Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER				

5089153413

CHEMISTRY **9701/51**

Paper 5 Planning, Analysis and Evaluation **October/November 2021**

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, use appropriate units and use an appropriate number of significant figures.

INFORMATION

- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **12** pages. Any blank pages are indicated.

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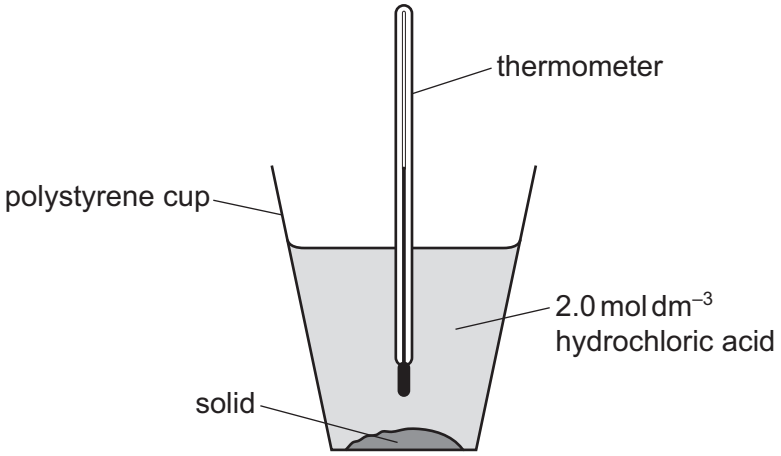
1 Potassium hydrogencarbonate, $KHCO_3$, decomposes when strongly heated to form potassium carbonate, K_2CO_3.

$$2KHCO_3(s) \rightarrow K_2CO_3(s) + CO_2(g) + H_2O(l)$$

A student plans to determine the value for the enthalpy change for this reaction, ΔH_r, which cannot be determined directly. The student carries out two separate experiments using the following apparatus.



Experiment 1 uses solid $KHCO_3$.

Experiment 2 uses solid K_2CO_3.

The following method is used for both experiments:

- Transfer 50.00 cm^3, an excess, of 2 mol dm^{-3} hydrochloric acid into a cup.
- After 2 minutes, record the temperature of the acid.
- Weigh approximately 0.0250 moles of solid.
- Add the solid to the acid, stir the mixture using a thermometer and record the temperature throughout the reaction.

Hazard information: 2 mol dm^{-3} hydrochloric acid is irritant, solid potassium hydrogencarbonate and solid potassium carbonate may cause irritation to the skin and eyes.

The equations for the two reactions are:

reaction 1 $KHCO_3(s) + HCl(aq) \rightarrow KCl(aq) + CO_2(g) + H_2O(l)$

reaction 2 $K_2CO_3(s) + 2HCl(aq) \rightarrow 2KCl(aq) + CO_2(g) + H_2O(l)$

(a) Suggest why it is not possible to measure ΔH_r for the decomposition reaction directly.

.....

..... [1]

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(b) (i) Calculate the mass of 0.0250 moles of each solid. Give your answers to **three** decimal places.

[A_r: K, 39.1; H, 1.0; C, 12.0; O, 16.0]

mass of $KHCO_3$ = ... g

mass of K_2CO_3 = ... g
[1]

(ii) The masses of solid are measured using a three decimal place balance.

Calculate the percentage error in the measurement of the mass of $KHCO_3$.

Show your working.

percentage error = ... [1]

(c) The student obtained the following results.

solid	initial temperature / °C	maximum / minimum temperature / °C	temperature change, ΔT / °C
$KHCO_3$	17.5	14.0	
K_2CO_3	19.0	20.5	

(i) Complete the table by calculating temperature change.

Use the formula $q = mc\Delta T$ to determine the energy change, q, that took place during **experiment 1**. Use q to calculate the enthalpy change of reaction 1, ΔH_1, in kJ mol^{-1}.

Include a sign in your answer.

Assume 1.00 cm^3 of solution has a mass of 1.00 g.
c = 4.18 J g^{-1} K^{-1}

ΔH_1 = ... kJ mol^{-1} [2]

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[Turn over

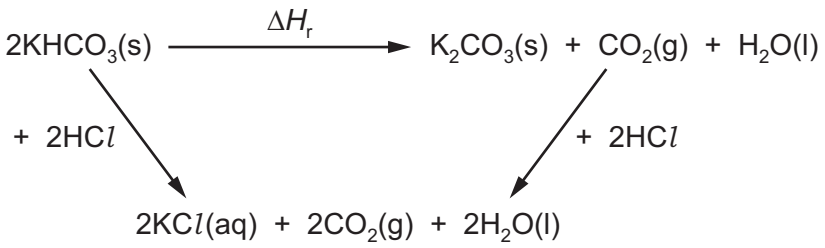
(ii) Use the formula $q = mc\Delta T$ to determine the energy change, q, that took place during **experiment 2**. Use q to calculate the enthalpy change of reaction 2, ΔH_2, in kJ mol^{-1}.

Include a sign in your answer.

Assume 1.00 cm^3 of solution has a mass of 1.00 g.
$c = 4.18\,\text{J g}^{-1}\,\text{K}^{-1}$

ΔH_2 = ... kJ mol^{-1} [2]

(d) Use the following cycle to calculate ΔH_r.



ΔH_r = ... kJ mol^{-1} [2]

(e) A textbook states the value of the enthalpy change for the decomposition of potassium hydrogencarbonate as +76.0 kJ mol^{-1}.

Suggest **two** reasons why the experimental value is different to the actual value.

1 .....

2 .....
[2]

(f) Suggest **one** improvement to the apparatus which would reduce the difference between the experimental value and the actual value.

..... [1]

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(g) Name a suitable piece of apparatus which should be used to measure the volume of acid used in **experiment 1**.

..... [1]

(h) Apart from wearing safety glasses and a lab coat, state **one** safety precaution which must be taken during **experiment 1**. Explain your answer.

.....

.....

..... [1]

[Total: 14]

2 The rate of reaction between calcium carbonate, $CaCO_3$, and hydrochloric acid, HCl, can be followed by collecting and measuring the volume of carbon dioxide produced at 30-second intervals.

The equation for the reaction is:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

(a) A student plans to collect the carbon dioxide by displacement of water.

Draw a labelled diagram of the apparatus that could be used to carry out this experiment.

The apparatus should allow the accurate recording of the volume of carbon dioxide produced.

[3]

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Question 2 continues on the next page.

(b) The student carried out the investigation using an excess of calcium carbonate with dilute hydrochloric acid. The student stopped timing after 330 seconds had passed. The volume of carbon dioxide produced was 93 cm^3.

V_{final} is the final volume of carbon dioxide collected at 330 seconds.
V_t is the volume of carbon dioxide collected at each interval of time, t.

$V_{final}-V_t$ is proportional to the concentration of hydrochloric acid at a given time.

time, t / s	volume of carbon dioxide collected / cm^3	$V_{final}-V_t$ / cm^3
0	0	
30	22	
60	37	
90	50	
120	61	
150	68	
180	75	
210	78	
240	79	
270	87	
300	90	
330	93	

(i) Complete the table. [1]

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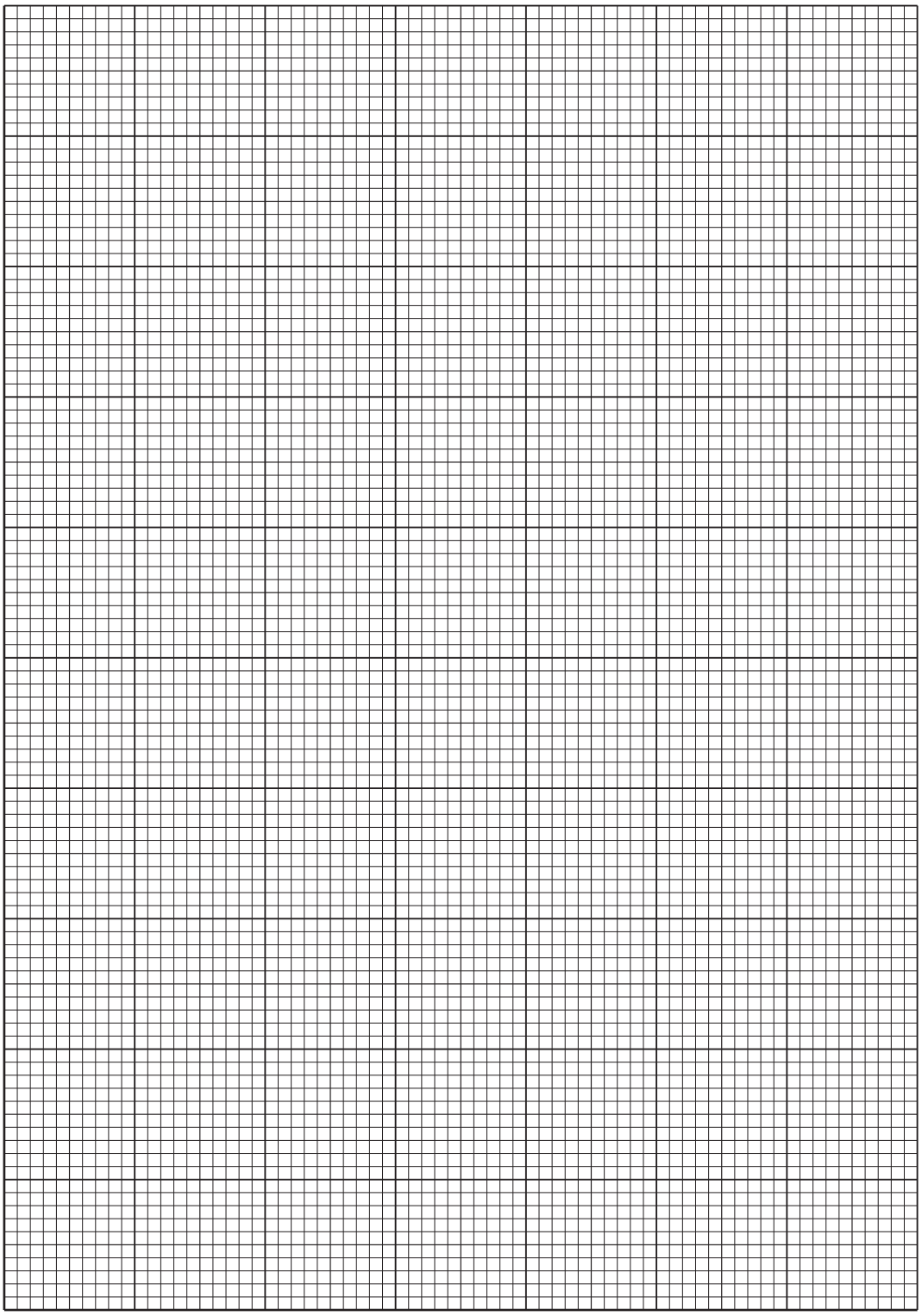
(ii) Plot a graph of $V_{final}-V_t$ (y-axis) against time, t (x-axis).

Use a cross (×) to plot each data point. Draw a curved line of best fit.

$V_{final}-V_t$ / cm^3



time, t / s

[2]

(iii) Circle the point which you consider to be most anomalous. [1]

(iv) Suggest **one** reason for this anomalous point.

.....

..... [1]

(v) Draw construction lines on the graph to calculate two consecutive half-lives for this reaction. Use these half-lives to determine the mean half-life, $t_{\frac{1}{2}}$.

first half-life = ... s

second half-life = ... s

mean half-life, $t_{\frac{1}{2}}$ = ... s
[2]

(vi) The rate constant, k, for this reaction can be calculated using the following expression.

$$t_{\frac{1}{2}} = \frac{0.693}{k}$$

Calculate k.

If you did not obtain a value for $t_{\frac{1}{2}}$ in **(v)** you may use 95 seconds. This is **not** the correct answer.

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

(c) State how an increase in temperature would affect the value of k for this reaction. Explain your answer.

.....

..... [1]

(d) Calcium carbonate is a component of antacid tablets.

An alternative method of studying the rate of reaction between calcium carbonate and hydrochloric acid is:

- Place one antacid tablet into a beaker.
- Add 50 cm^3, **an excess**, of 2.0 mol dm^{-3} hydrochloric acid and start the stop-clock immediately.
- Record the time taken for the fizzing to stop.

(i) An antacid tablet typically contains 1.0 g of $CaCO_3$.

Complete columns A, B and C in the table to show four more concentrations of **excess** HC*l*(aq) which would allow this method to be carried out.

Each sample of HC*l*(aq) must be made by dilution of 2.0 mol dm^{-3} HC*l*.

[A_r: Ca, 40.1; C, 12.0; O, 16.0]

A	B	C	D
volume of 2.0 mol dm^{-3} HC*l* / cm^3	volume of distilled water / cm^3	concentration of HC*l* / mol dm^{-3}	time taken for fizzing to stop / s
50.0	0.0	2.0	

[2]

(ii) Identify the dependent variable in this investigation.

..... [1]

(iii) Suggest how the reliability of the results could be improved.

.....

..... [1]

[Total: 16]

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