Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/52**

Paper 5 Planning, Analysis and Evaluation **February/March 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 **16** pages. Any blank pages are indicated.

1 Brass is an alloy of copper and zinc.
An experiment is completed to find the percentage by mass of copper in a sample of brass.

In the experiment, the sample of brass is reacted with an excess of concentrated nitric acid, HNO_3. This forms a solution containing $Cu^{2+}(aq)$ ions. The amount of $Cu^{2+}(aq)$ ions formed is determined by titration.

A student uses the following method.

step 1 Weigh a glass beaker and record the mass.

step 2 Add approximately 1.00 g of powdered brass to the beaker and record the mass of the beaker and the brass.

step 3 Transfer the brass into conical flask **A** which contains excess concentrated HNO_3.

step 4 Reweigh the glass beaker and record the mass.

step 5 Add aqueous sodium carbonate, $Na_2CO_3(aq)$, dropwise to flask **A** until a precipitate of copper(II) carbonate, $CuCO_3(s)$, appears. Then add dilute ethanoic acid dropwise until the precipitate is fully dissolved.

step 6 Transfer all the contents of flask **A** to a 100.0 cm^3 volumetric flask and make up to the mark with distilled water. This is solution **B**.

step 7 Transfer 10.0 cm^3 of solution **B** into conical flask **C**.

step 8 Add 10 cm^3, an excess, of aqueous potassium iodide, KI(aq), to flask **C**.

step 9 Titrate the contents of flask **C** against 0.0600 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3(aq)$, using starch solution as an indicator.

step 10 Repeat steps 7 to 9 until concordant results are obtained.

(a) Both copper and zinc in brass react with concentrated HNO_3 in **step 3**.

reaction 1 $Zn(s) + 4HNO_3(aq) \rightarrow Zn(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$

reaction 2 $Cu(s) + 4HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$

Suggest why **step 3** in the experiment should be completed in a fume cupboard.

.... [1]

(b) Explain why the glass beaker is reweighed in **step 4**.

....

.... [1]

(c) Name a suitable piece of apparatus to transfer the 10.0 cm^3 of solution **B** in **step 7**.

.... [1]

(d) Identify the substance used to rinse the burette before **step 9** is done for the first time.

.... [1]

(e) In **step 9**, 0.0600 $mol\,dm^{-3}$ $Na_2S_2O_3(aq)$ is used.
This solution is prepared from 0.200 $mol\,dm^{-3}$ $Na_2S_2O_3(aq)$ before the experiment.

Describe how to make a 100.0 cm^3 standard solution of 0.0600 $mol\,dm^{-3}$ $Na_2S_2O_3(aq)$ from the 0.200 $mol\,dm^{-3}$ $Na_2S_2O_3(aq)$ solution.

Give the name and capacity of any apparatus you would use.

Write your answer in a series of numbered steps.

....

....

....

....

....

.... [3]

(f) The measurements collected during **steps 1** to **4** are shown in Table 1.1.

Table 1.1

mass of glass beaker / g	25.55
mass of glass beaker containing powdered brass / g	26.65
mass of glass beaker after transferring brass to conical flask **A** / g	25.65

Determine the mass of powdered brass added to conical flask **A**.

mass of powdered brass = ... g [1]

(g) The volumes measured in each of the titrations are shown in Table 1.2.

Table 1.2

	rough titration	titration 1	titration 2	titration 3
final burette reading / cm^3	24.05	24.80	45.35	22.50
initial burette reading / cm^3	3.25	4.50	24.80	2.10
titre / cm^3				

(i) Complete Table 1.2. [1]

(ii) Calculate a suitable mean titre to use in the calculations.

mean titre = ... cm^3 [1]

(iii) Calculate the percentage error in the titre in titration 3.
Show your working.

percentage error = ... % [1]

(h) In **step 8**, $Cu^{2+}(aq)$ ions react with $I^-(aq)$ ions. The ionic equation for the reaction is shown.

reaction 3 $2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$

In **step 9**, $Na_2S_2O_3(aq)$ reacts with $I_2(aq)$ formed in reaction 3. The equation for the reaction is shown.

reaction 4 $I_2(aq) + 2Na_2S_2O_3(aq) \rightarrow Na_2S_4O_6(aq) + 2NaI(aq)$

(i) Using a second sample of brass, another student determined the mean titre to be $17.35\,cm^3$ of $0.0600\,mol\,dm^{-3}$ $Na_2S_2O_3(aq)$.
Calculate the amount, in mol, of $Na_2S_2O_3$ in this student's mean titre.

amount of $Na_2S_2O_3$ = ... mol [1]

(ii) Use the equation for reaction 4 and your answer to **(h)(i)** to determine the amount, in mol, of I_2 that reacted with the $Na_2S_2O_3$.

amount of I_2 = ... mol [1]

(iii) Use the equation for reaction 3 and your answer to **(h)(ii)** to determine the amount, in mol, of Cu^{2+} in $10.0\,cm^3$ of their solution **B**.

amount of Cu^{2+} = ... mol [1]

(iv) Calculate the mass of copper present in the second sample of powdered brass.

mass of copper = ... g [1]

(v) The mass of the second sample of powdered brass was 1.05 g.
Calculate the percentage by mass of copper in the second sample of powdered brass.
Give your answer to **three** significant figures.

percentage by mass of copper = ... % [1]

[Total: 16]

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2 Ester **X** has the formula CH_3COOR.
R is an alkyl group with the general formula C_nH_{2n+1}.
Ester **X** undergoes alkaline hydrolysis with aqueous potassium hydroxide, KOH(aq).
The resulting mixture is acidified with dilute hydrochloric acid, $HCl(aq)$.
The organic products of the hydrolysis after acidification are ethanoic acid, CH_3COOH, and an alcohol, ROH. Once the identity of ROH is found, the structure of ester **X** can then be determined.

A student uses the following steps.

step 1 Equal molar quantities of ester **X** and KOH(aq) are placed in a round-bottomed flask.

step 2 A few drops of a suitable indicator are added to show whether a reaction has occurred.

step 3 A substance is added to promote smooth boiling.

step 4 The reaction mixture is set up for reflux and heated for 30 minutes.

step 5 After 30 minutes, the reaction mixture in the round-bottomed flask is acidified by adding $HCl(aq)$ dropwise.

step 6 Thin-layer chromatography is carried out on the reaction mixture.

(a) **(i)** Complete the diagram in Fig. 2.1 to show the apparatus used for reflux in **step 4**. Label the diagram.

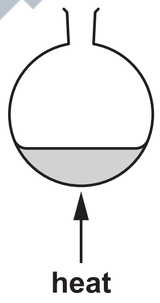

Fig. 2.1

[2]

(ii) Suggest the type of substance added to promote smooth boiling in **step 3**.

.... [1]

(b) As the reaction proceeds in **step 4**, the indicator changes colour.

Table 2.1 shows the colours of three different indicators at pH 1.0 and at pH 14.0 and the pH range over which the indicators change colour.

Table 2.1

indicator	colour at pH 1.0	pH range over which it changes colour	colour at pH 14.0
thymolphthalein	colourless	9.5–10.5	blue
methyl orange	red	3.0–4.5	yellow
bromocresol green	yellow	4.0–5.5	blue

Use the table to identify a suitable indicator.
Explain your choice.

indicator ....

explanation ....

....

.... [2]

(c) In **step 6**, a small sample of the reaction mixture is analysed along with samples of ester **X** and ethanoic acid.

Fig. 2.2 shows the chromatogram produced.

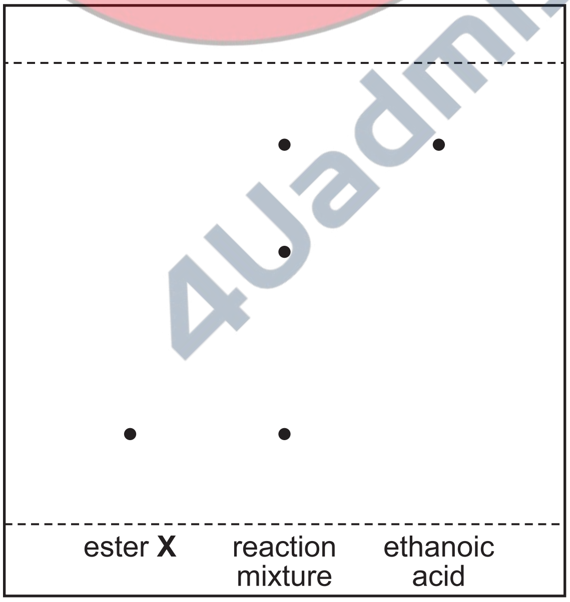

Fig. 2.2

State what feature of the chromatogram shows that the hydrolysis is incomplete.

....

.... [1]

(d) Suggest an experimental process that could be used to extract the alcohol, ROH, from the reaction mixture.

.... [1]

(e) Fig. 2.3 shows an infrared spectrum of the ROH extracted in **(d)**.

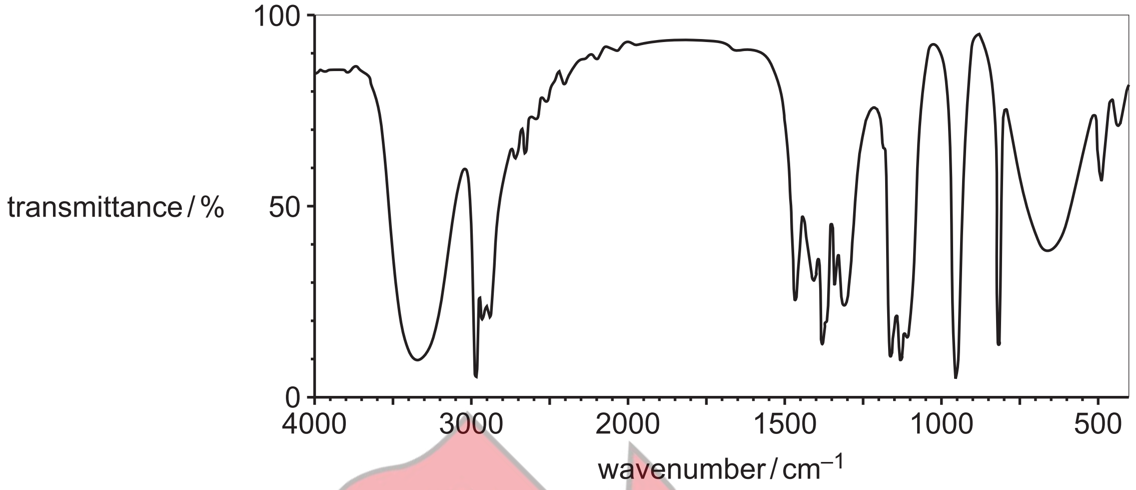

Fig. 2.3

Table 2.2

bond	functional groups containing the bond	characteristic infrared absorption range (in wavenumbers) / cm^{-1}
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3650

Use Table 2.2 to explain how the infrared spectrum in Fig. 2.3 shows that the ROH extracted does **not** contain any ester **X**.

....

.... [1]

(f) Fig. 2.4 shows the proton (^1H) NMR spectrum of compound ROH.

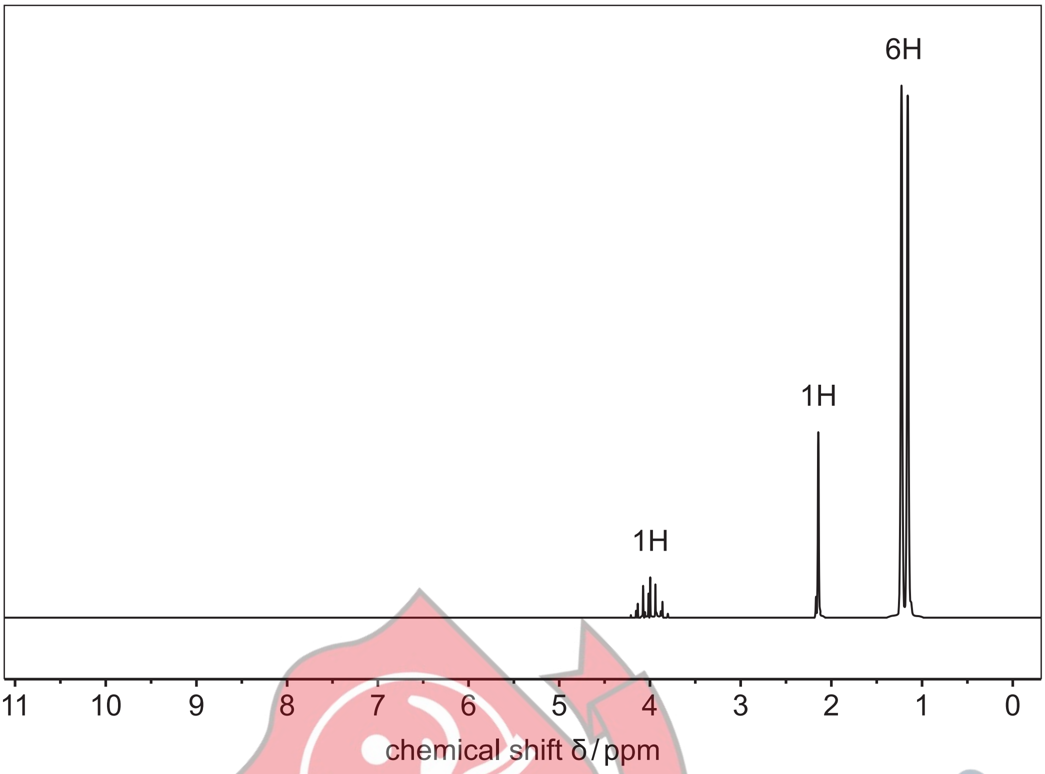

Fig. 2.4

Table 2.3 shows some relevant (^1H) NMR information.

Use Table 2.3 to complete Table 2.4, and state the name of ROH.

Table 2.3

environment of proton	example	chemical shift range δ / ppm
alkane	–**C**H_3, –**C**H_2–, >**CH**–	0.9–1.7
alkyl next to C=O	**C**H_3–C=O, –**C**H_2–C=O, >**CH**–C=O	2.2–3.0
alkyl next to aromatic ring	**C**H_3–Ar, –**C**H_2–Ar, >**CH**–Ar	2.3–3.0
alkyl next to electronegative atom	**C**H_3–O, –**C**H_2–O, –**C**H_2–C*l*	3.2–4.0
attached to alkene	=C**H**R	4.5–6.0
attached to aromatic ring	**H**–Ar	6.0–9.0
aldehyde	**H**COR	9.3–10.5
alcohol	RO**H**	0.5–6.0
phenol	Ar–O**H**	4.5–7.0
carboxylic acid	RCOO**H**	9.0–13.0

Table 2.4

chemical shift δ / ppm	splitting pattern	relative peak area	structure responsible for the peak
1.2	doublet	6	$-CH_3$
		1	
	multiplet	1	

Name of ROH ....

[3]

(g) Draw the displayed formula for ester **X**.

[2]

(h) Ester **X** will undergo hydrolysis with water in the presence of H_2SO_4(aq) under reflux, using a similar procedure.
Suggest why **none** of the indicators in Table 2.1 would change colour in this experiment.

.... [1]

[Total: 14]

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Important values, constants and standards

molar gas constant	$R = 8.31\,\text{J}\,\text{K}^{-1}\,\text{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,\text{C}\,\text{mol}^{-1}$
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	$V_\text{m} = 22.4\,\text{dm}^3\,\text{mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_\text{m} = 24.0\,\text{dm}^3\,\text{mol}^{-1}$ at room conditions
ionic product of water	$K_\text{w} = 1.00 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,\text{kJ}\,\text{kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J}\,\text{g}^{-1}\,\text{K}^{-1}$)

The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

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											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 –