



Cambridge International AS & A Level

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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.

- 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.

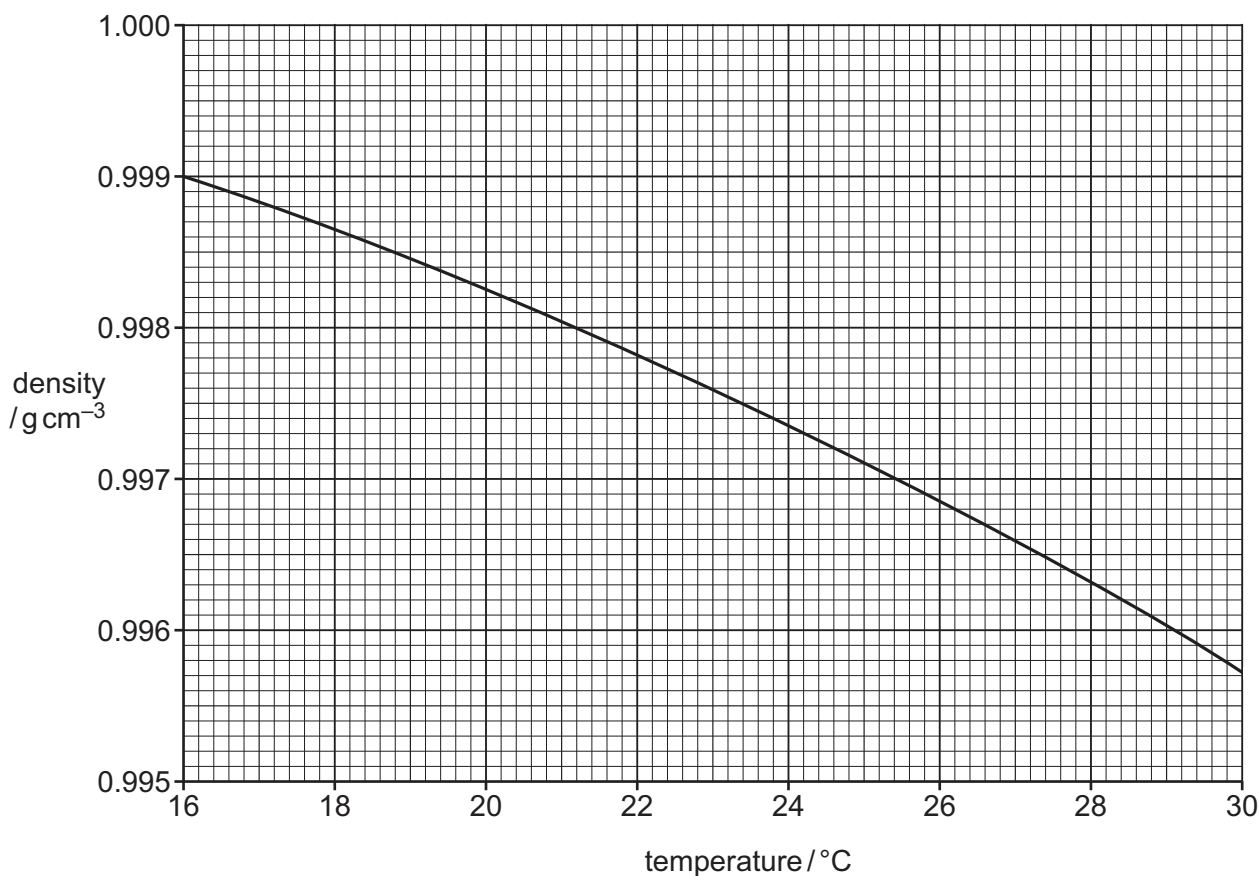


Fig. 1.1



- (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 = cm³ [2]

- (b) Another student determines the volume of a different conical flask to be 129.56 cm³. 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 cm³ 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 m³

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, $M^{n+}(\text{aq})$, of metal **M**.

The student prepares 100.0 cm^3 of 1.00 mol dm^{-3} aqueous copper(II) nitrate, $\text{Cu}(\text{NO}_3)_2(\text{aq})$, to use in the experiment.

- (a) Calculate the mass of $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}(\text{s})$ required to prepare 100.0 cm^3 of 1.00 mol dm^{-3} $\text{Cu}(\text{NO}_3)_2(\text{aq})$.

mass = g [1]

- (b) Describe the steps the student should take to prepare 100.0 cm^3 of 1.00 mol dm^{-3} $\text{Cu}(\text{NO}_3)_2(\text{aq})$ 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 $M^{n+}(aq)$ on the measured cell potential, E_{cell} .

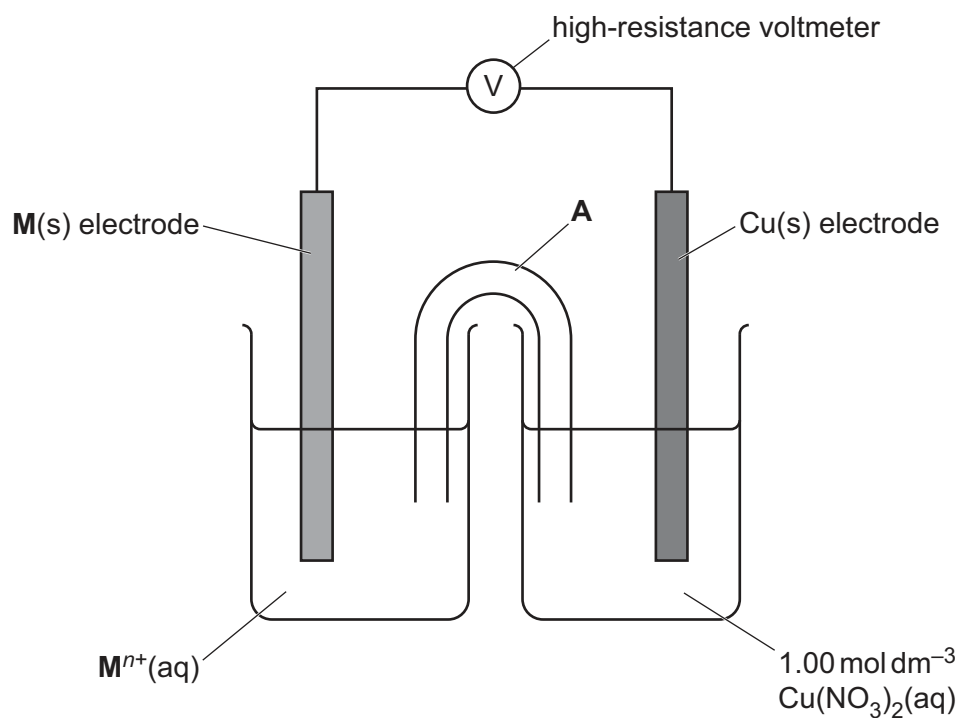


Fig. 2.1

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 $M^{n+}(aq)$.

Table 2.1 shows the results obtained by the student.

Table 2.1

concentration of $M^{n+}(aq)$ / mol dm^{-3}	cell potential, E_{cell}/V	$\log [M^{n+}]$	electrode potential of $M^{n+}(aq)/M(s)$ /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 $M^{n+}(aq)/M(s) = E_{\text{Cu}} - E_{\text{cell}}$

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

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 $M^{n+}(aq)/M(s)$ and $\log [M^{n+}]$. Use a cross (x) to plot each data point. Draw a straight line of best fit.

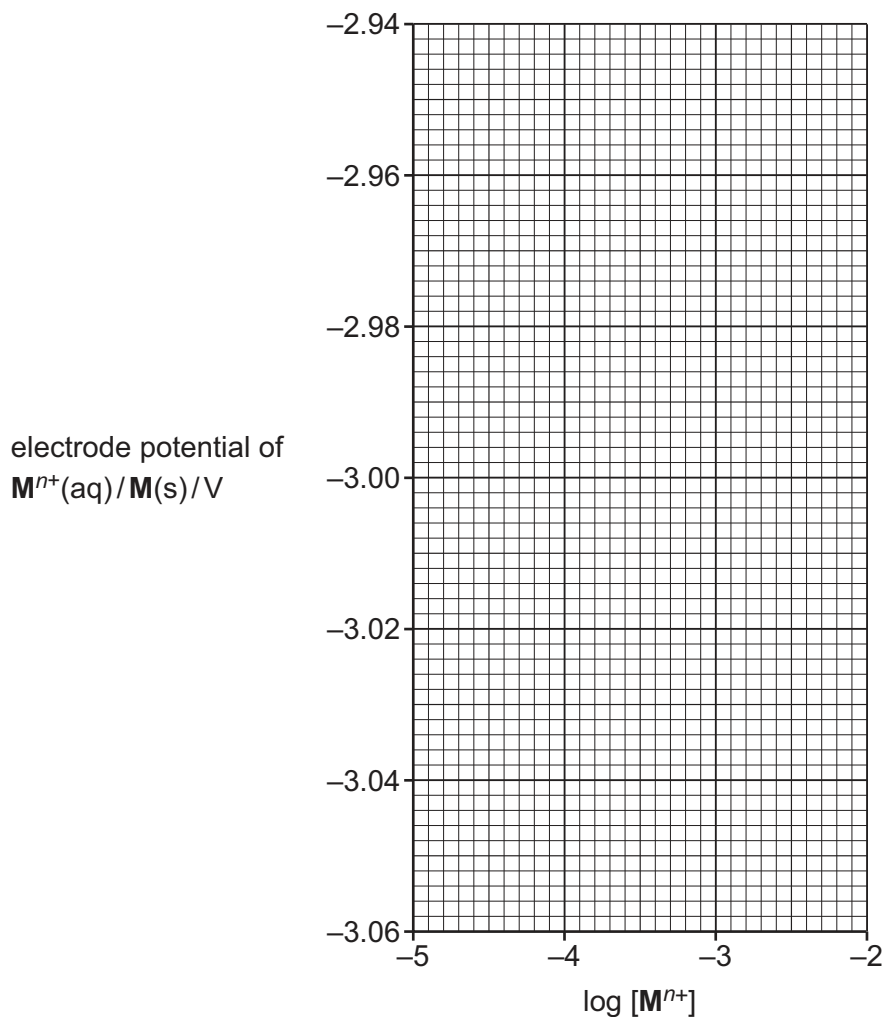


Fig. 2.2

[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,



the Nernst equation can be written as shown.

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

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 $\text{M}^{n+}(\text{aq})$.

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 J g ⁻¹ K ⁻¹)

