1 Sodium hydrogencarbonate, $NaHCO_3$, is used as baking soda in cooking. Baking soda may also contain small amounts of other chemicals.
In this experiment, you will determine the percentage purity by mass of an impure sample of $NaHCO_3$ by titration with sulfuric acid.

FA 1 is 0.0500 mol dm^{-3} sulfuric acid, H_2SO_4.
FA 2 is impure $NaHCO_3$.
methyl orange

(a) Method

Preparing a solution of FA 2

- Weigh the stoppered container of **FA 2**. Record the mass in the space below.
- Tip all the **FA 2** into the beaker.
- Reweigh the container with its stopper. Record the mass.
- Calculate and record the mass of **FA 2** used.
- Add approximately 100 cm^3 of distilled water to the **FA 2** in the beaker.
- Stir the mixture with a glass rod until all the **FA 2** has dissolved.
- Transfer this solution into the 250 cm^3 volumetric flask.
- Wash the beaker with distilled water and transfer the washings to the volumetric flask.
- Rinse the glass rod with distilled water and transfer the washings to the volumetric flask.
- Make up the solution in the volumetric flask to the mark using distilled water.
- Shake the flask thoroughly.
- This solution of impure $NaHCO_3$ is **FA 3**. Label the flask **FA 3**.

Results

mass of container + FA2 / g	16.34
mass of container + residual FA2 / g	14.33
mass of FA2 used / g	2.01

Titration

- Fill the burette with **FA 1**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add several drops of methyl orange.
- Perform a rough titration and record your burette readings in the space below.

Final burette reading / cm^3	21.65
Initial burette reading / cm^3	0.00
Volume of FA1 used / cm^3	21.65

The rough titre is ....21.65.... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 1** added in each accurate titration.

Keep FA 1 for use in Question 2.

Final burette reading / cm^3	43.50	21.50	
Initial burette reading / cm^3	22.00	0.00	
Volume of FA1 used / cm^3	21.50	21.50	
	✓	✓	

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 1** to be used in your calculations.
Show clearly how you obtained this value.

$\frac{21.50 + 21.50}{2} = 21.50$

25.0 cm^3 of **FA 3** required ......21.50...... cm^3 of **FA 1**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate the number of moles of sulfuric acid present in the volume of **FA 1** calculated in **(b)**.

$n = cV$

$= 0.0500 \times \frac{21.50}{1000}$

moles of H_2SO_4 = ...1.075×10^{-3}...... mol

(ii) Balance the equation for the reaction of sulfuric acid and sodium hydrogencarbonate. State symbols are not required.

..2..$NaHCO_3$ + ..1..H_2SO_4 → ..1..Na_2SO_4 + ..2..CO_2 + ..2..H_2O

(iii) Using your answers to **(i)** and **(ii)**, calculate the number of moles of sodium hydrogencarbonate used in each titration.

mole ratio $NaHCO_3 : H_2SO_4$

2 : 1

x : 1.075×10^{-3} ✗

moles of $NaHCO_3$ = ...2.15×10^{-3}...... mol

(iv) Using your answer to **(iii)**, calculate the mass of sodium hydrogencarbonate present in the mass of **FA 2** used to prepare **FA 3**.

25.0 cm³ — 2.15 x10⁻³ mol
250 cm³ — x

0.0215 mol

m = mol x Mr
= 0.0215 x 84
= 1.81 g

mass of $NaHCO_3$ = 1.81 g

(v) Calculate the percentage purity by mass of the impure sodium hydrogencarbonate sample, **FA 2**.

$\frac{1.81}{2.01} \times 100 = 90.1$

percentage purity by mass of impure $NaHCO_3$, **FA 2** = 90.1 %

(vi) What did you assume about the impurities in **FA 2** when you calculated the percentage purity?

The impurity does not react with sulfuric acid and sodium hydrogen carbonate.

(vii) A volumetric flask was labelled 250.0 ±0.10 cm³.

Calculate the maximum percentage error when using this volumetric flask.

$\% \text{ error} = \frac{\text{error}}{\text{Volume}} \times 100 = \frac{0.10}{250.0} \times 100$

maximum percentage error = 0.040 %

[7]

[Total: 16]

2 When baking soda is heated, carbon dioxide is produced. In this experiment you will investigate the reaction taking place when the sodium hydrogencarbonate in baking soda is thermally decomposed.

FA 4 is baking soda (impure $NaHCO_3$). Its composition is the same as that of **FA 2**.

(a) Method

Record all your readings in the space below.

- Weigh the crucible with its lid.
- Transfer all the **FA 4** from the container into the crucible.
- Weigh the crucible, lid and **FA 4**.
- Calculate and record the mass of **FA 4** used.
- Place the crucible and contents on a pipe-clay triangle.
- Heat gently, with the lid on, for approximately one minute.
- Heat strongly, with the lid off, for a further three minutes.
- Replace the lid and leave the crucible to cool for at least five minutes.

- When it is cool, weigh the crucible with its lid and contents.
- Heat strongly, with the lid off, for a further two minutes.
- Replace the lid and leave the crucible to cool for at least five minutes.
- When it is cool, weigh the crucible with its lid and contents.
- Calculate and record the mass of residue obtained.
- This residue is **FA 5**. Keep this for use in **2(d)**.

Results

mass of crucible + Lid / g	34.80
mass of crucible with Lid + FA4 / g	36.83
mass of FA4 used / g	2.03
mass of crucible + Lid + residual solid / g	36.12 36.12
mass of residue / g	1.32

I	
II	
III	
IV	

[4]

(b) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Use the percentage purity by mass of **FA 2** you calculated in **1(c)(v)**, to calculate the mass of sodium hydrogencarbonate in the sample of **FA 4** that you weighed out.

(If you were unable to carry out the calculation in **1(c)(v)**, assume that the percentage purity by mass of **FA 2** is 95.8%.)

$\frac{2.03}{100} \times 90.1$

mass of $NaHCO_3$ in **FA 4** weighed out = 1.83 g

(ii) Calculate the mass of impurity present in your sample of **FA 4**.

2.03 − 1.83 = 0.200g

mass of impurity = 0.200 g

(iii) The impurity in **FA 4** does not decompose when it is heated.
This means that the residue, **FA 5**, contains the mass of impurity calculated in **(ii)** together with the solid decomposition product of sodium hydrogencarbonate.

Calculate the mass of the solid decomposition product.

1.32 − 0.200

mass of solid decomposition product = 1.12 g

(iv) Use your answers to **(i)** and **(iii)** to calculate the mass of solid decomposition product that would be obtained if 84.0 g of **pure** sodium hydrogencarbonate were heated.

1.83 — 1.12
84.0 — x ✗

50.4g

mass of solid decomposition product = 51.4 g

(v) A student carried out the experiment by heating to constant mass and calculated that heating 84.0 g of pure $NaHCO_3$ would produce 52.3 g of the solid decomposition product. The student then suggested the following equation for the thermal decomposition of sodium hydrogencarbonate.

$$NaHCO_3(s) \rightarrow NaOH(s) + CO_2(g)$$

Use data from the Periodic Table on page 12 to explain why the student's suggestion cannot be correct.

If student is correct then the mass of solid decomposition product would be 40. OR

mole ratio is 1: 1.3 not 1:1

[4]

(c) (i) Why was the lid put on while the crucible and its contents cooled?

Lid reduces absorption of water (vapour) by solid while cooling.

(ii) The experiment could be made more accurate by heating to constant mass or using a more accurate balance. Suggest a further improvement to make the experiment more accurate.

Repeat the experiment and ignore anomalous results to obtain consistent results. OR Use larger mass of FA4.

[2]

(d) (i) Pour a 1 cm depth of sulfuric acid, **FA 1**, into a test-tube.
Add some **FA 5** from the crucible to the acid in the test-tube.
Record all your observations.

Effervescence of a gas which form white ppt with Lime water.
Solid dissolves to form a colourless solution

(ii) Use your observation(s) in **(i)** to identify an anion present in **FA 5**.
Explain your answer.

identity Carbonate ion / CO_3^{2-}

explanation CO_2 gas Liberated when sulfuric acid was added.

(iii) Steam is one of **three** products obtained when sodium hydrogencarbonate is thermally decomposed.

Use your answer in **(ii)** to complete and balance the equation for the thermal decomposition of sodium hydrogencarbonate. Include state symbols.

2 $NaHCO_3(s) \rightarrow$ .... $H_2O(g)$ + ... $CO_2(g)$ + $Na_2CO_3(s)$

(iv) State whether the balanced equation in **(iii)** agrees with the student's results given in **2(b)(v)**.
Show working in order to explain your answer.

from equation mass of residue 84g → $\frac{106}{2}$g = 53g

Student get 52.3g. Equation supports the student result.

[4]

[Total: 14]

3 **Qualitative Analysis**

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.
Rinse and reuse test-tubes and boiling tubes where possible.

(a) (i) **FA 6** and **FA 7** are aqueous solutions.
Each solution contains one cation and one anion from those listed in the Qualitative Analysis Notes.

Use 1 cm depths of **FA 6** or **FA 7** in test-tubes for the following tests.
Complete the table by recording your observations.

test	*observations*	
	FA 6	**FA 7**
Add a few drops of aqueous barium chloride or aqueous barium nitrate, then	no change	white ppt
add dilute nitric acid.	no change	ppt remains insoluble
Add a few drops of aqueous silver nitrate.	white ppt	no change
Add a small spatula measure of sodium carbonate. Shake the mixture.	no reaction	effervescence of a gas which formed white ppt with Lime water

(ii) From your observations, deduce which solution, **FA 6** or **FA 7**, has the lower pH.
Give your evidence.

solution with lower pH ......FA7.......

evidence ....CO_2 gas given off with Sodium carbonate..........

....

[4]

(b) Choose **two** reagents that would allow you to identify the cations in **FA 6** and **FA 7**.

reagents ....aq. NaOH.. and ....aq. NH_3................................

Use these reagents to test solutions **FA 6** and **FA 7**.
Record all your observations in the space below.

tests	observations	
	FA6	FA7
To 1cm depth of solution add 1cm depth of aq. NaOH then in excess	off-white ppt, turned brown on contact with air; insoluble in excess	white ppt; soluble in excess
To 1cm depth of solution add 1 cm depth of aq. NH_3 then in excess	off-white ppt turned brown on contact with air; insoluble in excess	white ppt; insoluble in excess

[4]

(c) Deduce the chemical **formulae** of **FA 6** and **FA 7**.

FA 6 ....$MnCl_2$..

FA 7 ....$Al_2(SO_4)_3$.........................

[2]

[Total: 10]