VOLUMETRIC ANALYSIS

Volumetric analysis deals with the measurement of the volume of a solution by the titration method.

This analysis also known as ``quantitative analysis ".From volumetric analysis ,the concentration in grams per liter, molarity and relative molecular mass of a substance can be determined.

Titration involves running one solution, from burette; into a known volume of another solution containing an indicator until the two solutions have just reacted completely. This is shown by a change in colour of the indicator. At this end of the reaction is reached. The volume of the solution used from the burette is noted.

The end is a point when the acid is completely neutralized by a base. It is indicated by change in colour of the indicator used. Indicators which are suitable for particular type of acid-base reaction are given in the table below:

		Colour of indicator in		
Acid-base titration	Indicator	Acidic medium	Basic medium	
Strong acid/strong base	Any	……………………	……………………..	
Weak acid/strong base	phenolphthalein	Colorless	Pink/Red	
Strong acid/weak base	Methyl orange	Orange	Yellow	

During titration, the experiments are repeated several times to obtain consistent results from which the average volume of the solution used can be determined.
The readings on the burette are to two decimal places such as 20.00cm^3, 25.00cm^3 and 23.50cm^3.
The reading on the pipette is recorded to one decimal place for example 25.0cm^3, 20.0cm^3.

TO DETERMINE THE STOICHIOMETRY OF CHEMICAL REACTIONS.

WORKED EXAMPLE 1

To determine the concentration in grams per litre of sodium Hydroxide solution using standard dilute hydrochloric acid solution.

In an experiment on volumetric analysis, 0.1M solution of dilute hydrochloric acid was titrated against a solution of sodium hydroxide of unknown concentration, using a suitable indicator. The following results were obtained.

RESULTS

Volume of pipette used = *25.0 cm^3*

Titration number	1	2	3
Final burette reading/cm^3	*20.40*	*40.60*	*20.10*
Initial burette reading/cm^3	*0.00*	*20.40*	*0.00*
Volume of acid used/cm^3	*20.40*	*20.20*	*20.10*

Titre values used to calculate average volume of the acid are 20.20*cm^3 and 20.10cm^3*.

NOTE: consider two consistent values with a range of at least $^+$0.2

Average volume of acid used $= \dfrac{(20.20 + 20.10)}{2} = \dfrac{40.30\ cm^3}{2} = \underline{\underline{20.15\ cm^3}}$

Questions

(a) Write an equation for the reaction which took place

$$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$$

(b) Moles of the acid that reacted

Molarity of dilute hydrochloric acid was given in the question as 0.1M HCl.
Thus,
1000 cm^3 of solution contains 0.1 mole of HCl.
20.15 cm^3 of acid solution contain (20.15 x 0.1) moles of HCl.

1000

Therefore, moles of the hydrochloric acid that reacted = 0.002015 moles.

(c) Moles of sodium hydroxide that reacted

From the equation above, mole ration of NaOH : HCI = 1 : 1

1 mole of hydrochloric acid reacts with 1 mole of NaOH

0.002015 mole of hydrochloric acid reacted with $\left(\frac{0.002015 \times 1}{1}\right)$ *mole of NaOH*

Therefore, moles of sodium hydroxide that reacted = 0.002015 moles.

(d) Morality of sodium hydroxide,

25.0 cm^3 of solution contains 0.002015 moles of NaOH

1000cm^3 0f solution will contain $\left(\frac{1000 \times 0.002015}{25.0}\right)$ *moles of NaOH*

Therefore, molarity of sodium hydroxide solution = 0.0806 mole /dm^3

(e) Concentration in grams per liter of sodium hydroxide (Na=23, O=16,H=1)

Molar mass of NaOH = 23 + 1 + 16 = 40g

Molar mass of NaOH is the mass of 1 mole of NaOH

From (d) above, 1l of solution contains 0.0806moles of NaOH

Thus,

1 mole of sodium hydroxide weighs 40g

0.0806 moles of sodium hydroxide weighs $\left(\frac{40 \times 0.0806}{1}\right)$ *g*

$= 3.224 \approx 3.2$ g/l

Therefore, the concentration of sodium hydroxide in grams per liter is 3.2 g/l

WORKED EXAMPLE 2

To standardize a solution of sodium hydroxide using hydrochloric acid.

You are provided with the following solutions

BA1 which is a 0.02M Hydrochloric acid

BA2 which is sodium hydroxide solution of unknown concentration.

You are required to determine the concentration of sodium hydroxide.

During the titration experiment, 25.0cm3 of BA2 was pipetted in conical flask and was titrated with BA1 using an appropriate indicator, until *end point* is reached. And the experiment was repeated until consistent results were obtained and recorded.

Volume of pipette used = *25.0 cm^3*

Experiment	1	2	3
Final burette reading (cm^3)	*16.00*	*32.50*	*26.40*
Initial burette reading (cm^3)	*0.00*	*16.00*	*10.00*
Volume of BA1 used (cm^3	*16.00*	*16.50*	*16.40*

Volume of BA1 used to calculate the average volume = *16.50 cm^3 and 16.40 cm^3*

Average volume of acid solution that was used = $\frac{(16.50 + 16.40)}{2}$ cm^3 = 16.45cm^3

Questions:

(a) Write an equation for the reaction that took place between BA1 and BA2.

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

(b) Moles of BA1 that reacted; (ie mole of HCl in average volume ie 16.45cm3 of BA1)

BA1 is 0.02M hydrochloric acid solution. This means that 1000cm^3 of BA1 contains 0.02mole of HCl.

Thus,

1000cm^3 of BA1 contains 0.02moles of HCl

16.45 cm3 of BA1 contains $\frac{(0.02 \times 16.45)}{1000}$ *moles of HCl*

16.45 cm3 of BA1 contains 0.000329 moles of HCl.

Therefore, moles of BA1 that reacted = 0.000329moles.

(c) Moles of BA2 that reacted

From the equation above, mole ratio of BA1 (HCI) : BA2 (NaOH) = 1 : 1

1 mole of hydrochloric acid reacts with 1 mole of sodium hydroxide

Thus,

1 mole of HCI in BA1 reacts with 1 mole of NaOH in BA2

0.00329mole of BA1 reacted with $\left(\frac{0.000329 \times 1}{1}\right)$ *mole of BA2*

Therefore, moles of BA2 that reacted = 0.000329 moles.

(d) Concentration of sodium hydroxide in moles per litre of BA2.

Volume of BA2 used is the pipette volume ie 25.0cm3 of BA2 and this contains 0.000329moles of NaOH as in (c) above. Thus,

25.0 cm^3 of solution contains 0.00329 moles of sodium hydroxide

1000cm^3 0f solution will contain $\left(\frac{1000 \times 0.000329}{25.0}\right)$ *moles of sodium hydroxide*

Therefore, molarity of sodium hydroxide solution = 0.01316 mole /dm^3

(e) Concentration of sodium hydroxide in grams per liter of BA2 (Na=23, O=16,H=1)

Relative Formula Mass of NaOH = 23 + 16 + 1 = 40g and

Moles of NaOH in 1 l of BA2 is 0.01316 mole.

Thus,

1 mole of NaOH weighs 40 g

bn0.01316 mole of NaOH weighs $\left(\frac{0.01316 \times 40}{1}\right)$ *g = 0.5264g/l*

Therefore, concentration of sodium hydroxide in grams per litre of BA2 is 0.5264g/l

PRACTICAL ACTIVITIES

EXPERIMENT 1

You are provided with the following solutions

BA1 which is 0.1 M Hydrochloric acid

BA2 which is sodium hydroxide solution of unknown concentration.

You are required to determine the concentration of sodium hydroxide.

Volume of pipette used = ……………………………….cm^3

Experiment	1	2	3
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of BA1 used (cm^3)			

Values used for calculating average volume of BA1

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Find the average volume of BA1 used

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QUESTIONS.

(a) Write the equation for the reaction between BA1 and BA2

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(b) Calculate the number of:

(i) moles of BA_1 that reacted

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(ii)Moles of BA_2 used

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(iii) Concentration in moles per liter (molarity) of BA2

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(c) Determine the concentration in grams per litre of BA_2, (Na=23, O=16, H=1)

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EXPERIMENT 2

You are provided with the following solutions

BA_1, which contains *x g/l* of sodium hydroxide.

BA_2 contains 0.2M of hydrochloric acid

You are required to determine the concentration(x) g/l of BA_1

Procedures

Pipette 20.0cm^3 or 25.0cm^3 of BA_2 into a conical flask and titrate it with BA_1 from the burette using methyl orange indicator.

Repeat the titration until you obtain consistent results. Record the results in the table provided bellow.

Volume of pipette used………………………………………… cm^3

Experiment	1	2	3
Final burette reading (cm^3)			
Initial burette reading(cm^3)			
Volume of BA1 used (cm^3)			

Titre values used for calculating average volume of BA1.

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Find the average volume of BA1 used.

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QUESTIONS:

(a) Write the equation for the reaction between BA_1 and BA_2.

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(b) Calculate the number of:

(i) moles of BA_2 that reacted

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(ii) moles of BA1 used

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(iii)Concentration in moles per liter of BA1

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(c) Determine the concentration (x) in g/l of BA1 (Na=23, O=16, H=1)

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EXPERIMENT THREE

TO STANDARIZE A SOLUTION OF SODIUM HYDROXIDE USING SULPHURIC ACID

You are provided with

BA1, which is solution of sodium hydroxide of unknown concentration.

BA2, which is 0.05**M** sulphuric acid

You are required to determine the concentration of sodium hydroxide.

Procedures

Pipette 25.0cm^3 or 20.0cm^3 of BA_1 into a clean conical flask. Add 2 or 3 drops of phenolphthalein indicator. Titrate it with BA_2 until you get the end-point with permanent colour change. Repeat the procedure to get consistent results. Record your results in the table below.

Volume of pipette used = ……………………………………cm^3

Experiment	1	2	3
Final burette reading (cm^3)			
Initial burette reading(cm^3)			
Volume of BA2 used (cm^3)			

Titer values used for calculating average volume of BA2

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Find the average volume of BA2 used.

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QUESTIONS

(a) Write the equation for the reaction between BA1 and BA2.

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(b) Calculate the number of

(i) Moles of BA1 that reacted

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(ii) Molarity of BA1.

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(c) Determine the concentration in *g/l* of BA1. (Na=23, O=12, H=1).

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EXPERIMENT 4

You are provided with the following solutions:

BA1 is oxalic acid of unknown concentration.

BA2 contains 0.1M sodium hydroxide.

You are required to determine the concentration of oxalic acid.

Procedures

Pipette $20cm^3$ or $25cm^3$ of BA1 into a conical flask and titrate it with BA2 from the burette using phenolphalein indicator. The end product is when the colour just changes to pink.

Repeat the titration until you obtain consistent results. Enter your results in the table provided below.

Volume of pipette used………………………………………………………………….cm^3

Experiment	1	2	3
Final burette Reading(cm^3)			
Initial burette Reading(cm^3)			
Volume of BA2			

Used(cm^3)			

Titer values used for calculating average volume of BA2……..

Find the average volume of BA2 used.

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(a) Write the equation for the equation for the reaction between BA1

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(b) Calculate the number of:

(i)Moles of BA1 that reacted.

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(ii)Molarity of BA1

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(d)Determine the concentration of oxalic acid ($H_2C_2O_4$) in grams per liter (H=1,O=16,C=12).

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TO STANDARIZE A SOLUTION OF HYDROCHLORIC ACID USING SODIUM CARBONATE

EXPERIMENT 6

You are provided with the following solutions:

BA1 which contain 0.05M Sodium carbonate (Na_2CO_3)

BA2 which is a solution of hydrochloric acid of unknown concentration

You are required to determine the concentration of hydrochloric acid.

Procedure

Pipette 20cm^3 of BA1 into a conical flask and titrate it with BA2 from the burette using Methyl orange indicator until the yellow solution just changes to orange.

Repeat the titration until you obtain consistent results. Enter your results in the table provided below.

Volume of pipette used……………………………cm^3

Experiment	1	2	3
Final burette Reading(cm^3)			
Initial burette			

Reading(cm^3)			
Volume of BA2 Used (cm^3)			

Titre values used for calculating average volume of BA2……………………………………………………………………………………cm^3

Find the average volume of BA2 used.

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(a) Write the equation between sodium carbonate and hydrochloric acid.

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(b) Calculate the number of

(i) Moles of BA1 that reacted.

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(ii) Molarity of BA2(Concentration in moles per litre)

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(c) Determine the concentration of hydrochloric acid in grams per litre (H=1,O=16,CL=35.5)

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TO DETERMINE ATOMIC MASS OF A SUBSTANCE

EXPERIMENT NINE

You are provided with the following solutions:

Example

You are provided with the following solutions,

BA 1 which is a solution of a soluble carbonate $\mathbf{X_2CO_3}$ which is made by dissolving 2.65g of the carbonate to make 500cm3 of the solution

BA 2 is a solution of 0.2M hydrochloric acid.

You are required to determine the relative atomic mass of **X,** if the following results were obtained,

Volume of pipette used 25.0 cm^3

Final burette reading (cm^3)	12.80	32.50	22.60
initial burette reading (cm^3)	0.00	20.00	10.00
Volume of BA2 used (cm^3)	12.80	12.50	12.60

(a) Values used to calculate the average volume of BA2 12.50 and 12.60

(b) average volume of BA2 used $= \frac{(12.50 + 12.60\ )cm^3}{2}$

$= 12.55\ cm^3$

(c) the ionic equation for the reaction taking place is

$2H^{+}(aq) + CO_3^{2-}(aq) \longrightarrow CO_2(g) + H_2O(l)$

(d) number of moles of hydrochloric acid that reacted = $\frac{12.55 \times 0.2}{1000}$

= 0.00251moles

Mole ratio between the acid and the carbonate = 2: 1

Hence moles of the carbonate reacting = $\frac{0.00251}{2}$

= 0.00255

If 25.0cm^3 of the carbonate solution contains 0.00255 moles

500cm^3 of the solution contain $\frac{0.00255 \times 500}{25.0}$

= 0.0251 moles

If 0.0251 moles weigh 2.65g

1moles weighs $\frac{2.65}{0.0251}$

106g

$X_2CO_3 = 106$

$2X + 60 = 106$

$X = 23$

EXPERIMENT SEVEN

You are provided with the following solutions BA1 which contains 6.3g/1 of dibasic acid H2X

BA2 which contains 0.1m sodium hydroxide solution.

PROCEDURES

Pipette 20cm^3 or 25 cm^3 of BA2 into a clean conical flask and titrate it with BA1 from the burette using phenolphthalein indicator until the colour just changes.

Repeat the titration until you obtain consistent results. Enter your results in the provided.

Volume of pipette used………cm^3

Experiment	1	2	3
final burette reading (cm3)			

initial burette reading (cm3)			
volume of BA1 used (cm3)			

Titre values of BA1

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…………………………cm^3

Find the average volume of BA1 used.

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(a) Write the equation of the reaction between sodium hydroxide and an acid H_2X .

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Calculate the number of:

(I) moles of sodium hydroxide

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(iii) moles of Acid that reacted

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iii) The molar concentration of the acid

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(C) Determine the relative molecular mass of the acid H_2X

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EXPERIMENT EIGHT

You are provided with the following solutions:

BA1 which contains 0.2M of a metal hydroxide **$M(OH)_X$**

BA2 which contains 0.2M of hydrochloric acid.

You are required to determine the formula of metal hydroxide $M(OH)_X$ and the concentration of metal hydroxide $M(OH)_X$

PROCEDURES

Pipette 20.0cm^3/25.0cm^3 of **BA1** into a conical flask and titrate it with **BA2** from the burette using phenolphthalein indicator until you obtain consistent results. Enter your results in the table provided below

Volume of pipette used……………………………………………………………………………cm^3

Experiment	1	2	3
Final burette reading (cm^3)			
Initial burette reading(cm^3)			
Volume of **BA1** used (cm^3)			

The values of **BA1**

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…………………………………cm^3

Find the average volume of **BA1** used

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a) calculate the:

i) Number of moles of the acid used.

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Number of moles of the metal that reacted.

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Determine the

Formula of the metal hydroxide **M(OH)** $_x$

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Concentration in grams per liter of **M(OH)X**

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EXPERIMENT TEN

You are provided with the following solutions:

BA1which contains 0.05M of sulphuric acid

BA2 contain 4g of an alkali MOH per liter of solution

You are required to determine the relative formula mass of M.

PROCEDURES

Pipette 20cm3 or 25cm3 of BA2 into a conical flask and titrate it with BA1 from the burette using phenolphalein indicator until the pink colour just disappears. Repeat the titration until you obtain consistent results. Record your results in the table provided below.

Volume of pipette used……………………………………….cm^3

Experiment	1	2	3
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of BA1 used (cm^3)			

Titre values of BA1 that was used

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………………………………….Cm^3,

Find the average volume of BA1 used.

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Calculate the:

Number of moles of the acid used.

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Number of moles of the metal of the hydroxide that reacted

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Calculate the

Relative molecular mass of **MOH**

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Atomic mass of **M** (O=16.H=1)

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EXPERIMENT TEN

You are provided with the following solutions:

BA1which contains 0.2M of hydrochloric acid

BA2 which is a salt solution made by dissolving 10.6g of $\mathbf{X_2CO_3}$ in one litre of solution.

In this experiment you are required to determine the relative atomic mass of metal **X** in the compound , $\mathbf{X_2CO_3}$

PROCEDURES

Pipette 20cm^3 or 25cm^3 of BA2 into a conical flask and titrate it with BA1 from the burette using methyl orange indicator

Repeat the titration until you obtain consistent results. Record your results in the table below.

Volume of pipette used…………………………………………………cm3

Experiment	1	2	3
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of BA1 used (cm^3)			

State the volume of BA1

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…………………………………….cm^3,

Find the volume of BA1 used.

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Calculate the:

Number of moles of BA1 used

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ii) BA1 that reacted

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(b) Find the molarity of BA2

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C) Calculate the:

i) Relative formula mass of **X_2CO_3**

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iii) Determine the relative atomic mass of **X** in **X_2CO_3** (C=12,0=16)

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EXPERIMENT ELEVEN

You are provided with the following:

BA1 which is a solution containing 6.8g of an acid salt **$MHSO_4$** per litre of solution.BA2, which is a 0.025M solution of an alkali, **MOH**.

You are required to determine the atomic mass of **M**

MOH reacts with **$MHSO_4$** in reaction of 1:1 (where necessary use H=1, O=16,S=32)

PROCEDURE

Pipette 25.0cm3 or 20cm3 of BA2 into a clean conical flask and titrate it with BA1 from the burette using methyl orange indicator. BA1, which is a solution containing 6.8 of an acid , **$MHSO_4$** BA2 which

Repeated the titration until you obtain consistent results. Record your results in the table below.

Volume of pipette used…………………………………………………………….cm^3

Experiment No	1	2	3
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of BA1 used(cm^3)			

Volume of BA1 used to calculate average volume……………………………………………………………. cm^3

Average volume of BA1 used

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………………………………………cm^3

(a) calculate the;

(b) Number of moles of MOH that reacted.

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Number of moles of **$MHSO_4$** that reacted

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(c) Determine the relative atomic mass of **M**

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EXPERIMENT TWELVE

You are provide with the following:

BA1 which is 0.043 **M** sodium hydroxide solution

BA2 which is solution containing 6.35 g per liter of hydrated acid **Q**

You are required to determine the formula mass of the anhydrous acid. The acid **Q** reacts with sodium hydroxide in the ratio 1:2

PROCEDURES

Pipette 25.0cm^3 or 20.0cm^3 of BA1 into conical flask.

Add 2-3 drops of phenolphthalein indictor. Titrate solution with BA2 from the burette

Repeated titration until you obtain consistent results .Record your results in the table below.

Volume of pipette used……………………………………………………………………….cm3

Experiment No	1	2	3
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
volume of BA2 used (cm^3)			

Titre values used to obtain a average volume of BA2

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……………………………………cm^3

Average volume of BA2 used

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a) Calculate the ;

i)Number of moles of sodium hydroxide that reacted.

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ii)Number of moles of acid, **Q** that reacted.

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i) concentration in moles per litre of BA2

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e) The formula mass of the anhydrous acid **Q** (1 mole of the hydrated acid, **Q** contains 36g of water of crystallization)..

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EXPERIMENT THIRTEEN

You are provided with the following

DA1, which is 0.1**M** sodium hydroxide solution

DA2, which is a solution containing 12.7g of an organic acid, $\mathbf{CH_3\ (CH_2)_nCOOH}$ per liter of solution

You are required to determine the value of n.

Procedure

Pipette 25.0cm^3 /20.0cm^3 of DA1 conical flask,

Add 2-3 drops of phenolphthalein indicator and titrate solution with DA2 form the burette.

Repeat the titration until you obtain consistent results.

Record your results in the table below.

Results

Volume of pipette used……………………………………………………cm^3

Experiment No	1	2	3
Final burette reading(cm^3)			
Initial reading(cm^3)			
Volume DA2 used (cm^3)			

Values used to calculate average volume of DA2 used

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……cm3

Average volume of DA2 used

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…………………………………cm^3

Questions

(c)Calculate the;

(i)Number of moles of sodium hydroxide that reacted

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(iii)Number of the moles of the organic acid per liter of solution DA2 (sodium hydroxide reacts with the organic acid in the ration 1:1)

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(iv) Relative molecular mass of the organic acid.

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(v) Determine the value of n in $CH_3(CH)_nCOOH$.(H=1,O=16,C=12)

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EXPERIMENT 14

You are provided with the following

FA1 which is solution containing 12.6g of oxalic acid $\mathbf{H_2C_2O_4XH_2O}$ in 1 litre of solution.

FA2 which is 0.1M sodium hydroxide solution

You are required to determine the value of **X**

PROCEDURE

(a)Pipette $20cm^3$ (or $25.0cm^3$) of FA2 into a conical flask. Add 2-3 drops of phenolphthalein indicator and shake well

(b)Titrate the solution with FA1 from the burette

(c)Repeat the titration until you get consistent results

(d)Record your results in the table below results

Volume of pipette used………………………………………………cm^3

Experiment No	1	2	3
final burette reading (cm^3)			
Initial burette reading(cm^3)			

Volume of FA1 used(cm^3)			

Titre values used to calculate average volume of FA1

……
……………………cm^3

Average volume of FA1 used

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………………………………………

(a)Write the equation for the reaction

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…………………………………………

(b)Calculate the:

(i)Number of moles of the sodium hydroxide used

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(ii)Number of moles of the acid used

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(iii)Concentration of the acid in moles per dm^3

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(c)Relative formula mass of the acid

(d)Value of x.(H=1, C=12, O=16)

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DETERMINE THE BASICITY OF ACIDS (**HnX**)

EXPERIMENT 15

You are provided with the following solution

BA1 which is 0.1M sodium hydroxide.

BA2 which is 0.05M of an acid of formula **HnX**.

You are required to determine the basicity of an acid **HnX**.

PROCEDURE

Pipette $20cm^3$ (or $25.0cm^3$) of BA2 from the burette using meythl orange as an indicator. Repeat the titration until you obtain consistent results.

Enter your results in the table below:

Volume of pipette used…………………………………………………cm^3

Experiment number	1	2	3
Finalburettereading(cm^3)			
Initial burettereading(cm^3)			
VolumeofBA2 used (cm^3)			

(a)State the titre values used to calculate the average volume of BA2

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(b) Calculate the average volume of BA2 used

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(c)Calculate the number of

(i)Moles of BA1 that reacted

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(ii)Moles of BA2 used

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(d)Determine the basicity of an acid **HnX**

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EXPERIMENT 16

you are provided with the following solutions

BA1, that is a solution of sodium hydroxide made by dissolving 1g in 250cm^3 of distilled water to make a solution.

BA2, which is a solution of **HnX**. containing 0.1**M**.

In this experiment you are required to determine the basicity of an **HnX**.

PROCEDURE

Pipette 20cm^3 (or 25cm^3) of BA2 into a conical flask and titrate it with BA1 from the burette phenolphthalein as an indicator until the colour changes

Enter your results in the table below.

Volume of pipette used…………………………………………………………………………………..cm^3

Experiment number	1	2	3
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of BA1 used (cm^3)			

Titre values used to calculate the average volume of BA1

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………………………………………

Average volume of BA1 used

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………………………………………

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(a)Write an equation for the reaction between potassium hydroxide solution and acid **HnX.**

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(c)Calculate the number of

(i) Moles of BA1 used

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(ii)moles of the acid reacted

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e)Determine the reaction ratio, hence the value of n in **HnX**.

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EXPERIMENT 17

TO FIND THE NUMBER OF MOLES OF WATER OF CRYSTALISATION IN A MENTAL CARBONATE INSTRUCTION

You are provided with

BA1; made by dissolving 14.3g of metal, carbonate $\mathbf{M_2CO_3.nH_2O}$ in water to make 1 litre of solution.

BA2 IS 0.2 **M HCl**

You are required to find the number of moles of water of crystallization in the metal carbonate (i.e. the values of n In $\mathbf{M_2CO_3nH_2O}$)

Procedure

Pipette 20.0 / 25.0 cm^3 of BA1 into a conical flask. Add 2-3 drops of methyl orange indicator. Titrate with BA2

Record your results in the table below

Results

volume of pipette used ………cm^3

Experiment number	1	2	3
Final burette reading (cm^3)			
Initial burette reading(cm^3)			
volume of BA2 used(cm^3)			

Titer values used to find the average volume of BA2

………
………………………….cm^3

Average volume of BA2

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a) calculate the number of moles of

i) hydrochloric (BA2 used)

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ii) The metal carbonate (BA1) that reacted

(1 mole of $\mathbf{M_2CO_3}$ reacts with 2 moles of hydrochloric acid)

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b) calculate the molar concentration of the metal carbonate

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c) calculate the relative molecular mass of the metal carbonate(**$M_2CO_3.nH_2O$**)

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a) Find the value of n(M=23,C=12,O=16,H=1)

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<u>EXPERIMENT 18</u>

TO FIND THE MOLE RATIO FOR THE REACTION BETWEEN AN ACID AND AN ALKALI

INSTRUCTIONS

You are provided with BA1, which is A 0.05 M of an acid.

BA2 IS 0.1 M sodium hydroxide

You are required to find the mole ratio for the reaction between the acid and sodium hydroxide1.

Procedure

Pipette $25cm^3$ of BA2 into a conical flask. Titrate with using phenolphthalein indicator. Repeat to get consistent results in the table below

Volume of pipette used……………………………………..cm^3

Titration number	1	2	3
Final burette reading(cm^3)			
Initial burette reading(cm^3)			
volume of BA1 used (cm^3)			

Titre values to calculate the average volume of BA1………………………………………………………………………..cm^3

Average volume of BA1 used

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a) Write the equation for the reaction that place

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b) The number of moles BA2 used.

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c) The number of moles of BA1 used.

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d) Calculate the mole ratio for the reaction between the acid and sodium hydroxide

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EXPERIMENT 19

THE PERCENTAGE PURITY OF OXALIC ACID

INSTRUCTIONS

You are provided with solution

BA1 which was made by dissolving 8.0g of impure oxalic acid (**$H_2C_2O_4.2H_2O$**) in water to make 1 liter of solution.

BA2 is also a solution made by dissolving 1.0g of sodium hydroxide in 25cm3 of water

You are required to find the percentage of oxalic in the impure acid

PROCEDURE

Pipette 20.0 0r 25.0cm^3 of BA2 into a conical flask. Titrate with BA1 using phenolphthalein indicator. Repeat to get consistent results. Record four results in the table below.

RESULTS

Volume of pipette used……………………………………………………………………………………….cm^3

Titration number	1	2	3
Final burette reading (cm^3)			
Initial burette reading(cm^3)			
volume of BA1 used (cm^3)			

Titre values used to calculate the average volume of BA2.

………
……………………………. cm^3

Average volume of BA2

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a) Write the equation for the reaction between oxalic acid(**$H_2C_2O_4$**) and sodium hydroxide

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b) Calculate the molarity of sodium hydroxide

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c) calculate the number of moles of

i) BA2 used

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ii) BA1 that reacted

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d) calculate the:

i) Molarity of oxalic acid

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ii) concentration of oxalic acid in grams per liter

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Percentage of oxalic acid in the impure acid.

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<u>EXPERIMENT20</u>

TO FIND THE PERCENTAGE PURITY OF SODIUM CARBONATE

You are provided with

BA1, which is 0.1M hydrochloric acid

BA2 contains 8.0g of impure anhydrous sodium carbonate dissolved in water to make 1 liter of solution.

You are required to find the percentage of pure sodium carbonate in the impure sample.

Procedure

Pipette 20.0 or 25 .0cm^3 of BA2 into a conical flask. Titrate with BA1 using Methyl orange indicator. Repeat to get consistent results. Record all your results in the table below

Results

Volume of pipette used………………………………………….cm^3

Titration number	1	2	3
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of BA1 used (cm^3)			

Titer values used to find the average volume of BA1…………………………………………………………….cm^3

Average volume of BA1

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(a) Write the equation for the reaction that took place

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(b) Find the number of moles of BA1 used

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Find the concentration of sodium carbonate solution in

(1) Moles per liter

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(ii) Grams per liter (Na=23,O=16,C=12)

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THERMOMETRY

Background

Chemical reactions are usually accompanied by an energy change, energy can either be absorbed or evolved/given out. The most common form of energy change which occurs is heat change and at this level we shall concentrate on this form of energy change.

When a chemical reaction takes place with absorption of heat from the surrounding, the total energy of the products becomes greater/ higher than that of the reactants. Such a reaction is said to be an endothermic reaction. The energy change accompanying an endothermic reaction is positive (ΔH = positive) eg

$C(s) + 2S(s) \longrightarrow CS_2(l) \quad \Delta H = +17\ kjmol^{-1}$

On the other hand when a chemical reaction takes place with evolution of heat, the total energy of the products becomes less than that of the reactants. This type of reaction is known as an exothermic reaction. As a result the temperature of the surroundings increases. The energy change accompanying an exothermic reaction is negative (ΔH = negative)

$C(s) + O_2(g) \longrightarrow CO_2(g)\ \Delta H = -393.3\ kjmol^{-1}$

Enthalpy of neutralization

This is the heat given out when one mole of hydrogen ions reacts with one mole of hydroxide ions to form one mole of water.

Ie $H^+(aq) + {}^-OH(aq) \longrightarrow H_2O(l) \quad \Delta H$ = enthalpy of neutralization.

Example 1

An experiment to determine the enthalpy of neutralization between hydrochloric acid and sodium hydroxide solution.

NB when the reaction is between a trong acid and a strong base, the heat evolved is almost the same solong as they are all strong But if the reaction is between a a strong acid and a weak base or a weak acid and a strong base, the heat change is less as only ions are present in solution.

Procedure

(a) pipette 40cm3 of 1M hydrochloric acid into a plastic beaker and record the temperature of the acid solution as t_1

(b) Wash and dry the thermometer then take the temperature of the sodium hydroxide solution in a beaker t_2

(c) As rapidly as you can possibly , transfer 40cm3 of 1M sodium hydroxide solution into the beaker using a measuring cylinder. Use a washed and dried thermometer for stirring and record the maximum temperature obtained t_f

Specimen results

Initial temperature of hydrochloric acid t1 = 20.10°C

Final temperature of sodium hydroxide solution t2 = 19.70°C

Final (maximum temperature of the mixture = tf = 27. 50°C

What is the heat change for the reaction? If the density of the mixture is 1gcm^{-3}, the specific heat capacity of water = 4.2j /g /°C

Total volume of the mixture = 40 + 40 = 80cm^3,

Mass of the mixture = density x volume

= 1 x 80g

= 80g

Initial temperature of the mixture $= \frac{t_1 + t_2}{2}$

$= \frac{20.1 + 19.7}{2}$

= 19.90cm^3

Change in temperature = (27.50 – 19.90) °C

= 7.6 °C

Heat change = MCΔθ

= 80 x 4.2 x 7.6

= 2553.6 J

Moles of acid that reacted $= \frac{40 \times 1}{1000}$

= 0.04moles

If 0.04moles generate 2553.6J

1 mole generates $\frac{2553.6}{0.04}$

= 63840Jmol^{-1}

Experiment 1

In this experiment you will determine the standard heat of neutralization of hydrochloric acid by sodium hydroxide solution.

You are provided with the following solutions

DA1 which is 2M hydrochloric acid

DA2 which is sodium hydroxide solution

You are required to determine the heat of neutralization between the hydrochloric acid and sodium hydroxide.

Procedure

(i) Using a measuring cylinder, measure $50cm^3$ of DA1 into aplastic beaker and record the temperature as T1

(ii) Using another measuring cylinder measure $50cm^3$, put into another plastic beaker, using a clean thermometer record the temperature as T2.

(iii) Now quickly transfer DA2 into a beaker containing DA1 while stirring using a thermometer until you record the maximum temperature rise reached by the solution and record it as T3

Results:

Initial temperature of DA1 =……………………………………………………°C

Initial temperature of DA2 =………………………………………………….°C

Average initial temperature = $\frac{T1 + T2}{2}$ =……………………………… °C

Final temperature of the mixture T3 = …………………………………°C

(a) Calculate ;

(i) the temperature change

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(ii)heat of the reaction (density = $1gcm^{-3}$, specific heat capacity of water = 4.2J/g/°C)

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(iii) the molar heat of neutralization

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(b) Explain why plastic beakers were used instead of metallic ones/

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Experiment 2

In this experiment you will determine the enthalpy of neutralization of hydrochloric acid by sodium hydroxide by thermometric titration.

You are provided with the following solutions

BA1 which is 2M hydrochloric acid

BA2 which is 2M sodium hydroxide solution

You are required to determine the heat of neutralization between hydrochloric acid and sodium hydroxide.

procedure

(i) Measure 50cm3 of BA1 into a plastic beaker using a measuring cylinder. Measure and record its temperature and record it as T1

(ii) Take the temperature of BA2, and record it as T2 and put it in a burette.

(iii) Add 5cm3 of BA2 from the burette and stir carefully, with a thermometer. Note and record the maximum temperature of the mixture.

(iv) repeat procedure (iii) using 15 20, 25,30, 35, 40, 45, 50, 55 of BA2

Results

Initial temperature of BA1 =………………………………………………………………… °C

Initial temperature of BA2 =…………………………………………………………………°C

Average temperature of the mixture of = $\frac{T1 + T2}{2}$ = ……………………………………….°C

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Volume of BA2 used /cm^3	0	15	20	25	30	35	40	45	50	55	60
Remperature /^{oC}											
Temperature ΔHT/°C											

(a) Plot a graph of temperature rise against volume of BA2 added

(b) Using your graph determine molarity of the acid

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(c) Calculate the enthalpy of neutralization of hydrochloric acid by sodium hydroxide

(specific heat capacity of water = 4.2J/ g/ ^{-o}C, density of water = $1g/cm^3$)

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Experiment 3

Determination of the percentage of potassium hydroxide in its mixture with potassium sulphate

You are provided with BA1 which is a solution containing 60.2g of a mixture of potassium hydroxide and potassium sulphate per litre of the solution.

BA2 is a solution of 1M hydrochloric acid.

Procedure

(a) Measure and record the temperature of BA1.

(b) Pipette 20.0 / 25.0cm3 of BA1 into a plastic beaker .

(c) measure $10cm^3$of BA2 using a measuring cylinder and transfer it into a beaker containing BA1, gently stir with a thermometer and record the highest temperature attained by the mixture

(d) Repeat procedure (b) and (c) but this time using 15, 20, 25, 30 and $35cm^3$,

(e) enter your results in the table below.

Results

Volume of pipette used= ……………………………………………………………………………. cm^3

Volume of BA2 used/ cm^3	0	10	15	20	25	30	35
Temperature of the solution/°C							

(f)(i) plot a graph of temperature of the solution against volume of BA2 used.

(ii)using your graph determine the maximum volume of BA2 that reacted with BA1

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(iii)Calculate the number of moles of hydrochloric acid that reacted.

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(iv) what is the number of moles of potassium hydroxide that reacted.

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(v) What is the concentration in potassium hydroxide in BA1 in grams per litre (K = 39, O = 16, H = 1)

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(v) Calculate the percentage of potassium hydroxide in the mixture with potassium sulphate.

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RATES OF REACTIONS

The rate of reaction gives information on how fast the reaction proceeds.

Some reactions are fast e.g. when lead(II) chloride solution is added to dilute Sulphuric acid, a white precipitate is formed immediately. This reaction is very fast. While other reactions are slow e.g. rusting of iron.

Definition:

The rate of reaction can be defined as the amount of product formed per unit time

OR:

The amount of reactants used up per unit time.

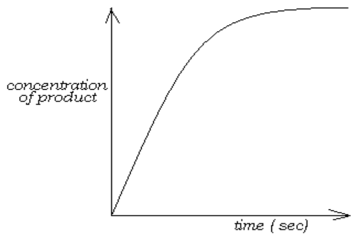
Rate = $\frac{\text{Amount}}{\text{Time}}$

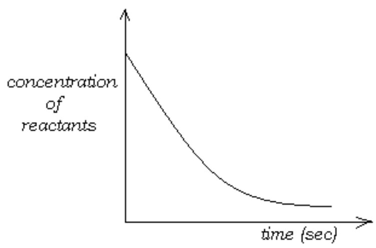
From the definition, therefore the rate of reaction can be determined by measuring the amount of product formed and the time taken for the formation of those products.

Or:

It can be determined by measuring the amount of reactants used up and the time taken.

The rate of reaction can be represented by the graphs below:





The amount of products formed in a given time depends on the concentration of the reactants present.

At the beginning of a reaction, the concentration of the reactants is high hence the reaction is high.

As the reactants get used up, the reaction slows down until it eventually comes to a stop when all the reactants have got used up

OR:

As the reaction time increases, the rate of reaction progressively decreases. This is because the rate of reaction is directly proportional to the concentration of the reactants present in the reaction mixture at any time.

<u>Experimental determination of the rate of reaction:</u>

Consider the reaction between calcium carbonate and dilute HCl.

Equation of reaction:

$$CaCO_{3\,(s)} + 2HCl_{\,(aq)} \longrightarrow CaCl_{2\,(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$$

The rate determination can be done in one of the two ways:

(i)Measuring the volume of carbon dioxide evolved with time.

(ii)Measuring the mass of reaction mixture with time as carbon dioxide escapes.

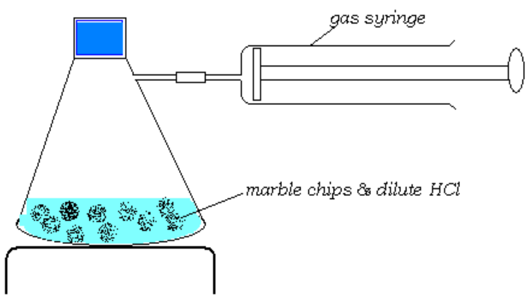
METHOD: 1.

50cm^3 of 0.2M hydrochloric acid is placed into a conical flask with a side arm fitted to a 100cm^3 gas syringe.

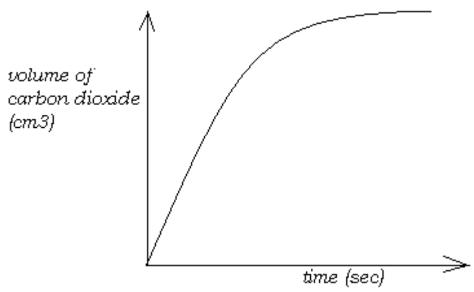
calcium carbonate is added to the acid. The bung is immediately replaced at the same time, a stop clock is started.

The volume of the gas is recorded at regular intervals until there is no more reaction taking place

Diagram showing the set up:



The volume of carbon dioxide is plotted against time and a graph with the shape below is obtained.



METHOD: 2.

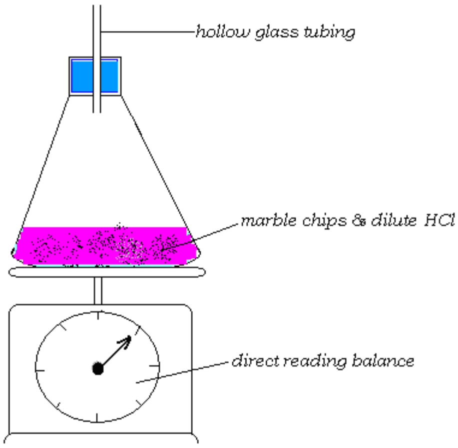
Since the volume of carbon dioxide in not to be measured, a large amounts of reactants can be used.

A flask containing 100cm^3 of 1M hydrochloric acid is weighed.

About 10g of marble chips are added carefully and the bung carrying a glass tubing (or loose cotton wool which stops the splashing of the acid) is immediately replaced. The stop clock is started at the same time.

All the weighing is conveniently done on a direct reading top pan balance.

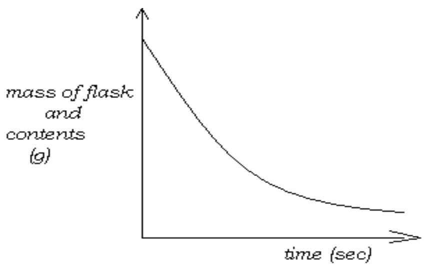
Diagram showing the set up of the apparatus



The mass of flask and contents is recorded at regular intervals of time.

A plot of mass of the flask and contents in it against time is made:

A graph of mass against time:



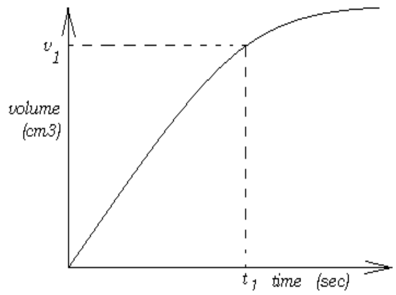
GRAPH INTERPRETATION:

A rate curve shows that the rate of reaction is highest at the beginning, then decreases and finally becomes zero. This is because the concentration of the acid is highest at the beginning then decreases with time.

The surface available on marble chips where the reaction is occurring also decreases; hence the reaction rate decreases with time until it becomes zero when all or both reactants are used up.

How to read the graphs of rates of reactions

a) volume of the gas at a given time:

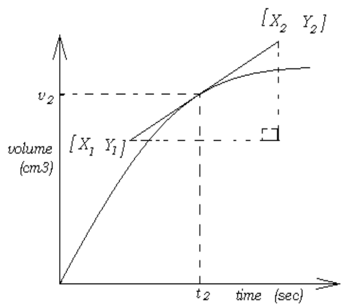


To find the volume of carbon dioxide produced at a given time t_1, draw a perpendicular to the time axis (X- axis) at that time then read the volume, V_1, where the perpendicular meets the curve as shown above.

b) Rate at a given time.

To find the rate of the reaction at time t_2, draw a tangent to the curve at that time.

The gradient of the curve is the rate of the reaction at that time. i.e. given the graph below



$$\text{Gradient} = \frac{Y_2 - Y_1}{X_2 - X_1}$$

The unites of rate of reaction above are **$cm^3 sec^{-1}$**

c) Average rate between two points:

To find the average rate of reaction between two points P and Q, divide the change in the volume by the change in time i.e. $^{Y}/_{X}$

d) End of reaction is the point at which the graph starts to level off as shown below:

Other substances that can be used instead of calcium carbonate and dilute hydrochloric acid include:

Magnesium and dilute hydrochloric acid. In this case measure the volume of hydrogen produced or the change in mass of the reactants with time.

Zinc and dilute Sulphuric acid. (Do as with magnesium and hydrochloric acid)

Hydrogen peroxide and manganese (IV) oxide catalyst. Measure the volume of oxygen produced

Factors affecting the rate of reaction:

The following are the factors that affect the rates of reactions:

Concentration of the reactants

- Temperature
- Surface area
- Catalyst
- Pressure
- Light.

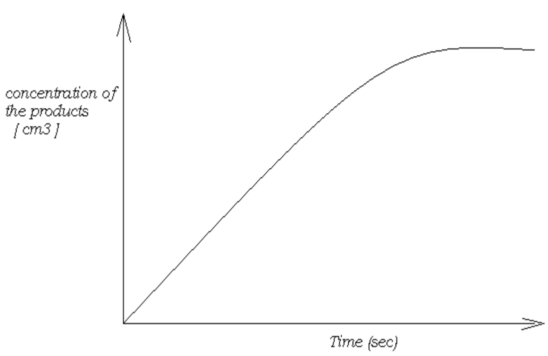
Concentration of the reactants:

concentration refers to how close together the solute particles are in a given reaction.

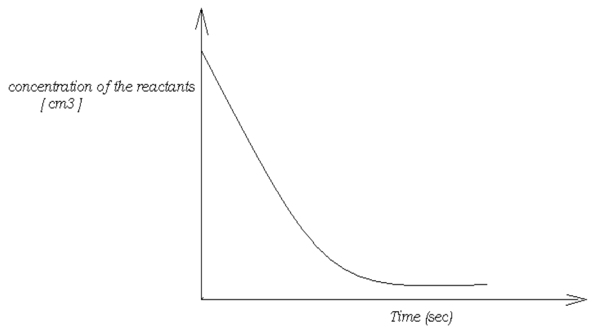
The rate of reaction is directly proportional to the concentration of the reactants.

i.e. the higher the concentration, the higher the frequency of collision of the reacting particles therefore high concentration of the reactant particles increases the rate of reaction.

This can be illustrated graphically as below:



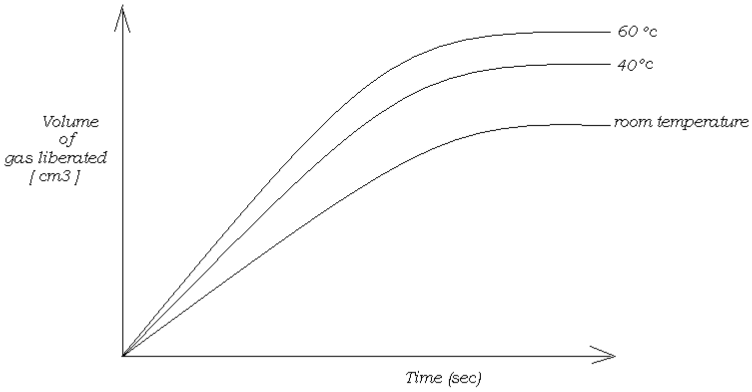
OR



Temperature:

when the temperature increases, the kinetic energy of the reacting particle increases and move faster. This increases the rate of collision between the reacting particles. The higher the temperature, the higher the rate of reaction.

A graph showing the volume against time at different temperatures:

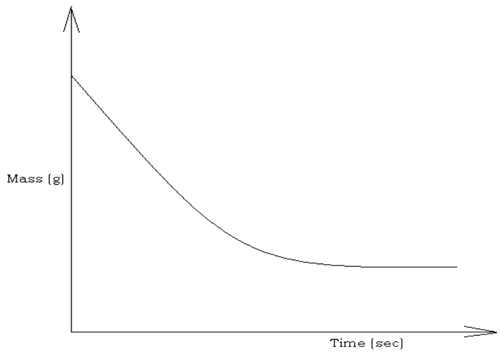


Surface area:

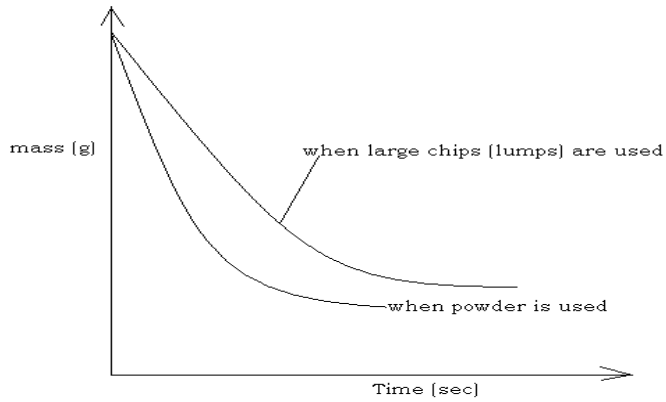
when the surface area of the reactants is high, the rate of reaction is also high (i.e. the rate of reaction is high when small/ powdered particles are used and slow when the reactant particles are big in size).

Small particles increase the rate of reaction.

Graph showing drop in mass of particles with time during the reaction.



Graph showing increase in volume of the product with time when different sizes of the reacting particles are used (i.e. powder and chips)



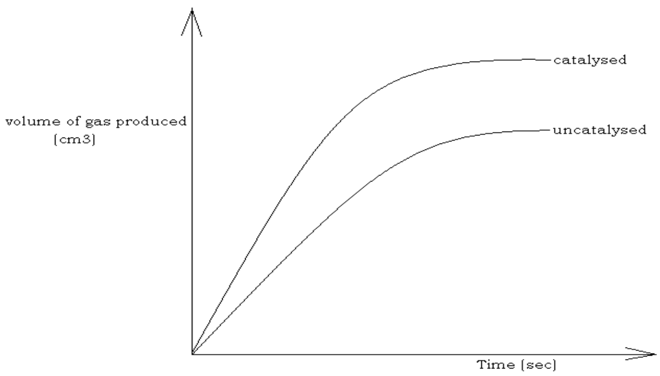
Catalyst:

is a substance which alters the rate of a chemical reaction but remains chemically unchanged at the end of reaction. Catalysts are specific i.e. a catalyst of a certain reaction may not catalyse another reaction.

Little amount of catalyst is effective but the greater the amount of catalyst the higher the rate of reaction.

Powdered catalyst is more effective than the one in lamp form. The rate of reaction is slow in reactions which are not catalyst.

Graph showing the rate of reaction in a catalyst reaction and the one which is not catalyst.



Pressure:

pressure affects mainly gaseous reactions because gases are compressible.

Increasing pressure in a gas brings the particles closer together hence increasing the rate of collision. This also increases the rate of reaction.

Light:

some reactions are affected by light. Such reactions are said to be **photosensitive** e.g reaction between silver nitrate and sodium chloride

$AgNO_{3\,(aq)}$ + $NaCl_{(aq)}$ → $AgCl_{(s)}$ + $NaNO_{3\,(aq)}$

White ppt

The ppt darkens due to light which catalyses the decomposition of silver chloride according to the equation

$2AgCl_{(s)} \xrightarrow{light} 2Ag_{(s)} + Cl_{2\,(g)}$

In the absence of light, the ppt remains white.

Note: the decomposition of silver chloride and silver bromide is used in photography.

Another reaction catalyst by light is photosynthesis, a process by which green plants manufacture their own food. It takes place during day according to the following equation:

$6CO_{2\,(g)} + 6H_2O_{(l)} \xrightarrow[Chlorophyll]{light} C_6H_{12}O_6 + 6O_{2\,(g)}$

Experiment to investigate how the rate of reaction varies with concentration between hydrochloric acid and sodium thiosulphate.

You are provided with the following solutions

DA1 which is a solution of sodium thiosulphate

DA2 is a solution of dilute hydrochloric acid.

Sodium thiosulphate reacts with hydrochloric acid according to the equation below

$Na_2S_2O_3$ (aq) 2HCl(aq) ⟶ NaCl(aq) + S(s) + SO_2(g) + H_2O(l)

OR

$S_2O_3^{2-}$ (aq) $2H^+$q) ⟶ S(s) + SO_2(g) + H_2O(l)

The rate of reaction can be monitored by following and noting the time taken for the precipitate to appear. The time taken for theprecipitate to appear varies with concentration of thiosulphate.

Procedure

(i) Arrange Six conical flasks and label them O, P, Q, R ,S and T

(ii) Add 30, 25, 20 ,15, 10, and 5 cm^3 of BA1 to the flasks O, P, Q, R ,S and T respectively.

(iii) Add 0, 5, 10 ,15, 20, and 25 cm^3 of distilled water to the flasks O, P, Q, R ,S and T respectively.

(iv) Mark a small cross using a black ink on a piece of paper and place flask O on the paper so that the cross is seen through the solution in the flask.

(v) Add 10cm^3, of BA2 to flask O and immediately start the clock.shake the mixture and place the flask back on the paper.

(vi) watch the cross through the solution from above stop the clock when the cross in no longer seen.

(vii) repeat procedure (v) and (vi) with flasks, P, Q, R ,S and T

(viii) record your results in the table below.

Flask	O	P	Q	R	S	T
Volume of acid(DA2)(cm^3)	10	10	10	10	10	10
Volume of thiosulphate(cm^3)	30	25	20	15	10	5
Time(s)	0	5	10	15	20	25
1/time(s^{-1})						

(a)Plot a graph of volume of sodium thiosulphate against time.

(b) use your graph to explain how the rate of reaction varies with concentration.

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(c) determine the slope of the graph when the volume of sodium thiosulphate is;

(i)20cm^3,

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(ii) 30cm^3

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(iii) 15cm^3

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(d) Explain why

(i)the volume of the acid in all cases has been kept constant.

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(ii) the volume of the total solution is the same in all experiments.

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Experiment 2

In this experiment you will investigate the effect of temperature on the rate of the reaction.

You are provided with the following solutions

FA1 is sodium thiosulphate solution

FA2 is a dilute solution of hydrochloric acid.

Hydrochloric acid reacts with sodium thiosulphate according to the equation below

$Na_2S_2O_3$ (aq) 2HCl(aq) $\longrightarrow$ NaCl(aq) + S(s) + SO_2(g) + H_2O(l)

OR

$S_2O_3^{2-}$ (aq) $2H^+$q) $\longrightarrow$ S(s) + SO_2(g) + H_2O(l)

The rate of reaction can be followed by noting the time taken for the precipitate to appear at a given temperature.

Procedure

(i) Mark across (X) with black ink on pa white piece of paper and place it on the table.

(ii) place a conical flask on the cross.

(iii) using a measuring cylinder, measure 5cm3 of BA2 and add at once to the solution of BA1 in the flask and at the same time start the stop clock, shake the mixtureand place it on the paper with the cross.

(iv) Record the temperature of the mixture, view the cross from above the mixture .

(v) Note and record the time taken for the cross not to be seen through the solution.

(the reaction takes place at room temperature)

(vi) Transfer 50cm^3 of of BA1 into the conical flask and heat the it up to 30°C

(vii) Add 5.0cm3 of BA2 to the solution and at the same time start the stop clock

(viii)shake to mix the mixture and place the the flask over the cross.

(ix)look at the cross through the mixture in the flask.

(x)Note and record the time taken for the cross to become invisible through the mixture in the flask.

(xI)repeat the procedure (vi) to (x) for the reaction at temperatures 40, 50 , 60 and 70 °C

Table of results

Temperature/ °C	Room temperature	30	40	50	60	70
Time(t) taken for the cross to disappear/s						
1/t(s^{-1})						

(xii) plot a graph of 1/t against temperature

(xiii) State and explain how the rate of reaction varies with temperature.

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QUALITATIVE ANALYSIS

Introduction

U.C.E qualitative analysis involves simple test tube experiments carried out to identify unknown ionic compounds. The ionic compounds contain **cations** and **anions**.

The ions occur freely in aqueous solutions of the compounds, i.e when the compounds dissolve in water.

- **Cations** are positively charged ions found in the compounds.

Table 1 shows examples of cation

Non-transition metal ions		Transition metal ions	
Name of cation	**Symbol**	**Name of cation**	**Symbol**
Aluminium ion	Al^{3+}	Copper ion	Cu^{2+}
Ammonium ion * **(* this is not metal ion)**	NH_4^+	Iron (ii) ion	Fe^{2+}
		Iron (iii) ion	Fe^{3+}
Barium ion	Ba^{2+}		
Calcium ion	Ca^{2+}		
Magnesium ion	Mg^{2+}		
Lead ion	Pb^{2+}		
Silver ion	Ag^+		
Zinc ion	Zn^{2+}		

- **Anions** are negatively charged ion.

Table 2 shows examples of anions

Name of anion	Formula
Carbonate ion	CO_3^{2-}
Hydrogen carbonate ion	HCO_3^-
Chloride ion	Cl^-
Nitrate ion	NO_3^-
Sulphate ion	SO_4^{2-}

1. PRELIMINARY TESTS ON SUBSTANCES.

This involves carrying out simple tests to determine the chemical nature of substances. The simple tests include the following:

(a) The appearance

(i) By looking at the colour of the substance the cation probably present in the substance may be predicted.

(ii) The nature of the substance, whether it is a powder or crystalline substance, shows the anion probably present in the unknown substance.

Below are some examples

Observed colour	Deduction.
(i) Green or green powder	Fe^{2+} or Cu^{2+} suspected (since it is green) CO_3^{2-} suspected (since it is powder.
(ii) Blue crystalline substance.	Cu^{2+} suspected (since it is blue). Cl^-, NO_3^- or SO_4^{2-} suspected. (since it is crystalline)
(iii) Yellow\brown solid or solution	Pb^{2+} or Fe^{3+} suspected.
(iv) White solid.	Al^{3+} ,Pb^{2+} Zn^{2+} , Ba^{2+}, Ca^{2+} ,Mg^{2+} , Ag^+ or NH_4^+ suspected.
(v) Crystalline substance.	Cl^-, NO_3^- or SO_4^{2-} suspected.
(vi) Powdered substance.	CO_3^{2-} suspected.

(b) Effect of heat on substances.

- 2 spatula ends full of the unknown substance is put in a dry test tube and heated, first gently then strongly.

- When heating any solid substance, make proper use of **moist blue and red litmus papers to test for any gases produced**.
  NOTE; that there is no specific instruction, on the question papers, for using litmus paper. So always remember to pick litmus paper or ask for it if not provided.
- This test gives a rough over view of the nature of the unknown substance.

Two main observations from this test can be used to identify the unknown substance. These include:

(i) The gases evolved during heating

Gases produced during heating show the nature of **anion** probably present in the unknown substance.

Table 3 shows characteristics of some common gases produced during heating.

Gas	Observation	Deduction
Carbon dioxide, CO_2	Colourless gas, turns blue litmus paper red, and turns lime water milky.	CO_3^{2-} suspected.
Sulphur dioxide, SO_2	Colourless gas, turns blue litmus paper red and bleaches it	SO_4^{2-} suspected
Ammonia, NH_3	Colourless gas with a choking smell and turns red litmus paper blue,	NH_4^+ suspected
Nitrogen dioxide, NO_2	Brown gas, turns blue litmus paper red.	NO_3^- suspected

(ii) Colour of residue

This gives a rough prediction of nature of the **cation** probably present in the unknown substance.

Table 4 shows the appearance of residues of different substances after heating

Observation	Deduction
Residue is brown solid when hot, and yellow solid when cold.	Residue is **PbO**, therefore Pb^{2+} suspected.

Residue is yellow solid when hot, and white solid when cold.	Residue is **ZnO**, therefore **Zn^{2+}** suspected
Residue is black solid when hot and when cold	Residue is **CuO**, therefore **Cu^{2+}** suspected
Residue is grey solid when hot and when cold	Residue is **FeO**, therefore **Fe^{2+}** suspected.
Residue is brown solid when hot and when cold	Residue is **Fe_2O_3**,therefore **Fe^{3+}** suspected.

(c) Solubility of substances in water

- The solubility of a substance in water gives a rough prediction of the nature of the anion probably present in the unknown substance.
- 2 spatula ends full of the unknown substance is dissolved in about $5cm^3$ of distilled water.
- Some substances are soluble in water, and they are said to **soluble** in water
- Some substances dissolve a little, leaving some solid in the mixture, they are said to be **sparingly soluble** in water.
- The mixture is filtered, using a filter paper, to obtain a filtrate and a residue.
- Solubility of the substance shows the nature of **anions** while the colour of the filtrate and residue show the nature of **cations** in the unknown compound.

<u>Table 3 shows observations and deductions on solubility of substances in water</u>

Observation	Deduction
White solid, soluble in water, forms a colourless solution.	Al^{3+}, Pb^{2+} or Zn^{2+} suspected, NO_3^-, Cl^- or SO_4^{2-} suspected
White solid, sparingly soluble in water, forms colourless filtrate and white residue.	Al^{3+}, Pb^{2+} or Zn^{2+} suspected CO_3^{2-} , Cl^- or SO_4^{2-} suspected
Green solid, sparingly soluble, to form colourless filtrate and green residue.	Fe^{2+}, Cu^{2+}, suspected CO_3^{2-}, SO_4^{2-}, or Cl^- suspected
Blue solid, soluble to form a blue solution.	Cu^{2+} suspected NO_3^- , Cl^- or SO_4^{2-} suspected

Brown solid, soluble in water to form brown solution	Fe^{3+} suspected NO_3^-, SO_4^{2-} or Cl^- suspected

(d) Dissolving substances in dilute acids

The acids mainly used are nitric acid and hydrochloric acid, these are used to dissolve oxides, hydroxides and carbonates that are insoluble in water.

The insoluble substance may be the residue after filtration, or a fresh sample of the unknown substance.

If the solid dissolves with effervescence of a colourless gas, then test the gas to identify it. As in the case of heating, the gas produced tells us the nature of the anion probably present in the substance.

Observation	Deduction
Colorless gas that turns damp blue litmus paper red and turns lime water milky.	*The gas CO_2 is given off, therefore CO_3^{2-} confirmed present.*
Colorless gas with a choking smell turns damp red litmus paper blue and forms dense white fumes with concentrated hydrochloric acid.	*The gas is NH_3, therefore NH_4^+ suspected*
Reddish brown fumes which turn damp blue litmus paper red	*The gas is NO_2, therefore NO_3^- suspected*
Colorless gas that turns damp blue litmus paper red and bleaches it.	*The gas is SO_2, therefore SO_4^{2-} suspected*

2. IDENTIFICATION OF ANIONS

The Anions that are commonly tested for at this level, are: SO_4^{2-}, CO_3^{2-} , Cl^- , and NO_3^-

(a) Test for carbonate, CO_3^{2-}

Action of ;dilute nitric acid or dilute hydrochloric acid.

Test	Observation	Deduction

To 2 spatula ends full of the unknown substance add $5cm^3$ of dilute nitric acid. * *(remember to use litmus papers and lime water when adding dilute acids to solid substances)	*Rapid effervescence occurs; Colourless gas was evolved; the gas turns lime water milky; and turns blue litmus paper to red was evolved; was evolved.*	*The colourless gas is CO_2, therefore, CO_3^{2-} confirmed present.*

(b) Test for Sulphate, SO_4^{2-}

Action of :

- Lead (ii) nitrate solution followed by dilute nitric acid.
- Barium nitrate solution followed by dilute nitric acid or
  Barium chloride solution followed by dilute hydrochloric acid

Test	Observation	Deduction
(i) To $1cm^3$ of the unknown solution add a few drops of Lead (ii) nitrate solution followed by a few drops of dilute nitric acid.	*White precipitate was formed; the precipitate is insoluble in dilute nitric acid.*	*SO_4^{2-} suspected*
(ii) To $1cm^3$ of the unknown solution add a few drops of Barium Nitrate solution followed by dilute Nitric Acid. To $1cm^3$ of the unknown solution add a few drops of Barium Chloride solution followed by dilute hydrochloric acid.	*White precipitate was formed; the precipitate is insoluble in the dilute acid.*	*SO_4^{2-} Confirmed present*

Explanation;

In (b)(i) Lead(ii) nitrate reacts with the sulphate ion to produce lead sulphate which is an insoluble white precipitate.

Equation;

$$Pb^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} \longrightarrow PbSO_{4\,(s)}$$

In (b)(ii) Barium(ii) nitrate reacts with the sulphate ion to produce Barium sulphate which is white precipitate insoluble in dilute nitric acid.
Equation;

$$Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \longrightarrow BaSO_{4\,(s)}$$

A similar reaction is seen with Barium chloride solution.

(c) Test for chloride ion, Cl^-

Action of ;

- Lead (ii) nitrate solution
- Silver nitrate solution

Test	Observation	Deduction
To 1cm3 of the unknown solution add a few drops of Lead (ii) nitrate solution and warm.	*White precipitate was formed; the precipitate dissolved on warming and reappeared on cooling.*	*Cl^- suspected*
To 1cm^3 of the unknown solution add a few drops of silver nitrate solution.	*White precipitate was formed; the precipitate turns to grey on exposure to light for a few minutes.*	*Cl^- confirmed present.*

(d) Test for nitrates, NO_3^-, (the brown ring-test)

Action of;

- Freshly prepared solution of Iron (ii) sulphate solution and
- Concentrated sulphuric acid

Test	Observation	Deduction
To 1cm3 of the unknown solution add 1cm3 of freshly prepared solution of Iron (ii) sulphate followed by a few drops of concentrated	*Brown ring is formed between two layers of colourless solutions.*	***NO_3^-** confirmed present.*

sulphuric acid, added on side of slanting test tube.		

3. IDENTIFICATION OF CATIONS.

(a) Action of Sodium Hydroxide solution

- Most cations form precipitate with sodium hydroxide solution, some of the precipitates formed are **soluble in excess** sodium hydroxide solution whereas others are **insoluble in excess** sodium hydroxide solution.

Test: To $1cm^3$ of each of the solutions add sodium hydroxide solution drop wise until in excess.

Observation		Deduction
(i)	White precipitate soluble in excess sodium hydroxide solution.	Al^{3+} , Pb^{2+} or Zn^{2+} suspected
(ii)	White precipitate insoluble in excess sodium hydroxide solution.	Ca^{2+} , Mg^{2+} or Ba^{2+} suspected
(iii)	Blue precipitate insoluble in excess sodium hydroxide solution	Cu^{2+} suspected
(iv)	Green precipitate insoluble in exces sodium hydroxide solution	Fe^{2+} suspected
(v)	Brown precipitate insoluble in excess sodium hydroxide solution.	Fe^{3+} suspected
(vi)	Colourless solution remains in excess sodium hydroxide solution. On warming, a colourless gas that turns red litmus paper to blue was evolved.	The gas is NH_3; therefore, NH_4^+ confirmed

Explanation

(a)(i) Cations such as **Al^{3+}, Pb^{2+}** or **Zn^{2+}** form white precipitates which are **soluble in excess sodium hydroxide solution** because these are **amphoteric cations** which form complex ions with excess **OH^-** ions.

- With drops of sodium hydroxide solution, white precipitate is formed.

Equation:

$$Pb^{2+}{}_{(aq)} + 2OH^-{}_{(aq)} \longrightarrow \underset{\text{White precipitate}}{Pb(OH)_{2\,(s)}}$$

- With excess of sodium hydroxide solution, the white precipitate dissolves to form a colourless solution containing the complex ion formed.

Equation:

$$\underset{\text{White precipitate}}{Pb(OH)_{2\,(s)}} + 2OH^-{}_{(aq)} \longrightarrow \underset{\text{colourless solution}}{Pb(OH)_4{}^{2-}{}_{(aq)}}$$

(b) Action of aqueous ammonia.

Most cations react with aqueous ammonia to form precipitates that are **insoluble in excess** ammonia solution, except for **Cu^{2+}** and **Zn^{2+}** ion. These ions form precipitates that are **soluble in excess** ammonia solution. This is due to formation of complex ions.

Test: To $1cm^3$ of the unknown solution add aqueous ammonia drop wise until in excess.

Observation		Deduction
(i)	*White precipitate insoluble in excess ammonia solution*	*Al^{3+}, or Pb^{2+} suspected*
(ii)	*White precipitate soluble in excess ammonia solution to form a colourless solution*	*Zn^{2+} confirmed present*
(iii)	*Blue precipitate soluble in excess ammonia solution to form a deep blue solution.*	*Cu^{2+} confirmed present.*
(iv)	*Green precipitate insoluble in excess ammonia solution.*	*Fe^{2+} confirmed present.*
(v)	*Brown precipitate insoluble in excess ammonia solution.*	*Fe^{3+} confirmed present.*

Explanations of observations in the table above:

(b)(ii) Reaction of Zn^{2+} with drops of aqueous ammonia

With few drops of ammonia solution, white precipitate of zinc hydroxide was formed.

Equation

$$Zn^{2+}_{(aq)} + 2OH^{-}_{(aq)} \longrightarrow Zn(OH)_{2(s)}$$

White precipitate

With excess aqueous ammonia, the white precipitate dissolved to form a colourless solution of *tetraaminezinc (ii) ion* which is a complex ion

Equation

$$Zn(OH)_{2\,(s)} + 4NH_{3(aq)} \longrightarrow [Zn(NH_3)_4]^{2+}{}_{(aq)} + 2OH^{-}{}_{(aq)}$$

White precipitate *colorless solution*

(b)(iii) Reaction of Cu^{2+} with drops of aqueous ammonia

With few drops of ammonia solution, blue precipitate of copper (ii) hydroxide was formed.

Equation

$$Cu^{2+}_{(aq)} + 2OH^{-}_{(aq)} \longrightarrow Cu(OH)_{2(s)}$$

Blue precipitate

With excess aqueous ammonia, the blue precipitate dissolved to form a deep blue solution of *tetraaminecopper (ii) ion* which is a complex ion

Equation

$$Cu(OH)_{2\,(s)} + 4NH_{3(aq)} \longrightarrow [Cu(NH_3)_4]^{2+}{}_{(aq)} + 2OH^{-}{}_{(aq)}$$

Blue precipitate *deep blue solution*

(c) Action of Potassium Iodide solution

Test	Observation	Deduction
To $1cm^3$ of the unknown solution add a few drops of Potassium Iodide solution.	*Bright yellow precipitate was formed*	*Pb^{2+} confirmed present.*

Ionic Equation

$$Pb^{2+}{}_{(aq)} + 2I^{-}{}_{(aq)} \longrightarrow PbI_{2\,(s)}$$

Yellow precipitate

(d) Action of dilute Hydrochloric Acid or **Sodium Chloride solution**

Test	Observation	Deduction
To $1cm^3$ of the unknown solution add a few drop of	*White precipitate was formed; the precipitate turns to*	*Ag^{+} confirmed present.*

dilute hydrochloric acid or sodium chloride solution.	*grey solid on exposure to light.*	

Worked Example 1

You are provided with a substance H which is containing one anion and one cation. Carry out the tests below to identify the ions present, identify any gases that may be given off. Record the observations and the deductions in the table below.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Identify the colour of the substance	substance H was white crystals	The substance may contain salts of $Pb^{2+,}$ Al^{3+}, Zn^{2+}, Ca^{2+}, or Mg^{2+} NO_3^-, SO_4^{2-} or Cl^- suspected.
(b) Heat a spatula endful of H gently and then strongly in a clean and dry test tube.	• The white crystals turn into a white powder, a colourless liquid condensate forms on the cooler parts of the test tube, the liquid turns white anhydrous copper(II) sulphate blue. • Colourless gas that turns blue litmus paper red and bleaches it, was evolved. • Residue is yellow when hot and white when cold	The substance is hydrated. It contains salts of $Pb^{2+,}$ Al^{3+}, Zn^{2+}, Ca^{2+}, or Mg^{2+} The gas is SO_2, therefore, SO_4^{2-} suspected.

		Residue is ZnO, hence Zn^{2+} suspected.
(c) To about a spatula endful of H in a test tube, add about $5cm^3$ of distilled water, shake vigorously, divide the resultant solution into four portions.	H dissolved in water to form a colourless solution.	The substance may contain salts of Pb^{2+}, Al^{3+}, Zn^{2+}, Ca^{2+}, or Mg^{2+}
(i) To the first portion add dilute sodium hydroxide solution drop wise until in excess	A white precipitate soluble in excess alkali forming a colourless solution	Pb^{2+}, Al^{3+}, or Zn^{2+} are suspected to be present
(ii) To the second portion add ammonia solution drop wise until in excess	A white precipitate soluble in excess alkali forming a colourless solution	Zn^{2+} are confirmed present
(iii) To the third portion add few drops of lead (II) nitrate solution followed by dilute nitric acid.	A white precipitate insoluble in the acid.	SO_4^{2-}, or Cl^- probably present
(iv) To the forth portion add few drops of barium nitrate solution.	A white precipitate insoluble in nitric acid.	SO_4^{2-} confirmed present

Cation in H is Zn^{2+}

Anion in H is SO_4^{2-}

Worked Example 2

You are provided with a substance G which is containing two anions and one cation. Carry out the tests below to identify the ions present, identify any gases that may be given off. Record the observations and the deductions in the table below.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of G gently and then strongly	G is a mixture of blue crystals and white powder.	Cu^{2+} suspected since G is blue.

in a clean and dry test tube.	A colourless gas that turns damp blue litmus paper red and lime water milky Residue was black powder,	$Pb^{2+,}$ Al^{3+}, Zn^{2+}, Ca^{2+}, or Mg^{2+} also suspected since G is white. SO_4^{2-} or CI^- suspected since G is crystalline. The gas is CO_2, hence CO_3^{2-} probably present Cu^{2+} suspected.
(b) To about a spatula endful of G in e test tube add 5cm^3 of distilled water, shake vigorously, filter collect both the residue and the filtrate. Divide the resultant solution into four portions.	A blue solid partly dissolves forming a pale blue filtrate and a pale blue residue.	Cu^{2+} are most likely present
(i) To the first portion add sodium hydroxide solution drop wise until in excess	A pale blue precipitate insoluble in excess.	Cu^{2+} are most likely present
(ii)To the first portion add ammonium hydroxide solution drop wise until in excess	A pale blue precipitate soluble in excess forming a deep blue solution.	Cu^{2+} are confirmed present
(iii) To the third portion add few drops of lead(II) nitrate solution followed by dilute nitric acid	A white precipitate insoluble in the acid	SO_4^{2-}, probably present
(iv) To the fourth portion add silver nitrate solution followed by ammonia solution.	A white precipitate insoluble ammonia solution	CI^- are confirmed present.
(c) Wash the residue carefully with distilled water, and to it add dilute nitric acid until it just dissolves. Divide the resultant solution into three portions.	The residue dissolves in the acid with effervescence of colourless gas which turns damp blue litmus paper red and lime water milky. Colourless solution is formed.	The gas is CO_2 hence CO_3^{2-} confirmed present. $Pb^{2+,}$ Al^{3+}, Zn^{2+}, Ca^{2+}, or Mg^{2+} are suspected.
(i) to the first portion add sodium hydroxide solution drop wise until in excess	A white precipitate soluble in excess sodium hydroxide forming a colourless solution	$Pb^{2+,}$ Al^{3+}, or Zn^{2+} are present

(ii) to the second portion add ammonia solution drop wise until in excess	A white precipitate insoluble in excess sodium hydroxide solution.	Pb^{2+} or Al^{3+} are suspected.
(iii) To the third portion add two drops of potassium iodide solution	A yellow precipitate is formed.	Pb^{2+} are confirmed present

Anions are CO_3^{2-} and Cl^-

Cations are Cu^{2+} and Pb^{2+}

Activities on Qualitative Analysis.

ACTIVITY 1

Complete the table below by working out the deductions about substance H1

TESTS	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of H in a clean and dry test tube gently and then strongly.	• A white sublimate is formed on cooler parts of the test tube. • A colourless gas that turns damp red litmus paper blue. • A colourless liquid condensate is formed on the cooler parts of the test tube ,it turns white anhydrous copper(II) sulphate blue. • A colourless gas that turns damp blue litmus paper red and lime water milky. • A yellow hot residue turns white when left to stand.	
(b) To about a spatula endful of H in a test tube, add about 5cm3 of distilled water. Shake	• It partly dissolves in water forming a colourless filtrate and a white residue.	

vigorously filter collect both thecresidue and the filtrate. Divide the filtrate into six portions		
(i) To the 1st portion add sodium hydroxide solution and warm	• a colourless solution and acolourless gas that turns damp red litmus paper blue is given off.	
(ii) To the 2nd portion add dilute nitric acid solution and then few drops of lead(II) nitrate solution.	• Awhite precipitate is formed	
(iii) To the 3rd portion add silver nitrate solution	• A white precipitate is formed.	
(c) To the residue in a test tube add dilute nitric acid until it just dissolves. Divide the resultant solution into two portions,	• The residue dissolved in the acid with effervescence of a colourless gas that turnnsturnslue litmus paper red and forms a white precipitate with calcium hydroxide solution.	
(i) To the 1st portion add sodium hydroxide solution dropwise until in excess	• A white precipitate that dissolves in excess forming a colourless solution.	
(ii) To the 2nd portion add ammonia solution drop wise until in excess	• A white precipitate that dissolves in excess forming a colourless solution	

Cations in H ……………………………. and …………………………………..

Anions in H …………………………… And ……………………………………

WORK SHEETS FOR CLASS OR GROUP ACTIVITIES.

ACTIVITY 1

You are provided with a substance C that contains one cation and one anion. Carry out the tests below to identify the ions present in C. Identify the gases that may be given off. Record your observations and deductions in the table below.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Note the colour and texture of substance C given to you		
(b) To about a spatula endful of C in a test tube, add about $5cm^3$ of distilled water. Shake vigorously filter collect both the residue and the filtrate. Divide the filtrate into five portions		
(i) To the 1^{st} portion add sodium hydroxide solution dropwise until in excess		
(ii) To the 2^{nd} portion add ammonia solution drop wise until in excess		
(iii) To the 3^{rd} portion add dilute nitric acid followed by few drops of lead(II) nitrate solution.		
(iv) to the 3^{rd} portion add few drops of barium nitrate solution.		

Cation in C ……………………………………………

Anion in C……………………………………………

ACTIVITY 2.

You are provided with a substance J that contains ona cation and one anion.Carry out the tests below to identify the ions present in J. Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a)) Heat a spatula endful of J in a clean and		

dry test tube gently and then strongly until no further change.		
(b) To about a spatula endful of J in a test tube, add about $5cm^3$ of distilled water. Shake vigorously. Divide the filtrate into five portions		
(i) To the 1st portion add sodium hydroxide solution dropwise until in excess		
(ii) To the 2nd portion add ammonia solution drop wise until in excess		
(iii) To the 3rd portion add dilute nitric acid followed by few drops of lead(II) nitrate solution.		
(iv) To the 4th portion add dilute nitric acid followed by drops of Barium nitrate solution.		
(v) Use the 5th portion to carry out a test of your own to identify the anion in J. **Test;**		

Cation in J …………………………………………….

Anion in J………………………………………………

ACTIVITY 3

You are provided with a substance K that contains one cation and one anion .Carry out the tests below to identify the ions present in J. Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) note the appearance of K		
(b) Heat a spatula endful of K in a clean and dry test tube gently and then strongly until no further change.		
(b) To about a spatula endful of K in a test tube, add dilute nitric acid until it just dissolves. Divide the resultant solution into two portions.		
(i) To the 1st portion add sodium hydroxide solution dropwise until in excess		
To the 2nd portion add ammonia solution drop wise until in excess		

Cation in K…………………………………………………

Anion in K……………………………………………….

ACTIVITY 4

You are provided with a substance Z that contains one cation and one anion .Carry out the tests below to identify the ions present in J. Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of Z in a clean and dry test tube gently and then strongly until no further change.		
(b To about a spatula endful of Z in a test tube, add about 5cm^3 of distilled water. Shake vigorously. Divide the filtrate into four portions		
(i) To the 1st portion add ammonium hydroxide solution drop wise until in excess		
(ii) To the 2nd portion add sodium hydroxide solution and warm the mixture.		
(iii) Use the 3rd portion to carry out a test of your own choice to to confirm the anion present. **Test;**		

Cation in Z…………………………………………………

Anion in Z…………………………………………………

(c) Write the ionic equation for the reaction taking place in,

b(ii)………

ACTIVITY 5

You are provided with a substance M that contains one cation and one anion .Carry out the tests below to identify the ions present in M. Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of M in a clean and dry test tube gently and then strongly until no further change.		
(b To about a spatula endful of Z in a test tube, add about $5cm^3$ of distilled water. Shake vigorously. Divide the filtrate into four portions		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii) To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		
(iii) To the 3rd portion add two drops of potassium iodide solution.		

Cation in M………………………………………………

Anion in M……………………………………………….

ACTIVITY 6

You are provided with a substance ***J*** that contains one cation and two anions .Carry out the tests below to identify the ions present in ***J*****.** Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of **J** in a clean and dry test tube gently and then strongly until no further change.		
(b To about a spatula endful of **J** in a test tube, add about $5cm^3$ of distilled water. Shake vigorously, filter and collect both the residue and the filtrate. Divide the filtrate into four portions		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii) To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		

(iii) To the 3rd portion two drops of lead(II) nitrate solution and warm the mixture		
(iv) To the 4th portion add acidified barium nitrate solution		
(c) Wash the residue carefully with distilled water, put it in a test tube and add dilute nitric acid until it just dissolves. Divide the solution into two portions.		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii)To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		

Cation in **J**………………………………………………

Anions in **J**…………………… and …………………………………….

ACTIVITY 7

You are provided with a substance ***M*** that contains two cations and one anion .Carry out the tests below to identify the ions present in ***M*** . Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of M in a clean and dry test tube gently and then strongly until no further change.		

(b To about a spatula endful of M in a test tube, add about $5cm^3$ of distilled water. Shake vigorously,		
(c) To the resultant solution add excess sodium hydroxide solution, filter, collect both the residue and the filtrate. To the filtrate add dilute nitric acid until its just acidic, divide the acidic solution into five portions.		
(ii) To the 1^{st} portion add sodium hydroxide solution drop wise until in excess.		
(iii) To the 2^{nd} portion add ammonia solution drop wise until in excess		
(iv) To the 3^{rd} portion add few drops lead(II) nitrate solution nitrate solution		
(v) to the 4^{th} portion add dilute nitric acid		

followed by few drops of barium nitrate solution		
(c) Wash the residue carefully with distilled water, put it in a test tube and add dilute nitric acid until it just dissolves. Divide the solution into two portions.		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii)To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		

Cations in M (i)………………………………… and (ii)……………………

Anion in M……………………………………………………….

ACTIVITY 8

You are provided with a substance ***Z*** that contains one cation and two anions .Carry out the tests below to identify the ions present in ***Z.*** Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of Z in a clean and dry test tube gently and then strongly until no further change.		

(b To about a spatula endful of Z in a test tube, add dilute nitric acid until it just dissolves.to the resultant solution add dilute sodium hydroxide solution until in excess, filter, collect both the residue and the filtrate. Divide the filtrate into tree portions.		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii) To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		
(iii) To the 3rd portion add few drops of potassium iodide solution		
(c) Wash the residue carefully with distilled water, put it in a test tube and add dilute nitric acid until it just dissolves. Divide the solution into two portions.		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii)To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		

Cation in Z ……………………….

Anions in Z ……………………… and ……………………………

ACTIVITY 9

You are provided with a substance ***P*** that contains one cation and two anions .Carry out the tests below to identify the ions present in ***P.*** Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of P in a clean and dry test tube gently and then strongly until no further change.		
(b To about a spatula endful of P in a test tube, add about $5cm^3$ of distilled water. Shake vigorously, to the resultant solution add sodium hydroxide solution until in excess, filter, collect both the residue and the filtrate. To the filtrate add dilute nitric acid until it is just acidic. Divide the acidic solution into four portions		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii) To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		
(iii) To the 3rd portion add lead(II) nitrate solution		

(iv) To the forth portion add barium nitrate solution followed by few drops of dilute nitric acid.		
(c) Wash the residue carefully with distilled water, put it in a test tube and add dilute nitric acid until it just dissolves. Divide the solution into two portions.		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii)To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		

Cations in P are: …………………………… and …………………

Anions in P is :……………………………………………

ACTIVITY 10

You are provided with a substance ***X*** that contains one cation and two anions .Carry out the tests below to identify the ions present in ***X*.** Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of X in a clean and dry test tube gently and then strongly until no further change.		

(b To about a spatula endful of X in a test tube, add about 5cm^3 of distilled water. Shake vigorously, to the resultant solution add sodium hydroxide solution until in excess, filter, collect both the residue and the filtrate. To the filtrate add dilute nitric acid until it is just acidic. Divide the acidic solution into four portions		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii) To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		
(iii) To the 3rd portion, add few drops of potassium iodide solution		
(iv) to the 4th portion add, lead(II) nitrate solution		
(v) To the 5th portion, add dilute nitric acid and then few drops of barium nitrate solution.		
(c) Wash the residue carefully with distilled water, put it in a test tube and add dilute nitric acid until it just dissolves. Divide the solution into two portions.		

(i) To the 1^{st} portion add sodium hydroxide solution drop wise until in excess		
(ii)To the 2^{nd} portion add ammonium hydroxide solution drop wise until in excess.		

Cations in **X** ………………………… and …………………

Anions in ***X***……………………………………

Activity 11

You are provided with substance R, which contains two cations and one anion.
You are required to identify the cations and anion in R.
Carry out the following tests on R and identify any gas (es) evolved.
Record your observations and deductions in the table below;

Test		Observation	Deduction
(a)	Dissolve two spatula ends full of R in about 5cm3 of water. Add aqueous sodium hydroxide to the solution drop wise until there is no further change. Filter and keep both the filtrate and the residue. To the filtrate add drops of dilute nitric acid until it is just acidic. Divide the filtrate into four parts:		
(i)	To the first part of the filtrate add sodium hydroxide solution drop wise until in excess.		
(ii)	To the second part of the filtrate add aqueous ammonia drop wise until in excess.		
(iii)	To the third part of the filtrate add lead (ii) nitrate		

	solution followed by a few drops of dilute nitric acid.		
(iv)	Use the fourth part of the filtrate to carry a test of your own choice to confirm the anion in R. **Test;**		
(b) (i)	Dissolve the residue in about 2cm3 of dilute nitric acid. Divide the resultant solution into two parts. To the first part of the solution add sodium hydroxide solution drop wise until in excess.		
(ii)	To the second part of the solution add Aqueous ammonia drop wise until in excess.		

Identify:

(i) The cations in R; …………………………………… and …………………………………………

(ii) The anion in R; …………………………………………

Activity 12

You are provided with substance T, which contains two cations and one anion.

You are required to identify the cations and anion in T.

Carry out the following tests on T and identify any gas(es) evolved.

Record your observations and deductions in the table below;

Test		Observation	Deduction
(a)	Dissolve two spatula ends full of T in about $5cm^3$ of dilute nitric acid and warm to dissolve. Add aqueous sodium hydroxide to the solution until there is no further change. Filter and keep both the filtrate and the residue.		
(b) (i)	To the filtrate add drops of dilute nitric acid until it is just acidic. Divide the filtrate into five parts: To the first part of the filtrate add sodium hydroxide solution drop wise until in excess.		
(ii)	To the second part of the filtrate add aqueous ammonia drop wise until in excess.		
(iii)	To the third part of the filtrate add a few drops of potassium iodide solution.		
(iv)	To the fourth part of the filtrate add lead (ii) nitrate solution followed by a few drops of dilute nitric acid.		

(v)	Use the fifth part of the filtrate to carry a test of your own choice to confirm the anion in T.		
(c) (i)	Dissolve the residue in about 2cm3 of dilute nitric acid. Divide the resultant solution into two parts. To the first part of the solution add sodium hydroxide solution drop wise until in excess.		
(ii)	To the second part of the solution add aqueous ammonia drop wise until in excess.		

(e) Identify:

(iii) The cations in T; …………………………………. and ……………………………………….

(iv) The anion in T; ………………………………………..

QUALITATIVE ANALYSIS

This involves carrying out various tests accurately, making correct observations in order to make valid deductions. it is concerned with identification of unknown substance provided that the cation(s) and anion(s) present in it

1. Cations (positiveiy charged ions). the common cations are ammonium ions (NH_4^+), Lead(II)ions(Pb^{2+}) , aluminium ions (Al^{3+}), magnesium ions (Mg^{2+}), calcium ions (Ca^{2+}), zinc ions (Zn^{2+}), iron(II) ions (Fe^{2+}),and iron(III) ions (Fe^{3+}).Some form coloured compounds like Cu^{2+}, Fe^{2+}, and Fe^{3+} while others form white compounds(colorless solutions)like the rest.
2. Anions (negatively charged ions). These include; sulphate ion(SO_4^{2-}),Carbonate ion (CO_3^{2-}), Nitrate ion (NO_3^-),chloride ion(CI^-)

PRELIMINARY TESTS

These are the first tests in which a student notes the first appearance, color ad smell of the substance.

The appearance

By looking at the appearance of the substance, you may suspect what the substance could be

Below are some examples

Observer colour	Probable ions
(i) Green or green solid solution	Fe^{2+} or Cu^{2+}
(ii) Blue or black solid solution	Cu^{2+}
(iii)Black solid	An oxide(e.g.CuO)
(IV)Yellow\brownish solid or solution	Lead(II)oxide(for the case of solid)or Iron(III)salt present

Solubility of water

Note the solubility of a substance in water

Anions	**Solubility**
(i)Nitrate(NO_3^-)	All are soluble
(ii)Chloride(Cl^-)	All are soluble except AgCl (Silverchloride) ,$PbCl_2$(Lead(II)chloride) $PbCl_2$ is soluble in hot water

(iii)Sulphate ion(SO_4^{2-})	All are soluble except $PbSO_4$, $BaSO_4$ $CaSO_4$ ($CaSO_4$ is sparingly soluble in water)
(iv)Carbonate ion (CO_3^{2-})	All are insoluble except carbonates of group I metals and Ammonium carbonate.

NB: Dissolving in water does not involve gases ie no gases are usually given off but instead it tests whether the given substance can dissolve in water. Ione is instructed to dissolve in water and filter, it means the substance is a mixture of a soluble component and an insoluble one. At this point its important for a student to identify the colour of the residue and the filtrate and mention them in the observations.

(b).**Action of heat**

A little sample of the substances are heated in a dry hard glass tube, first gently and then strongly.

When heating the substance, note any gas given off or vapour given off; or if the substance sublimes or if it produces a sound on decomposition; and the colour of the solid or residue formed. The gaseous products can be tested using wet pieces of litmus papers, lime water and acidified potassium dichromate solution or by the smell.

Below are some of the likely observations on heating, and appropriate deductions:

(c) **Dissolving in dilute acids**

The acids mainly used are nitric acid and hydrochloric acid, these are mainly used to dissolve insoluble oxides, insoluble hydroxides and insoluble carbonates which may be in the residue after filtration, or a fresh sample. When the solid dissolves with effwervescence of a colourless gas, test the gas to identify it.

Observation	Deduction
Colorless vapour that condenses into a colorless liquid on cooler parts of the test tube and the liquid turns white anhydrous copper(II)sulphate blue	Liquid is water, hydrated salt
Colorless gas that turns damp blue litmus paper pink and lime water	CO_2,given off, CO_3^{2-},HCO_3^- present
Colorless gas with a choking smell turns damp red litmus paper blue and forms dense	The gas is NH_3,NH_4+ present

white fumes with concentrated hydrochloric acid.	
Reddish brown fumes which turn damp blue litmus paper red	The gas is NO_2,NO_3- present
Colorless gas that turns damp blue litmus paper red and orange acidified potassium dichromate solution green	The gas is SO_2,SO_4^{2-} present
Cracking sound produced	Lead(II)nitrate Pb^{2+} present
A yellow residue that turns white on cooling	Residue is ZnO,Zn^{2+} present
Brown residue which turns white on cooling	Residue is PbO,Pb^{2+} present
Black residue	Residue is CuO,Cu^{2+} present

IDENTIFICATION OF CATIONS

i) Action of sodium hydroxide solution

To the solution in a test tube, sodium hydroxide is added drop wise until in excess

Below are expected observations and deductions:

Observations	Deductions
The solution remains colorless	Probably NH_4+ present
White precipitate soluble in excess to form colorless solution	Probably $Pb^{2+,}$ Al^{3+}, Zn^{2+}
White precipitate, insoluble in excess	Probably Ca^{2+}, Mg^{2+} present
Colorless gas with choking smell and turns red litmus paper blue was given off on warming	The gas is NH_3,NH_4^+ present $NH_4^+ (aq) + {}^-OH(aq) \longrightarrow NH_3(g) + H_2O(l)$
Blue precipitate insoluble in excess	Cu^{2+} present
Green precipitate insoluble in excess, precipitate turns brown on standing	Fe^{2+} present
Brown precipitate insoluble in excess	Fe^{3+} present

ii) Action of ammonia solution (aqueous ammonia/ammonium hydroxide)

To the solution in attest tube, add aqueous ammonia drop wise until in excess.

White precipitate soluble in excess to form colorless solution	Zn^{2+} present
White precipitate insoluble in excess	Al^{3+},Pb^{2+} or Mg^{2+} probably present
Blue precipitation, soluble in excess to form a deep blue solution	Cu^{2+} present
Green precipitate insoluble in excess	Fe^{2+} present
Brown precipitate insoluble in excess	Fe^{3+} present

IDENTIFICATION OF ANIONS

Here a variety of reagents are used

Test	Observation	Deductions
Add $Ba(NO_3)_2$or $BaCl_2$ solution	white precipitate formed	$SO4^{2-}$ probably present
Add barium nitrate solution followed by dilute HNO_3 or barium chloride solution followed by dilute hydrochloric acid	white precipitate insoluble in dilute HNO_3 or white precipitate insoluble in the dilute HCI	$SO4^{2-}$ confirmed present
Add lead(II)nitrate solution	white precipitate	$SO4^{2-}$, $CO3^{2-}$ or CI^- probably present
Add lead(II)nitrate solution followed by dilute HNO_3	white precipitate insoluble in the acid	$SO4^{2-}$ or CI- probably present
Add lead(II)nitrate solution and boil/warm	white precipitate, soluble on warming an reappear on cooling	Cl^- confirmed present
Add dilute nitric acid or dilute HCI to the unknown solid/solution	Effervescence of colorless gas that turns damp blue litmus paper pink and lime water milky	NO_3^- confirmed present
Add freshly prepared iron(II)sulphate solution and then carefully add concentrated H_2SO4 down the sides of the test tube.	Brown ring formed at the junction of the two layers	NO_3^- confirmed present

Add copper turning followed by concentrated H_2SO_4 and warm	Evolution of reddish brown fumes that turns damp blue litmus paper red.	The gas is NO_2, NO_3^- present

CONFIRMATION TEST

J Confirmatory test for cations

Zn^{2+}	To a solution add ammonia solution drop wise until in excess	white precipitate soluble in excess to form colorless solution Zn^{2+} (aq) + 2OH-(aq)…………..Zn(OH)2(aq)
Pb^{2+}	a) To a solution add KI solution	Yellow precipitate………$Pb^{2+(}$aq) + 2I-(aq)……PbI_2(s)
	b) To a solution add dilute hydrochloric acid and boil	White precipitate soluble on warming and reappears on cooling.
		Pb^{2+}(aq) + $2CI^-$(aq)……..PbCl2(aq)
Cu^{2+}	To a solution add ammonia solution, drop wise until in excess	Blue precipitate soluble in excess to form a deep blue solution Cu^{2+} (aq)+$2Cl^-$(aq)……$Pbcl_2$(aq)
Fe^{2+}	To a solution add ammonia solution dropwise until in excess	Green precipitate insoluble in excess
Fe^{3+}	To a solution add ammonia solution dropwiseuntil in excess	Reddish brown -precipitate insoluble in excess

(iii)Confirmatory test for Anions

Dissolve a little of the substance in cold water. Then carry out the identification test for the anion

Nitrate (NO_3^-)

To 1cm3 of the solution in a test tube, add 1cm of freshly prepared solution of iron (II) sulphate. Hold the tube in a slanting position and very carefully add concentrated sulphuric acid down the side of the test tube. Brown ring is formed this is called the **Brown ring test.**

Chloride (Cl^-)

Add dilute nitric acid followed by silver nitrate acid solution. A white precipitate is formed

$Ag^+ (aq) + Cl^-(aq) \longrightarrow AgCl(s)$

To a sample of the solution, add lead (II) nitrate solution and warm. White precipitate that dissolves on warming to form a colourless solution. The precipitate reappears on cooling.

Pb^{2+} (aq) +2Cl-…………$PbCl_2$(s)

Sulphate

Add dilute nitric acid followed by barium nitrate solution or add hydrochloric acid followed by barium chloride solution or dilute hydrochloric acid followed by barium chloride solution in both cases, white precipitate is formed

Ba^{2+} (aq) +SO4 $^{2-}$ (aq)……….BaSO4(s)

Carbonate (CO_3 $^{2-)}$ and hydrogen carbonate (HCO_3^-)

Add magnesium sulphate or magnesium chloride solution. White precipitate indicates presence of a carbonate

Mg^{2+} + CO_3 $^{2-}$……………..$MgCO_3$(s)

Example 1

You are provided with a substance H which is containing one anion and one cation. Carry out the tests below to identify yhe ions present, identify any gases that may be given off. Record the observations and the deductions in the table below.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Identify the colour of the substance	The substance is made of white crystals	The substance may contain salts of Pb^{2+}, Al^{3+}, Zn^{2+}, Ca^{2+}, OR Mg^{2+}
(b) Heat a spatula endful of H gently and then strongly in a clean and dry test tube.	The white crystals turn into a white powder, a colourless liquid condensate forms on the cooler parts of the test tube, the liquid turns white anhydrous copper(II) sulphate blue.	The substance is hydrated. It contains salts of Pb^{2+}, Al^{3+}, Zn^{2+}, Ca^{2+}, OR Mg^{2+}

(c) To about a spatula endful of H in a test tube, add about 5cm3 of distilled water, shake vigorously, divide the resultant solution into four portions.	It dissolves in water forming a colourless solution	The substance may contain salts of Pb^{2+}, Al^{3+}, Zn^{2+}, Ca^{2+}, OR Mg^{2+}
(i) To the first portion add dilute sodium hydroxide solution drop wise until in excess	A white ppt soluble in excess alkali forming a colourless solution	Pb^{2+}, Al^{3+}, OR Zn^{2+} are present
(ii) To the second portion add ammonia solution drop wise until in excess	A white ppt soluble in excess alkali forming a colourless solution	Zn^{2+} are confirmed present
(iii) To the third portion add few drops of lead (II) nitrate solution followed by dilute nitric acid.	A white ppt insoluble in the acid.	$SO4^{2-}$, or CI^{-} probably present
(iv) To the forth portion add few drops of barium nitrate solution.	A white ppt	$SO4^{2-}$ confirmed present

Cation in H is Zn^{2+}

Anion in H is $SO4^{2-}$

Example 2

You are provided with a substance G which is containing two anions and one cation. Carry out the tests below to identify the ions present, identify any gases that may be given off. Record the observations and the deductions in the table below.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of G gently and then strongly in a clean and dry test tube.	The pale blue solid forms a black powder, A colourless gas that turns damp blue litmus paper red and lime water milky	Transition metal ions are present $SO4^{2-}$, $CO3^{2-}$, HCO_3^{-} or CI^{-} probably present
(b) To about a spatula endful of G in e test tube add 5cm3 of distilled warer, shake vigorously, filter collect both the residue and the filtrate.	A blue solid partly dissolves forming a pale blue filtrate and a pale blue residue	Cu^{2+} are most likely present

Divide the resultant solution into four portions.		
(i) To the first portion add sodium hydroxide solution drop wise until in excess	A pale blue ppt insoluble in excess	Cu^{2+} are most likely present
(ii)To the first portion add ammonium hydroxide solution drop wise until in excess	A pale blue ppt soluble in excess forming a deep blue solution	Cu^{2+} are confirmed present
(iii) To the third portion add few drops of lead(II) nitrate solution followed by dilute nitric acid	A white ppt insoluble in the acid	$SO4^{2-}$, or CI^{-} probably present
(iv) To the fourth portion add silver nitrate solution.	A white ppt	CI^{-} are confirmed present
(c) Wash the residue carefully with distilled water, and to it add dilute nitric acid until it just dissolves. Divide the resultant solution into three portions.	The residue dissolves in the acid with effervescence of s colourless gas which turns damp blue litmus paper red and lime water milky forming a colourless solution.	CO_2 gas hence $CO3^{2-}$ are confirmed present. $Pb^{2+,}$ Al^{3+}, Zn^{2+}, Ca^{2+}, OR Mg^{2+} are present.
(i) to the first portion add sodium hydroxide solution drop wise until in excess	A white ppt soluble in excess alkali forming a colourless solution	$Pb^{2+,}$ Al^{3+}, OR Zn^{2+} are present
(ii) to the second portion add ammonia solution drop wise until in excess	A white ppt insoluble inexcess	Pb^{2+} OR Al^{3+} are present
(iii) To the third portion add two drops of potassium iodide solutoon	A yellow ppt is formed	Pb^{2+} are confirmed present

Anions are $CO3^{2-}$ and CI^{-}

Cations are Cu^{2+} and Pb^{2+}

ACTIVITY 1

Complete the table below by working out the deductions about substance H1

TESTS	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of H in a clean and dry test tube gently and then strongly.	• A white sublimate is formed on cooler parts of the test tube.	

	• A colourless gas that turns damp red litmus paper blue. • A colourless liquid condensate is formed on the cooler parts of the test tube ,it turns white anhydrous copper(II) sulphate blue. • A colourless gas that turns damp blue litmus paper red and lime water milky. • A yellow hot residue turns white when left to stand.	
(b) To about a spatula endful of H in a test tube, add about 5cm3 of distilled water. Shake vigorously filter collect both thecresidue and the filtrate. Divide the filtrate into six portions	• It partly dissolves in water forming a colourless filtrate and a white residue.	
(i) To the 1st portion add sodium hydroxide solution and warm	• a colourless solution and acolourless gas that turns damp red litmus paper blue is given off.	
(ii) To the 2nd portion add dilute nitric acid solution and then few drops of lead(II) nitrate solution.	• Awhite precipitate is formed	
(iii) To the 3rd portion add silver nitrate solution	• A white precipitate is formed.	
(c) To the residue in a test tube add dilute nitric acid until it just dissolves. Divide the resultant solution into two portions,	• The residue dissolved in the acid with effervescence of a colourless gas that turnnsturnslue litmus paper red and forms a white precipitate with calcium hydroxide solution.	

(i) To the 1st portion add sodium hydroxide solution dropwise until in excess	• A white precipitate that dissolves in excess forming a colourless solution.	
(ii) To the 2nd portion add ammonia solution drop wise until in excess	• A white precipitate that dissolves in excess forming a colourless solution	

Cations in H ……………………………. and …………………………………..

Anions in H ……………………………. And ……………………………………

ACTIVITY 1

You are provided with a substance C that contains ona cation and one anion.Carry out the tests below to identify the ions present in C. Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Note the colour and texture of the substance given to you		
(b) To about a spatula endful of C in a test tube, add about 5cm3 of distilled water. Shake vigorously filter collect both the residue and the filtrate. Divide the filtrate into five portions		
(i) To the 1st portion add sodium hydroxide solution dropwise until in excess		
(ii) To the 2nd portion add ammonia solution drop wise until in excess		
(iii) To the 3rd portion add dilute nitric acid followed by few drops of lead(II) nitrate solution.		
(iv) to the 3rd portion add few drops of barium nitrate solution.		

Cation in C ……………………………………………..

Anion in C……………………………………………

ACTIVITY 2.

You are provided with a substance J that contains ona cation and one anion.Carry out the tests below to identify the ions present in J. Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a)) Heat a spatula endful of J in a clean and dry test tube gently and then strongly until no further change.		
(b) To about a spatula endful of J in a test tube, add about 5cm3 of distilled water. Shake vigorously. Divide the filtrate into five portions		
(i) To the 1^{st} portion add sodium hydroxide solution dropwise until in excess		
(ii) To the 2^{nd} portion add ammonia solution drop wise until in excess		
(iii) To the 3^{rd} portion add dilute nitric acid followed by few drops of lead(II) nitrate solution.		
(iv) To the 4^{th} portion add dilute nitric acid solution.		
(v) Use the 5^{th} portion to carry out a test of your own to identify the anion in J		

Cation in J …………………………………………….

Anion in J……………………………………………

ACTIVITY 3

You are provided with a substance K that contains one cation and one anion .Carry out the tests below to identify the ions present in J. Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) note the appearance of K		
(b) Heat a spatula endful of K in a clean and dry test tube gently and then strongly until no further change.		
(b) To about a spatula endful of K in a test tube, add dilute nitric acid until it just dissolves. Divide the resultant solution into two portions.		
(i) To the 1st portion add sodium hydroxide solution dropwise until in excess		
To the 2nd portion add ammonia solution drop wise until in excess		

Cation in K………………………………………………

Anion in K……………………………………………..

ACTIVITY 4

You are provided with a substance Z that contains one cation and one anion .Carry out the tests below to identify the ions present in J. Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of Z in a clean and dry test tube gently and then strongly until no further change.		
(b To about a spatula endful of Z in a test tube, add about 5cm3 of distilled water. Shake vigorously. Divide the filtrate into four portions		

(i) To the 1st portion add ammonium hydroxide solution drop wise until in excess		
(ii) To the 2nd portion add sodium hydroxide solution and warm the mixture.		
(iii) Use the 3rd portion to carry out a test of your own choice to to confirm the anion present.		

Cation in Z………………………………………………

Anion in Z……………………………………………..

(c) Write the ionic equation for the reaction taking place in,

b(ii)……

ACTIVITY 5

You are provided with a substance M that contains one cation and one anion .Carry out the tests below to identify the ions present in M. Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of M in a clean and dry test tube gently and then strongly until no further change.		
(b To about a spatula endful of Z in a test tube, add about 5cm^3 of distilled water. Shake vigorously. Divide the filtrate into four portions		

(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii) To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		
(iii) To the 3rd portion add two drops of potassium iodide solution.		

Cation in M………………………………………………

Anion in M……………………………………………..

ACTIVITY 6

You are provided with a substance **J** that contains one cation and two anions .Carry out the tests below to identify the ions present in **J.** Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of M in a clean and dry test tube gently and then strongly until no further change.		
(b To about a spatula endful of Z in a test tube, add about $5cm^3$ of distilled water. Shake vigorously, filter and collect both the residue and the filtrate. Divide the filtrate into four portions		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii) To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		
(iii) To the 3rd portion two drops of lead(II) nitrate solution and warm the mixture		
(iv) To the 4th portion add acidified barium nitrate solution		

(c) Wash the residue carefully with distilled water, put it in a test tube and add dilute nitric acid until it just dissolves. Divide the solution into two portions.		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii)To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		

Cation in M………………………………………………

Anions in M……………………

ACTIVITY 7

You are provided with a substance **M** that contains two cations and one anion .Carry out the tests below to identify the ions present in **M** . Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of M in a clean and dry test tube gently and then strongly until no further change.		
(b To about a spatula endful of Z in a test tube, add about $5cm^3$ of distilled water. Shake vigorously,		
(c) to the resultant solution add excess sodium hydroxide solution, filter, collect both the residue and the filtrate. To the filtrate add dilute nitric acid until its just acidic, divide the acidic solution into five portions.		
(ii) To the 1st portion add sodium hydroxide solution drop wise until in excess.		

(iii) To the 2nd portion add ammonia solution drop wise until in excess		
(iv) To the 3rd portion add few drops lead(II) nitrate solution nitrate solution		
(v) to the 4th portion add dilute nitric acid followed by few drops of barium nitrate solution		
(c) Wash the residue carefully with distilled water, put it in a test tube and add dilute nitric acid until it just dissolves. Divide the solution into two portions.		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii)To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		

Cation in M (i)………………………………… and (ii)…………………….

Anion in M……………………………………………………….

ACTIVITY 8

You are provided with a substance **Z** that contains one cation and two anions .Carry out the tests below to identify the ions present in **Z.** Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of M in a clean and dry test		

tube gently and then strongly until no further change.		
(b To about a spatula endful of Z in a test tube, add dilute nitric acid until it just dissolves.to the resultant solution add dilute sodium hydroxide solution until in excess, filter, collect both the residue and the filtrate. Divide the filtrate into tree portions.		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii) To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		
(iii) To the 3rd portion add few drops of potassium iodide solution		
(c) Wash the residue carefully with distilled water, put it in a test tube and add dilute nitric acid until it just dissolves. Divide the solution into two portions.		

(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii)To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		

Cation in M (i)……………………… and (ii)………………………

Anions in M(i) ……………………

ACTIVITY 9

You are provided with a substance **P** that contains one cation and two anions .Carry out the tests below to identify the ions present in **P.** Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of M in a clean and dry test tube gently and then strongly until no further change.		
(b To about a spatula endful of Z in a test tube, add about 5cm^3 of distilled water. Shake vigorously, to the resultant solution add sodium hydroxide solution until in excess, filter, collect both the residue and the filtrate. To the filtrate add dilute nitric acid until it is just acidic. Divide the acidic solution into four portions		

(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii) To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		
(iii) To the 3rd portion add lead(II) nitrate solution		
(iv) to the forth portion add acidified barium nitrate solution.		
(c) Wash the residue carefully with distilled water, put it in a test tube and add dilute nitric acid until it just dissolves. Divide the solution into two portions.		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii)To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		

Cations in P are: …………………………… and …………………

Anions in P is :…………………………………………

ACTIVITY 10

You are provided with a substance **X** that contains one cation and two anions .Carry out the tests below to identify the ions present in **X.** Identify the gases that may be given off.

TEST	OBSERVATIONS	DEDUCTIONS
(a) Heat a spatula endful of M in a clean and dry test tube gently and then strongly until no further change.		
(b To about a spatula endful of Z in a test tube, add about $5cm^3$ of distilled water. Shake vigorously, to the resultant solution add sodium hydroxide solution until in excess, filter, collect both the residue and the filtrate. To the filtrate add dilute nitric acid until it is just acidic. Divide the acidic solution into four portions		
(i) To the 1^{st} portion add sodium hydroxide solution drop wise until in excess		
(ii) To the 2^{nd} portion add ammonium hydroxide solution drop wise until in excess.		
(iii) To the 3^{rd} portion, add few drops of potassium iodide solution		

(iv) to the 4th portion add, lead(II) nitrate solution		
(v) to the 5th portion, add dilute nitric acid and then few drops of barium nitrate solution.		
(c) Wash the residue carefully with distilled water, put it in a test tube and add dilute nitric acid until it just dissolves. Divide the solution into two portions.		
(i) To the 1st portion add sodium hydroxide solution drop wise until in excess		
(ii)To the 2nd portion add ammonium hydroxide solution drop wise until in excess.		

Cations in <u>**X**</u> …………………………… and …………………

Anions in **X**…………………………………………

Activity 11

You are provided with a substance X that contains one anion and two cations. Carry out the following tests to identify the ions and identify any gas(es) that may be given off

TEST	OBSERVATIONS	DEDUCTIONS
(a)Heat a spatula endful of X in a dry test gently and strongly		

(b)Dissolve 2 spatula endful of X in 5cm3 of water . Divide the solution into 4 portions.		
(i)To the first portion add sodium hydroxide solution drop wise until in excess		
(ii)To the second portion add add aqueous ammonia drop wise until in excess until in excess		
(iii)To the third portion add few drops of lead(II) nitrate solution.		
(iv)Use the fourth portion to carry out a test of your own choice to confirm the anion in X. ………………………………………………………………. ………………………………………………………………. ……………………………………………………………….. ……………………………………………………………….		

(c)

(i) The cation in X are …………………………………………………………………. and …………………………………………………………

(ii)The anion in X is…………………………………………………………………………

Activity 12

You are provided with a substance W that contains one anion and two cations. Carry out the following tests to identify the ions and identify any gas(es) that may be given off

TEST	OBSERVATIONS	DEDUCTIONS
(a)Heat a spatula endful of W in a dry test gently and strongly		
(b)Dissolve 2 spatula endful of W in 6cm^3 of water . Divide the solution into 6 portions.		
(i)To the first portion add sodium hydroxide solution drop wise until in excess		
(ii)To the second portion add aqueous ammonia drop wise until in excess until in excess		

(iii)To the third portion add 2-3 drops of Potassium iodide solution.		
(iv)Use the fourth portion add lead(II) nitrate solution warm and cool under cold water		
(v)To the fifth portion add silver nitrate solution and then add ammonia solution until in excess		
(vi)To the sixth portion add dilute nitric acid followed by barium nitrate solution.		

(c)Identify the,

(i) The cation in W are ………………………………………………………………….

(ii) Anions in W …………………………………………………….and…………………………………………………………

Activity 13

You are provided with a substance V that contains one cation and two anions. Carry out the following tests to identify the ions and identify any gas(es) that may be given off

TEST	OBSERVATIONS	DEDUCTIONS

(a)Heat a spatula endful of V in a dry test gently and strongly		
(b)Dissolve 2 spatula endful of V in $6cm^3$ of water . Divide the solution into 5 portions.		
(i)To the first portion add sodium hydroxide solution drop wise until in excess		
(ii)To the second portion add aqueous ammonia drop wise until in excess until in excess		
(iii)To the third portion add few drops of lead(II) nitrate solution warm and cool under cold water.		

(iv)To the fourth portion add silver nitrate solution followed by aqueous ammonia drop wise until in excess.		
(v)To the fifth portion add $2cm^3$ of magnesium ribbon and allow to stand.		

(c)Identify the

(i)Cation in V ………………………………………………………………………………………

(ii) The anions in V are ……………………………………………………………. and ……………………………………………………………