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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

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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.

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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, $MnSO_4(aq)$.

Solution **Y** is alkaline aqueous potassium iodide, KI(aq).

(a) Calculate the mass of solid hydrated manganese(II) sulfate, $MnSO_4{\bullet}H_2O(s)$, needed to make 100.0 cm^3 of solution **X**.

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

mass of $MnSO_4{\bullet}H_2O(s)$ = ... g [1]

(b) The student is given a small beaker containing the mass of $MnSO_4{\bullet}H_2O(s)$ 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 cm^3 of distilled water in a 250 cm^3 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, $Mn(OH)_3(s)$, 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 1.00×10^{-3} $mol\,dm^{-3}$ aqueous sodium thiosulfate, $Na_2S_2O_3(aq)$. 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 = ... cm^3 [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**

$$4Mn^{2+}(aq) + 8OH^-(aq) + O_2(aq) + 2H_2O(l) \rightarrow 4Mn(OH)_3(s)$$

step 5

$$2Mn(OH)_3(s) + 2I^-(aq) + 6H^+(aq) \rightarrow I_2(aq) + 6H_2O(l) + 2Mn^{2+}(aq)$$

step 7

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

(i) Calculate the amount, in mol, of iodine, $I_2(aq)$, in 25.0 cm^3 of solution **Z**.

amount of $I_2(aq)$ = ... mol [1]

(ii) Use your answer to **(f)(i)** and the equations given to calculate the amount, in mol, of dissolved oxygen, $O_2(aq)$, in 500.0 cm^3 of solution **Z**.

amount of $O_2(aq)$ 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 $O_2(aq)$ in 500.0 cm^3 of solution **Z** = 7.12×10^{-5} 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 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.

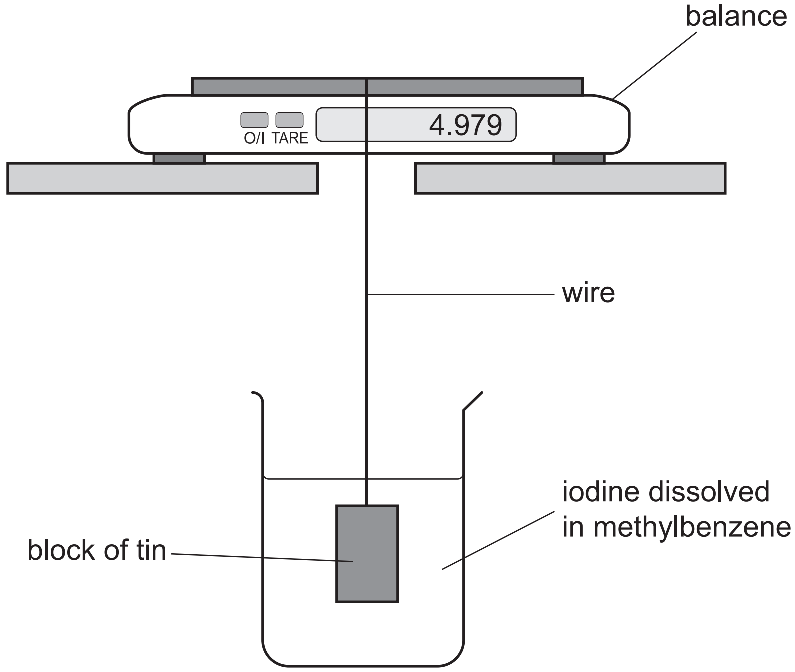

Fig. 2.1

(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.

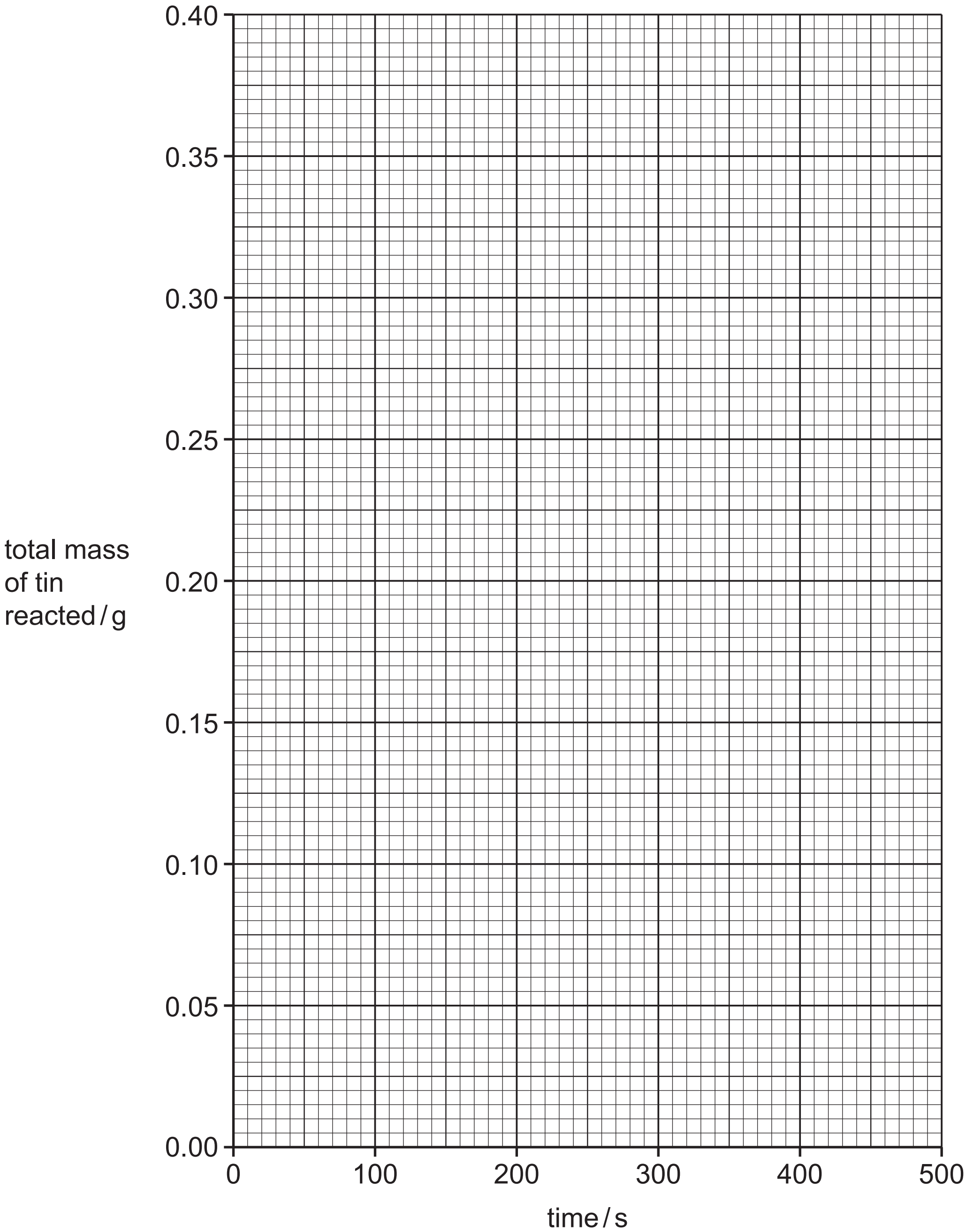

Fig. 2.2

[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 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 mol dm^{-3} I_2 solution used / cm^3	volume of methylbenzene used / cm^3	$[I_2]$ / 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.

$$\text{rate} = k\,[I_2]^2$$

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	$R = 8.31\,J\,K^{-1}\,mol^{-1}$
Faraday constant	$F = 9.65 \times 10^4\,C\,mol^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23}\,mol^{-1}$
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 144.2	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
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 –