1 **(a)** When sodium carbonate is crystallised from solution, it forms crystals of hydrated sodium carbonate, $Na_2CO_3 \cdot xH_2O$, where x is the amount of water of crystallisation present.

You are going to determine the amount of water of crystallisation in $Na_2CO_3 \cdot xH_2O$.

In this question, you will perform a titration and the equation for the reaction in the titration is as follows:

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$$

The data from the titration will then be used to calculate:
- the molar concentration of Na_2CO_3 in **Q**,
- the relative molecular mass, M_r, of $Na_2CO_3 \cdot xH_2O$ and hence the value of x.

Read all the instructions below carefully before starting the experiment in Question 1.

Instructions

P is 1.50 mol/dm^3 aqueous hydrochloric acid.
Q contains 200 g/dm^3 of $Na_2CO_3 \cdot xH_2O$ in deionised water.

(i) Fill the burette with **P**.

Use the pipette to transfer 25.0 cm^3 of **Q** into a conical flask.

Add a few drops of the methyl orange indicator to the solution in the conical flask.

Add **P** from the burette, swirling the flask constantly.

At the end-point, one drop of **P** will turn methyl orange from yellow to orange.

Record your titration results in the table below. Repeat the titration as many times as you consider necessary to achieve consistent results.

Results

[5]

(ii) From your titration results, obtain an average volume of **P** to be used in your calculations. Show clearly how you obtained this volume.

average volume of **P** = …… cm^3 [1]

(iii) **P** is 1.50 mol/dm^3 aqueous hydrochloric acid.

Use your answer from **(a)(ii)** and the equation for the reaction to calculate the molar concentration of Na_2CO_3 in **Q**.

molar concentration of **Q** = …… mol/dm^3 [2]

(iv) Use your answer from **(a)(iii)** to calculate the M_r of $Na_2CO_3 \cdot xH_2O$ to 1 decimal place; and hence the value of x to the nearest whole number.
You **must** show your working.

[M_r: Na_2CO_3, 106; H_2O, 18]

M_r of $Na_2CO_3 \cdot xH_2O$ = ……

x = …… [2]

(v) Before the start of the experiment, a student accidentally rinsed the pipette with solution **P** instead of solution **Q**, before filling it up with solution **Q**.

Describe and explain the effect this would have on the amount of water of crystallisation.

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……..

…….. [2]

(b) Gravimetric analysis is a laboratory technique used to determine the amount of a substance by measuring its mass. The amount of water of crystallisation in sodium carbonate crystals can also be determined gravimetrically.

The water of crystallisation in sodium carbonate crystals can be removed by heating. Sodium carbonate crystals do not decompose at temperatures achievable by a Bunsen flame.

Use this information to outline a step-wise procedure to determine the value of x in sodium carbonate crystals, $Na_2CO_3 \cdot xH_2O$, gravimetrically.

In your procedure you should include:

- the apparatus you would use,
- the measurements you would take (tabulated in a recording table), and
- explain how your measurements would help to determine the value of x.

You can assume the apparatus and reagents normally found in school laboratory are available.

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…… [6]

[Total: 18]

2 The surrounding temperature changes when sodium carbonate reacts with aqueous hydrochloric acid.

In this experiment, you will investigate the enthalpy change of this reaction.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$$

Read all the instructions below carefully before starting the experiment in Question 2.

Instructions

1. Weigh the container labelled **X** with the sodium carbonate.
2. Using a measuring cylinder, add 100 cm^3 of hydrochloric acid, which is an excess, to the Styrofoam cup and measure the temperature of the acid. Record the initial temperature in the table.
3. Start a stopwatch and measure the temperature of the acid every minute for 2 minutes. Record the temperatures.
4. At 3 minutes, transfer the sodium carbonate from the container to the Styrofoam cup. Stir the contents and continue to measure, and record, the temperature every minute up to 8 minutes.
5. Reweigh the container with any residual solid.

(a) (i) Record your results below:

mass of container with sodium carbonate = …….. g

mass of container after adding sodium carbonate to the cup = …….. g

time / min	0	1	2	3	4	5	6	7	8
temperature / ^oC									

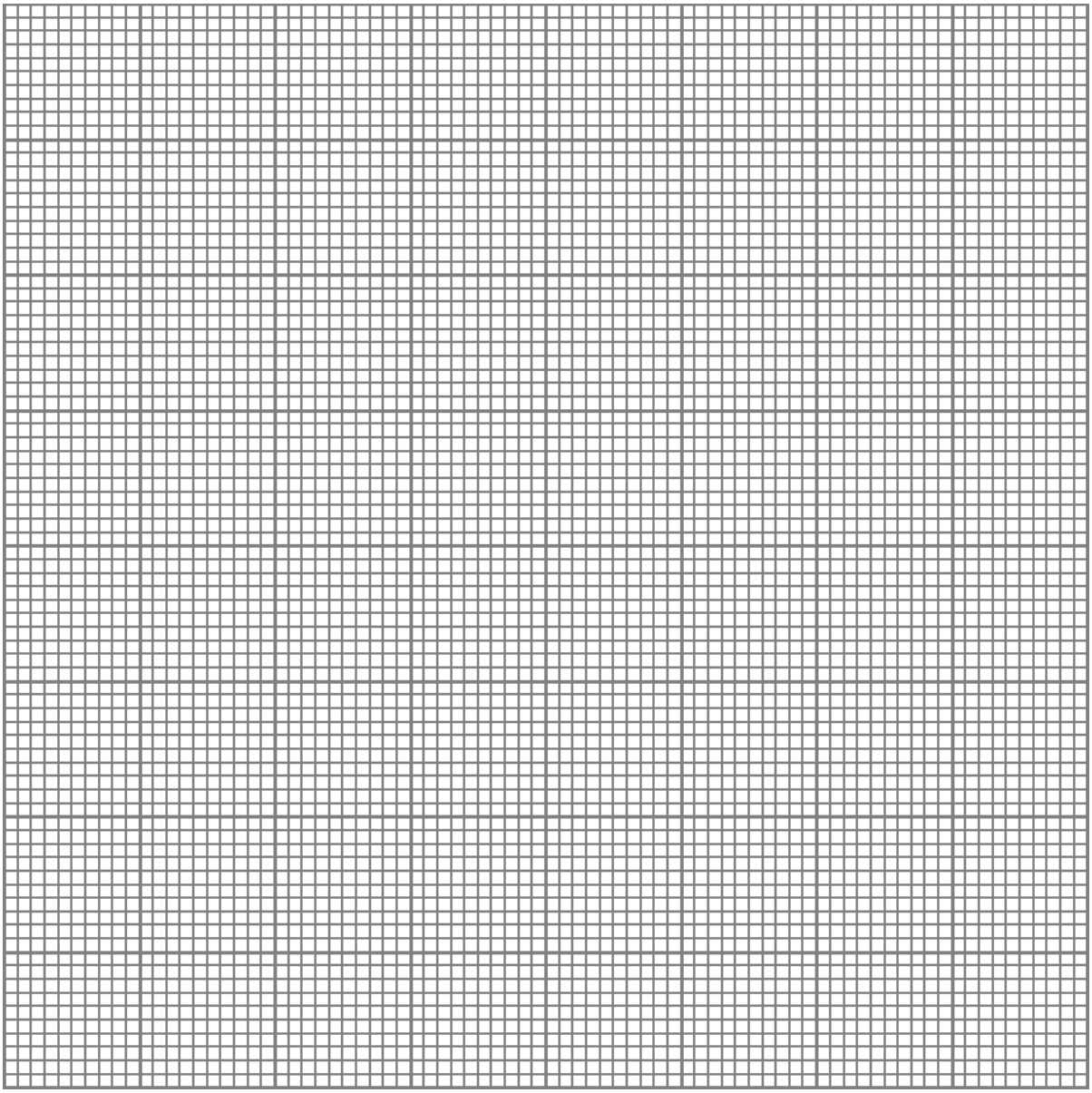
[2]

(ii) Use your results to plot a graph of temperature against time on the grid below.

Complete the graph by drawing two straight lines of best fit. One line should be drawn using data from 0 to 2 minutes and the other line should be drawn using data from 4 to 8 minutes.

Extend both of these lines to 3 minutes.

Draw a vertical line at 3 minutes to connect these lines.



Use your lines from the graph to calculate the maximum temperature change in the experiment.

maximum temperature change = …… ^{o}C [5]

(iii) The amount of heat change in this experiment can be calculated using the expression shown.

heat change (in J) = mass of solution (in g) x maximum temperature change (in ^{o}C) x 4.2

Use the expression to calculate, in J, the amount of heat change.

Assume that 1.0 cm^3 of solution has a mass of 1.0 g.

amount of heat change = …… J [1]

(iv) Calculate the number of moles of sodium carbonate used in the experiment.

[M_r: Na_2CO_3, 106]

number of moles of Na_2CO_3 = …… mol [1]

(v) Calculate the enthalpy change of reaction, in kJ/mol, when one mole of sodium carbonate reacts with hydrochloric acid. Include a sign to indicate if this is an exothermic or endothermic reaction.

enthalpy change of reaction = …… kJ/mol [2]

(vi) State **one** source of error in the results obtained and explain the effect this would have on the value of the enthalpy change of reaction calculated. Suggest therefore **one** improvement you could make to the experiment to reduce this error.

error …….

effect on the value of the enthalpy change of reaction calculated ……

……..

……..

improvement ……....

…… [3]

(b) It is thought that the solid sample of sodium carbonate used is contaminated with barium carbonate.

Describe briefly how you can test to see if any barium carbonate is present in the solid sample of sodium carbonate. Include expected observations in your answer.

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……..

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……..

…… [2]

[Total: 16]

3 Transition elements are found between Groups 2 and 13 on the Periodic Table. These elements can form compounds with a wide range of oxidation states and these compounds tend to be coloured.

Y is a solid sample of a transition metal compound.

Read all the instructions below carefully before starting the experiment in Question 3.

Instructions

(a) Carry out the following tests on **Y**. You should test and identify any gases evolved. Record your observations in the table. If no change is observed for a test, write 'no observable change'.

The volumes given below are approximate and should be estimated rather than measured unless instructed otherwise.

test	instructions	observations
1	To the test-tube containing **Y**, carefully add dilute nitric acid to a depth of approximately 5 cm. **Keep the solution for use in Tests 2 and 3.**	
2	Add a 1 cm depth of the solution from Test 1 into a clean test-tube. Add aqueous sodium hydroxide slowly with shaking until no further change is seen.	
	Leave test-tube to stand for 5 minutes.	
3	Add 1 cm depth of the solution from Test 1 into a clean test-tube. Add a few drops of aqueous silver nitrate.	

[4]

(b) Use the result of your tests to explain why the cation present cannot be Fe^{2+} (aq).

……..

…… [1]

(c) Use the results of your tests to explain why the anion present cannot be CO_3^{2-} (aq).

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…… [1]

[Total: 6]

END OF PAPER

NOTES FOR QUALITATIVE ANALYSIS

Test for anions

anion	test	test result
carbonate (CO_3^{2-})	add dilute acid	effervescence, carbon dioxide produced
chloride (Cl^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
nitrate (NO_3^-) [in solution]	add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced
sulfate (SO_4^{2-}) [in solution]	acidify with dilute nitric acid, then add aqueous barium nitrate	white ppt.

Test for aqueous cations

cation	effect of aqueous sodium hydroxide	effect of aqueous ammonia
aluminium (Al^{3+})	white ppt., soluble in excess giving a colourless solution	white ppt., insoluble in excess
ammonium (NH_4^+)	ammonia produced on warming	-
calcium (Ca^{2+})	white ppt., insoluble in excess	no ppt.
copper(II) (Cu^{2+})	light blue ppt., insoluble in excess	light blue ppt., soluble in excess giving a dark blue solution
iron(II) (Fe^{2+})	green ppt., insoluble in excess	green ppt., insoluble in excess
iron(III) (Fe^{3+})	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess
zinc (Zn^{2+})	white ppt., soluble in excess giving a colourless solution	white ppt., soluble in excess giving a colourless solution

Test for gases

gas	test and test result
ammonia (NH_3)	turns damp red litmus paper blue
carbon dioxide (CO_2)	gives white ppt. with limewater (ppt. dissolves with excess CO_2)
chloride (Cl_2)	bleaches damp litmus paper
hydrogen (H_2)	"pops" with a lighted splint
oxygen (O_2)	relights a glowing splint
sulfur dioxide (SO_2)	turns aqueous acidified potassium manganate(VII) from purple to colourless