Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

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

CHEMISTRY **9701/53**

Paper 5 Planning, Analysis and Evaluation **May/June 2023**

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.

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1 The partition coefficient, K_{pc}, shows the distribution of a solute between two immiscible solvents. K_{pc} is determined by measuring the concentration of the solute in each solvent.

The organic solvent ethoxyethane, $CH_3CH_2OCH_2CH_3$, and water are immiscible. A student is asked to find K_{pc} of butanedioic acid, $HOOCCH_2CH_2COOH$, between ethoxyethane and water.

The expression for K_{pc} when butanedioic acid is in equilibrium between ethoxyethane and water is shown.

$$K_{pc} = \frac{[HOOCCH_2CH_2COOH(ethoxyethane)]}{[HOOCCH_2CH_2COOH(aq)]}$$

[density: ethoxyethane, 0.71 g cm^{-3}; water, 1.00 g cm^{-3}]

The student uses the following method to find the partition coefficient. A diagram of the apparatus is shown in Fig. 1.1.

step 1 Add 30.0 cm^3 of distilled water to a separating funnel.

step 2 Weigh by difference 2.81 g of butanedioic acid into the separating funnel.

step 3 Stopper the separating funnel and shake it until the butanedioic acid has dissolved.

step 4 Remove the stopper and add 30.0 cm^3 of ethoxyethane to the separating funnel.

step 5 Replace the stopper and shake the separating funnel gently.

step 6 Place the separating funnel into a clamp. Allow the liquids to settle so that the two layers can be seen.

step 7 Remove the stopper and open the separating funnel tap to allow the lower layer to run into a beaker labelled **A**. Run the upper layer into a beaker labelled **B**.

step 8 Transfer 10.0 cm^3 of the aqueous layer into a conical flask. Titrate with 0.500 mol dm^{-3} NaOH(aq). Use thymolphthalein as the indicator.

step 9 Take 10.0 cm^3 of the ethoxyethane layer and add 10.0 cm^3 of water to it. Titrate this mixture with 0.100 mol dm^{-3} NaOH(aq). Use thymolphthalein as the indicator.

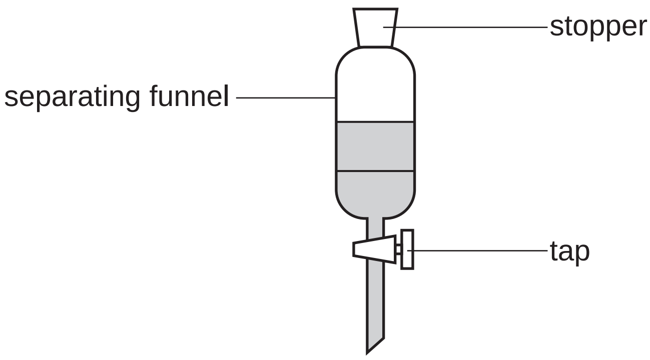

Fig. 1.1

(a) **(i)** State whether beaker **A** in step 7 contains the aqueous layer or the ethoxyethane layer.

Explain your answer.

Beaker **A** contains the .... layer.

explanation ....

.... [1]

(ii) Identify the piece of apparatus that should be used in step 8 to transfer 10.0 cm^3 of the aqueous layer.

.... [1]

(iii) Suggest why water is added to the ethoxyethane layer in step 9 before the titration can take place.

....

.... [1]

(b) For a 2.81 g sample of butanedioic acid, the titre for the aqueous layer is 27.25 cm^3 and the titre for the ethoxyethane layer is 22.50 cm^3.

The equation for the reaction between butanedioic acid and sodium hydroxide is shown.

$$HOOCCH_2CH_2COOH + 2NaOH \longrightarrow NaOOCCH_2CH_2COONa + 2H_2O$$

(i) Calculate the concentration of butanedioic acid in the aqueous layer.

concentration of butanedioic acid = ... mol dm^{-3} [1]

(ii) Calculate the partition coefficient, K_{pc}.

K_{pc} = ... [2]

(iii) Explain why the student is only able to repeat the titration in step 8 once.

....

....

.... [1]

(iv) Suggest how you would modify the procedure to ensure the student can repeat the titration in step 8 more than once.

....

.... [1]

(v) A different student forgets to shake the separating funnel in step 5.

Describe the effect this would have on the calculated K_{pc} value. Explain your answer.

effect on K_{pc} ....

explanation ....

....
[1]

[Total: 9]

2 Paper chromatography can be used to separate the individual amino acids formed when tripeptides are hydrolysed.

One molecule of a tripeptide produces three amino acid molecules when hydrolysed.

A student is asked to identify the amino acids formed from the hydrolysis of three different tripeptides, **A**, **B** and **C**, using paper chromatography.

Fig. 2.1 shows the results of the student's chromatography experiment.

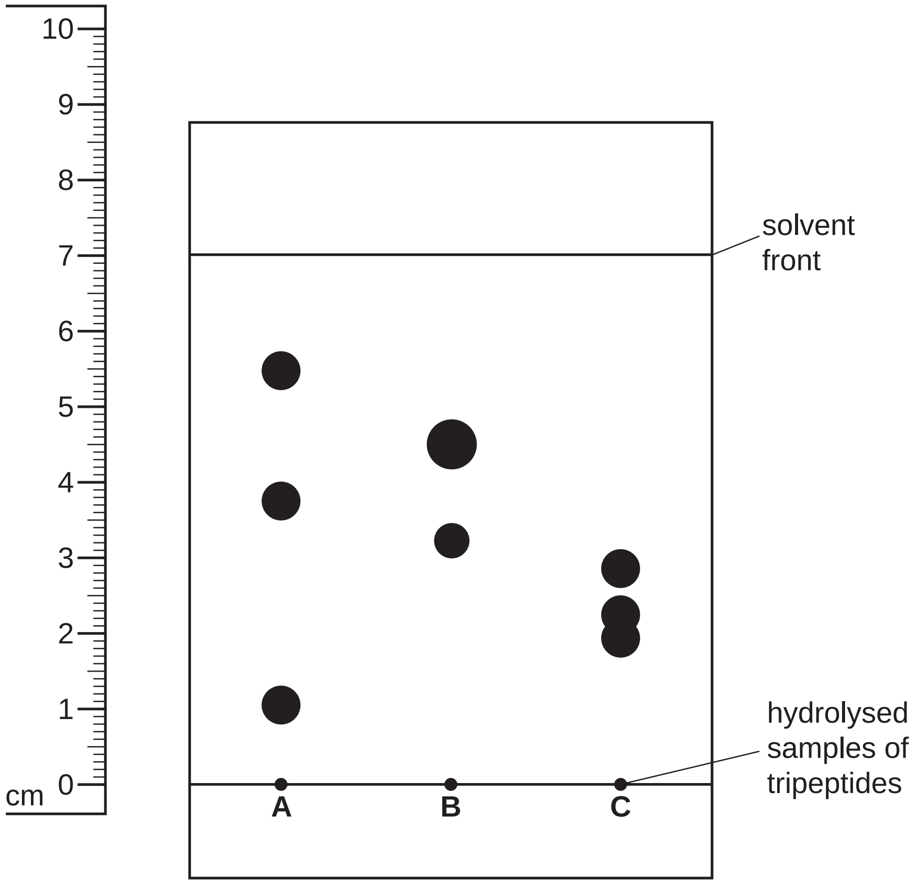

Fig. 2.1

The individual amino acids can be identified from their R_f values.

$$R_f = \frac{\text{distance travelled by the amino acid spot}}{\text{distance travelled by the solvent front}}$$

(a) Suggest why each sample is applied to the chromatography paper using a thin capillary tube rather than a dropping pipette.

....

.... [1]

(b) Suggest why it is necessary to spray a developing agent over the chromatography paper before the chromatogram can be analysed.

....

.... [1]

(c) Table 2.1 shows R_f values for some amino acids in the solvent used in Fig. 2.1.

Table 2.1

amino acid	R_f value
lysine	0.14
glycine	0.26
serine	0.27
glutamic acid	0.30
alanine	0.38
proline	0.43
tryptophan	0.50
valine	0.60
leucine	0.73

Use the data in Table 2.1 to identify the amino acids in tripeptide **A**.

....

.... [2]

(d) Suggest why the hydrolysed sample of **B** produces only two spots.

....

.... [1]

(e) Two of the spots from the hydrolysed sample of **C** overlap.

(i) State the reason for the overlap.

....

.... [1]

(ii) Suggest an improvement to the method that would allow the overlapping spots to be distinguished clearly.

....

.... [1]

[Total: 7]

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3 A scientist is asked to find the rate of decomposition of an aromatic diazonium compound and determine the order of the reaction with respect to the aromatic diazonium compound.

(a) The scientist is given 1.02 g of an aromatic diazonium compound in a 50 cm^3 beaker.

Describe the steps the scientist should take to make a 100.0 cm^3 standard solution containing 1.02 g of this compound.

Give the name and capacity of the apparatus the scientist should use.

Write your answer using a series of numbered steps.

....

....

....

....

....

....

.... [3]

(b) Benzenediazonium chloride, an aromatic diazonium compound, decomposes in solution to produce phenol and nitrogen gas. The scientist warms 50 cm^3 of the solution to 50 °C. The scientist records the volume of nitrogen gas produced at different times during the decomposition.

(i) Identify the piece of apparatus that should be used to maintain the temperature of the solution.

.... [1]

(ii) Identify the dependent variable.

.... [1]

(iii) Suggest why the scientist does **not** monitor the reaction by measuring the loss in mass.

....

.... [1]

(c) Table 3.1 shows the results of the experiment.

Table 3.1

time, t / min	volume, V_t / cm^3	$V_{final} - V_t$ / cm^3
0	0.0	
5	17.3	
9	27.0	
16	39.5	
21	42.6	
28	49.0	
36	52.8	
final	57.2	0.0

V_{final} is the final volume of nitrogen gas measured once the decomposition is complete.

V_t is the volume collected at time = t.

$V_{final} - V_t$ is proportional to the concentration of the benzenediazonium chloride.

(i) Complete Table 3.1. [1]

(ii) Plot a graph on the grid in Fig. 3.1 to show the relationship between $V_{final} - V_t$ and time. Use a cross (×) to plot each data point.

Draw a curved line of best fit through the plotted points.

[2]

(iii) Circle the **one** point on the graph that you consider to be most anomalous. [1]

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

Assume no error was made in the measurement of volume.

....

.... [1]

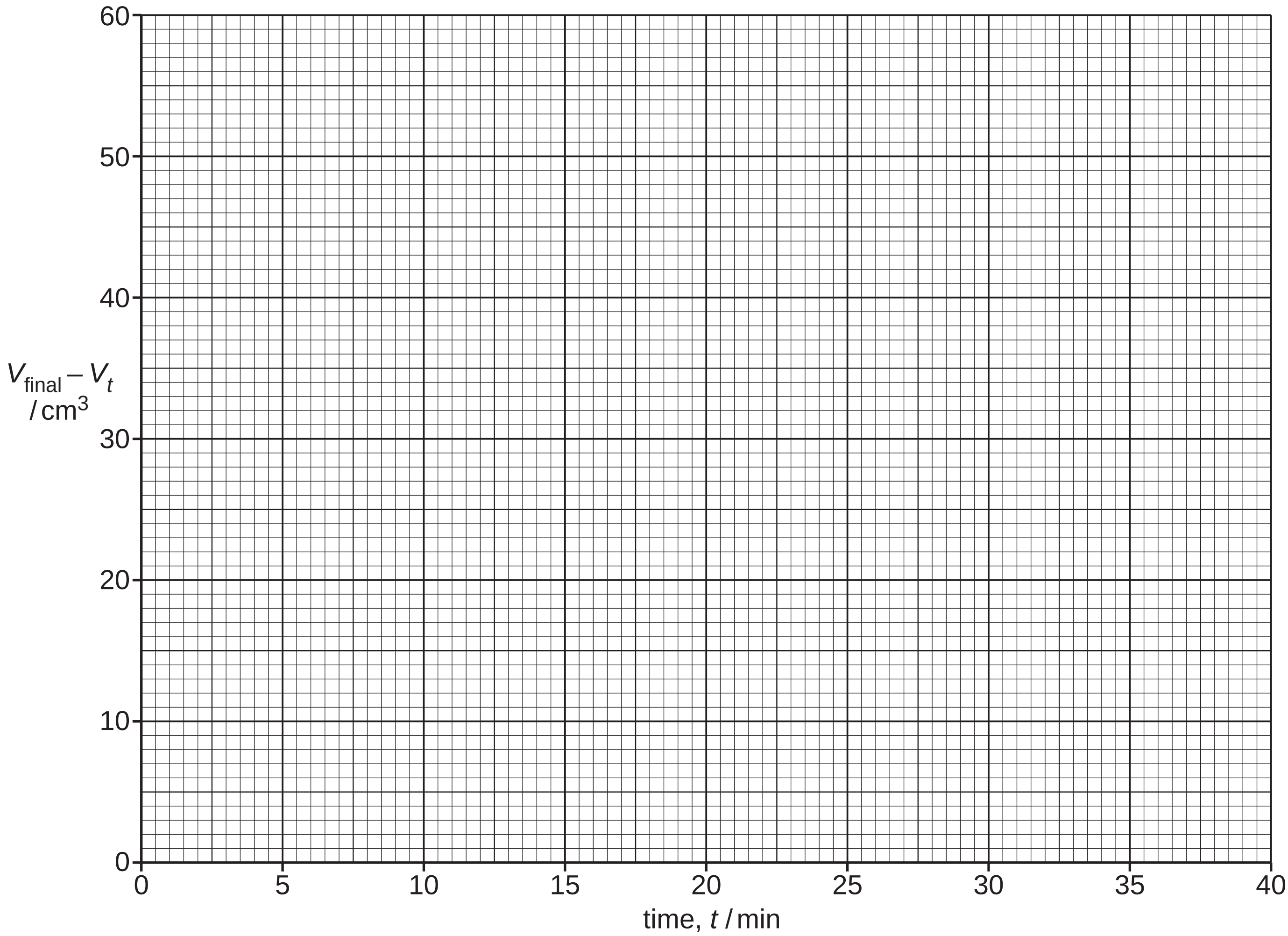

Fig. 3.1

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(v) Use your graph to find the first two successive half-lives, $t_{1/2}$, for this reaction.

State the coordinates of both points you used in each of your calculations.

first $t_{1/2}$: coordinates .... and ....

half-life = ... min

second $t_{1/2}$: coordinates .... and ....

half-life = ... min
[2]

(vi) Use your answer to **(c)(v)** to state the order of the reaction with respect to the benzenediazonium chloride. Explain your answer.

If you were unable to obtain an answer to **(c)(v)** you may use the values 8.6 min and 11.0 min for the half-lives. These are **not** the correct values.

order = ...

explanation ....

....
[1]

[Total: 14]

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Important values, constants and standards

molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Faraday constant	$F = 9.65 \times 10^{4}\,\mathrm{C\,mol^{-1}}$
Avogadro constant	$L = 6.022 \times 10^{23}\,\mathrm{mol^{-1}}$
electronic charge	$e = -1.60 \times 10^{-19}\,\mathrm{C}$
molar volume of gas	$V_m = 22.4\,\mathrm{dm^3\,mol^{-1}}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,\mathrm{dm^3\,mol^{-1}}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,\mathrm{mol^2\,dm^{-6}}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,\mathrm{kJ\,kg^{-1}\,K^{-1}}$ ($4.18\,\mathrm{J\,g^{-1}\,K^{-1}}$)

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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 144.4	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 –

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