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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME						
CENTRE NUMBER						
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* 0 4 9 8 3 7 3 1 4 5 *

CHEMISTRY **9701/54**

Paper 5 Planning, Analysis and Evaluation **May/June 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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[Turn over

1 The relative molecular mass, M_r, of an unknown volatile liquid, **Y**, can be determined experimentally.

A student uses the following method to determine the volume of a conical flask.

step 1 Weigh a dry conical flask.

step 2 Fill the conical flask completely with distilled water.

step 3 Weigh the conical flask when filled with distilled water.

step 4 Use a thermometer to measure the temperature of the distilled water in the conical flask.

The student collects the results shown in Table 1.1.

Table 1.1

mass of dry flask / g	31.022
mass of flask filled with water / g	161.175
temperature of water in flask / °C	23.0
laboratory atmospheric pressure / kPa	99.0

(a) Fig. 1.1 shows the variation of the density of water with temperature.

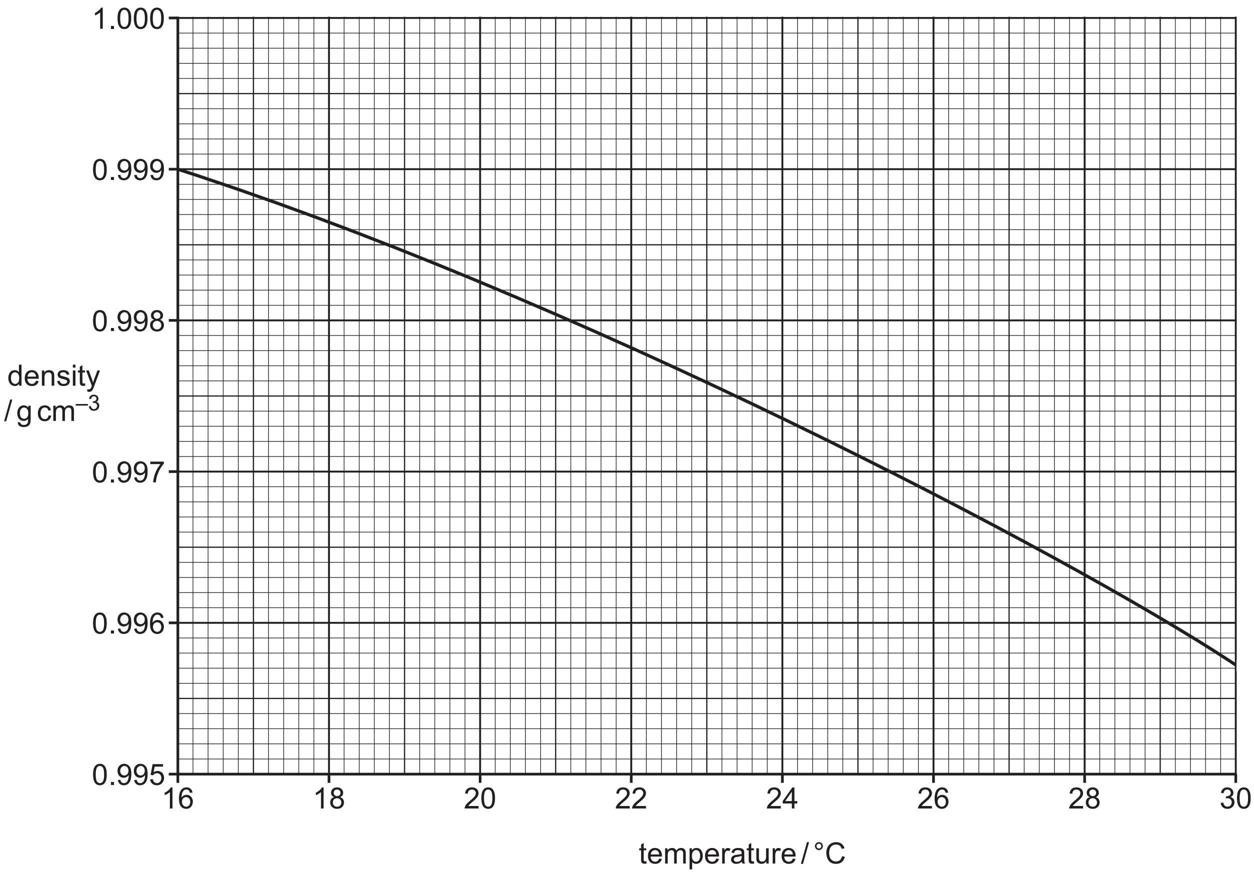

Fig. 1.1

DO NOT WRITE IN THIS MARGIN

(i) Use Fig. 1.1 to determine the density of water at 23.0 °C.
Give your answer to **four** decimal places.

density of water = ... $g\,cm^{-3}$ [1]

(ii) Calculate the volume of the flask, using the density of water determined in **(a)(i)**.

volume of flask = ... cm^3 [2]

(b) Another student determines the volume of a different conical flask to be 129.56 cm^3. This conical flask is used to determine the M_r of unknown volatile liquid **Y**.

The following method is used.

step 1 Cover the opening of the dry conical flask with aluminium foil and secure using a rubber band.

step 2 Weigh the conical flask, aluminium foil and rubber band. Record the mass.

step 3 Use a syringe with a needle to make a small hole in the aluminium foil and inject approximately 5 cm^3 of **Y** into the conical flask. Remove the syringe.

step 4 Place the conical flask in a water-bath containing boiling water.

step 5 Allow all of **Y** to evaporate. Keep the conical flask containing vaporised **Y** in the boiling water for a further 3 minutes.

step 6 Carefully remove the conical flask from the boiling water and dry the outside surface thoroughly.

step 7 Weigh the conical flask, aluminium foil, rubber band and contents. Record this mass.

(i) Suggest why the conical flask containing vaporised **Y** is kept in boiling water for 3 minutes in step 5.

....

.... [1]

(ii) Suggest why it is **not** necessary to determine the mass of liquid **Y** injected into the conical flask by the syringe in step 3.

....

.... [1]

(iii) The student thinks that **Y** is toxic. Other than wearing safety glasses and a lab coat, state **one** safety precaution that must be taken when carrying out this experiment.

.... [1]

(c) Table 1.2 shows the student's results.

Table 1.2

temperature of water-bath / °C	100.0
laboratory atmospheric pressure / kPa	99.0
mass of conical flask, aluminium foil and rubber band measured in step 2 / g	31.123
mass of conical flask, aluminium foil, rubber band and **Y** measured in step 7 / g	31.429
mass of **Y** in flask in step 7 / g	0.306
volume of conical flask used / cm^3	129.56

(i) Calculate the percentage error in the mass measured in step 2.

Show your working.

percentage error = ... [1]

(ii) The student assumes that the vapour formed from liquid **Y** is an ideal gas. The ideal gas equation is shown.

$$pV = nRT$$

p = pressure of gas measured in Pa

V = volume of gas in m^3

n = number of moles of gas

R = molar gas constant

T = temperature in K

Use the ideal gas equation and the results in Table 1.2 to calculate the amount, in mol, of **Y** in the conical flask in step 7.

Assume that the temperature of the vapour formed from liquid **Y** is 100 °C.

amount of **Y** = ... mol [2]

(iii) Calculate the M_r of **Y**.

M_r of **Y** = ... [1]

(d) The actual temperature of the vapour formed from liquid **Y** is less than 100 °C. Describe and explain the effect this has on the calculated value of the M_r.

effect on calculated M_r ....

explanation ....

.... [1]

(e) The boiling point of methylbenzene is 111 °C.
Suggest why the M_r of methylbenzene **cannot** be determined using this method.

....

.... [1]

[Total: 12]

2 A student carries out an experiment to determine the charge of an aqueous ion, $\mathbf{M}^{n+}$(aq), of metal **M**.

The student prepares $100.0\,cm^3$ of $1.00\,mol\,dm^{-3}$ aqueous copper(II) nitrate, $Cu(NO_3)_2$(aq), to use in the experiment.

(a) Calculate the mass of $Cu(NO_3)_2{\bullet}3H_2O$(s) required to prepare $100.0\,cm^3$ of $1.00\,mol\,dm^{-3}$ $Cu(NO_3)_2$(aq).

mass = ... g [1]

(b) Describe the steps the student should take to prepare $100.0\,cm^3$ of $1.00\,mol\,dm^{-3}$ $Cu(NO_3)_2$(aq) starting from the mass calculated in **(a)** supplied in a small beaker.

Give the name and capacity of any apparatus used.

Write your answer using a series of numbered steps.

....

....

....

....

....

....

.... [3]

(c) The student sets up the electrochemical cell shown in Fig. 2.1 to investigate the effect of changing the concentration of $\mathbf{M}^{n+}$(aq) on the measured cell potential, E_{cell}.

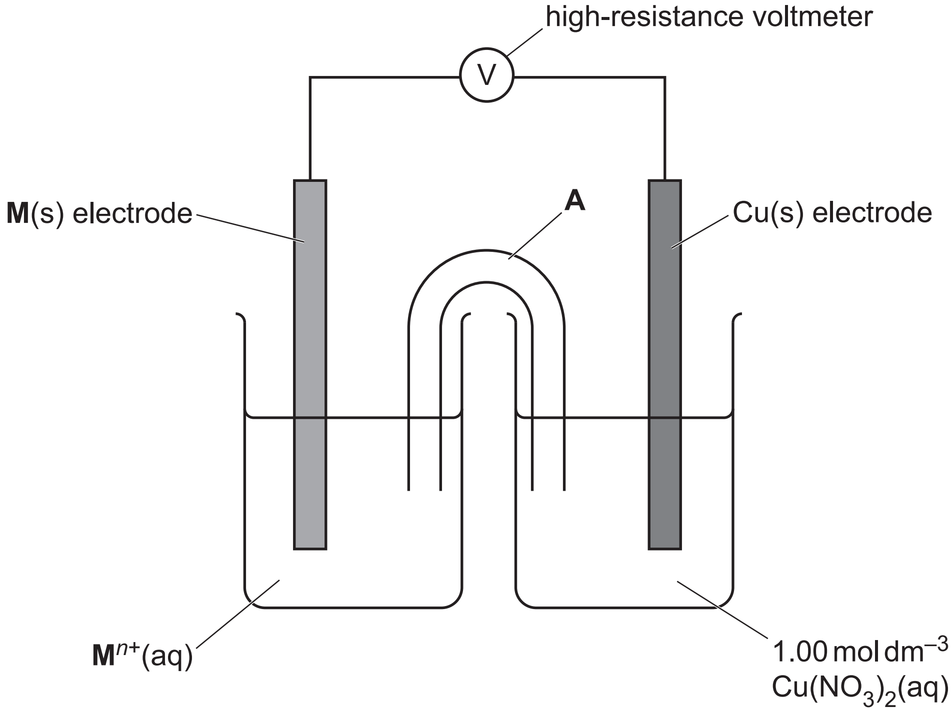

Fig. 2.1

Suggest the function of the item labelled **A** in Fig. 2.1.

....

.... [1]

(d) The student uses the apparatus in Fig. 2.1 to measure the cell potentials, using six solutions each with a different concentration of $\mathbf{M}^{n+}$(aq).

Table 2.1 shows the results obtained by the student.

Table 2.1

concentration of $\mathbf{M}^{n+}$(aq) / mol dm^{-3}	cell potential, E_{cell} / V	log [$\mathbf{M}^{n+}$]	electrode potential of $\mathbf{M}^{n+}$(aq) / $\mathbf{M}$(s) / V
1.00×10^{-2}	3.295	–2.00	
5.00×10^{-3}	3.304	–2.30	
1.00×10^{-3}	3.325	–3.00	
5.00×10^{-4}	3.343	–3.30	
1.00×10^{-4}	3.354	–4.00	
1.00×10^{-5}	3.384	–5.00	

electrode potential of $\mathbf{M}^{n+}$(aq) / $\mathbf{M}$(s) = $E_{Cu} - E_{cell}$

electrode potential of Cu^{2+}(aq) / Cu(s), E_{Cu} = 0.337 V

Complete Table 2.1. Record your values to **three** decimal places.

[1]

(e) Identify the independent variable in this experiment.

.... [1]

(f) **(i)** Plot a graph on the grid in Fig. 2.2 to show the relationship between the electrode potential of $\mathbf{M}^{n+}$(aq) / **M**(s) and log [$\mathbf{M}^{n+}$]. Use a cross (×) to plot each data point. Draw a straight line of best fit.

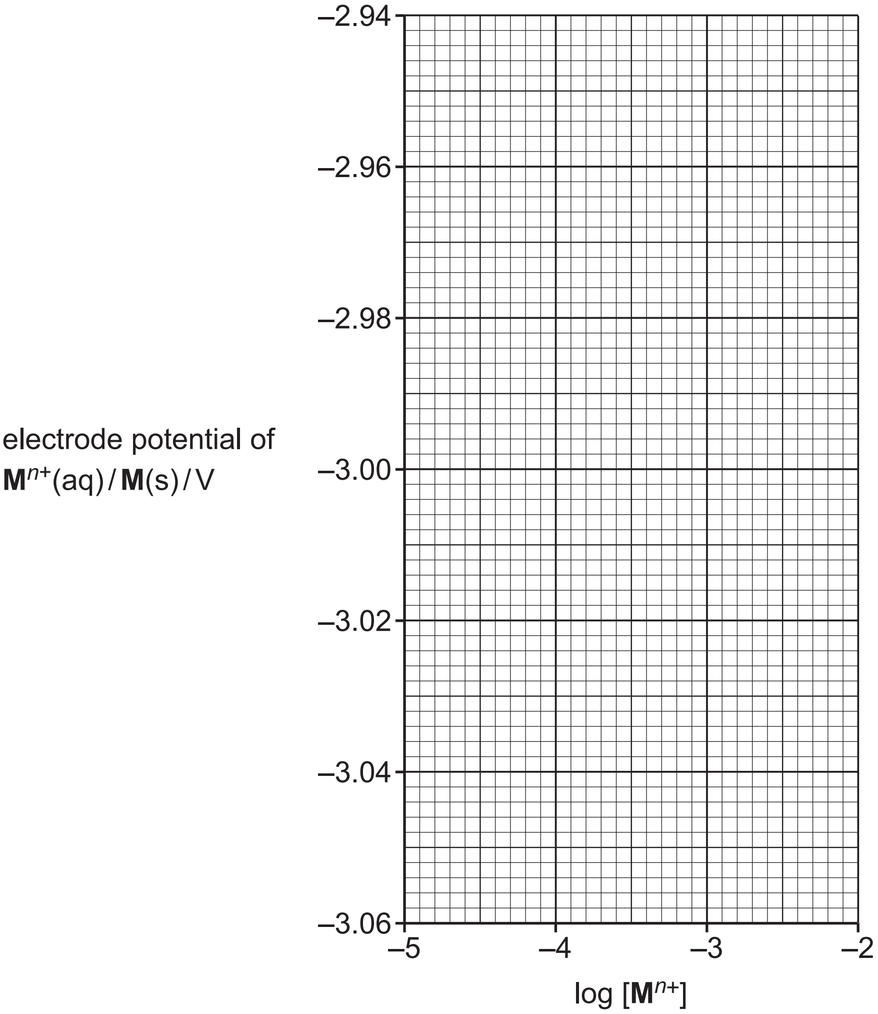

Fig. 2.2

[2]

(ii) Circle the **one** point on the graph that you consider to be most anomalous.

Suggest **one** reason why this anomaly may have occurred during the experimental procedure. Assume no error was made in the measurement of the cell potential.

....

.... [1]

(iii) Suggest how the reliability of the data shown in Table 2.1 could be improved.

....

.... [1]

(g) **(i)** Use 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 the gradient to **three** significant figures.

coordinates 1 .... coordinates 2 ....

gradient = ... [2]

(ii) For the electrode equilibrium,

$$\mathbf{M}(s) \rightleftharpoons \mathbf{M}^{n+}(aq) + ne^-,$$

the Nernst equation can be written as shown.

$$E = E^{\ominus} + \frac{2.303\,RT}{nF}\log[\mathbf{M}^{n+}]$$

E = electrode potential
$E^{\ominus}$ = standard electrode potential
R = molar gas constant
T = temperature in K
F = Faraday constant

The equation for a straight line is $y = mx + c$.

State which parts in the Nernst equation correspond to y, m and c.

y = ...

m = ...

c = ...
[3]

(iii) Use the value that you calculated for the gradient of your line of best fit in **(g)(i)** and the Nernst equation to calculate the value of n in $\mathbf{M}^{n+}$(aq).

The experiment is carried out at 25.0 °C.

(If you were unable to determine an answer to **(g)(i)**, then use the value 0.0285 for the gradient. This is **not** the correct value.)

n = ... [2]

[Total: 18]

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											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			**Key** atomic number atomic symbol name relative atomic mass								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	3	4	5	6	7	8	9	10	11	12	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 –