* 0000800000001 *

Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME						
CENTRE NUMBER						
CANDIDATE NUMBER						

* 6 7 8 9 4 2 1 3 0 1 *

CHEMISTRY **9701/53**

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.

DC (IP) 354974

1 Grignard reagents have the general formula RMgX, where R is a hydrocarbon group and X is a halogen. The Grignard reagent C_6H_5MgBr is used as an intermediate in the reaction between bromobenzene, C_6H_5Br, and ethanal, CH_3CHO, to prepare 1-phenylethanol, $C_6H_5CH(OH)CH_3$. An organic solvent, ethoxyethane, is used.

The equations for the three reactions that take place during the preparation are shown.

reaction 1 $Mg + C_6H_5Br \rightarrow C_6H_5MgBr$

reaction 2 $C_6H_5MgBr + CH_3CHO \rightarrow C_6H_5CH(CH_3)OMgBr$

reaction 3 $C_6H_5CH(CH_3)OMgBr + H^+ \rightarrow C_6H_5CH(OH)CH_3 + Mg^{2+} + Br^-$

The preparation involves the following steps.

step 1 Set up the apparatus shown in Fig. 1.1 with approximately 1.25 g of Mg powder and 5 cm^3 of ethoxyethane in the round-bottomed flask.

step 2 Add 0.0500 mol of liquid C_6H_5Br to the round-bottomed flask dropwise using the tap funnel. Leave until reaction 1 is complete.

step 3 Dissolve 3.00 cm^3 of CH_3CHO in 15 cm^3 of ethoxyethane and add this solution to the round-bottomed flask using the tap funnel. Leave until reaction 2 is complete.

step 4 Remove the condenser, tube **Y** and the tap funnel from the round-bottomed flask.

step 5 Add 40 cm^3 of dilute hydrochloric acid, $HCl(aq)$, to the round-bottomed flask so that reaction 3 takes place.

step 6 Transfer the contents of the round-bottomed flask to a separating funnel. Allow the liquids to settle so that two layers are formed.

step 7 Open the tap of the separating funnel and run the lower layer into a beaker labelled **A**. Run the upper layer into a beaker labelled **B**.

step 8 Allow the ethoxyethane to evaporate from the beaker containing $C_6H_5CH(OH)CH_3$.

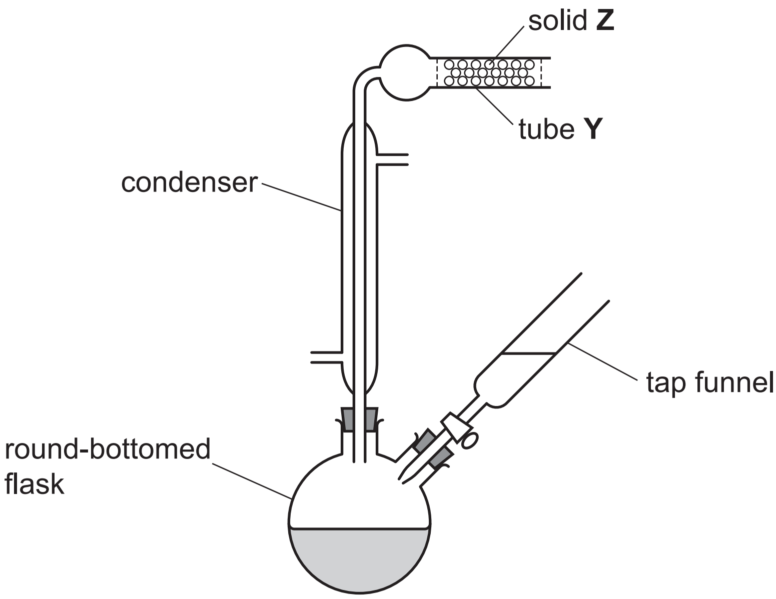

Fig. 1.1

Some relevant data are shown in Table 1.1.

Table 1.1

substance	density / $g\,cm^{-3}$	boiling point / °C	hazard
bromobenzene	1.50	156	flammable, toxic, skin irritant
distilled water	1.00	100	non-hazardous
ethoxyethane	0.714	35	flammable, toxic
ethanal	0.788	21	flammable, eye and respiratory irritant
1-phenylethanol	1.01	204	flammable, toxic, eye irritant

(a) Use the information in Table 1.1 to suggest why the following safety precautions are used.

- wearing chemically resistant gloves

 ....

- using a fume hood

 ....
[2]

(b) Dry apparatus and reagents are essential for steps 1–3.

(i) Suggest how the glassware shown in Fig. 1.1 should be dried before use in step 1.

.... [1]

(ii) The ethoxyethane contains a small amount of water.
Suggest how the water can be removed from the ethoxyethane before use in steps 1 and 3.

.... [1]

(c) Fig. 1.1 shows the apparatus for steps 1–3.

(i) Draw a labelled arrow on Fig. 1.1 to show where the water enters the condenser. [1]

(ii) Suggest why solid **Z** is used.

.... [1]

(iii) Give **one** reason why the apparatus does **not** have a bung at the end of tube **Y**.

.... [1]

(d) In step 1, approximately 1.25 g of Mg powder is needed.
Outline how the student should accurately weigh by difference using a weighing boat so that the exact mass of Mg transferred into the flask is known. Include a results table, with appropriate headings, ready for the student to fill in.

....

....

....

[2]

(e) Use the information in Table 1.1 to determine the volume, in cm^3, of bromobenzene used in step 2.

[M_r: C_6H_5Br, 156.9]

volume of C_6H_5Br = ... cm^3 [1]

(f) The bromobenzene is added dropwise in step 2.
Suggest **one** reason why the bromobenzene is **not** added all at once.

.... [1]

(g) Suggest why a measuring cylinder is a suitable piece of apparatus to measure 40 cm^3 of hydrochloric acid in step 5.

....

.... [1]

(h) The separating funnel used in steps 6 and 7 is shown in Fig. 1.2. The final product, 1-phenylethanol, is in the ethoxyethane layer.

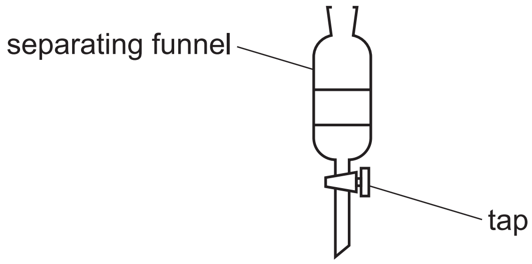

Fig. 1.2

State whether beaker **A** or beaker **B** contains the layer with 1-phenylethanol after step 7. Explain your answer using the information given in Table 1.1.

beaker ....

explanation ....

....

[1]

(i) The overall reaction can be represented as shown in Fig. 1.3.

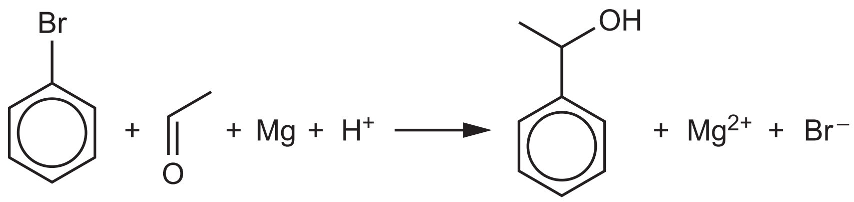

Fig. 1.3

(i) At the end of step 8, 2.17 g of 1-phenylethanol is obtained.
Determine whether bromobenzene or ethanal is the limiting reagent and hence calculate the percentage yield of 1-phenylethanol.
Show your working.

[M_r: $C_6H_5CH(OH)CH_3$, 122.0]

percentage yield of $C_6H_5CH(OH)CH_3$ = ... % [2]

(ii) Suggest why the infrared spectrum of the product detected the presence of a C=O peak.

....

.... [1]

[Total: 16]

2 An experiment is carried out to determine the rate constant, *k*, for the hydrolysis of ethyl ethanoate, $CH_3COOC_2H_5$, using a hydrochloric acid, $HCl(aq)$, catalyst.

The equation for the reaction is shown.

$$CH_3COOC_2H_5 + H_2O \xrightarrow{H^+} CH_3COOH + C_2H_5OH$$

The rate equation for this reaction is shown.

$$\text{rate of reaction} = k\,[CH_3COOC_2H_5]$$

The progress of the reaction is followed by determining how the concentration of acid changes with time.
A portion of the reaction mixture is removed every 5 minutes and titrated with sodium hydroxide, NaOH(aq). A final titration is carried out after 180 minutes.

A student carries out the following steps.

step 1 Add 70 cm^3 of iced water to seven separate small conical flasks. Add a few drops of phenolphthalein indicator to each flask. Phenolphthalein is pink in alkaline conditions and colourless in acidic conditions.

step 2 Use a measuring cylinder to transfer 100 cm^3 of 0.200 mol dm^{-3} $HCl(aq)$ into a large conical flask.

step 3 Add 5.00 cm^3 of $CH_3COOC_2H_5$ to the large conical flask and swirl the flask to mix the contents. Start a stopwatch.

step 4 Transfer 10.00 cm^3 of reaction mixture to one of the small conical flasks containing the iced water and indicator. Record the time. Shake the small flask.

step 5 Carry out a single titration of the mixture in the small conical flask using 0.15 mol dm^{-3} NaOH(aq).

step 6 Repeat steps 4 and 5 at the times shown in Table 2.1 using a different small conical flask for each titration.

(a) Give **two** reasons that explain why the use of iced water in step 4 decreases the rate of reaction.

reason 1 ....

reason 2 ....
[2]

(b) Describe the observation that is used to determine the end-point of the titrations.

.... [1]

(c) The results of the experiment are shown in Table 2.1.
V_t is the titre at a given time, t.
V_∞ is the final titre at t = 180 min when the reaction is assumed to be complete.

Table 2.1

1	2	3	4
time, t/min	titre, V_t/cm^3	$(V_\infty - V_t)$/cm^3	$\log[(V_\infty - V_t)/cm^3]$
0	12.00		
5	16.40		
10	22.15		
15	23.45		
20	26.30		
25	28.70		
180	45.70		

(i) Complete Table 2.1.
Give your answers in column 3 to **two** decimal places and your answers in column 4 to **four** significant figures. [2]

(ii) Plot a graph on the grid in Fig. 2.1 to show the relationship between $\log[(V_\infty - V_t)/cm^3]$ and time, t. Use a cross (×) to plot each data point.

Draw a straight line of best fit.
[2]

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

Suggest **one** reason to explain the anomalous point you have circled.

Assume no error was made in the experimental value of the titre.

....

.... [1]

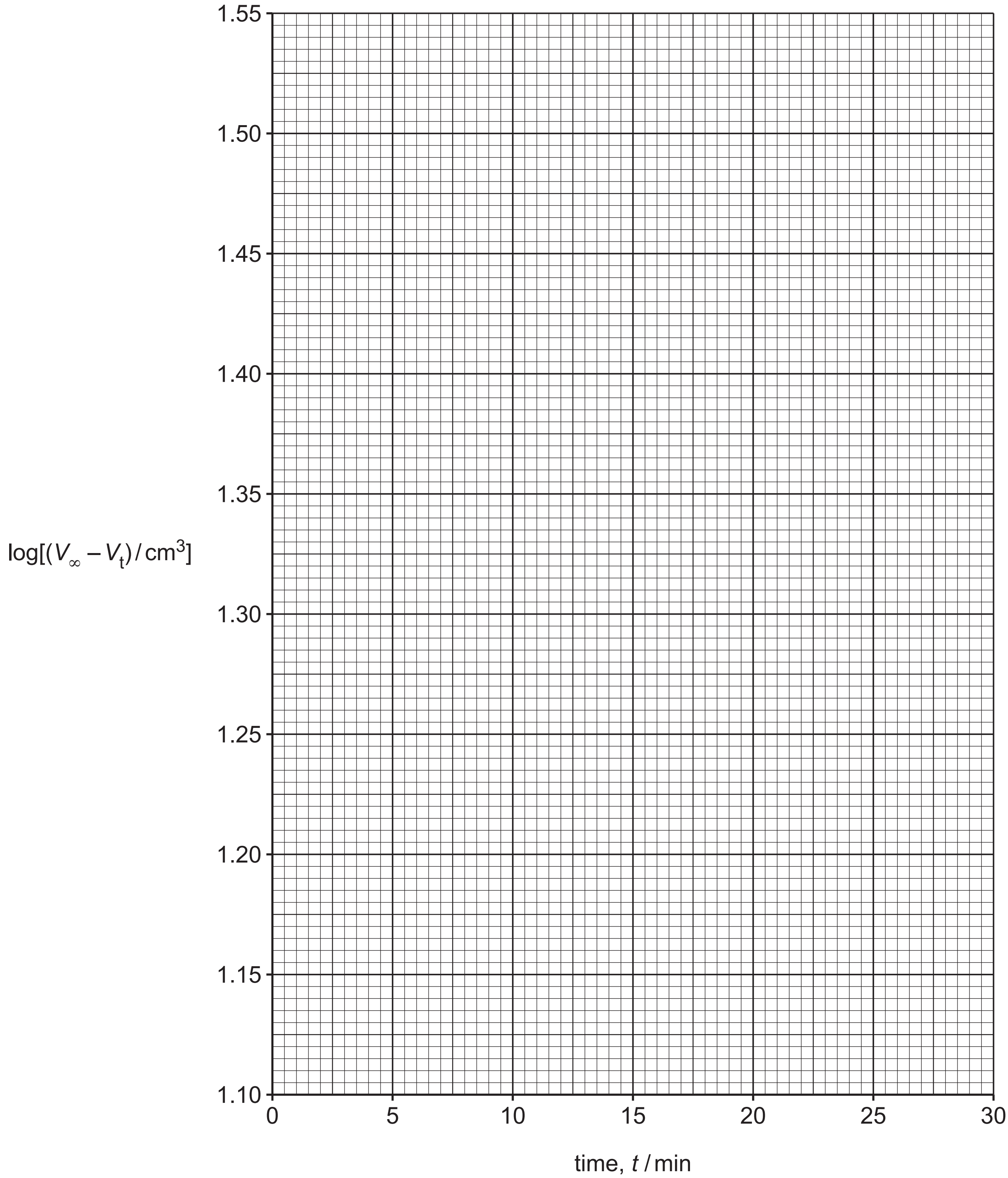
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
$\log[(V_\infty - V_t) / cm^3]$
0
5
10
15
20
25
30
time, t / min

Fig. 2.1

(iv) Determine the gradient of your line of best fit in Fig. 2.1.

State the coordinates of both points you use 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 = ... min^{-1}
[2]

(d) The equation of the straight line plotted in Fig. 2.1 is shown.

$$\log[(V_\infty - V_t)/\mathrm{cm}^3] = -\frac{kt}{2.303} + \text{constant}$$

Use the gradient determined in **(c)(iv)** to calculate a value for k in s^{-1}.

[If you were unable to determine an answer to **(c)(iv)**, then use the value $-0.0312\ min^{-1}$ for the gradient. This is **not** the correct answer.]

k = ... s^{-1} [2]

(e) Use your graph in Fig. 2.1 to state whether you consider the results to be reliable. Give a reason for your answer.

....

.... [1]

(f) k increases with temperature.
A second experiment is carried out at a higher temperature.

Sketch a suggested line of best fit on Fig. 2.1 for the second experiment. [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	$L = 6.02 \times 10^{23}\,\text{mol}^{-1}$
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

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 –