



Answer **all** the questions in the spaces provided.

1 Investigation of an organic compound and an inorganic compound

FA 1 is an aqueous solution of an organic compound, **Y**, which contains two different functional groups.

FA 2 contains two cations and one anion.

You will perform tests to identify:

- the functional groups in **Y** and hence deduce its possible structure
- the ions present in **FA 2**.

- (a) (i) Carry out the following tests. Carefully record your observations in Table 1.1.
The volumes given below are approximate and should be estimated rather than measured.

Test and identify any gases evolved.

If there is no observable change, write **no observable change**.

Table 1.1

tests		observations
1	To a 1 cm depth of dilute sulfuric acid in a test-tube, add 2 cm of aqueous potassium manganate(VII). Then add 1 cm depth of FA 1 . Allow to stand for 10 minutes, with occasional shaking. Continue with the remaining parts of Question 1.	Upon addition of FA1, purple manganate (VII) decolourises On standing, solution remains colourless. Some effervescence observed
2	To a 2 cm depth of FA 1 in a test-tube, add all of the solid sodium carbonate provided in the stoppered tube.	Effervescence of gas that gives white ppt with limewater. The gas is CO ₂
3	Test solution FA 1 with Universal Indicator paper.	Universal indicator paper turns dark red. The colour corresponds to pH 1. 

[3]





- (II) The molecular formula of **Y** is $C_4H_4O_4$. Draw one possible structure for **Y**. Use your observations in Table 1.1.

[1]

- (b) (i) To a 1 cm depth of **FA 2** in a test-tube, add aqueous ammonia slowly, with shaking, until no further change is seen. Record all your observations.

Green ppt formed is insoluble in excess $NH_3(aq)$

The green ppt turns brown upon standing.

[2]

- (ii) Deduce the identity of one of the cations in **FA 2** using your results in (b)(i).

[1]





- (iii) Devise and perform a series of simple tests to identify the anion and the remaining cation in **FA 2**. Your tests should be based on the Qualitative Analysis Notes on pages 15–16 and should use only the bench reagents provided. Record your tests and observations in the space below.

Any test requiring heating MUST be performed in a boiling tube.

The remaining cation does not form an insoluble hydroxide in excess sodium hydroxide. The anion is not a nitrate, nitrite or sulfite ion.

To test for cation:

To 1cm depth of FA2, add NaOH(aq) in excess. Filter the suspension and collect the filtrate for subsequent tests. [to isolate the 2 nd cation in the filtrate]	Green residue that turns brown on standing. Filtrate is colourless.
To test for Ba ²⁺ /Ca ²⁺ :	
To test for Al ³⁺ /Zn ²⁺ :	
To test for NH ₄ ⁺ :	

To test for anion:

To test for CO ₃ ²⁻ :	
To test for SO ₄ ²⁻ :	
To test for Cl ⁻ , Br ⁻ , I ⁻ :	

[5]

- (iv) Use your observations in (b)(iii) to deduce the identity of the other cation and the anion in **FA 2**.

cation NH₄⁺

anion SO₄²⁻

[2]
[Total: 14]

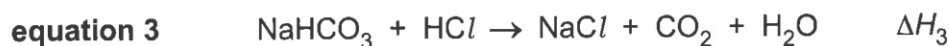
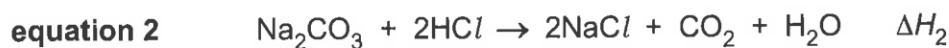


2 Determination of the molar enthalpy change of a reaction by an indirect method

Sodium hydrogencarbonate decomposes according to equation 1.



Sodium carbonate and sodium hydrogencarbonate each react with hydrochloric acid.



In this question, you will perform an experiment to determine a value for ΔH_2 . You will use data provided to calculate ΔH_3 and hence a value for ΔH_1 .

You are provided with:

- solid **FA 3**, Na_2CO_3
- **FA 4**, 2.0 mol dm^{-3} hydrochloric acid, HCl .

(a) (i) Determination of the molar enthalpy change of reaction, ΔH_2

In this experiment, you will measure the temperature of hydrochloric acid in a polystyrene cup at regular time intervals, before and after sodium carbonate is added. You will analyse your results graphically to obtain an accurate value for the temperature change caused by the reaction.

You will use this value to calculate the heat change, q , for the experiment and hence determine a value for the molar enthalpy change of the reaction, ΔH_2 .

In the space provided on page 6, prepare tables in which to record for your experiment:

- all weighings to an appropriate level of precision
- all values of temperature, T , to an appropriate level of precision
- all values of time, t , recorded to 0.5 min.

It is important that you measure each temperature at the specified time.

Procedure

1. Weigh the capped container containing solid **FA 3**. Record the mass in your table on page 6.
2. Place one polystyrene cup inside another polystyrene cup and place both in a glass beaker.
3. Use the measuring cylinder to transfer 50 cm^3 of **FA 4** (an excess) into the polystyrene cup.
4. Carefully stir the **FA 4** in the polystyrene cup with the thermometer. Read and record the temperature, T . Start the stopwatch ($t = 0.0 \text{ min}$). The stopwatch must be left to run for the rest of the experiment.
5. Continue to stir **FA 4**. Read and record T every 0.5 minute for two minutes.
6. At **exactly** 2.5 minutes, transfer all the solid **FA 3** to the polystyrene cup. Stir the mixture but do not read T .





7. Continue to stir the mixture. Read and record T at $t = 3.0$ min and every 0.5 min until $t = 8.0$ min.
8. Reweigh the empty capped container. Record this mass in your table below.

Results

Mass of FA3 in capped container / g	9.429
Mass of empty capped container / g	5.272
Mass of FA3 used / g	4.157

Time/min	Temp/ °C
0.0	30.2
0.5	30.2
1.0	30.2
1.5	30.2
2.0	30.2
2.5	-
3.0	36.0
3.5	36.2
4.0	36.1

Time/min	Temp/ °C
4.5	35.9
5.0	35.8
5.5	35.7
6.0	35.6
6.5	35.6
7.0	35.4
7.5	35.2
8.0	35.2

[3]

- (II) Plot a graph of temperature, T , on the y-axis, against time, t , on the x-axis, on the grid in Fig. 2.1.

Draw a best-fit straight line taking into account all of the points before $t = 2.5$ min.

Draw another best-fit straight line taking into account all of the points after the temperature of the mixture has started to fall steadily.

Extrapolate (extend) both lines to $t = 2.5$ min.

[3]



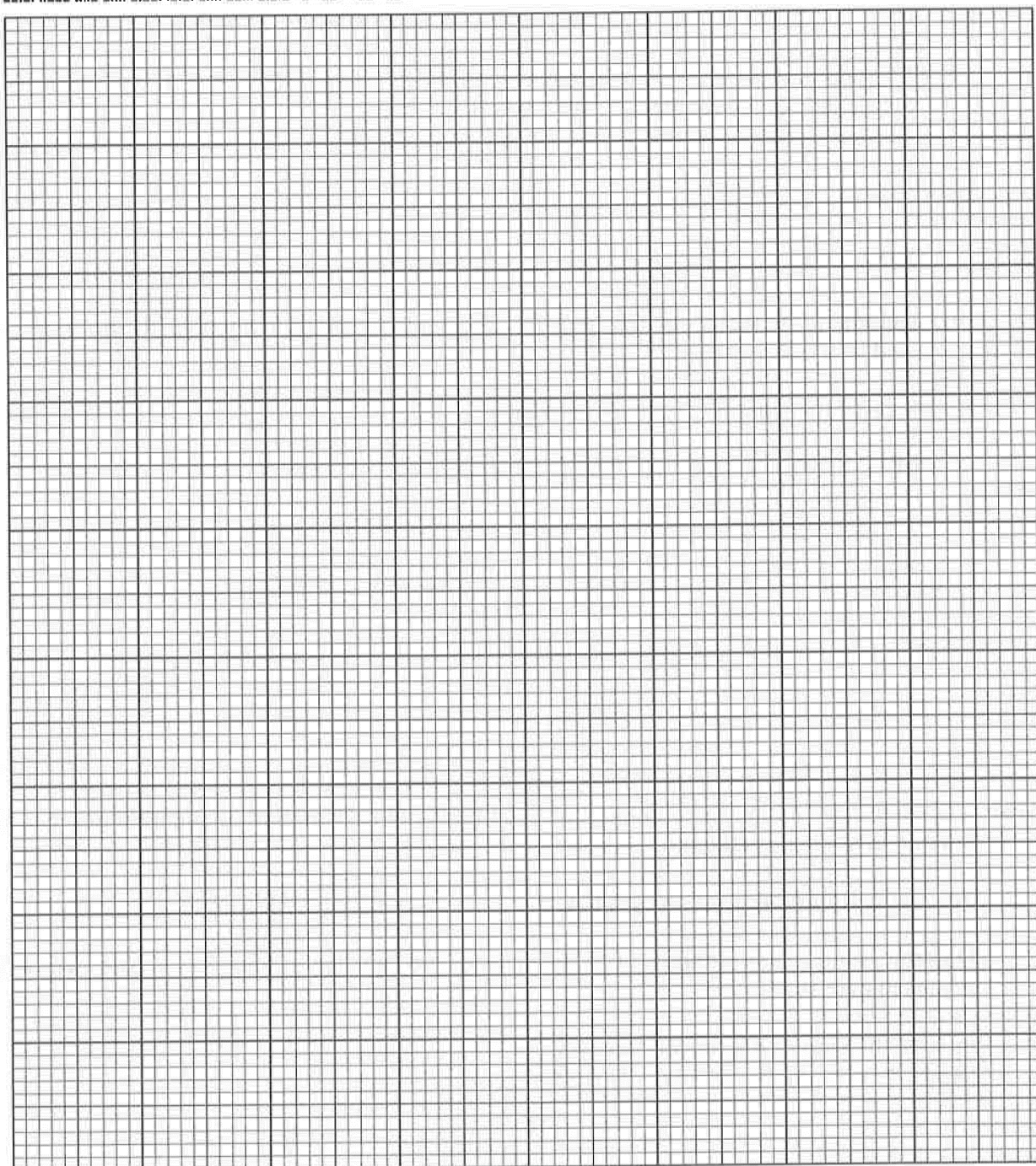


Fig. 2.1

- (iii) From your graph, read the minimum temperature, $T_{\min}$, and the maximum temperature, $T_{\max}$, at $t = 2.5$ min. Record these values in the spaces below.

Calculate the temperature change, ΔT , at $t = 2.5$ min.

$T_{\min} = \dots\dots\dots$

$T_{\max} = \dots\dots\dots$

$\Delta T = \dots\dots\dots$

[1]





- (iv) Calculate the heat change, q , for your experiment using the value you calculated in (a)(iii).

Assume that the specific heat capacity of the reaction mixture is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$, and that the density of the reaction mixture is 1.00 g cm^{-3} .

$$q = \dots\dots\dots [1]$$

- (v) Determine the molar enthalpy change, ΔH_2 , for the reaction in equation 2. The hydrochloric acid is in excess.

Include the sign of ΔH_2 in your answer.

[A_r : C, 12.0 O, 16.0 Na, 23.0]

$$\Delta H_2 = \dots\dots\dots [3]$$

- (b) A student repeats the experiment, but uses 4.00 g of sodium hydrogencarbonate, NaHCO_3 , instead of sodium carbonate.

The temperature **decreases** by 6.6°C .

Determine the molar enthalpy change, ΔH_3 , for the reaction in equation 3. The hydrochloric acid is in excess.

Include the sign of ΔH_3 in your answer.

[A_r : H, 1.0 C, 12.0 O, 16.0 Na, 23.0]

$$\Delta H_3 = \dots\dots\dots [2]$$



- (c) Calculate a value for ΔH_1 for the reaction in equation 1.

Use your answers from (a)(v) and (b).

$$\Delta H_1 = \dots\dots\dots [5]$$

- (d) Which piece of apparatus causes the greatest percentage error in your experiment? Explain why.

.....
 [1]

[Total: 19]





3 Determination of the amount of water of crystallisation in sodium carbonate crystals, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$

When sodium carbonate is crystallised from solution, it forms crystals of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

In this question, you will perform a titration. The data from the titration will be used to calculate:

- the concentration of Na_2CO_3 in **FA 5**
- the M_r of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ and hence the value of x .

FA 5 contains 10.8 g dm^{-3} of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ in deionised water.

FA 6 is $0.100 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

Solution I is methyl orange indicator.

(a) (i) Titration of **FA 5** against **FA 6**

- Fill the burette with **FA 6**.
- Use the pipette to transfer 25.0 cm^3 of **FA 5** into a 250 cm^3 conical flask.
- Add a few drops of **Solution I** to the same conical flask.
- Titrate the mixture in the conical flask until the end-point is reached.
- Record your titration results, to an appropriate level of precision, in the space provided below.
- Repeat points 2 to 5 until consistent results are obtained.

Titration results

Titration	1	2
Final burette reading / cm^3	19.20	38.50
Initial burette reading / cm^3	0.00	19.20
Volume of FA 6 used / cm^3	19.20	19.30

[3]

- (ii) From your titrations, obtain a suitable volume of **FA 6** to be used in your calculations. Show clearly how you obtained this volume.

volume of **FA 6** = cm^3 [4]



- (b) (i) The equation for the reaction in the titration is shown.



Calculate the concentration of Na_2CO_3 in **FA 5**.

concentration of Na_2CO_3 = mol dm^{-3} [1]

- (ii) Determine the M_r of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ and hence the value of x .

You **must** show your working.

[A_r : H, 1.0 C, 12.0 O, 16.0 Na, 23.0]

M_r of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ =

x = [2]





- (c) (i) The reaction in the titration produces carbon dioxide. Some carbon dioxide dissolves in the solution. Dissolved carbon dioxide is acidic.

Methyl orange indicator changes colour over a pH range of 3.1 to 4.4.

Explain why the dissolved carbon dioxide does **not** decrease the end-point of the titration.

.....

 [1]

- (ii) A student follows the procedure described using sodium carbonate crystals with a different amount of water of crystallisation. The student calculates the value of x in these crystals to be 6.94. The formula of these crystals is $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

Calculate the difference between the actual value and the student's calculated value as a percentage. This is the percentage error.

Percentage error =% [1]

- (iii) The student calculates that the maximum total percentage error of the whole procedure is 1.08%.

Did the student perform the experiment well? Explain your answer.

.....
 [1]





The amount of water of crystallisation in sodium carbonate crystals can also be determined gravimetrically (by weighing).

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.

Plan an investigation to determine the value of x in sodium carbonate crystals, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, gravimetrically.

- approximately 10 g of sodium carbonate crystals, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$
- the equipment normally found in a school or college laboratory.

- the apparatus you would use
- the quantities you would use
- the procedure you would follow
- the measurements you would make (you may find it useful to label measurements in your plan as M1, M2 etc.)
- how you would ensure that an **accurate** and **reliable** value of x is obtained.

[illegible]

[6]

- [A_r: H, 1.0 C, 12.0 O, 16.0 Na, 23.0]

[3]

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Qualitative Analysis Notes

[ppt. = precipitate]

(a) Reactions of aqueous cations

cation	reaction with	
	NaOH(aq)	NH ₃ (aq)
aluminium, Al ³⁺ (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH ₄ ⁺ (aq)	ammonia produced on heating	—
barium, Ba ²⁺ (aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. with high [Ca ²⁺ (aq)]	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe ²⁺ (aq)	green ppt., turning brown on contact with air insoluble in excess	green ppt., turning brown on contact with air insoluble in excess
iron(III), Fe ³⁺ (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg ²⁺ (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn ²⁺ (aq)	off-white ppt., rapidly turning brown on contact with air insoluble in excess	off-white ppt., rapidly turning brown on contact with air insoluble in excess
zinc, Zn ²⁺ (aq)	white ppt. soluble in excess	white ppt. soluble in excess

**(b) Reactions of anions**

anion	reaction
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives pale cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil; NO liberated by dilute acids (colourless $\text{NO} \rightarrow$ (pale) brown NO_2 in air)
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	SO_2 liberated with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in dilute strong acids)

(c) Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, 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

(d) Colour of halogens

halogen	colour of element	colour in aqueous solution	colour in hexane
chlorine, Cl_2	greenish yellow gas	pale yellow	pale yellow
bromine, Br_2	reddish brown gas/liquid	orange	orange-red
iodine, I_2	black solid/purple gas	brown	purple

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