur can be seen.

step 5 Allow the apparatus to cool and weigh the crucible, lid and residue.

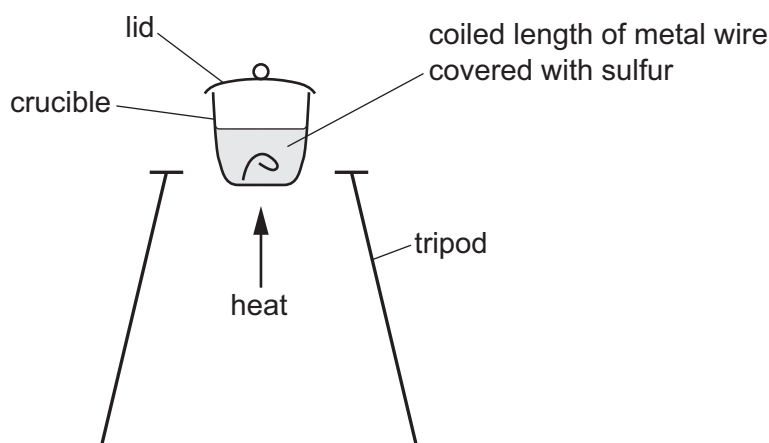


Fig. 2.1

- (a) (i) Fig. 2.1 shows how the apparatus is set up when heating the crucible in **step 4**.

Identify the missing piece of apparatus used to support the crucible during heating.

..... [1]

- (ii) Suggest why the students heat their crucibles in a fume hood in **step 4**.

.....
 [1]

- (iii) Suggest why a large quantity of powdered sulfur is used in **step 3**.

.....
 [1]





(b) Five students each use a different mass of **M**.

Their results are shown in Table 2.1.

Complete Table 2.1 by inserting values for the mass of **M** and the mass of sulfur which reacts for each student.

Table 2.1

	student 1	student 2	student 3	student 4	student 5
mass of crucible and lid/g	34.15	38.28	35.68	33.70	36.84
mass of crucible, lid and M /g	35.58	39.42	36.54	34.27	37.13
mass of crucible, lid and residue after heating/g	36.04	39.70	36.74	34.42	37.19
mass of M /g					
mass of sulfur which reacts/g					

[1]

(c) Identify the independent variable in this experiment.

..... [1]





- (d) (i) Plot a graph on the grid in Fig. 2.2 to show the relationship between mass of sulfur which reacts and mass of **M**.

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

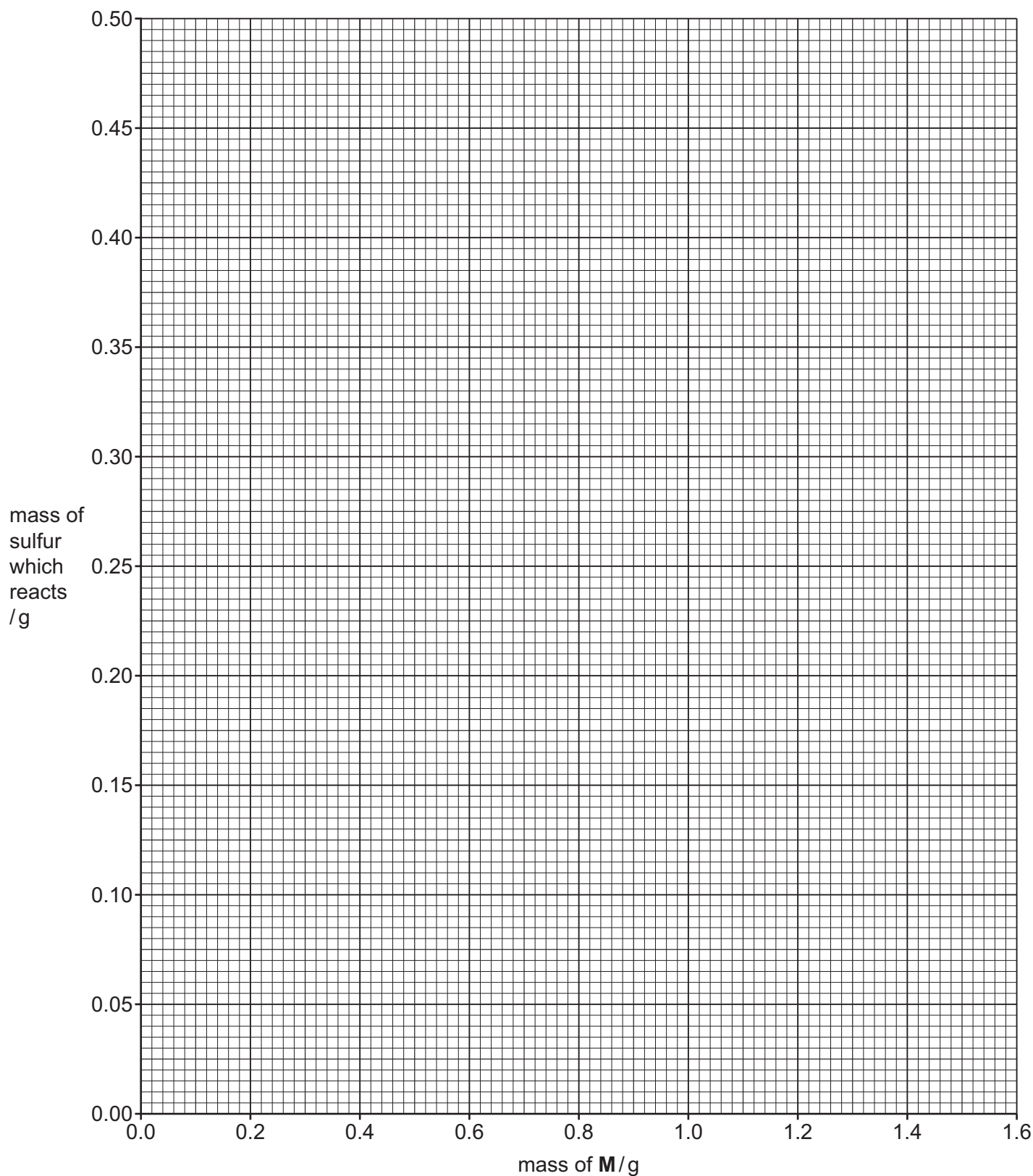


Fig. 2.2





(ii) 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 the measurement of any mass.

.....
 [2]

(e) Determine the gradient of your 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]

(f) Use your line of best fit in Fig. 2.2 to determine if the results obtained by the students are reliable.

Explain your answer.

.....

 [1]





(g) Another student suggests that the metal **M** used in the experiment is strontium, Sr, which forms strontium sulfide, SrS, when heated with sulfur.

(i) Deduce the gradient of the line of best fit for the graph of mass of sulfur which reacts against mass of strontium for the compound SrS.

gradient [1]

(ii) Use your answer to (i) to explain if the results of the experiment support the student's suggestion.

.....
 [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	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
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) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ 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)





DO NOT WRITE IN THIS MARGIN





The Periodic Table of Elements

Group																											
1	2	Key												13	14	15	16	17	18								
		1 H hydrogen 1.0																									
3	4	atomic number atomic symbol name relative atomic mass												5	6	7	8	9	10	11	12	13	14	15	16	17	18
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													Al aluminum 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5			Ar argon 39.9						
Na sodium 23.0	Mg magnesium 24.3																										
19	20	21	22	23	24	25	26	27	28	29	30			31	32	33	34	35			36						
K potassium 39.1	Ca calcium 40.1	Sc scandium 45.0	Ti titanium 47.9	V vanadium 50.9	Cr chromium 52.0	Mn manganese 54.9	Fe iron 55.8	Co cobalt 58.9	Ni nickel 58.7	Cu copper 63.5	Zn zinc 65.4			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	39	40	41	42	43	44	45	46	47	48			49	50	51	52	53			54						
Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Zr zirconium 91.2	Nb niobium 92.9	Mo molybdenum 95.9	Tc technetium —	Ru ruthenium 101.1	Rh rhodium 102.9	Pd palladium 106.4	Ag silver 107.9	Cd cadmium 112.4			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	57–71 lanthanoids		72	73	74	75	76	77	78	79			81	82	83	84	85			86						
Cs caesium 132.9	Ba barium 137.3			Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0			Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	At astatine —			Rn radon —						
87	88	89–103 actinoids		104	105	106	107	108	109	110	111			113	114	115	116	117			118						
Fr francium —	Ra radium —			Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —			Cn copernicium —	Nh nihonium —	Fl flerovium —	Lv livermorium —	Ts tennessine —			Og oganesson —						



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CHEMISTRY

9701/53

Paper 5 Planning, Analysis and Evaluation

October/November 2024

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 uses the following method to determine the percentage by mass of the painkiller aspirin, $C_9H_8O_4(s)$, in some tablets.

step 1 Grind five tablets into a powder.

step 2 Use a weighing boat to accurately weigh by difference approximately 0.4 g of powdered tablets into a pear-shaped flask containing anti-bumping granules.

step 3 Add 25 cm^3 of aqueous 1 mol dm^{-3} sodium hydroxide, NaOH(aq) , to the pear-shaped flask, forming mixture **A**.

step 4 Reflux mixture **A** for 20 minutes.

step 5 Allow mixture **A** to cool and then filter into a small beaker. Label the filtrate solution **B**.

step 6 Add 30 cm^3 of alkaline aqueous iodine to solution **B** and leave to stand for 1 hour. A precipitate, **C**, $(C_6H_2I_2O)_2(s)$, will form.

step 7 Filter the resulting mixture under reduced pressure. Wash the residue, **C**, with a small volume of cold distilled water.

step 8 Allow solid **C** to dry.

step 9 Weigh solid **C** and record its mass.

Alkaline aqueous iodine is irritating to the skin and eyes.

- (a) Identify an appropriate precaution, other than eye protection and a lab coat, that the student should take when using alkaline aqueous iodine.

.....
 [1]

- (b) Describe how the student should carry out **step 2**. Include a results table, with appropriate headings, for the student to fill in.

.....



(c) Complete Fig. 1.1 to show how **step 4** is carried out in the laboratory.

Label your diagram fully.

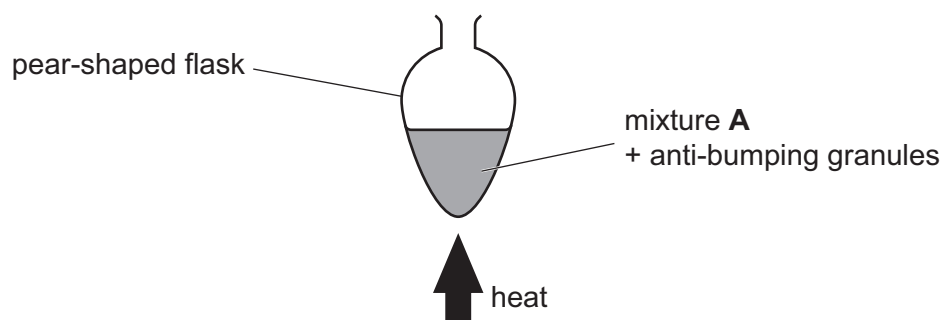


Fig. 1.1

[2]

(d) (i) The student uses a measuring cylinder to measure the volume of alkaline aqueous iodine in **step 6**. Suggest why this is a suitable piece of apparatus to use.

.....
 [1]

(ii) Suggest why the student leaves the mixture to stand for 1 hour in **step 6**.

.....
 [1]

(iii) Explain why the residue is washed in **step 7**.

.....
 [1]

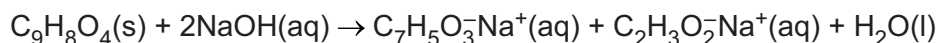
(iv) Explain why hot distilled water is **not** used in **step 7**.

.....
 [1]

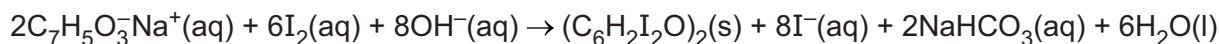




- (e) The equation for the reaction between aspirin, $\text{C}_9\text{H}_8\text{O}_4(\text{s})$, and $\text{NaOH}(\text{aq})$, which takes place in **step 4**, is shown.



The equation for the reaction in which solid **C**, $(\text{C}_6\text{H}_2\text{I}_2\text{O})_2(\text{s})$, is formed in **step 6** is shown.



The student's results are shown in Table 1.1.

Table 1.1

mass of powdered tablets added to the pear-shaped flask in step 2	0.409 g
mass of dry $(\text{C}_6\text{H}_2\text{I}_2\text{O})_2(\text{s})$ recorded in step 9	0.764 g

- (i) Calculate the amount, in mol, of $(\text{C}_6\text{H}_2\text{I}_2\text{O})_2(\text{s})$ collected in **step 9**.

$[M_r: (\text{C}_6\text{H}_2\text{I}_2\text{O})_2, 687.6]$

amount of $(\text{C}_6\text{H}_2\text{I}_2\text{O})_2$ mol [1]

- (ii) Use your answer to (i) to calculate the mass, in g, of $\text{C}_9\text{H}_8\text{O}_4(\text{s})$ in the powdered tablets added to the flask in **step 2**.

mass of $\text{C}_9\text{H}_8\text{O}_4(\text{s})$ g [1]

- (iii) Use your answer to (ii) to calculate the percentage by mass of aspirin, $\text{C}_9\text{H}_8\text{O}_4(\text{s})$, in the tablets.

If you were unable to obtain an answer to (ii) you may use 0.374 g for the mass of $\text{C}_9\text{H}_8\text{O}_4(\text{s})$. This is **not** the correct value.

percentage by mass $\text{C}_9\text{H}_8\text{O}_4(\text{s})$ in the tablets [1]





- (f) Another student follows the same method but does not allow solid **C** to dry completely in **step 8**.

State and explain the effect that this has on the calculated percentage by mass of aspirin, $C_9H_8O_4(s)$, in the tablets.

.....

.....

..... [1]

[Total: 13]





- 2 Crystal violet, $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{s})$, is a purple dye.

Some light is absorbed when it passes through $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$.

Absorbance is the proportion of light absorbed at a particular wavelength. This is measured using a colorimeter.

A graph of absorbance against wavelength for $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$ is shown in Fig. 2.1.

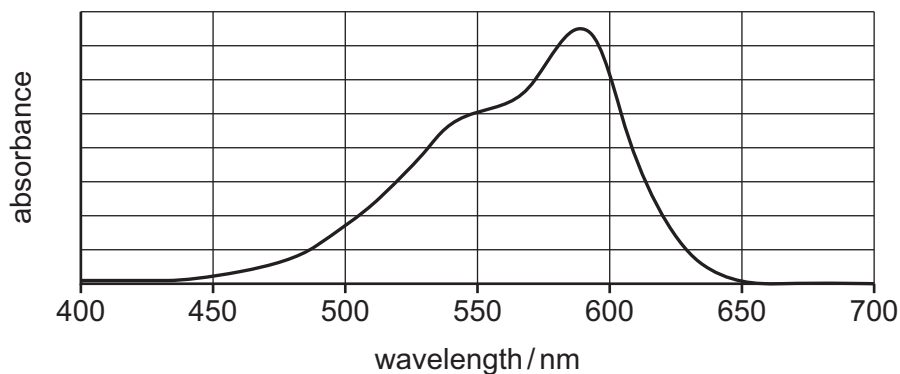


Fig. 2.1

A student investigates how to determine the concentration of aqueous crystal violet, $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$, using colorimetry.

- (a) Suggest the best wavelength of light to use in the colorimeter when measuring the concentration of $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$.

wavelength = ...nm [1]





(b) Solution **D** is 500.0 cm^3 of $2.50 \times 10^{-2}\text{ mol dm}^{-3}$ $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$.

(i) Calculate the mass of $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{s})$ needed to prepare solution **D**.

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

$[M_r: \text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{s}), 407.5]$

mass of $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{s}) = \dots\dots\dots\text{g}$ [1]

(ii) The student is given a small beaker containing the mass of $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{s})$ calculated in (i).

Describe how the student should prepare 500.0 cm^3 of solution **D**.

Include the name and capacity of the key apparatus which should be used and describe how the student should ensure the volume is exactly 500.0 cm^3 .

.....

.....

.....

.....

.....

.....

..... [3]





- (c) A small sample of solution **D** was diluted to form solution **E**, $2.50 \times 10^{-4} \text{ mol dm}^{-3}$ $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl(aq)}$.

The student prepares solutions 2 to 6 as shown in Table 2.1.

The total volume needed for each of solutions 2 to 6 is 20.00 cm^3 .

Each solution is placed into a colorimeter and the absorbance is measured.

- (i) Complete Table 2.1 to show the volumes of solution **E** and distilled water needed to prepare each of the solutions from 2 to 6. Give all volumes to **two** decimal places.

Table 2.1

solution	volume of $2.50 \times 10^{-4} \text{ mol dm}^{-3}$ $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl(aq)}$ (solution E) $/\text{cm}^3$	volume of distilled water $/\text{cm}^3$	$[\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl(aq)}]$ $/\text{mol dm}^{-3}$	absorbance
1	0.00	20.00	0.00	0.000
2			0.50×10^{-4}	0.191
3			1.00×10^{-4}	0.270
4			1.50×10^{-4}	0.545
5			2.00×10^{-4}	0.711
6			2.50×10^{-4}	0.860

[1]

- (ii) Identify the dependent variable.

..... [1]



(d) (i) Plot a graph of absorbance against $[\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})]$ on the grid in Fig. 2.2.

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

Draw a straight line of best fit.

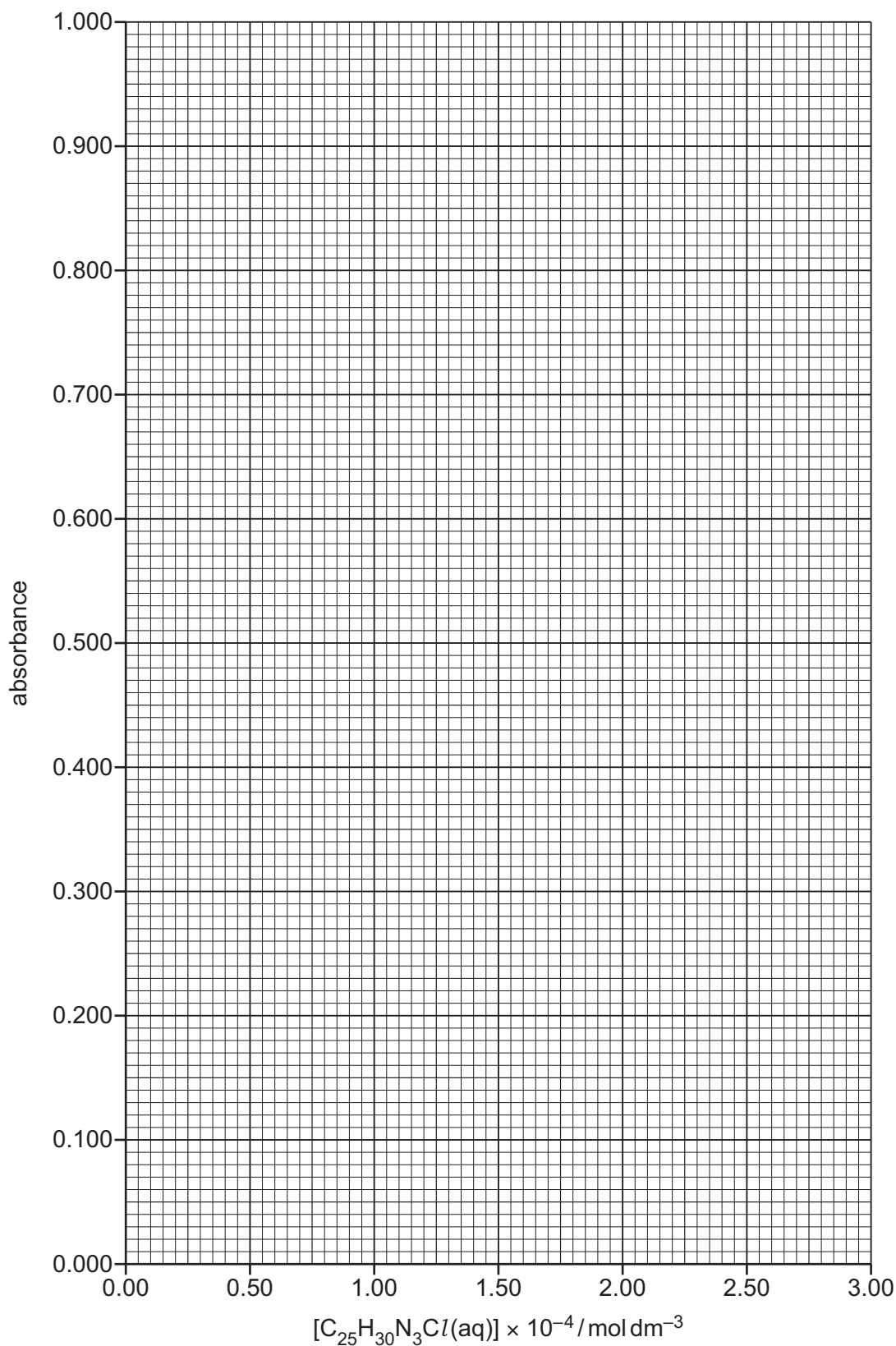


Fig. 2.2



- (ii) 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 the measurement of absorbance.

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

- (iii) State the relationship between $[C_{25}H_{30}N_3Cl(aq)]$ and absorbance.

..... [1]

- (iv) Suggest how the student could improve the reliability of the data obtained in the experiment in (c).

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



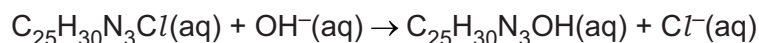


Question 2 continues on the next page.





- (e) The student carries out a further experiment to examine the kinetics of the reaction between crystal violet, $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$, and aqueous sodium hydroxide, $\text{NaOH}(\text{aq})$.



The disappearance of the purple colour as the reaction proceeds can be monitored by measuring how the absorbance of light by the mixture changes using a colorimeter.

The student mixes 5 cm^3 of solution 6 with 5 cm^3 of $\text{NaOH}(\text{aq})$, a large excess, and immediately starts the stopwatch.

The resulting mixture is then placed in a colorimeter. The absorbance of this mixture is measured every 100 seconds after starting the stop-watch.

Fig. 2.3 shows a graph of the student's results.

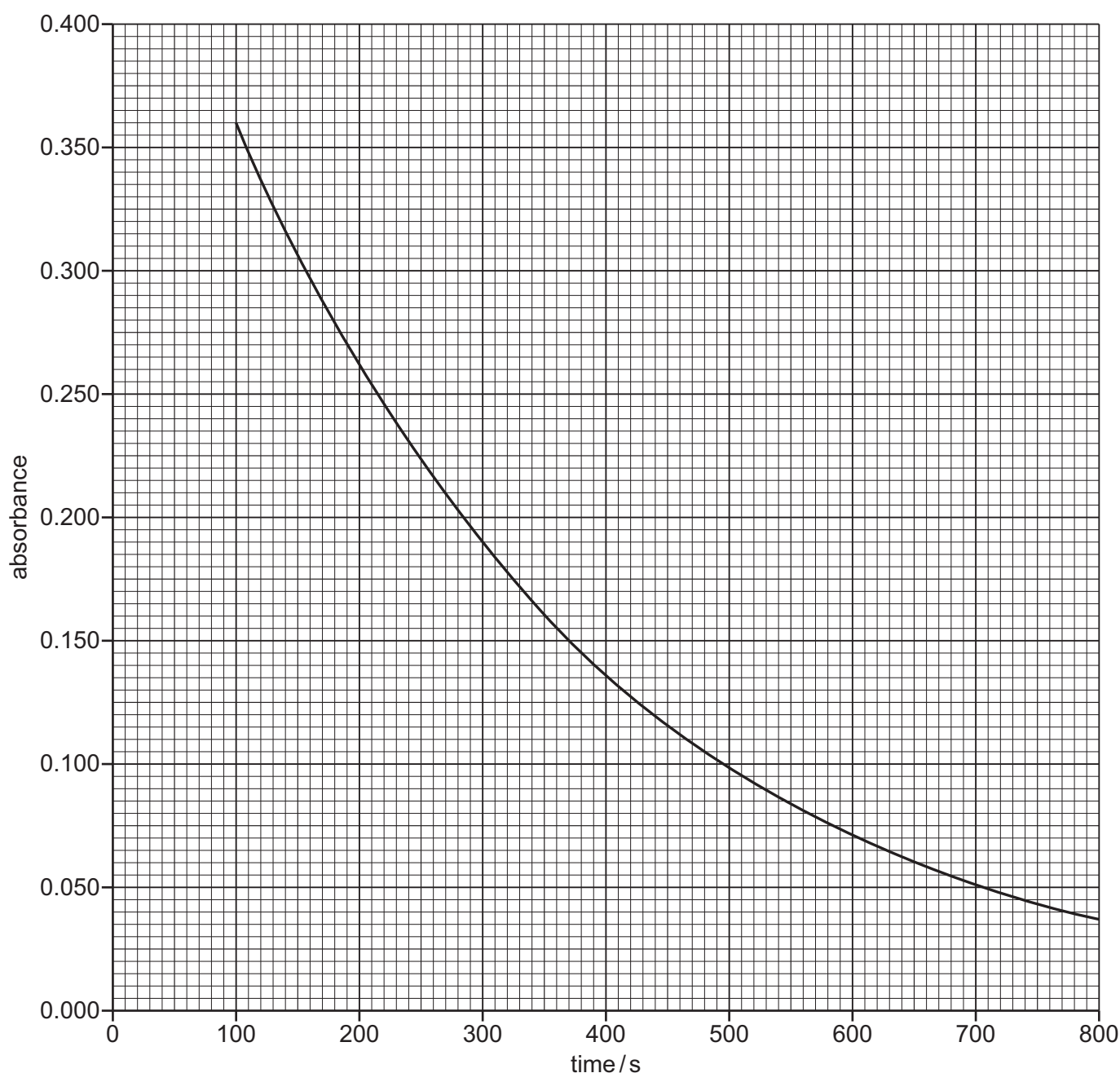


Fig. 2.3





- (i) Suggest why it is **not** possible for the student to measure the absorbance of the mixture at $t = 0$ s.

.....
 [1]

- (ii) Use the graph in Fig. 2.3 to find the half-life, $t_{1/2}$, starting at 100 s.

State the coordinates of both points on the line of best fit used in your calculation.

coordinates 1 coordinates 2

half-life s
 [2]

- (iii) Another student repeats the experiment at a different temperature and measures two half-life values. The values obtained are 420 s and 425 s.

Use these values to deduce the order of the reaction with respect to $\text{C}_{25}\text{H}_{30}\text{N}_3\text{Cl}(\text{aq})$.
 Explain your answer.

order = ...

explanation
 [1]

[Total: 17]





**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) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ 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)



Group																		
1	2	Key										13	14	15	16	17	18	
		atomic number atomic symbol name relative atomic mass																
3	4																2	
Li lithium 6.9	Be beryllium 9.0															He helium 4.0		
11	12																	
Na sodium 23.0	Mg magnesium 24.3																	
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	
K potassium 39.1	Ca calcium 40.1	Sc scandium 45.0	Ti titanium 47.9	V vanadium 50.9	Cr chromium 52.0	Mn manganese 54.9	Fe iron 55.8	Co cobalt 58.9	Ni nickel 58.7	Cu copper 63.5	Zn zinc 65.4	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	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	
Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Zr zirconium 91.2	Nb niobium 92.9	Mo molybdenum 95.9	Tc technetium —	Ru ruthenium 101.1	Rh rhodium 102.9	Pd palladium 106.4	Ag silver 107.9	Cd cadmium 112.4	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	57–71 lanthanoids	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	
Cs caesium 132.9	Ba barium 137.3		Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	At astatine —	Rn radon —	
87	88	89–103 actinoids	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	
Fr francium —	Ra radium —		Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganeson —	

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
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	208.9
84	Po	polonium	—
85	At	astatine	—
86	Rn	radon	—
87	Fr	francium	—
88	Ra	radium	—
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	—

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
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	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	—