

Chemistry – Paper 3 (Practical)

Subject content:

Practical Assessment (Paper 3) [1h 50 mins, 40 marks]

Skill areas:

- Planning (P)
- Manipulation, measurement and observation (MMO)
- Presentation of data and observations (PDO)
- Analysis, conclusions and evaluation (ACE)

The assessment of Planning (P) will have a weighting of 15%.

The assessment of skill areas MMO, PDO and ACE will have a weighting of 85%.

This paper consists of a variable number of compulsory practical questions.

A copy of the *Notes for Qualitative Analysis* will be provided.

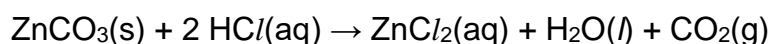
Planning (P)

- identify key variables for a given question/problem
- outline an experimental procedure to investigate the question/problem
- describe how the data should be used to reach a conclusion
- identify the risks of the experiment and state precautions that should be taken to keep risks to a minimum

Solid **X** is a mixture containing only zinc carbonate and an unreactive substance.

Suggest an experiment you could do to determine the percentage of zinc carbonate in solid **X**.

You should state clearly what quantities you would measure and how you would use your results to calculate the percentage of zinc carbonate in **X**.



1. Measure 1.0 g of solid X using electronic balance + place in test tube
2. Add excess hydrochloric acid to X
3. When effervescence stops, filter mixture to obtain residue
4. Wash + dry + weigh residue (unreactive substance)
5. % of zinc carbonate = $\frac{1 \text{ g} - \text{mass of unreactive substance}}{1 \text{ g}} \times 100\%$

OR



1. Measure 1.0 g of solid X using electronic balance
2. Place solid X in crucible / dry hard glass test tube + heat for 10 mins
3. Allow test tube and its contents to cool + measure mass of solid X after heating
4. Repeat heating and cooling of solid X until constant mass is obtained (to ensure that carbonate has fully decomposed)
5. Difference in two masses = mass of carbon dioxide produced
6. No. of moles of $\text{CO}_2 = \frac{\text{difference in mass}}{44 \text{ g/mol}}$
7. No. of moles of $\text{ZnCO}_3 = \text{no. of moles of } \text{CO}_2$
8. Mass of $\text{ZnCO}_3 = \text{no. of moles of } \text{ZnCO}_3 \times \text{molar mass of } \text{ZnCO}_3$
9. % mass of $\text{ZnCO}_3 = \frac{\text{mass of } \text{ZnCO}_3}{1 \text{ g}} \times 100\%$

Mark scheme:

- Variables – constant and independent
- Procedure
- Apparatus
- Processing of data (include how % mass is calculated)

Metal carbonates decompose to form metal oxides and carbon dioxide on heating. For example,



The ease of decomposition of metal carbonates depends on the order of reactivity of the metals. Suggest an experiment you could carry out to determine the relationship between the ease of decomposition of zinc carbonate, copper(II) carbonate, magnesium carbonate and calcium carbonate and the position of these metals in the reactivity series.

You should state clearly what quantities you would measure and how you would use your results to determine the position of the metals in the reactivity series.

1. Measure 1.0 g of zinc carbonate using electronic balance + place in dry test tube
2. Connect test tube to graduated gas syringe
3. Heat test tube + start stopwatch immediately
4. Record volume of gas produced after 5 mins
5. Repeat using copper(II) carbonate, magnesium carbonate, calcium carbonate
6. Compare volume of gas collected from heating the four carbonates

If the volume of gas produced by heating copper(II) carbonate is the largest followed by zinc carbonate followed by magnesium carbonate and the smallest volume is obtained by heating calcium carbonate,

then the reactivity of the metals in increasing order is copper, followed by zinc, magnesium and calcium.

Mark scheme:

- Variables – constant and independent
- Procedure
- Apparatus
- Processing of data

[Note: this approach assumes that the metal carbonate has not fully decomposed after 5 min of heating. The data collected will help us to determine the initial rate of decomposition and draw conclusion about the stability of the metal carbonate.]

Reason: although mass of carbonates used is kept constant, the number of moles of carbonate used is different. Hence, the volume of carbon dioxide produced when the metal carbonate fully decomposed will be different. It will not be a fair test if we were to compare the volume of carbon dioxide produced when the metal carbonate is allowed to fully decompose]

R is a solution of acid. Describe a method you could use to determine its concentration.

You can assume that all the apparatus and reagents normally found in a school laboratory are available. You should include the measurements you would take and how you would use your results to calculate the concentration of the acid in R.

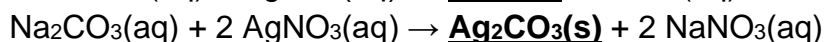
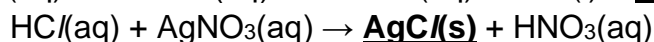
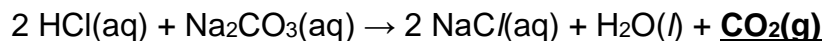
You may not use a titration method.

1. Add 25.0 cm³ acid to excess magnesium (reactive metal) / calcium carbonate (carbonate)
2. Collect and measure total volume of gas produced (hydrogen or carbon dioxide) using graduated gas syringe
3. Calculate no. of moles of gas (volume ÷ molar volume)
4. Using mole ratio, calculate no. of moles of acid
5. Concentration of acid = $\frac{\text{no. of moles of acid}}{\text{volume of acid}}$

Mark scheme:

- Identify appropriate metal / carbonate
- Ensure that acid is the limiting reactant
- State the measurements made and the apparatus used
- Processing of data to determine concentration of acid

You are provided with three solutions P, Q and R. These three solutions contain dilute hydrochloric acid, aqueous sodium carbonate and aqueous silver nitrate. With no other reagents available, describe an experiment you will carry out to identify P, Q and R. You should give full experimental details and the results you would expect.



Add P to Q	Identity of R	Add P to R	Identity of P	Identity of Q
effervescence	silver nitrate	white precipitate	hydrochloric acid	sodium carbonate
		brown precipitate	sodium carbonate	hydrochloric acid
white precipitate	sodium carbonate	effervescence	hydrochloric acid	silver nitrate
		brown precipitate	silver nitrate	hydrochloric acid
brown precipitate	hydrochloric acid	effervescence	sodium carbonate	silver nitrate
		white precipitate	silver nitrate	sodium carbonate

Add P to Q.

If there is effervescence, one of them is hydrochloric acid while the other is sodium carbonate. Then R will be silver nitrate.

Add P to silver nitrate (R).

If a white precipitate is formed, then P is hydrochloric acid. Q will be sodium carbonate.

If a brown precipitate is formed, P is sodium carbonate while Q is hydrochloric acid.

OR

Add P to Q.

If a white precipitate is formed, one of them is hydrochloric acid while the other is silver nitrate. Then R will be sodium carbonate.

Add P to sodium carbonate (R).

If there is effervescence, then P is hydrochloric acid. Q will be silver nitrate.

If a brown precipitate is formed, P is silver nitrate while Q is hydrochloric acid.

OR

Add P to Q.

If a brown precipitate is formed, one of them is silver nitrate while the other is sodium carbonate. Then R will be hydrochloric acid.

Add P to hydrochloric acid (R).

If there is effervescence, then P is sodium carbonate. Q will be silver nitrate.

If a white precipitate is formed, P is silver nitrate while Q is sodium carbonate.

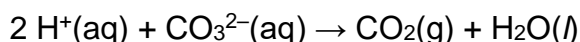
2018 O-Level

Sea shells are used to make cement because of their high carbonate content.

Cockle shells, which are a type of sea shell, are said to contain nearly 60% carbonate, CO_3^{2-} , by mass.

Given 1 g of cockle shells, outline a method by which the percentage mass of carbonate in the shell can be determined.

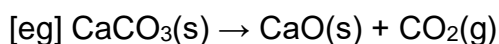
You can assume all the apparatus and reagents normally found in the school laboratory are available. In your method you should note any assumptions that you make, including measurements you would take and explain how you would use your results to determine the percentage by mass of carbonate in the cockle shells.



Assumption: Only carbonate and no other substance present in cockle shells would react with hydrochloric acid

1. Place crushed cockle shells in boiling tube
2. Add excess hydrochloric acid to cockle shells
3. Connect boiling tube to graduated gas syringe using delivery tube
4. Measure volume of gas produced using graduated gas syringe
5. No. of moles of CO_2 = volume of $\text{CO}_2 \div 24 \text{ dm}^3/\text{mol}$
6. No. of moles of CO_3^{2-} = no. of moles of CO_2
7. Mass of CO_3^{2-} = no. of moles of CO_3^{2-} \times molar mass of CO_3^{2-} (60 g/mol)
8. % mass of CO_3^{2-} = $\frac{\text{mass of carbonate}}{1 \text{ g}} \times 100\%$

OR



Assumption: Only carbonate and no other substance present in cockle shells would decompose to form carbon dioxide

1. Place crushed cockle shells in crucible / dry hard glass test tube + heat for 10 mins
2. Allow test tube and its contents to cool + measure mass of residue after heating
3. Repeat heating and cooling until mass of residue remains constant (to ensure carbonate has fully decomposed)
4. Difference in the two masses = mass of carbon dioxide produced
5. No. of moles of CO_2 = difference in mass \div molar mass (44 g/mol)
6. No. of moles of CO_3^{2-} = no. of moles of CO_2
7. Mass of CO_3^{2-} = no. of moles of CO_3^{2-} \times molar mass of CO_3^{2-} (60 g/mol)
8. % mass of CO_3^{2-} = $\frac{\text{mass of carbonate}}{1 \text{ g}} \times 100\%$

Mark scheme:

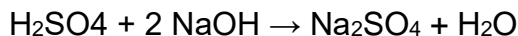
- Variables – constant and independent
- Procedure
- Apparatus
- Processing of data (include how % mass is calculated)
- Assumptions made

[REMINDERS:

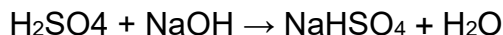
- *Should propose a suitable method that involved releasing carbon dioxide from the carbonate in the shells either by adding acid or heating*
- *Percentage by mass of carbonate could be calculated from volume of gas produced*
- *Detail out how to react all the carbonate present in the sea shells + show how experimental data should be processed to produce the percentage required*
- *Remember to include any assumption(s) made*
- *Should not give chemically unfeasible methods such as e.g. the shells were dissolved in water, the carbonate was precipitated from the shells, or described ones which did not answer the question, e.g. determined the mass of the materials in the shell that did not react with an acid.]*

2019 O-Level

Sodium sulfate Na_2SO_4 is produced when sulfuric acid is neutralised by sodium hydroxide.



Sodium hydrogensulfate NaHSO_4 can also be produced from sulfuric acid and sodium hydroxide.



Both sodium sulfate and sodium hydrogen sulfate are soluble in water.

Outline a method to obtain crystals of sodium hydrogensulfate using 1.0 mol/dm^3 sulfuric acid and aqueous sodium hydroxide of unknown concentration.

1. Pour 1.0 mol/dm^3 sulfuric acid into burette
2. Pipette 20 cm^3 of sodium hydroxide into conical flask
3. Add a few drops of screened methyl orange into conical flask
4. Add sulfuric acid from burette into conical flask until screened methyl orange turns grey / colourless
5. Record volume of acid used
6. Using chemical equation given, 1 mole of sulfuric acid requires 2 moles of sodium hydroxide to completely react to produce sodium sulfate but only require one mole of sodium hydroxide to produce one mole of sodium hydrogen sulfate
7. Repeat experiment without indicator, using twice the titrated volume of acid with same volume of alkali to obtain solution of sodium hydrogen sulfate

Crystallisation:

8. Pour sodium hydrogen sulfate solution into evaporating dish + heat until saturated
9. Allow solution to cool for crystals to form
10. Filter mixture to obtain residue, sodium hydrogen sulfate
11. Dry sodium hydrogen sulfate crystals between sheets of filter papers

2020 O-Level

Some cleaning products contain a solution of sulfamic acid, represented by the chemical formula HA. You are to determine the relative molecular mass, M_r , of sulfamic acid by planning an experiment.

The M_r can be determined by reacting some solid sulfamic acid with aqueous sodium carbonate and measuring the volume of carbon dioxide produced.

The equation for the reaction is shown.



Use this information to outline a method to determine the M_r of sulfamic acid.

Your method should use gas collection by the displacement of water.

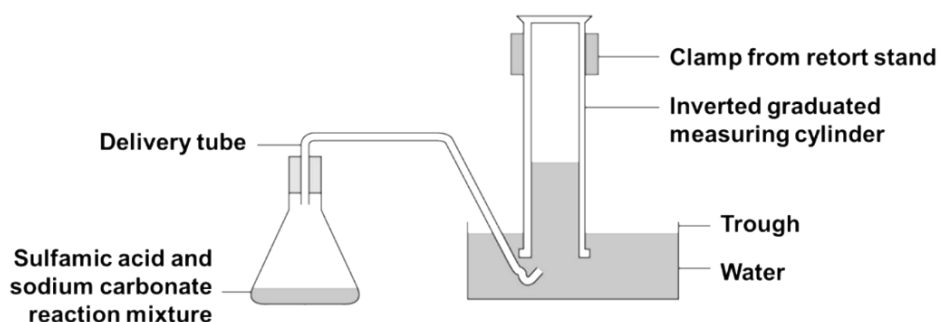
In your method, you should include:

- the apparatus you would use
- the measurements you would take
- an explanation of how you would use your results to determine the M_r of sulfamic acid.

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

You may wish to use a labelled diagram to illustrate your answer.

1. Fill 100 cm³ measuring cylinder with water + invert over trough of water
2. Insert end of delivery tube into bottom of measuring cylinder, submerged in water



3. Measure 5.0 g of HA using weighing balance + place in conical flask
4. Measure 100 cm³ of aqueous sodium carbonate with another measuring cylinder.
5. Pour aqueous sodium carbonate into conical flask + immediately stopper conical flask with delivery tube connected
6. Record volume of water displaced by carbon dioxide gas produced during reaction when all the sulfamic acid has reacted
7. Processing data:

$$\text{Volume of CO}_2 = x \text{ cm}^3$$

$$\text{No. of moles of CO}_2 = x/24000 \text{ mol}$$

$$\text{No. of moles of HA} = x/24000 \text{ mol} \times 2$$

$$\text{Molar mass of HA} = \frac{\text{mass of HA}}{\text{no. of moles of HA}} = \frac{5 \text{ g}}{\frac{x}{24000} \text{ mol} \times 2}$$

M_r of HA has same numerical value as molar mass

Note:

[Carbon dioxide dissolves in water. Use a graduated gas syringe instead so that all carbon dioxide produced will be present in graduated gas syringe for accurate volume measurement.]

2021 O-Level

Many metal ores contain carbonates of the metal. The amount of carbonate can be determined by reacting the ore with acid.

A student is investigating a metal ore. The method being used requires a solution of 0.100 mol/dm^3 hydrochloric acid.

The student is provided with a solution of hydrochloric acid that contains 36.5 g/dm^3 of acid.

Outline what the student should do to prepare 100 cm^3 of 0.100 mol/dm^3 hydrochloric acid from the solution provided. Include the names and volumes of any apparatus used and the volumes of solutions that are needed.

You can assume that all apparatus normally found in a school laboratory is available.

[Mr: HCl, 36.5]

1. Pipette 10.0 cm^3 of 36.5 g/dm^3 of hydrochloric acid + place in 250 cm^3 beaker
2. Fill burette with water + add 90.00 cm^3 of distilled water into beaker
3. Stir mixture in beaker thoroughly using glass rod

Mark scheme:

- Appropriate use of measuring instrument – pipette or burette (rej. measuring cylinder)
- Correct volume of hydrochloric acid and distilled water needed
- Procedure

Manipulation, measurement and observation (MMO)

- set up apparatus correctly by following written instructions or diagrams
- use common laboratory apparatus and techniques to collect data and make observations
- describe and explain how apparatus and techniques are used correctly
- make and record accurate observations with good details and measurements to appropriate degree of precision
- make appropriate decisions about measurements or observations

Presentation of data and observations (PDO)

- present all information in appropriate form
- present quantitative data to appropriate number of d.p./s.f.
- manipulate measurements effectively for analysis - plot graph

Data recording:

Burette	Pipette	Measuring cylinder
2 d.p. ($\pm 0.05 \text{ cm}^3$)	1 d.p. (exact)	1 d.p. ($\pm 0.5 \text{ cm}^3$)
Thermometer	Stopwatch	Calculated answers
1 d.p. ($\pm 0.5^\circ\text{C}$)	whole number ($\pm 1 \text{ s}$)	3 s.f.

Plot graph: A [**y-axis**] against B [**x-axis**]

Analysis, conclusions and evaluation (ACE)

- analyse and interpret data or observations appropriately in relation to the task
- draw conclusion(s) from interpretation of experimental data or observations and underlying principles
- make predictions based on their data and conclusions
- identify significant sources of errors and explain how they affect the results
- state and explain how to overcome or reduce significant errors, including how experimental procedures may be improved

Experimental techniques

1. Titration

- e.g. acid-base titration (with suitable indicators – methyl orange, screened methyl orange, thymolphthalein)
- other types of titrations may be required, and sufficient working details will be given where appropriate

Sufficient no. of titrations with good end-point - 2 titres within 0.10 cm^3

Titration table format:

Experiment no.	1	2	3
Final burette volume of X / cm^3	24.50	35.50	45.45
Initial burette volume of X / cm^3	0.50	10.50	20.40
Volume of X used / cm^3	24.00	25.00	25.05
Best titration results		✓	✓

2. Speeds of reaction that involve measuring of quantities

- e.g. temperature, volume, length, mass, or time measurements

Measure quantities of products or reactants at regular time intervals

- 1) volume of gas produced
- 2) decrease in mass of reaction mixture
- 3) time taken for precipitate formed
- 4) time taken for coloured solution decolourised

3. Separation techniques

Simple paper chromatography

- 1) Draw starting line near bottom of chromatography paper
- 2) Put a drop of food colouring on starting line. Allow it to dry.
- 3) Dip paper into glass tank containing solvent (e.g. ethanol). Solvent soaked up by paper dissolves dyes.
- 4) Leave apparatus to stand for a while. Solvent travels up paper, carrying dyes along.
The more soluble the dye is in solvent, the further it will move up the paper.

Filtration

- 1) Pour mixture into filter funnel lined with filter paper
- 2) Collect filtrate in conical flask
- 3) Collect residue + dry on filter paper

Simple distillation

- 1) In distillation flask, heat solution until boil
- 2) In condenser, water vapour cools into pure water + pure water collected in conical flask
- 3) Solution in distillation flask becomes more concentrated as distillation continue → solid residue of salt left



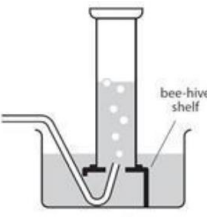
Crystallisation

- 1) Pour salt solution into evaporating dish
- 2) Heat solution until becomes saturated
- 3) Allow solution to cool + crystals form
- 4) Filter mixture to obtain residue – crystals
- 5) Dry crystals b/w sheets of filter paper

4. Salt preparation

- 1) titration
- 2) acid + excess insoluble solid
- 3) precipitation

5. Gas collection

1) displacement of water	2) downward delivery	3) upward delivery
		

6. Drying gases with use of drying agents

- 1) concentrated sulfuric acid
- 2) quicklime
- 3) fused calcium chloride

7. Displacement reactions

- 1) metals displacement reaction
- 2) halogen displacement reaction
- 3) displacement of ammonia from ammonium salts

8. Test for oxidising and reducing agents

- 1) Test for reducing agent: use acidified potassium manganate(VII) as oxidising agent
- 2) Test for oxidising agent: use aqueous potassium iodide as reducing agent

9. Qualitative inorganic analysis involving element / compound / mixture

- reactions of cations, reactions of anions and tests for gases
- reactions involving ions not included in the Notes for Qualitative Analysis may be tested: not expected to identify the ions but only to draw conclusions of a general nature

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
lead(II) (Pb^{2+})	white ppt., soluble in excess giving a colourless solution	white 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

[Lead(II) ions can be distinguished from aluminium ions by the insolubility of lead(II) chloride.]

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.
iodide (I^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	yellow 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 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)
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

Use 1 cm depth of solution (1 ~ 2 cm³) for each test + add reagents slowly, ensuring good mixing, until no further change is seen

Observations

- 1) **colour change**
- 2) **ppt formed**
- 3) **gas evolved** (gas test for identity)

Before performing each part, ask yourself what are you testing for

→ predict identity of substance & only perform necessary tests

Heat strongly VS heat gently

Strongly	Gently
<ul style="list-style-type: none">• open hole completely (non-luminous flame)• hold test tube above flame	<ul style="list-style-type: none">• open hole halfway (luminous flame)• hover test tube above flame

1) presence of unsaturation (C=C)

→ add aqueous bromine

Observation	Conclusion
Reddish-brown aqueous bromine decolourise rapidly	unsaturated (C=C present)
Reaction mixture remain reddish-brown	saturated (C=C absent)

2) presence of alcohols

→ add acidified potassium manganate(VII)

Observation	Conclusion
Purple acidified potassium manganate(VII) turn colourless	alcohol present
Reaction mixture remain purple	alcohol absent

3) presence of carboxylic acids

→ add magnesium (reactive metal)

Observation	Conclusion
Effervescence of colourless odourless gas + gas test for H ₂	carboxylic acid present
No effervescence	carboxylic acid absent

OR

→ add magnesium carbonate (metal carbonate)

Observation	Conclusion
Effervescence of colourless odourless gas + gas test for CO ₂	carboxylic acid present
No effervescence	carboxylic acid absent

11. Energy changes

Measure temp change

- 1) Dissolve solid in water
- 2) Reaction b/w two aqueous solutions e.g. acid-alkali neutralisation

12. Data loggers

Topic	Sensor used
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Endothermic & exothermic reactions	Temperature
Cooling curve	Temperature
Measuring speed	Light gate
Acids & alkalis	pH

13. **Mole concept & chemical calculations**

- Carry out simple calculations as detailed in theory syllabus
- Formulae for mole calculations & energy changes

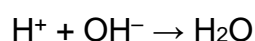
2019 O-Level Chemistry Practical

Breakdown:

Part	Content needed	Lab skills needed
1. Neutralisation <i>16 marks, 45 mins</i>	<ul style="list-style-type: none">• Mole ratio• Limiting reactant• Solution concentration• Acids and bases	<ul style="list-style-type: none">• Use burette• Use measuring cylinder• Measure temperature• Plot graph
2. Decomposition <i>20 marks, 50 mins</i>	<ul style="list-style-type: none">• Mass and moles• Mole ratio• Qualitative analysis	<ul style="list-style-type: none">• Heat using Bunsen burner• Measure mass• Record data in table• Test for anions
3. Salt Preparation <i>4 marks, 15 mins</i>	<ul style="list-style-type: none">• Salt preparation• Titration• Separation techniques	<ul style="list-style-type: none">• None, as you are not required to carry out your plan

Questions:

- 1 A strong acid and aqueous sodium hydroxide solution react in a neutralisation reaction.



P is a 0.75 mol/dm³ strong acid

Q is 1.25 mol/dm³ NaOH solution

Read the instructions before you carry out any experiments.

1. Fill the burette with P. Using a measuring cylinder, add 10 cm³ of Q into a styrofoam cup. Place the styrofoam cup in a beaker.
2. Measure the temperature of Q in the styrofoam cup and record it in the table below.
3. Add 40 cm³ of P to the styrofoam cup and stir the mixture. Record the maximum temperature reached and the temperature rise in the table below.

Rinse your styrofoam cup and repeat the steps with different volumes of P and Q as in the table below.

- (a) Record the initial temperature of Q, maximum temperature and calculate the temperature rise and write your answers in the table below. [4]

Volume of P used / cm ³	Volume of Q used / cm ³	Initial temperature of Q / °C	Maximum temperature / °C	Temperature rise / °C
<u>40</u>	<u>10</u>	<u>30.0</u>	<u>33.0</u>	<u>3.0</u>
<u>35</u>	<u>15</u>	<u>30.0</u>	<u>34.5</u>	<u>4.5</u>
<u>30</u>	<u>20</u>	<u>30.0</u>	<u>36.0</u>	<u>6.0</u>
<u>25</u>	<u>25</u>	<u>30.0</u>	<u>38.0</u>	<u>8.9</u>
<u>20</u>	<u>30</u>	<u>30.0</u>	<u>39.0</u>	<u>9.0</u>
<u>15</u>	<u>35</u>	<u>30.0</u>	<u>37.5</u>	<u>7.5</u>
<u>10</u>	<u>40</u>	<u>30.0</u>	<u>35.5</u>	<u>5.5</u>

- (b) Draw a graph of the temperature rise against the volume of Q used. Draw two intersecting straight lines as best fit lines. [4]

- (c) (i) Use your graph to determine the volume of Q used to get the highest possible maximum temperature rise. [1]

volume of Q used 27.5 cm³

- (ii) Find the number of moles of Q in your answer for (c)(i). [1]

$$27.5 \text{ cm}^3 = 0.0275 \text{ dm}^3$$

$$\text{No. of moles of Q} = 0.0275 (1.25)$$

$$= 0.034375 \text{ mol}$$

$$= 0.0344 \text{ mol (3 s.f.)}$$

number of moles of Q 0.0344 mol

- (iii) Calculate the volume of P used to neutralise the volume of Q in (c)(i). [1]

$$50 - 27.5 = 22.5 \text{ cm}^3$$

volume of P used 22.5 cm³

- (d) Using your answer in (c)(iii), calculate the concentration of H⁺ ions in P. [2]

$$[\text{H}^+] = 0.034375 / 0.0225$$

$$= 1.5288 \text{ mol/dm}^3$$

$$= 1.53 \text{ mol/dm}^3$$

concentration of H⁺ ions in P 1.53 mol/dm³

- (e) Suggest an identity for the strong acid P and explain why you think so. [2]

Sulfuric acid

It is dibasic and produces 2 mol of H⁺ ions upon ionisation of 1 mol of acid. This is especially true as the calculated concentration of ions is around twice the concentration of P.

- (f) Suggest two ways to improve the accuracy of the results obtained. [2]

Use a magnetic stirrer to ensure consistency in speed of stirring instead of stirring manually. Inconsistency in the speed of stirring affects the rate of reaction, and ultimately the temperature.

Cover the styrofoam cup with a lid to minimise heat loss to the surroundings to obtain more accurate readings of temperature.

- 2 Sodium carbonate decomposes when heated according to the equation below.



R is an impure sample of sodium hydrogencarbonate as it contains impurities. The impurity is a sodium compound that does not decompose on heating. You are to determine the percentage of sodium hydrogencarbonate in S and identify the impurity in this question.

Read the instructions before you carry out any experiments.

1. Measure the mass of an empty test tube with the electronic balance. Add about 1.5 g of R and measure the mass of the test tube with its contents.
2. Gently heat the test tube with R for 3 minutes. Leave the test tube in the test tube rack to cool before you measure the mass of the test tube with its contents again.

You may proceed to answer parts (d) and (e) in the meantime as you wait for the test tube to cool.

- (a) Present your measurements in an appropriate format in the space below. [4]

item	mass / g
empty test tube	<u>18.60</u>
test tube with R	<u>20.20</u>
test tube with R decomposed	<u>19.82</u>

(b) (i) Use your measurements to fill in the blanks below. [2]

mass of R used	<u>1.50 g</u>
change in mass after heating	<u>0.38 g</u>

(ii) Based on your answers in (b)(i) calculate the mass of sodium hydrogencarbonate that was present in R. [2]

[M_r : NaHCO_3 ; 84.0, Na_2CO_3 ; 106.0, H_2O ; 18.0, CO_2 ; 44.0]

Mass of CO_2 = 0.38 g

No. of moles of CO_2 = $0.38/44 = 0.0086363$ mol

No. of moles of $\text{NaHCO}_3 = 2 (0.0086363) = 0.017272$

Mass of $\text{NaHCO}_3 = 84.0 (0.017272) = 1.45$ g (to 3.s.f.)

mass of sodium hydrogencarbonate present 1.45 g

(iii) Calculate the percentage by mass of sodium hydrogencarbonate in R. [1]

$$\begin{aligned}\% \text{ by mass} &= 1.45/1.5 \times 100\% \\ &= 96.667\% \\ &= 96.7\% (3.s.f.)\end{aligned}$$

percentage by mass of NaHCO_3 in R 96.7%

(c) (i) Suggest why heating the test tube with R for 3 minutes once may not be an accurate method to determine the percentage by mass of sodium hydrogencarbonate. [1]

Not all sodium hydrogencarbonate may have completely decomposed when heating once for 3 minutes. Hence, volume of carbon dioxide evolved is lesser than actual.

(ii) Suggest one way in which you could improve the experiment to obtain more accurate results of the percentage by mass of sodium hydrogencarbonate in R. [1]

Instead of finding the mass of carbon dioxide evolved, measure volume of carbon dioxide evolved using a graduated gas syringe.

You are provided with S which is a sample of the impurity present in R. You are to carry out tests to determine the identity of S.

- (d) (i)** To the sample of S, add dilute nitric acid until no further changes are seen. You should test and name any gas evolved. [3]

Effervescence was observed upon the addition of dilute nitric acid.

The gas evolved formed a white precipitate in limewater.

The gas is thus carbon dioxide.

- (ii)** To 2 cm depth of solution from **(d)**, add 1 cm depth of aqueous silver nitrate. [1]

A white precipitate formed

- (iii)** To 2 cm depth of solution from **(d)**, add 1 cm depth of aqueous barium nitrate. [1]

No observable change as the solution remained clear

Use your solution from **(d)** to carry out the tests in **(e)**.

- (e) (i)** Suggest why nitric acid was added in excess to carry out the tests in **(d)(ii)** and **(d)(iii)**. [1]

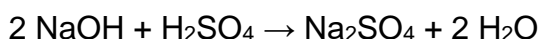
Nitric acid was added in excess as the aqueous silver nitrate and aqueous barium nitrate has to be acidified before they can be used to test for the relevant anions. (avoid false positive for formation of insoluble silver/barium carbonate)

- (ii)** Explain why nitric acid was used instead of hydrochloric acid or sulfuric acid. [2]

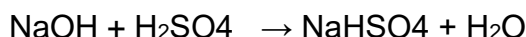
Nitric acid was used as all nitrates are soluble.

The use of hydrochloric acid or sulfuric acid leads to unwanted precipitation when coupled with aqueous barium nitrate or aqueous silver nitrate and thus, precipitation would always occur whether the anion in question is present or not.

- 3 Sodium sulfate is formed as a salt in the reaction between sodium hydroxide and sulfuric acid.



Sodium hydrogensulfate can also be formed as in the reaction below.



You are provided with a sample of sulfuric acid of unknown concentration and 1.0 mol/dm³ sodium hydroxide. You may assume apparatus commonly found in a school laboratory are available. Describe a method you could use to obtain crystals of sodium hydrogensulfate.

[4]

1. Fill a burette with the sulfuric acid. Using a pipette, transfer 25.0 cm³ of 1.0 mol/dm³ sodium hydroxide to a conical flask. Add a few drops of indicator (such as methyl orange) to the NaOH in the conical flask.
2. Titrate sodium hydroxide against sulfuric acid and add sulfuric acid a little at a time until a colour change is observed to indicate complete neutralisation.
3. Repeat the steps without the indicator and with a volume of sulfuric acid half of that used to attain complete neutralisation.
4. Heat the resulting mixture until a saturated solution is achieved and let the mixture to cool. Crystals of sodium hydrogensulfate will appear. Recover the crystals by filtration, wash the sodium hydrogensulfate crystals with cold distilled water and dry them between two pieces of filter paper.