Cambridge Assessment International Education

# Cambridge International AS & A Level

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| CANDIDATE NAME | | | | | | | | | |
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*3847256097*

**CHEMISTRY** **9701/51**

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.

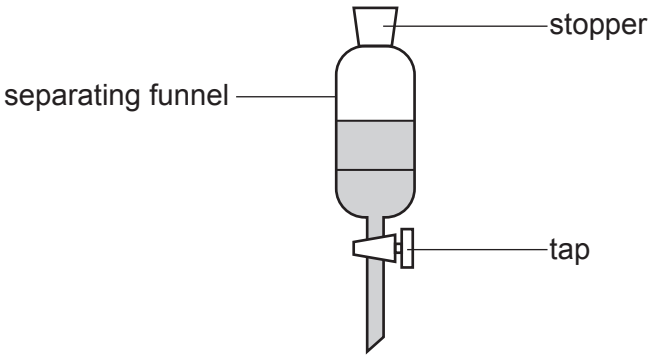



**Fig. 1.1**

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**(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.

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

**(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]

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**(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.

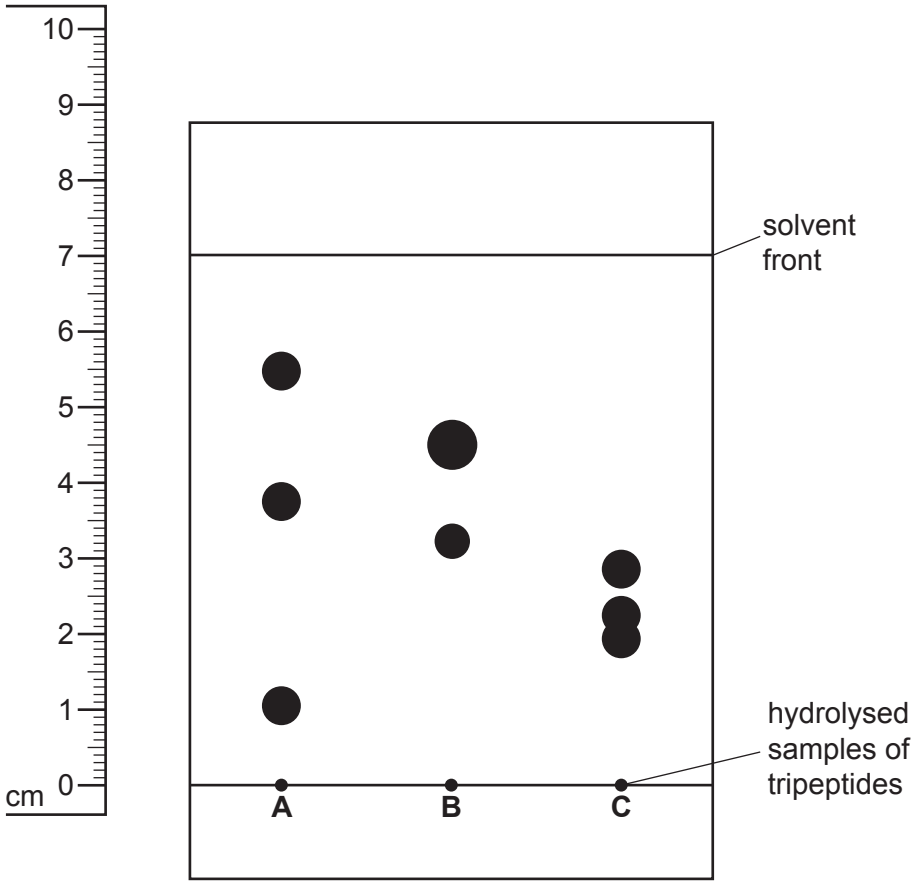



**Fig. 2.1**

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]

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**(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]

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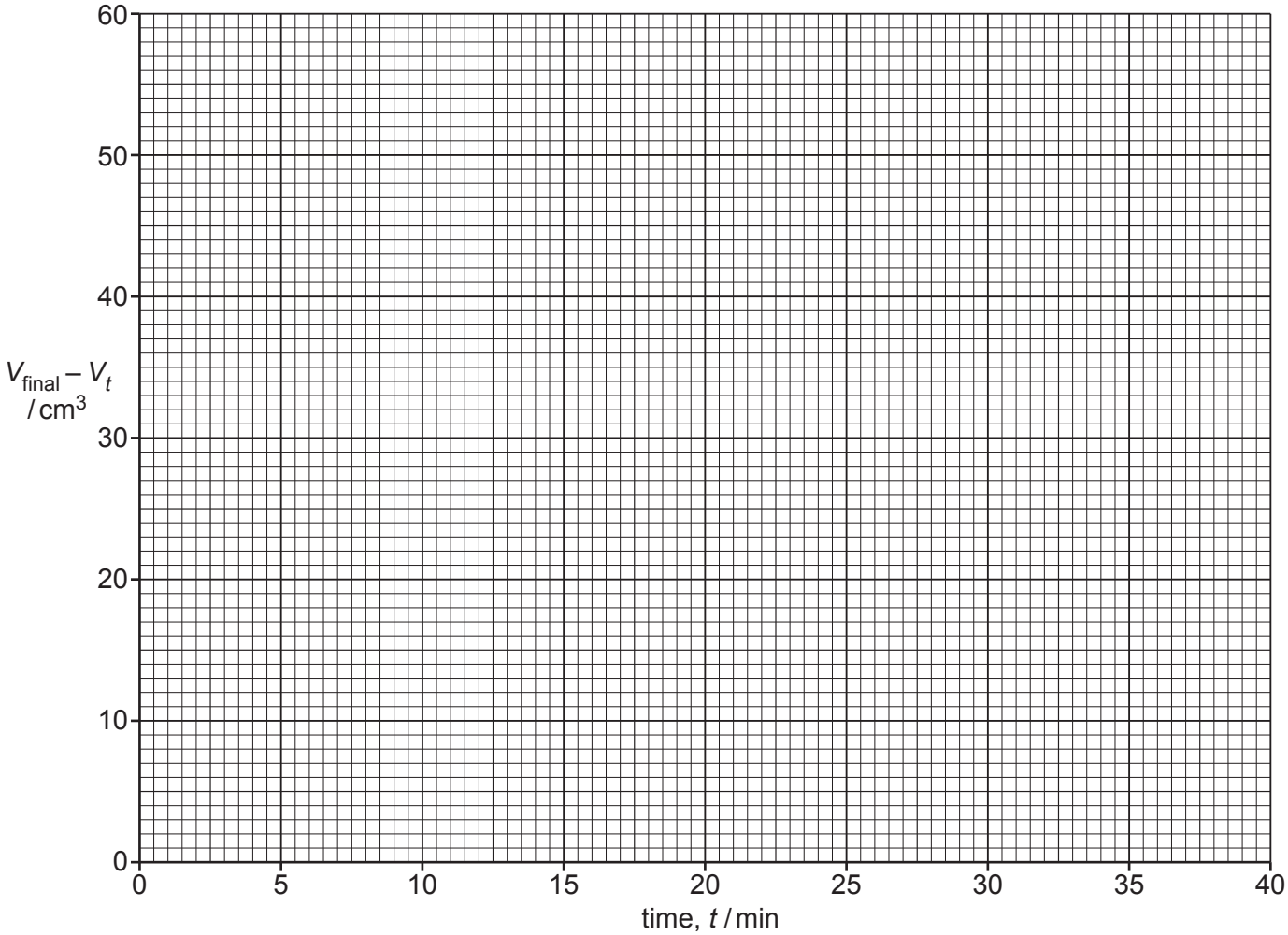



**Fig. 3.1**

**(v)** Use your graph to find the first two successive half-lives, $t_{½}$, for this reaction.

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

first $t_{½}$: coordinates ..... and .....

half-life = ..... min

second $t_{½}$: 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 | $R = 8.31\,\text{J K}^{-1}\,\text{mol}^{-1}$ |
| Faraday constant | $F = 9.65 \times 10^{4}\,\text{C mol}^{-1}$ |
| Avogadro constant | $L = 6.022 \times 10^{23}\,\text{mol}^{-1}$ |
| 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)<br>$V_m = 24.0\,\text{dm}^3\,\text{mol}^{-1}$ 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 | $c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$) |

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## 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 | | | | | | | | | | | 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 – |

**Key**

atomic number
**atomic symbol**
name
relative atomic mass

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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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