Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

CHEMISTRY **9701/52**

Paper 5 Planning, Analysis and Evaluation **October/November 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 (CE/FC) 311844/4

1 Thermometric titrations can be used to determine the standard enthalpy change of neutralisation.

The maximum temperature reached in a thermometric titration occurs at the point of neutralisation between an acid and an alkali.

A diagram of the apparatus used is shown in Fig. 1.1.

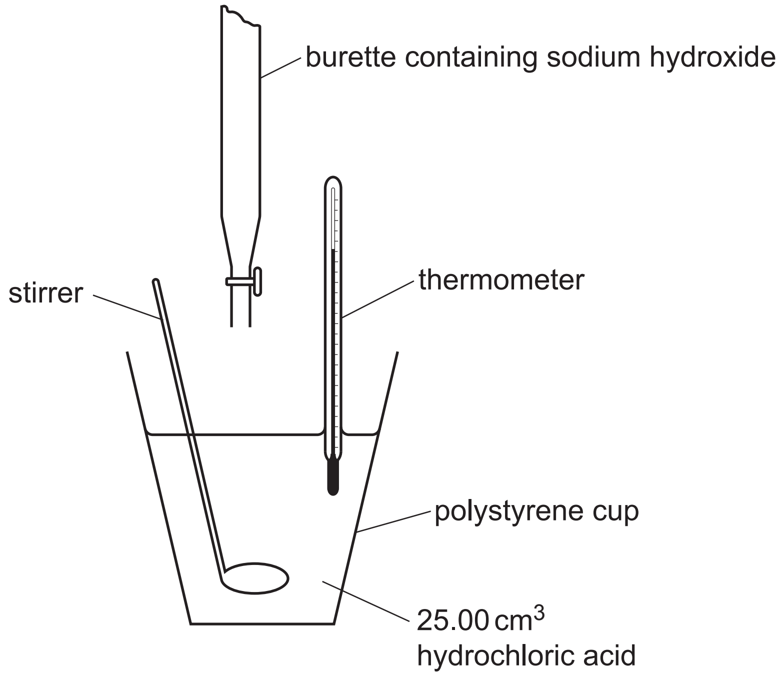


Fig. 1.1

A student uses the following method.

Step 1 Transfer 25.00 cm^3 of 1.00 mol dm^{-3} dilute hydrochloric acid, $HCl(aq)$, to a polystyrene cup.

Step 2 Place a thermometer with 0.2 °C divisions into the $HCl(aq)$ in the polystyrene cup and leave it for 3 minutes. Record the temperature.

Step 3 Add 5.00 cm^3 aqueous sodium hydroxide, $NaOH(aq)$, from a burette. Stir and record the temperature of the solution in the polystyrene cup.

Step 4 Immediately add another 5.00 cm^3 of $NaOH(aq)$. Stir and record the temperature of the solution in the polystyrene cup.

Step 5 Repeat Step 4 until there is no further increase in temperature. Once the temperature starts to decrease, repeat Step 4 three more times.

The student obtains the results shown in Table 1.1.

Question 1 continues on the next page.

Table 1.1

volume of NaOH(aq) added / cm^3	temperature / °C
0.00	18.8
5.00	21.3
10.00	23.8
15.00	26.4
20.00	27.4
25.00	26.2
30.00	25.1
35.00	24.0
40.00	23.2

(a) **(i)** Plot a graph of temperature (*y*-axis) against volume of NaOH(aq) added (*x*-axis) on the grid. Use a cross (×) to plot each data point.

Draw two straight lines of best fit. One for the rise in temperature and one for the fall in temperature. Extrapolate the two lines so they intersect. [2]

(ii) Use your graph to determine the maximum temperature change of the mixture. Assume the initial temperature of NaOH(aq) is 18.8 °C.

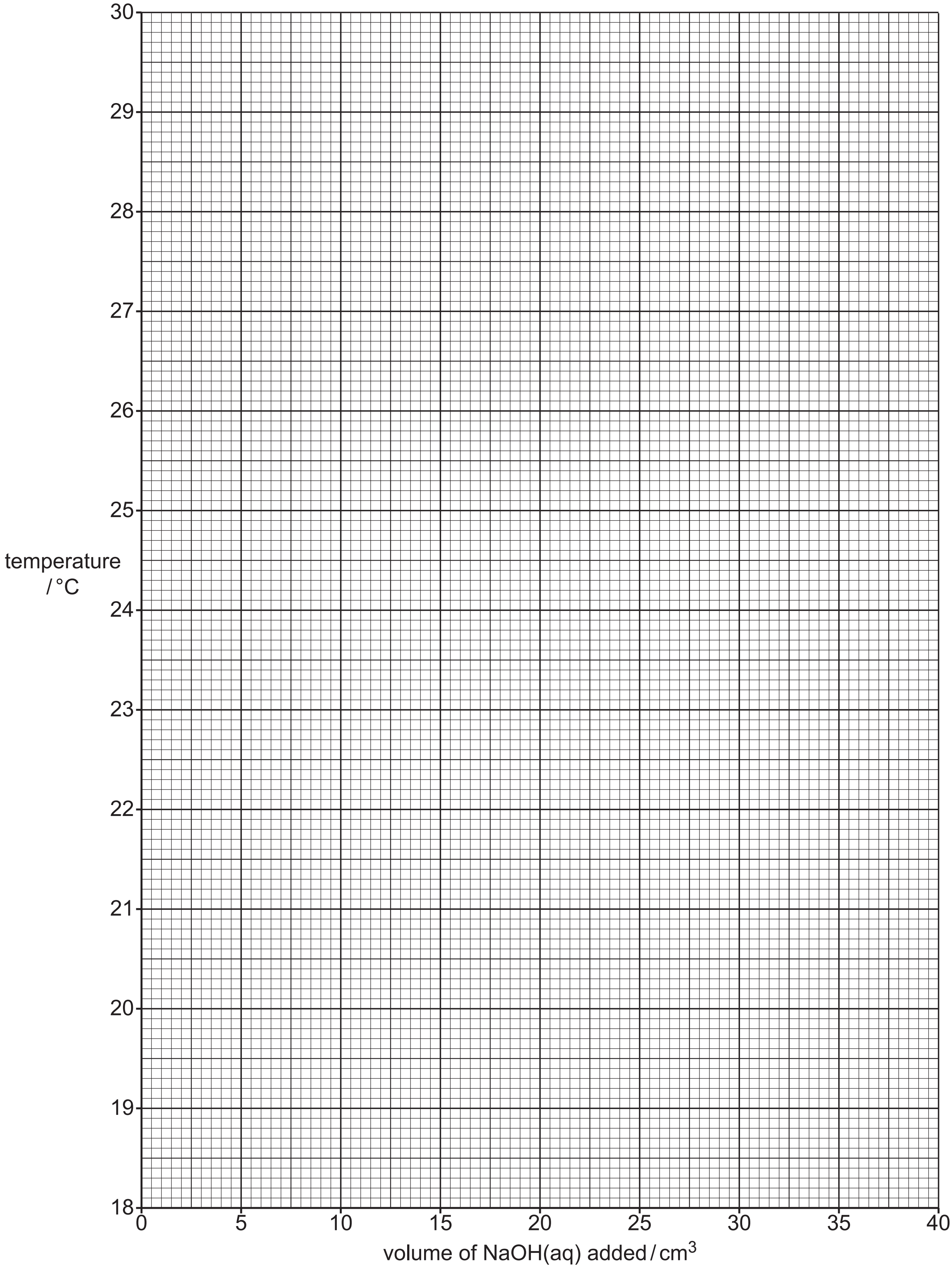
maximum temperature change of the mixture = ... °C [1]

(iii) Use your graph to determine the volume of NaOH(aq) needed to neutralise 25.00 cm^3 of 1.00 mol dm^{-3} HC*l*(aq).

volume of NaOH(aq) = ... cm^3 [1]

(iv) Use your answer to **(iii)** to calculate the concentration of NaOH(aq) in mol dm^{-3}.

concentration of NaOH(aq) = ... mol dm^{-3} [2]


30
29
28
27
26
25
24
23
22
21
20
19
18
temperature / °C
0
5
10
15
20
25
30
35
40
volume of NaOH(aq) added / cm3

(v) Suggest why a titration using an indicator is more accurate than a thermometric titration.

....

.... [1]

(b) Suggest a suitable piece of apparatus for the transfer of 25.00 cm^3 of 1.00 mol dm^{-3} $HCl(aq)$ in **Step 1**.

.... [1]

(c) Determine the percentage error of the measured temperature increase when the first 5.00 cm^3 of NaOH(aq) is added.

Show your working.

percentage error = ... [1]

(d) The standard enthalpy change of neutralisation, $\Delta H^{\ominus}_{neut}$, is defined as the enthalpy change when one mole of $H_2O(l)$ forms from $H^+(aq)$ and $OH^-(aq)$.

In another experiment a student finds that 22.10 cm^3 of 1.00 mol dm^{-3} of NaOH(aq) increases the temperature by 6.0 °C when added to 25.00 cm^3 of 1.00 mol dm^{-3} of $HCl(aq)$.

The equation for the reaction between HC*l* and NaOH is shown.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

Use the formula $\Delta H = -mc\Delta T$ to determine the standard enthalpy change of neutralisation, $\Delta H^{\ominus}_{neut}$, in kJ mol^{-1}.

Assume the mass of 1.00 cm^3 of solution is 1.00 g.

$\Delta H^{\ominus}_{neut}$ = ... kJ mol^{-1} [2]

(e) The theoretical value for the standard enthalpy change of neutralisation in the reaction between $HCl(aq)$ and $NaOH(aq)$ is $-57.6\,kJ\,mol^{-1}$.

Give **one** reason why the value you obtained in **(d)** differs from the theoretical value.

If you were unable to obtain an answer to **(d)**, use $-46.4\,kJ\,mol^{-1}$. This is **not** the correct answer.

....

....

.... [1]

(f) Suggest why the standard enthalpy change of neutralisation determined using ethanoic acid is less exothermic than the standard enthalpy change using hydrochloric acid.

....

....

....

....

.... [2]

[Total: 14]

2 A student investigates the rate of reaction when zinc reacts with dilute hydrochloric acid, $HCl(aq)$.

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

The student uses the following method.

Step 1 Accurately weigh 1.00 g of zinc foil.

Step 2 Add 50 cm^3 of 2.00 mol dm^{-3} $HCl(aq)$ to a conical flask.

Step 3 Add the zinc foil to the 50 cm^3 of $HCl(aq)$ in the flask and immediately start a timer.

Step 4 Stop the timer when 20.0 cm^3 of $H_2(g)$ has been collected.

Step 5 Repeat **Steps 1** to **4** using lower concentrations of $HCl(aq)$.

(a) Complete Fig. 2.1 to show the apparatus that the student can use to collect and measure the volume of hydrogen produced. Label your diagram.

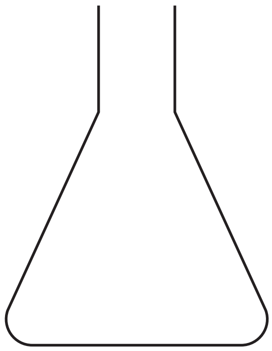


Fig. 2.1

[3]

(b) The student wants to perform a similar experiment using 0.100 mol dm^{-3} HCl(aq).

Describe how the student should make a standard solution of 250.0 cm^3 of 0.100 mol dm^{-3} HCl(aq) starting from a solution of 2.00 mol dm^{-3} HCl(aq).

Give the name and size of any key apparatus which should be used and describe how the student should ensure the volume is exactly 250.0 cm^3.

Write your answer using a series of numbered steps.

....

....

....

....

.... [3]

(c) The student carries out further experiments using higher concentrations of HCl(aq).

(i) The student wears chemically resistant gloves when using 6.00 mol dm^{-3} HCl(aq). Suggest why.

.... [1]

(ii) The student obtains the results shown in Table 2.1.

Table 2.1

concentration of HCl / mol dm^{-3}	time (t) taken to collect 20 cm^3 of H_2 / s	1/t / s^{-1}
2.00	15.62	
3.00	10.41	
4.00	7.81	
5.00	6.25	
6.00	5.24	

In these experiments 1/t can be considered to be proportional to the initial rate of reaction.

Complete the table by calculating 1/t for each concentration.
Give your answers to **three** significant figures. [1]

(iii) Use your data from Table 2.1 to produce a sketch graph of 1/*t* against concentration in Fig. 2.2.
It is **not** necessary to include a scale on the axes.
Label the sketched line '**A**'.

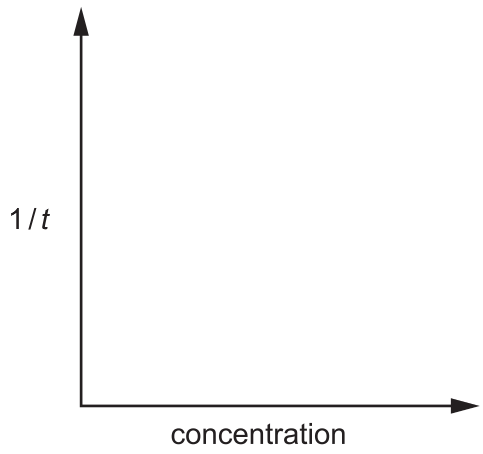


Fig. 2.2 [1]

(iv) On Fig. 2.2 sketch a second line to show the graph of concentration against 1/*t* if powdered zinc is used in the experiment instead of zinc foil.
Label this line '**B**'. [1]

(v) Using your data in Table 2.1, deduce the rate equation for the reaction between Zn(s) and HC*l*(aq).

rate =

[1]

(d) At higher concentrations than those shown in Table 2.1, significant temperature increases occur.

(i) Suggest how line '**A**' in Fig. 2.2 would be different at these higher concentrations. Explain your answer.

....

....

.... [2]

(ii) Suggest **one** way in which the temperature increase may be minimised.

.... [1]

(e) The zinc foil has an oxide layer.

(i) Suggest how the oxide layer can be removed before weighing the zinc foil.

....

.... [1]

(ii) If the student does **not** remove the oxide layer, the initial rate of reaction is lower than it should be.
Explain why the initial rate of reaction is lower than it should be.

....

....

.... [1]

[Total: 16]

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 –