Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

9663523034

CHEMISTRY **9701/52**

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 **12** pages.

DC (LK/SG) 309547/6

1 Three students are asked to prepare samples of benzoic acid, C_6H_5COOH, from the alkaline hydrolysis of methyl benzoate, $C_6H_5COOCH_3$. Sodium benzoate, C_6H_5COONa, is the salt formed, which is then acidified with hydrochloric acid to form C_6H_5COOH.

$$C_6H_5COOCH_3(l) + NaOH(aq) \rightarrow C_6H_5COONa(aq) + CH_3OH(l)$$

$$C_6H_5COONa(aq) + HCl(aq) \rightarrow C_6H_5COOH(s) + NaCl(aq)$$

The students use the following method.

step 1 Put 1.242 g of liquid methyl benzoate into a 50 cm^3 round-bottomed flask.

step 2 Prepare 100.0 cm^3 of 1.00 $mol\,dm^{-3}$ aqueous sodium hydroxide, NaOH(aq).

step 3 Add 10 cm^3, an excess, of the prepared NaOH(aq) to the round-bottomed flask.

step 4 Add some anti-bumping granules to the round-bottomed flask.

step 5 Fit a condenser to make reflux apparatus. Reflux the reaction mixture for 20 minutes.

step 6 Allow the reaction mixture to cool and carefully pour the liquid into a beaker.

step 7 Acidify the liquid with dilute hydrochloric acid.

step 8 Filter the mixture formed in step 7.

step 9 Purify the benzoic acid by recrystallisation from hot water. Filter, dry and record the mass of pure benzoic acid obtained.

(a) (i) Calculate the volume of methyl benzoate used in step 1.
Give your answer to the nearest 0.05 cm^3.

[density: methyl benzoate, 1.08 $g\,cm^{-3}$]

volume of methyl benzoate = ... cm^3 [1]

(ii) Identify a suitable piece of apparatus to measure the volume of methyl benzoate required in step 1.

.... [1]

(iii) Calculate the mass of NaOH(s) that is needed to prepare the solution in step 2.

mass of NaOH(s) = ... g [1]

(b) Student 1 added the mass of NaOH(s) calculated in **(a)(iii)** into a beaker.

Describe the steps the student should take to make $100.0\,cm^3$ of $1.00\,mol\,dm^{-3}$ NaOH(aq).

Give the name and capacity of any apparatus that should be used.
Write your answer using a series of numbered steps.

....

....

....

....

....

.... [3]

(c) Student 2 prepared $0.100\,mol\,dm^{-3}$ NaOH(aq) instead of $1.00\,mol\,dm^{-3}$ NaOH(aq) in step 2.

State how this would affect the final mass of benzoic acid formed. Explain, using calculations, how you came to this conclusion.

[M_r: methyl benzoate, 136; benzoic acid, 122]

effect on mass ....

explanation

....

....

....
[2]

(d) **(i)** Explain why it is necessary to reflux the mixture in step 5.

....

.... [1]

(ii) Explain why a naked flame is **not** used in step 5.

.... [1]

(iii) Explain the purpose of transferring the liquid in step 6.

.... [1]

(e) **(i)** Explain what the students should do to confirm that the mixture has been acidified in step 7.

....

.... [1]

(ii) Describe what you would expect to observe as the sodium benzoate mixture is acidified in step 7.

.... [1]

(f) Suggest why it is necessary to cool the mixture before filtering in step 9.

....

.... [1]

(g) Pure benzoic acid has a melting point of 122 °C. The product made by student 1 has a melting point of 119 °C.

This student suggests the melting point of the product was lower than expected because it contained some water.

Explain what the student should do to ensure that the product no longer contains water.

....

.... [1]

(h) **(i)** Calculate the maximum mass of benzoic acid that can be formed from 1.242 g of methyl benzoate.

[M_r: methyl benzoate, 136; benzoic acid, 122]

maximum mass of benzoic acid = ... g [1]

(ii) Student 3 produces 0.825 g of benzoic acid from 1.242 g of methyl benzoate.

Calculate the percentage yield of benzoic acid produced by student 3.

percentage yield = ... [1]

[Total: 17]

2 Pure water dissociates according to the equation shown.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The equilibrium constant for this reaction is known as K_w, the ionic product of water.

$$K_w = [H^+(aq)]\,[OH^-(aq)]$$

At 25 °C, K_w has a value of $1.00 \times 10^{-14}\,mol^2\,dm^{-6}$. The pH of pure water at 25 °C is 7.00.

A student finds the pH of pure water at 35 °C is 6.84. The student investigates how temperature affects the pH of pure water and determines a value for the enthalpy change for the dissociation of water, ΔH.

The student records the pH of pure water at different temperatures. A line of best fit from the results of the student's investigation is shown in Fig. 2.1.

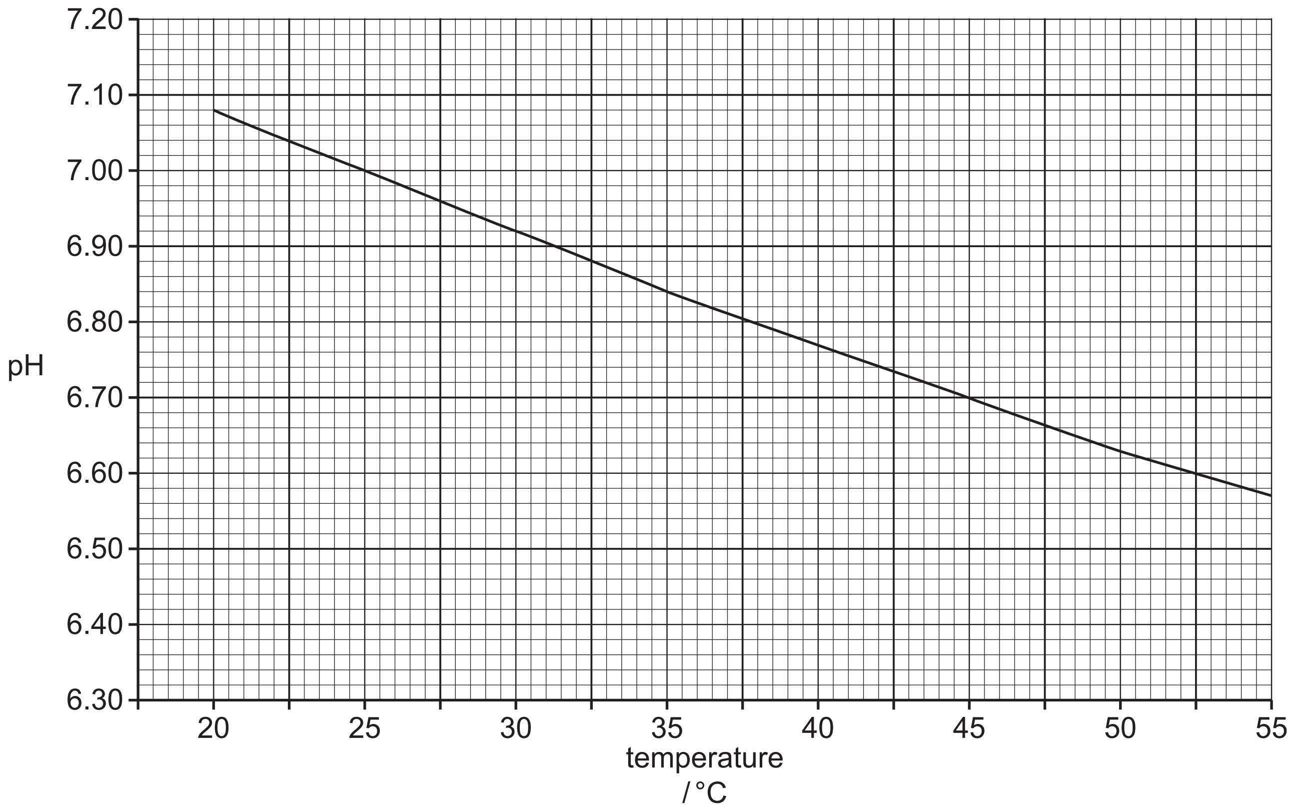


Fig. 2.1

(a) **(i)** Use Fig. 2.1 to calculate the hydrogen ion concentration of pure water at 45 °C.

$pH = -\log [H^+(aq)]$

hydrogen ion concentration = ... $mol\,dm^{-3}$ [1]

(ii) Calculate the value of K_w for pure water at 45 °C.

K_w = ... $mol^2\,dm^{-6}$ [1]

(iii) State the relationship between K_w and temperature.

....

.... [1]

(b) The student determines K_w at a range of temperatures.

The results are shown in Table 2.1.

Table 2.1

temperature, T / K	$\frac{1}{T}$ / K^{-1}	K_w / $mol^2 dm^{-6}$	log K_w
283		2.93×10^{-15}	
293		6.81×10^{-15}	
303		1.47×10^{-14}	
313		2.92×10^{-14}	
323		5.48×10^{-14}	
333		1.09×10^{-13}	
343		1.45×10^{-13}	

(i) Complete Table 2.1.

Record $\frac{1}{T}$ to **three** significant figures using standard form. Record log K_w to **two** decimal places.

[2]

(ii) Plot a graph on the grid to show the relationship between log K_w and $\frac{1}{T}$. Use a cross (×) to plot each data point.

Draw a line of best fit. [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 there was no error in determining K_w.

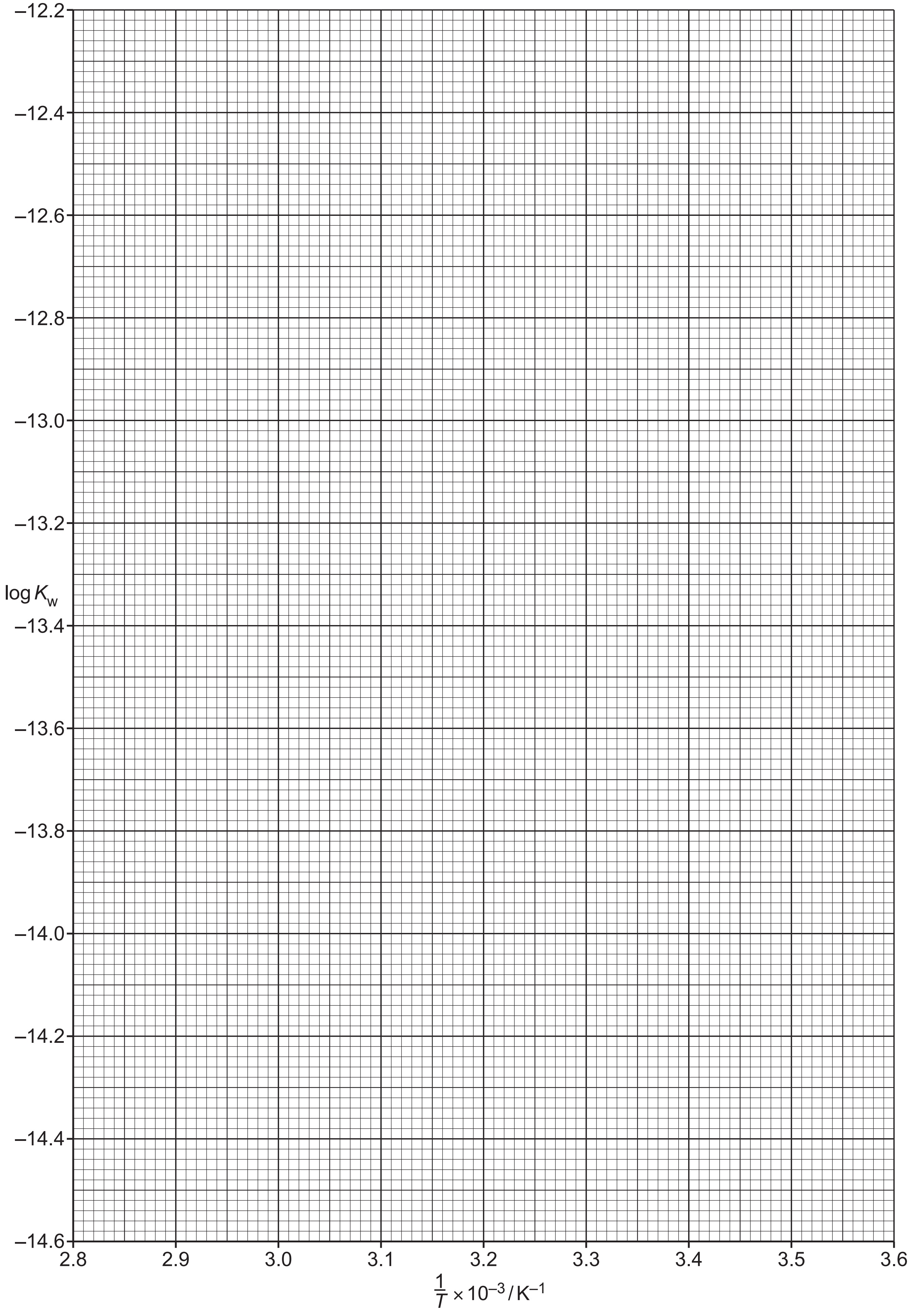
....

.... [1]

(v) Use your graph 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.

coordinates 1 .... coordinates 2 ....

gradient = ...
[2]


–12.2
–12.4
–12.6
–12.8
–13.0
–13.2
log K_w
–13.4
–13.6
–13.8
–14.0
–14.2
–14.4
–14.6
2.8
2.9
3.0
3.1
3.2
3.3
3.4
3.5
3.6
$\frac{1}{T} \times 10^{-3}$ / K^{-1}

(vi) The relationship between log K_w and $\frac{1}{T}$ is given by the equation shown.

$$\log K_w = \frac{-\Delta H}{2.303RT} + \text{constant}$$

Use the gradient determined in **(b)(v)** to calculate a value for the enthalpy change, in $kJ\,mol^{-1}$, for the dissociation of water, ΔH.

If you were unable to determine a value for the gradient in **(b)(v)**, use the value –2550. This is **not** the correct value.

ΔH = ... $kJ\,mol^{-1}$ [2]

[Total: 13]

Important values, constants and standards

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

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 144.4	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 –