Chapter one: QUALITATIVE ANALYSIS.

Introduction

Qualitative analysis is the identifications of cations and anions in given samples of substances. Compounds can only be identified by carrying out sample tests which identify the ions present. The identification follows a scientific procedure in which conclusions (or deductions) are made on observations from tests or experiments.
Qualitative analysis reactions are usually carried out in tests tubes using small quantities of reagents, even if reagents are in excess. Large quantities of reagents are wasteful and small quantities usually give observable and reliable results. Large quantities can also result in dangerous reaction which cannot be controlled and give unreliable results or wrong observations and conclusions.

This section forms question number two of chemistry paper 545/3 or paper 545/4. It is mainly based on the chemistry of salts which is learnt in senior two. Students are therefore advised to revise the chemistry of salts in order to present quality work in this section. Safety is the most important aspect for students of chemistry in the laboratory; therefore students should take caution and responsibility. Students should revise all rules and regulations of the laboratory before performing practical.
Qualitative analysis requires a student to carry out a number of sample tests on one or more substances mixed, the observation is recorded from which deduction about the substance is made.

Unless the quantity is specified, volumes of about $1cm^3$ for liquids and almost 0.2g for solids are sufficient to use in qualitative test tube reactions. The reactions occur mainly in aqueous solution. The results can positive or negative. The positive indicates the expected result is present and negative test indicates that the expected result is absent.

The reactions with both dissolved and undissolved ions produce various precipitates and gases. Each ion has its own particular properties which can be used to identify it.

The tests are qualitative and require careful observations deductive and thinking. The qualitative analysis in this case will be limited to the following ions.
The cations considered at this level include:
White substance

1. Zinc ions Zn^{2+}
2. Lead (ii) ions Pb^{2+}
3. Aluminium ions Al^{3+}
4. Calcium ions Ca^{2+}
5. Ammonium ions NH_4^+
6. Magnesium ions Mg^{2+}

Coloured substances

7. Copper (ii) ions Cu^{2+}
8. Iron (ii) ions Fe^{2+}
9. Iron (iii) ions Fe^{3+}

At this level, the anions considered include:

1. Sulphate ions SO_4^{2-}
2. Chloride ions Cl^-
3. Carbonate ions CO_3^{2-}
4. Nitrate ions NO_3^-
5. Iodide ions I^-
6. Bromide Br^-
7. Sulphite ions SO_3^{2-}

During qualitative analysis there are three major phase namely.

- Preliminary tests which give a clue about the composition the compound given.
- Precipitation reactions of cations (confirmatory tests for cations)
- Precipitation reactions of anions (confirmatory tests for anions)

PRELIMINARY TESTS.

These are tests carried out to give you a clue of the possible cations and anions present in a given substance. The word probably is used. These include, colour of the substance, smell and solubility of the substance in water, action of heat, formation of precipitates and gases. In some qualitative analysis exercises, a short list of ions can be given as present and in this case the ions identified from the preliminary tests alone.

However, in others, preliminary tests alone are not sufficient to completely identify the ions. Further tests would have to be performed before the ion could be clearly identified; an additional or extra test which identifies an anion or cation conclusively is known as **confirmatory test**. A confirmatory test clearly identifies an ion. There can be more than one confirmatory test for a particular ion. On such test is sufficient to confirm the ion.

The following notes are useful in the identification of ions.

a) **Colour**: cations in their solid or dissolved aqueous solution have characteristic colours.
   (i) Mg^{2+}, Ca^{2+}, Ba^{2+}, Al^{3+}, Zn^{2+}, NH_4^+, and Pb^{2+} are colourless or white solid.
   (ii) Cu^{2+} is blue.
   (iii) Fe^{2+} is green
   (iv) Fe^{3+} is yellow or brown.
   (v) NO_3^-, SO_4^{2-},Cl^-,or hydrated compound is a crystalline substance.

b) Action of heat on solids

When solids are heated they decompose and gases are usually given off. These gases usually give useful information about the anions present in the unknown substance. A wide range of different gases can be given off and all must be identified with physical and chemical tests. Most gases can be identified by one or a combination of the following properties.

The colour, smell, effect on litmus paper, action on splint and the usual confirmatory tests can carried out on some gases e.g. for SO_2, is a colourless gas with an irritating smell, it turns moist blue litmus paper red and then bleached, and turns acidified dichromate solution from orange to green.

Procedure

- Put a small portion of the unknown substance in a clean dry test tube.
- Heat gently at first the more strongly.
- Observe the colour changes on the solid and observe the gases and vapours given off and identify them by their colours, smell, effect on litmus and their confirmatory test.
- Record the colour of the residues left after the heating which is usually an oxide of the metal and some of the metal oxides have certain characteristic colours. These can also be used to give useful information about the cation present in the unknown substance.

The table below shows the possible observations and deductions that can made when a substance is heated.

Observations	Deduction
A colourless liquid forms on the upper parts of the test tube which turns white anhydrous copper (II) sulphate blue and blue cobalt (II) chloride paper pink.	Water of crystallization Substance is hydrated, HCO_3^- , OH^-, or HSO_4^- probably present.
A reddish brown gas with an irritating smell and turns moist blue litmus paper red is given off	NO_2 is evolved probably NO_3^- present
A colourless gas which turns moist blue litmus paper red and acidified potassium dichromate from orange to green	SO_2 is evolved probably SO_3^{2-} or SO_4^{2-} present
A colourless gas with a chocking/pungent smell which turns moist red litmus paper blue and forms dense white fumes with Conc. HCI	NH_3 is given off and NH_4^+ is present
A colourless gas which turns damp blue litmus paper red and lime water milky	CO_2 is given off and CO_3^{2-} or HCO_3^- present
Colourless gas with an irritating smell, turns blue litmus paper red and forms dense white fumes with Conc. NH_3	HCl gas probably Cl^- present

Greenish yellow gas with a very sharp irritating smell bleaches damp litmus paper.	Cl_2 gas evolved probably Cl^- present
white (smoky) fumes with chocking smell turns blue litmus paper red and forms a white precipitate with $BaCI_2$ or $Ba(NO_3)$ solution	SO_3 gas evolved probably SO_4^{2-} or HSO_4^- present
Colour of the residue (Observation)	**Possible metal oxide formed (Deduction)**
The residue is black	Cu, FeO, Fe_3O_4 is formed probably Cu^{2+}, Fe^{2+}, Fe^{3+}, probably present.
Yellow residue when hot and turns white on cooling	ZnO is formed probably Zn^{2+} present
Red-brown residue when hot and turns yellow when cold	PbO is formed probably Pb^{2+} present
Pale green solid leaves a reddish brown residue after heating	Fe_2O_3 formed, Fe^{2+} salt oxidized to Fe^{3+}
Green solid leaves black solid after heating	CuO or FeO formed hence Cu^{2+} or Fe^{2+} present
A yellow substance forms a reddish brown residue	Fe_2O_3 formed probably Fe^{3+} present
White sublimate forms on the walls of the test tube	NH_4^+ probably present
Cracking sound heard (decrepitation occurs)	Possibly $Pb(NO_3)_2$ present.

Notes

- ✓ Litmus paper must be damp
- ✓ Which testing for gases with litmus paper, do not touch the mouth of the inner walls of the test tube. Hold the test paper in the mouth of test tube without touching the tube.
- ✓ Have the litmus paper, delivery tube, and other necessary apparatus ready before a reagent is poured onto a test substance. Any gases produced may diffuse away quickly.\

General rules on solubility of common salts.

This information can be used to predict formation of precipitates.

Salts	Soluble	Insoluble
Nitrates	All nitrates are soluble in water	None
Chlorides	All chlorides are soluble except lead (II) chloride and silver chloride	-lead (II) chloride (only soluble in hot water) -silver chloride
Sulphates	All sulphates are soluble except lead (II) sulphate, barium sulphate and calcium sulphate	-lead (II) sulphate -barium sulphate -calcium sulphate is only sparingly soluble
Carbonates	Carbonates of group 1 and ammonium carbonate	All carbonates are insoluble except those group 1 and ammonium carbonate
Hydrogen carbonates	All are soluble	None
Sulphites	Sulphites of group 1 and ammonium sulphite	All sulphites are insoluble except those of group 1 and ammonium sulphite

NB:

- Sparingly soluble salts in most cases are a mixture of a soluble and an insoluble salt. During filtration, a soluble salt forms the filtrate and an insoluble salt forms the residue.
- Dilute acids are used to dissolve solids that do not dissolve in water. In case the reaction is slow warm the mixture.

Observation	Deduction
Solid dissolves in acid with bubbles of a colourless gas that forms a white precipitate with lime water (turns lime water milky)	An insoluble salt of CO_3^{2-} present
Substance dissolves in an acid on warming	An insoluble compound Probably O^{2-} or Cl^- present

Group Activity

1. You are provided with the following substances labeled

   A - $Pb(NO_3)_2$

   B - $ZnCO_3$

   C - $FeSO_4 . 7H_2O$

   D - $CuSO_4 . 5H_2O$

   E - NH_4Cl

a) Heat each solid using a small portion strongly until no further change occurs on the solid

b) Observe the colour changes on each solid and identify the gases by colour, smell, effect on litmus paper and a confirmatory test if any.

PRECIPITATION REACTIONS AND CONFIRMATORY TESTS OF THE CATIONS

Precipitation is due to formation of insoluble metal hydroxides, chlorides, sulphates.
Sodium hydroxide and ammonium hydroxide (ammonia solution) are commonly used to detect cations in solutions by precipitating them out as insoluble metal hydroxide.
Some insoluble hydroxides will dissolve when excess reagent is added. **Therefore, it is important to record the observation with few drops and when excess reagent is added**.
In case the precipitate dissolves then record the colour of the solution formed.
Examples of these reactions include;

a) Copper (II) ions Cu^{2+}

(i) Using sodium hydroxide solution, a blue precipitate insoluble in excess is formed.
Equation: $Cu^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Cu(OH)_{2(s)}$

(ii) (**Confirmatory test**): using aqueous ammonia solution, a blue precipitate soluble in excess forming a deep blue solution.
Equation: $Cu^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Cu(OH)_{2(s)}$
In excess ammonia solution, the blue precipitate dissolves forming a deep blue solution. The deep blue solution is a complex ion, tetra amine copper (ii) ions.
Equation: $Cu(OH)_{2(s)} + 4NH_{3(aq)} \longrightarrow Cu(NH_3)_4{}^{2+}{}_{(aq)} + 2OH^-_{(aq)}$

b) Iron (II) ions Fe^{2+}

(i) Using sodium hydroxide solution, a dirty green precipitate insoluble in excess is formed, turns brown on standing. This is because oxygen in air oxidizes iron (II) ions to iron (III) ions.
Equation: $Fe^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Fe(OH)_{2(s)}$

(ii) Using ammonia solution forms a dirty green precipitate insoluble is excess, turns brown on standing due to aerial oxidation of iron (II) ions to iron (III) ions.
Equation: $Fe^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Fe(OH)_{2(s)}$

(iii) (**Confirmatory test**): using potassium hexacyanoferate (III) solution, a dark blue precipitate is formed.

c) Iron (III) ions Fe^{3+}

(i) Using sodium hydroxide solution, a brown precipitate insoluble in excess is formed.
Equation: $Fe^{3+}_{(aq)} + 3OH^-_{(aq)} \longrightarrow Fe(OH)_{3(s)}$

(ii) Using ammonia solution, a brown precipitate insoluble in excess is formed.
Equation: $Fe^{3+}_{(aq)} + 3OH^-_{(aq)} \longrightarrow Fe(OH)_{3(s)}$

(iii) (**Confirmatory test**): Using potassium hexacyanoferate (II) solution, a dark blue precipitate is formed.

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(iv) (**Confirmatory test**): Using potassium thiocyanate solution; a deep red solution is formed.

d) Zinc ions Zn^{2+}

(i) Using sodium hydroxide solution, a white precipitate soluble in excess forming a colourless solution.

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

The white precipitate zinc hydroxide dissolves because it is amphoteric therefore reacts with sodium hydroxide forming a soluble complex ion, Called zincate ion.

Equation: $Zn(OH)_{2(s)} + 2OH^-_{(aq)} \longrightarrow Zn(OH)_4{}^{2-}{}_{(aq)}$

(ii) (**Confirmatory test**): using ammonia solution, a white precipitate soluble in excess forming a colourless solution.

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

The precipitate dissolves because zinc hydroxide reacts with ammonia forming a soluble complex ion, called tetra amine zinc ions.

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

e) Lead (II) ions Pb^{2+}

(i) Using sodium hydroxide solution, a white precipitate which dissolves in excess forming a colourless solution.

Equation: $Pb^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Pb(OH)_{2(s)}$

The precipitate dissolves because lead (II) hydroxide is amphoteric and therefore reacts with sodium hydroxide solution forming a soluble complex ion called plumbate ion.

Equation: $Pb(OH)_{2(s)} + 2OH^-_{(aq)} \longrightarrow Pb(OH)_4{}^{2-}{}_{(aq)}$

(ii) Using ammonia solution, a white precipitate insoluble in excess ammonia is formed.

Equation: $Pb^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Pb(OH)_{2(s)}$

(iii) (**Confirmatory test**): using potassium iodide solution, a bright yellow precipitate is formed.

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

(iv) (**Confirmatory test**): using dilute hydrochloric acid and warm, a white precipitate soluble on warming and re-appears on cooling.

Equation: $Pb^{2+}_{(aq)} + 2CI^-_{(aq)} \longrightarrow PCI_{2(s)}$

(v) (**Confirmatory test**): using potassium dichromate solution, a yellow precipitate is formed.

Equation: $Pb^{2+}_{(aq)} + CrO_4{}^{2-}{}_{(aq)} \longrightarrow PbCrO_{4(s)}$

(vi) Using dilute sulphuric acid, a white precipitate is formed.

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

(vii) Using sodium carbonate solution, a white precipitate is formed.

Equation: $Pb^{2+}_{(aq)} + CO_3^{2-}_{(aq)} \longrightarrow PbCO_{3(s)}$

f) <u>Aluminium ions Al^{3+}</u>

(i) Using sodium hydroxide solution, a white precipitate which dissolves in excess forming a colourless solution.

Equation: $Al^{3+}_{(aq)} + 3OH^-_{(aq)} \longrightarrow Al(OH)_{(s)}$

The precipitate dissolves because the Aluminium hydroxide is amphoteric and reacts with sodium hydroxide forming a soluble complex ion called Aluminate ion.

Equation: $Al(OH)_{3(S)} + OH^-_{(aq)} \longrightarrow Al(OH)_4^-{}_{(aq)}$

(ii) Using ammonia solution, a white precipitate insoluble in excess is formed.

Equation: $Al^{3+}_{(aq)} + 3OH^-_{(aq)} \longrightarrow Al(OH)_{3(s)}$

(iii) (**Confirmatory test**), 2 drops of litmus solution, test solution if not acidic add dilute hydrochloric acid and then add dilute ammonia solution until the solution is just acidic.

Observation: Blue lake forms by absorbing $Al(OH)_3$ precipitate in aqueous NH_3 leaving the solution almost colourless.

g) <u>Ammonium ions NH_4^+</u>

Add sodium hydroxide and heat the mixture. Smell the mixture, Ammonium ion form no precipitate. On warming, acolourless gas with a chocking smell and turns moist red litmus paper blue is given off (**This is the Confirmatory test for NH_4^+**)

Equation: $NH_4^+{}_{(aq)} + OH^-_{(aq)} \longrightarrow NH_{3(g)} + H_2O_{(l)}$

h) <u>Calcium ions Ca^{2+}, Barium ions Ba^{2+} and Magnesium ion Mg^{2+}</u>

Using sodium hydroxide solution, these ions form a white precipitate insoluble in excess.

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

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

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

NB:

- In carrying out tests, it is important to use known reagents and conditions that give characteristics results such as formation of gases and precipitates.
- The test must be practical and the student should be familiar with the expected result in order to make correct conclusions.
- Knowledge of the reagent and expected observations are important in order to make conclusions. A student who does not know what the reagent is testing for cannot make correct conclusions from the observations. Therefore knowledge of the test reagents, what they test for and the expected result is important in identifying ions e.g. When dilute sodium hydroxide is added to a solid substance and the mixture warmed, if a pungent smelling gas is produced, it indicates the presence of NH_4^+ ions, if both the test and expected observation is not known, the correct conclusion of NH_4^+ cannot be drawn easily.

Forms of unknowns and tests

The substance that appears in practical examinations may be single compounds or mixture of compounds, and may contain more than two ions. Tests can be performed on unknown solutions, solids or their mixture. Insoluble solids can be dissolved with dilute or concentrated acids. The acids react with the insoluble substance to form their soluble ions on which tests can be carried out in solution.

Example: group activity

Solution A contains Pb^{2+}or AI^{3+} or Zn^{2+}.

Carryout the following tests and identify the ions present.

(a) Add dil. NaOH in drops and the in excess.
(b) Add dil. NH_3 in drops and then in excess
(c) Add dil. HCl, heat the mixture well and allow it to cool.
(d) Carry out a test a test of your own choice to confirm the cation present in A.

Record the results obtained in the table below.

	Tests	**Observations**	**Deductions**
(a)	Dil. NaOH was added to A drop-wise until in excess.		
(b)	Dil. NH_3 was added to A drop-wise until in excess.		

(c)	Dil. HCl was added to A, the mixture was heated and then cooled.		
(d)	Carry out the test to confirm the cation in A		

Note:

- ✓ When an unknown is given and it is required to find the ions in it, it requires a systematic elimination of the ions through preliminary and further tests. A confirmatory test may be necessary to determine the ion conclusively. Specific tests are carried out and the ions present deducted from the results.
- ✓ This requires a student to have good knowledge of what the reagents test for and the conditions of reactions and what observations to expect.
- ✓ The tests are always based on small amount of reactants, small quantities give observations and reliable results than the large quantities.
- ✓

Marking logical observations and deductions.

- ➢ Care should be taken to add initially one or two drops of the reagent and then excess if that is what is required.
- ➢ Observations of the effect of adding the reagents drop-wise and then in excess can lead to the drawing of correct observations. For example, in a test, addition of drops of dilute sodium hydroxide solution to a given solution may produce a precipitate, the correct deduction is that Mg^{2+}, Ca^{2+}, Zn^{2+}, Pb^{2+} and Al^{3+} ions are present. However on addition of excess alkali, the precipitate dissolves. The correct deduction now is Zn^{2+},Pb^{2+} and Al^{3+} ions are present. Ca^{2+} and Mg^{2+} ions are eliminated because $Mg(OH)_2$ and $Ca(OH)_2$ precipitates do not dissolve in excess sodium hydroxide solution. They are not amphoteric.
- ➢ Further tests can be carried out to discover which of the ions, Zn^{2+},Pb^{2+} and Al^{3+} ions are present.
- ➢ A deduction can therefore cover one or more ions and you must record all the ions which are pointed out by a certain observation.

General solubility rules.

(a) Water soluble compounds

- NO_3^-, all nitrates of common metals are soluble in water.
- All salts of Na^+, K^+ and NH_4^+ are soluble in water.
- SO_4^{2-}, all sulphates are soluble except $CaSO_4$, $PbSO_4$, and $BaSO_4$.
- All chloride (Cl^-), bromide (Br^-) and iodide (I^-) are soluble except those of Pb^{2+} and Ag^+.
- HCO_3^-, all hydrogen carbonates are soluble.

(b) Mainly water insoluble compounds.

- CO_3^{2-}, all carbonates are insoluble except those of group 1 metals and $(NH_4)_2CO_3$.
- All oxides (O^{2-}) and hydroxides are insoluble except those of group 1 metals, Na^+, K^+ and NH_4^+.
- SO_3^{2-}, all sulphites are insoluble except those group 1 elements and $(NH_4)_2SO_3$.

NB: These rules are useful in prediction formation of precipitate in qualitative analysis.

Formation of precipitates.

Precipitates are formed when two solutions containing ions that form an insoluble compound are mixed.

The ions come together to form the precipitates or crystals e.g. lead (II) sulphate precipitate from a mixture of lead (II) nitrate solution and aqueous solution of a sulphate, e.g. aqueous sodium sulphate.

$$Pb(NO_3)_2\ _{(aq)} + Na_2SO_4\ _{(aq)} \longrightarrow PbSO_4\ _{(s)} + 2NaNO_4\ _{(aq)}$$

If the cation is known, e.g. Pb^{2+} in this case the anion present can be predicted. On the other hand if the anion is known the cation can be predicted.

The prediction is based general knowledge of solubility of substance in water. It is important to state the colour and nature of the precipitate formed.

Insoluble salts however precipitate from solution. Note the colour and nature of the precipitate.

Example

Aqueous solutions of the following salts are mixed together in the test tube.

(a) $Pb(NO_3)_2\ _{(aq)}$ and $Na_2SO_4\ _{(aq)}$

(b) $ZnCl_2\ _{(aq)}$ and $Zn(NO_4)_2\ _{(aq)}$

(c) $Na_2CO_3\ _{(aq)}$ and $Zn(NO_3)_2\ _{(aq)}$

(d) $KI\ _{(aq)}$ and $Pb(NO_3)_2\ _{(aq)}$

Solution:

(a) $Pb(NO_3)_2\ _{(aq)} \longrightarrow Pb^{2+}\ _{(aq)} + 2NO_3^-\ _{(aq)}$

$Na_2SO_4\ _{(aq)} \longrightarrow 2Na^+\ _{(aq)} + SO_4^{2-}\ _{(aq)}$

All nitrates are soluble, therefore $NaNO_3$, cannot be precipitated but all sulphates are soluble excess $PbSO_4$,$BaSO_4$ and $CaSO_4$. Therefore $PbSO_4$ will be precipitated.

(b) No precipitate will be formed, because all the ions present, Zn^{2+}, Cl^-, and NO_3^-, no cation and anion pair to form an insoluble salt. Possible combinations of $Zn(NO_3)_2$ and $ZnCl_2$ are all soluble salts.

(c) The ions present are Na^+, CO_3^{2-}, Zn^{2+} and NO_3^-. CO_3^{2-} all insoluble except only those of group 1 and $(NH_4)_2CO_3$. Therefore $ZnCO_3$ will be precipitated because it is insoluble in water.

These generalizations are useful in predicting formation of precipitates in qualitative analysis.

For example, if the addition of an aqueous solution of lead (II) nitrate to an unknown solution produces a white precipitate, it indicates the unknown solution cations one or more types of anions which form an insoluble compound with Pb^{2+} ions. These are Cl^-, SO_4^{2-}, SO_3^{2-} or CO_3^{2-}.

The following generalizations can be derived from the results of the above experiment.

- ✓ Any soluble salt and any of the three soluble carbonates, Na_2CO_3, K_2CO_3 and $(NH_4)_2CO_3$ forms a white precipitate of an insoluble metal carbonate. Because all carbonates are insoluble except those of group 1 and ammonium carbonate.
- ✓ Any soluble salt + lead (II) nitrate forms a precipitate of an insoluble lead (II) salt because most of lead (II) salts are insoluble except lead (II) nitrate. The precipitates are identified by their colours.
- ✓ Any barium salt and any soluble sulphate forms a white precipitate of barium sulphate.
- ✓ Any soluble sulphite and any soluble barium salt forms a white precipitate of barium sulphite.
- ✓ Any soluble chloride and silver nitrate solution produces a white precipitate if silver chloride.

These generalizations will help you answer many related questions on theory paper.

Sample question

Aqueous solution of the following salts were mixed together in the test tubes. State what was observed and write the ionic equations for the reaction that took place in each case.

(a) $CaCl_{2(aq)}$ and $NaCO_{3(aq)}$

(b) $NaI_{(aq)}$ and $Pb(NO_3)_{2\,(aq)}$

(c) $Ba(NO_3)_2$ and $H_2SO_{4\,(aq)}$

Solution:

(a) Observation: white precipitate is formed.

Equation: $Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \longrightarrow CaCO_{3\,(s)}$

(b) Observation: yellow precipitate is formed

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

(c) Observation: white precipitate is formed

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

Summary of the reactions of the cations

Reagent	Observation	Deduction
Sodium hydroxide Solution	A white precipitate insoluble in excess sodium hydroxide solution	Ca^{2+}, Ba^{2+}, or Mg^{2+} Present
	A white precipitate soluble in excess forming a colourless solution	Zn^{2+}, AI^{3+} or Pb^{2+} Present
	A blue precipitate insoluble in excess sodium hydroxide solution	Cu^{2+} present
	A dirty green precipitate insoluble in excess sodium hydroxide solution	Fe^{2+} present
	A brown precipitate insoluble in excess sodium hydroxide solution	Fe^{3+} present
	No observable change, on warming, a colourless gas with a pungent chocking smell, turns damp red litmus paper blue and forms dense white fumes with Con. HCI	NH_3 gas evolved NH_4^+ present
Ammonia Solution	A white precipitate insoluble in excess ammonia solution	Pb^{2+}, Mg^{2+} or AI^{3+} Present
	A white precipitate soluble in excess ammonia solution forming a colourless solution	Zn^{2+} present
	A dirty green precipitate insoluble in excess ammonia solution	Fe^{2+} present
	A blue precipitate soluble in excess in excess ammonia solution forming a deep blue solution	Cu^{2+} present
	A brown precipitate insoluble in excess ammonia solution	Fe^{3+} present
Potassium Iodide solution	A bright yellow precipitate is formed	Pb^{2+} present
	No observable change	Al^{3+} present
	White precipitate in a brown solution	Cu^{2+} present
Potassium Hexacyanoferrate(II) solution	A dark blue precipitate formed	Fe^{3+} present
	Brown precipitate is formed	Cu^{2+} presents
Potassium thiocyanate solution	Deep red solution formed	Fe^{3+} present

Potassium hexacyanoferrate (III) solution	A dark blue precipitate formed	Fe^{2+} present
Dilute sulphuric acid	A white precipitate formed	Pb^{2+}, Ba^{2+} or Ca^{2+} Present
	No observable change	Mg^{2+} present
Aluminium thiocynanate	Deep red solution	Fe^{3+} present
Hydrogen peroxide and warm	Effervescence occurs and a colourless gas which relights a glowing splint. Blue solution turns brown	O_2, evolved Fe^{2+} present.
Copper (II) sulphate and zinc powder	Solution changes from blue to colourless. A brown solid is formed	Cu^{2+} present

ACIDIFYING THE FILTRATE

Back ground information

This test involves a reaction between two cations in solution with a reagent mostly sodium hydroxide or ammonia solution.

One of the cations forms a precipitate which does not dissolve and the other forms a precipitate which dissolves in excess reagents forming a soluble complex.

On filtering, the insoluble precipitate forms the residue on the filter paper while the soluble complex drops down and is collected as the filtrate.

Acidifying this filtrate involves freeing the cation in the complex. The acid is added drop-wise until the solution is just acidic. This is indicated by formation of a precipitate until it just dissolves, immediately stop adding the acid because the solution is now just acidic. Adding excess acid may affect your results.

In most cases a ***precipitate appears until it just dissolves*** *as the acid is being added drop-wise to the filtrate.*

Note

- Always add excess reagent (**NaOH or NH_4OH**) in order to dissolve the soluble precipitate.
- Shake if necessary for the soluble precipitate to dissolve.

If the above is not done, the filtrate collected will not contain the complex and acidifying it will show no change and the solution obtained will give negative tests only.

Worked out examples.

(a) Using sodium hydroxide

This reagent is used to separate two cations, one of which forms a precipitate that does not dissolve in excess i.e. Fe^{2+}, Cu^{2+}, Ca^{2+}, Ba^{2+}, Fe^{3+}
and one which dissolves in excess sodium hydroxide i.e. Zn^{2+}, Pb^{2+} or Al^{3+}

You are provided with a substance B which contains two cations and one anion. Carryout the following tests on B to identify the ions present. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a)Heat a spatula end full of B in a dry hard test tube strongly until no further change.	Colourless gas that turns moist blue litmus paper red and lime water milky. A black residue is formed	CO_2 gas evolved CO_3^{2-} probably present CuO formed, Cu^{2+} present.
(b)To one spatula end full of B in the test tube, add dilute nitric acid to dissolve. To the solution obtained, add sodium hydroxide drop-wise until in excess and shake. Filter and keep both filtrate and the residue. **Experiment for separating the two cations i.e Zn^{2+} (soluble) from Cu^{2+} (insoluble)**	B dissolves in the acid with bubbles of a colourless gas that turns moist blue litmus paper red and lime water milky. A blue precipitate insoluble in excess. A blue residue and a colourles filtrate are formed on filtering.	CO_2 is given off, CO_2^{2-} present Cu^{2+} present. Zn^{2+}, Pb^{2+}, Al^{3+} present in the filtrate.
(c)To 2cm^3 of the filtrate, add dilute nitric acid until the solution is just acidic. Divide the resultant solution into 2 portions. **Experiment for freeing the cation from the complex i.e Zn^{2+} from $[Zn(OH)4]^{2-}$**	A white precipitate forms and dissolves in the acid	Zn^{2+} present
(i)To the first portion, add sodium hydroxide drop-wise until in excess.	A white precipitate soluble in excess forming a colourless solution.	Zn^{2+}, Pb^{2+}, Al^{3+}, present
(ii)To the second portion, add ammonia solution drop-wise until in excess.	A white precipitate soluble in excess forming a colourless solution.	Zn^{2+} present

(d)Wash the residue with distilled water and add dilute nitric acid. Divide the solution into 2 portions.	Residue dissolves forming a blue solution.	Cu^{2+} present.
(i)To the first portion, add sodium hydroxide drop-wise until in excess.	A blue precipitate insoluble in excess.	Cu^{2+} present
(ii)To the second portion, add ammonia solution drop-wise until in excess.	A blue precipitate soluble in excess forming a deep blue solution.	Cu^{2+} present

Identify the; anion present: CO_3^{2-} Cations present: Cu^{2+} and Zn^{2+}

(b) Using ammonia solution

This reagent is used to separate two cations of which one dissolves in excess ammonia solution e.g. Zn^{2+} or Cu^{2+} and the other does not dissolve in excess ammonia e.g. Pb^{2+}, Al^{3+}, Fe^{2+}, Fe^{3+} etc.

You are provided with substance B which contains two cations and one anion. Carryout the following tests on B to identify the ions present. Record your observations and deductions in the table below.

Tests	**Observations**	**Deductions**
(a)Heat a spatula end full of B in a dry hard test tube strongly until no further change	Colourless gas that turns moist blue litmus paper red and turns lime water milky. Residue is reddish brown	CO_3^{2-} gas evolved CO_3^{2-} probably present Fe_2O_3 formed Fe^{2+} probably present
(b)To one spatula end full of B in the test tube, add dilute nitric acid to dissolve. To the resultant solution, add ammonium hydroxide solution drop-wise until in excess and shake. Filter and keep both the filtrate and residue. **Experiment for separating the two cations.** **i.e Cu^{2+} (soluble in ammonia) from Fe^{2+} (insoluble in ammonia)**	B dissolves in the acid with bubbles of a colourless gas that turns lime water milky. A dirty green precipitate insoluble in excess. A green residue and blue filtrate is formed on filtering.	CO_2 is given off. CO_3^{2-} present An insoluble salt of Fe^{2+} present in the residue and Cu^{2+}, present in the filtrate

(c)To 2cm^3 of the filtrate, add dilute nitric acid until the solution is just acidic. Divide the resultant solution into 2 portions. **Experiment for freeing the cation from the complex i.e Cu^{2+} from $[Cu(NH_4)]^{2+}$**	A blue precipitate forms and dissolves in the acid	Cu^{2+} present
(i)To the first portion, add sodium hydroxide drop-wise until in excess.	A blue precipitate insoluble in excess.	Cu^{2+} present
(ii)To the second portion, add ammonia solution drop-wise until in excess.	A blue precipitate soluble in excess forming a deep blue solution.	Cu^{2+} present
(d)Wash the residue with distilled water and add dilute nitric acid. Divide the resultant solution into 2 portions.	Residue dissolves to form a green solution	Fe^{2+} present
(i)To the first portion, add sodium hydroxide drop-wise until in excess.	A dirty green precipitate insoluble in excess. Turns brown on standing	Fe^{2+} present Fe^{2+} oxidized to Fe^{3+}
(ii)To the second portion, add ammonia solution drop-wise until in excess.	A dirty green precipitate insoluble in excess. Turns brown on standing.	Fe^{2+} present Fe^{2+} oxidized to Fe^{3+}

The cation present Cu^{2+} and Fe^{2+}.
The anion present CO_3^{2-}

PRECIPITATION REACTIONS OF ANIONS

Detection of anions is based on;

Precipitation of anions out of solution as insoluble salts of SO_4^{2-}, Cl^-, CO_3^{2-}.

Example;

(a) Insoluble sulphates include;
lead (II) sulphate, barium sulphate and calcium sulphate.

(b) Insoluble chlorides include;
lead (II) chloride and silver chloride.

(c) Insoluble carbonates include;
All metal carbonates will form precipitates except sodium carbonate, potassium carbonate and
Ammonium carbonate which are soluble.

Test reagent for anions in solution, observations and deductions

Reagent	Observation	Deduction
Lead (II) nitrate solution	White precipitate is formed	Cl^-, SO_4^{2-}, CO_3^{2-} or SO_3^{2-} present
lead (II) nitrate solution + dil. HNO_3	White precipitate insoluble in dilute nitric acid	Cl^-, and SO_4^{2-} present
	White precipitate soluble in dilute nitric acid	SO_4^{2-} present
Lead (II) nitrate solution + dilute nitric acid + heat	white precipitate insoluble in dilute nitric acid	
	(i) White precipitate dissolves on heating and reappears on cooling.	SO_4^{2-} absent $PbCl_2$ salt formed Cl^- confirmed present
	(ii) White precipitate does not dissolve on heating	Cl^- absent $PbSO_4$ salt formed SO_4^{2-} confirmed present
Barium nitrate or barium chloride solution	White precipitate is formed	SO_4^{2-}, CO_3^{2-}, SO_3^{2-} present
Barium nitrate solution + dilute nitric acid	White precipitate insoluble in dilute nitric acid	SO_4^{2-} confirmed
silver nitrate solution + dilute nitric acid	(i) White precipitate formed	Cl^- confirmed
	(ii) Pale yellow precipitate formed	Br^- confirmed
	(iii) Yellow precipitate	I^- confirmed

Preliminary tests for anions

(a) Test: **Action of dilute HCl or H_2SO_4 acid.**

Add dilute acid to the solid substance in the test tube. If there is no reaction warm gently but do not boil.

Observation		Deduction
(i)	Effervescences of a colourless, odourless gas that that turns lime water milky and damp blue litmus paper red	CO_2 gas evolved, CO_3^{2-} or HCO_3^- present
(ii)	In the cold or on heating, a colourless gas with a pungent smell turns blue litmus paper red and bleaches it. It turns acidified potassium dichromate solution from orange to green	SO_2 gas evolved, SO_3^{2-} present
(iii)	Evolution of bad smelling gas (rotten egg smell), turns blue litmus paper red and turns paper soaked in lead (II) Ethanoate solution black	H_2S gas evolved, S^{2-} present
(iv)	Solid dissolves in acid but no gas evolved	CO_3^{2-}, HCO_3^- or S^{2-} absent Cl^-, SO_4^{2-}, NO_3^-, Br^- or I^- probably present

(b) Test: **Action of concentrated sulphuric acid.**

Add cold concentrated sulphuric acid to the solid substance in the test tube. If there is no reaction warm gently but do not boil.

Observation		Deduction
1.	Vigorous effervescence of a colourless, oudourless gas that turns lime water milky	CO_2 gas produced CO_3^{2-} confirmed
2.	I the cold or on heating, colourless gas with a pungent smell turns blue litmus paper red and bleaches it. It turns acidified potassium dichromate solution from orange to green	SO_2 gas SO_3^{2-} present
3.	Evolution of a bad smelling gas (rotten egg smell), turns blue litmus paper red and turns paper soaked in lead (II) Ethanoate solution	H_2S gas evolved S^{2-} present
4.	Effervescence of fuming, pungent smelling chocking gas. Gas turns moist blue litmus paper red and forms dense white fumes with Conc. NH_3	HCl gas Cl^- present
5.	Frothy effervescence of red brown vapour, pungent smelling fuming gas. Gas turns blue litmus paper red and reddish brown liquid is formed	Br_2 gas produced Br- present
6.	Colourless, pungent fuming gas. Gas turns blue litmus paper red. Black solid is formed.	HI gas, I^- present

7. Colourless, pungent smelling vapour forms. Vapour turns blue litmus paper red and fumes in air. Red brown vapour forms on heating.	HNO_3 vapour and NO_2 gas produced NO_3^- present.
8. Solid dissolves, no gas produced, no precipitate forms.	Cl^-, Br^-, I^- and NO_3^- probably absent SO_4^{2-} probably present

Note: concentrated sulphuric acid oxidizes some of the hydrogen bromide and hydrogen iodide to red drown liquid bromine and violet iodine respectively.

$2HBr_{(g)} + H_2SO_{4(l)} \longrightarrow Br_{2(g)} + SO_{2(g)} + 2H_2O_{(l)}$

Confirmatory tests for the anions.

a) Sulphate ions SO_4^{2-}

(i) Add a few drops of lead (II) nitrate solution or lead (II) Ethanoate a white precipitate is formed.
Equation: $Pb^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \longrightarrow PbSO_{4(s)}$

(ii) Add a few drops of barium nitrate solution followed by dilute nitric acid, a white precipitate insoluble in the acid is formed.
Equation: $Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \longrightarrow BaSO_{4(s)}$

(iii) Add a few drops of barium chloride followed by dilute hydrochloric acid, a white precipitate insoluble in the acid is formed.
Equation: $Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \longrightarrow BaSO_{4(s)}$

b) Carbonate ions CO_3^{2-}

(i) Add a few drops of lead (II) nitrate solution followed by dilute nitric acid, a white precipitate soluble in the acid with bubbles of a colourless gas that turns lime water milky.
Equation: $Pb^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \longrightarrow PbCO_{3(s)}$

(ii) Add a few drops of dilute mineral acid preferably dilute nitric acid, bubbles or effervescences of a colourless gas that turns lime water milky.
Equation: $2H^+_{(aq)} + CO_3^{2-}{}_{(aq)} \longrightarrow CO_{2(g)} + H_2O_{(l)}$

(iii) Add lead (II) nitrate or lead ethanoate solution, white precipitate of lead (II) carbonate is formed which dissolves in dilute acid forming a colourless solution.
Equation: $Pb^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \longrightarrow PbCO_{3\,(s)}$

(iv) Add silver nitrate solution, a white precipitate of silver nitrate is formed. The precipitate dissolves in aqueous ammonia or dilute nitric acid forming a clourless solution.
Equation: $Ag^+_{(aq)} + CO_3^{2-}{}_{(aq)} \longrightarrow Ag_2CO_{3\,(s)}$

c) **Nitrate ions NO_3^-** **Brown ring test**

(i) Add freshly prepared iron (II) sulphate solution followed by concentrated sulphuric acid carefully down the walls of the test tube in tilted position so that the acid sinks to the bottom a brown ring test forms at the junction.

d) **Chloride ions Cl^-**

(i) Add a few drops of lead (II) nitrate solution and warm, a white precipitate dissolves on warming and reappears on cooling.
Equation: $Pb^{2+}_{(aq)} + Cl^-_{(aq)} \longrightarrow PbCl_{(s)}$

(ii) Add a few drops dilute nitric acid followed by silver nitrate solution, a white precipitate is formed. The precipitate darkens on standing in light readily dissolves in ammonia solution forming a complex.
Equation: $Ag^+_{(aq)} + Cl^-_{(aq)} \longrightarrow AgCl_{(s)}$

e) **Iodide ions I^-**

(i) Add lead (II) nitrate solutions, a yellow precipitate is formed.
Equation: $Pb^{2+}_{(aq)} + 2I^-_{(aq)} \longrightarrow PbI_{2(s)}$

f) **Hydrogen carbonate ions, HCO_3^-**

(i) Boil the solution of the unknown and add a few drops of phenolphthalein indicator.
Observation:
Bubbles of colourless gas are formed which turn lime water milky. The resultant solution turns phenolphthalein indicator pink.

(ii) Add magnesium sulphate solution and boil.
Observation:
A white precipitate is formed on boiling.

g) **Sulphite ions SO_3^{2-}**

(i) Add lead (II) nitrate solution followed by dil. HNO_3. White precipitate is formed. The precipitate is soluble in dil. HNO_3.
Equation: $Pb^{2+}_{(aq)} + SO_3^{2-}{}_{(aq)} \longrightarrow PbSO_{3(s)}$
$PbSO_{3(s)} + 2H^+{}_{(aq)} \longrightarrow SO_{2(g)} + H_2O_{(l)} + Pb^{2+}{}_{(aq)}$

(ii) Add aqueous barium chloride or barium nitrate followed by dil. HNO_3. A white precipitate soluble in dil. HNO_3 confirms sulphite ions.
Equation: $Ba^{2+}_{(aq)} + SO_3^{2-}{}_{(aq)} \longrightarrow BaSO_{3(s)}$
$BaSO_{3(s)} + 2H^+{}_{(aq)} \longrightarrow SO_{2(g)} + H_2O_{(l)} + Ba^{2+}{}_{(aq)}$

h) **Bromide ions Br^-**

(i) Add lead (II) nitrate solution. A yellow precipitate is formed
Equation: $Pb^{2+}{}_{(aq)} + 2Br^-_{(aq)} \longrightarrow PbBr_{2(s)}$

(ii) Add silver nitrate solution followed by dilute nitric acid. Cream or light yellow precipitate insoluble in dil. HNO_3 and darkens on standing in light.
Equation: $Ag^+{}_{(aq)} + Br^-_{(aq)} \longrightarrow AgBr_{(s)}$

Sample question

1. Name the reagent that can be used to distinguish between the following pairs of ions in aqueous solution and state what would be observed when each of the following ion is treated with the reagent named

(a) $SO_3^{2-}{}_{(aq)}$ and $SO_4^{2-}{}_{(aq)}$

Reagent: Barium nitrate solution or Barium chloride solution followed by dil. Nitric acid or hydrochloric acid.

Observation: $SO_3^{2-}{}_{(aq)}$ - A white precipitate soluble in dilute acid.

$SO_4^{2-}{}_{(aq)}$ - A white precipitate insoluble in dilute acid.

Note:

Similarly lead (II) nitrate solution followed by nitric acid can be used and the observations are as above

Alternatively, we can use dil. HCl or H_2SO_4.

Observation: SO_3^{2-} Effervescence is produced

SO_4^{2-} No effervescence is produced

(b) $HCO_3^{2-}{}_{(aq)}$ and $CO_3^{2-}{}_{(aq)}$

Reagent: Magnesium chloride solution or magnesium sulphate solution

Observation: $CO_3^{2-}{}_{(aq)}$ White precipitate of $MgCO_3$ is formed

$HCO_3^{-}{}_{(aq)}$ No precipitate is formed in cold but on heating a white precipitate is formed.

Equations: $Mg^{2+}{}_{(aq)} + CO_3^{2-}{}_{(aq)} \longrightarrow MgCO_{3(s)}$

$Mg^{2+}{}_{(aq)} + HCO_3^{-}{}_{(aq)} \longrightarrow Mg(HCO_3)_{2\,(aq)}$

Explanations

When the solution is heated, magnesium hydrogen carbonate decomposes to form a white precipitate of magnesium carbonate.

$Mg(HCO_3)_{2\,(aq)} \longrightarrow MgCO_{3(s)} + CO_{2(g)} + H_2O_{(l)}$

(c) **Reagent**: silver nitrate solution.

Observation: Cl^- White precipitate of AgCl is formed

I^- Yellow precipitate of AgI is formed

Or we can use lead (II) nitrate solution

Observation: Cl^- White precipitate of $PbCl_2$ is formed

I^- yellow precipitate of PbI_2 is formed

WORKED EXAMPLES

Example 1

You are provided with substance **Z** which contains **one cation** and **two anions**. Carry out the following tests to identify the cations and anions in **Z**. identify any gases evolved.

Tests	**Observations**	**Deductions**
Heat a spatula end-full of **Z** in a dry test tube until there is no further change	A colourless gas evolved, gas turns moist blue litmus paper red, gas turns lime water milky Residue is yellow when hot, white when cold	Gas is CO Hence CO_3^{2-}, HCO_3^- present Residue is ZnO Hence Zn^{2+} present
Dissolve two spatula end-full of **Z** in distilled water, filter and keep both the filtrate and residue	Partialy dissolves forming a colourless solution and a white residue	Zn^{2+}, Pb^{2+}, Al^{3+}, Ba^{2+}, Mg^{2+}, Ca^{2+}, probably present
Divide the filtrate into four equal portions, To the first portion, and sodium hydroxide solution drop wise until excess.	White precipitate, dissolves in excess forming a colourless solution	Zn^{2+}, Pb^{2+}, Al^{3+}, probably present
To the second portion, add ammonia solution drop wise until excess.	White precipitate, soluble in excess forming a colourless solution.	Zn^{2+}, confirmed present
To the third portion, add 3 drops of lead (II) nitrate.	White precipitate.	SO_4^{2-}, Cl^-, SO_3^{2-}, CO_3^{2-}, probably present
Carry out a test of your own to confirm the anion in **Z** To the fourth portion, add barium nitrate solution followed by dilute nitric acid.	White precipitate insoluble in dilute nitric acid.	SO_4^{2-}, confirmed present
Dissolve the residue in dilute hydrochloric acid and divide the resultant solution into two equal portions.	Dissolves with effervescence evolving a colourless gas, gas turns moist blue litmus paper red, gas turns lime water milky. A colourless solution is formed	Gas is CO_2 Hence CO_3^{2-}, confirmed present
To the first portion, add sodium hydroxide solution drop wise until excess	White precipitate soluble in excess forming a colourless solution.	Zn^{2+}, Pb^{2+}, Al^{3+}, probably present
To the second portion, add ammonia solution drop wise until excess	White precipitate, soluble in excess ammonia solution forming a colourless solution	Zn^{2+}, confirmed present

Identify the;

(i) Cation in **Z**. Zn^{2+}

(ii) Anions in **Z**. CO_3^{2-}, SO_4^{2-}

Example 2

You are provided with substance **X** which contains **one cation** and **two anions**. Carryout the following tests to identify the cations and anions present in **X**.

Test	**Observation**	**Deduction**
(a)To 2 spatula end-full of **X** add about 5cm^3 of water and shake well. Filter and keep both the residue and the filtrate.	**X** is white powdery crystalline solid, partiary soluble forming a colourless filtrate and a white residue.	Al^{3+}, Zn^{2+}, Pb^{2+},probably present CO_3^{2-}, NO_3^-, SO_4^{2-}, CI^-, probably present
(b)Divide the filtrate into four portions. (i)To the first portion, add dilute sodium hydroxide solution drop wise until in excess	A white precipitate, soluble in excess forming a coloueless solution.	Al^{3+}, Zn^{2+}, Pb^{2+}, probably present
(ii)To the second portion, add dilute aqueous ammonia drop wise until in excess.	A white precipitate insoluble in excess.	Pb^{2+}, Al^{3+}, Mg^{2+}, probably present
(iii)To the third portion, add drops of potassium iodide solution	A yellow precipitate is formed	Pb^{2+} confirmed present
(iv)To the fourth portion, add copper fillings followed by conc. sulphuric acid and boil	A white precipitate was formed on addition of the acid. On boiling, a brown gas which turned moist blue litmus paper red was given off. A green blue solution was formed.	Gas is NO_2, NO_3^- confirmed present
(c)Wash the residue in (a) above and place it in a test tube. Add dilute HCI	Effervescence with evolution of a colourless gas, gas turns moist blue litmus paper red and lime water milky.	Gas is CO_2, CO_3^{2-}, confirmed present

(d) (i) Cation in **X**. Pb^{2+}

(ii) Anions in **X**. NO_3^- and CO_3^{2-}

Example 3

You are provided with substance **Y** that contains **one cation** and **one anion**. Carry out the following tests to identify the cations and anions in **Y**. identify any gases that may be evolved. Record your observations and deductions in the table below.

Tests	Observations	Deductions
a)Appearance of **Y**	**Y** is a green crystalline substance	Fe^{2+}, Cu^{2+} probably present
b)Place a spatula end-full of **Y** in a dry test tube then heat strongly until there is no further change	A colourless vapour that condenses to a colourless liquid is given off. The liquid turns white anhydrous copper (II) sulphate blue. A colourless gas with an irritating smell is evolved, gas turns blue litmus paper red, gas forms misty fumes in air and dense white fumes with conc. Ammonia solution. Black residue is formed	Water of crystallization from hydrated salt or HCO_3^-, OH^- Gas is HCl, Cl^- probably present CuO, FeO, Fe_3O_4, Cu^{2+}, Fe^{2+}, Fe^{3+}, probably present
c) To a spatula end-full of **Y** in a test tube add $5cm^3$ of distilled water and shake. Divide the solution into 4 portions. (i)To the first portion, add sodium hydroxide solution drop wise until in excess	Dissolves forming a pale blue solution Pale blue precipitate insoluble in excess sodium hydroxide.	Cu^{2+} probably present Cu^{2+} present
(ii)To the second portion, add dilute ammonia solution drop wise until in excess	Blue precipitate soluble in excess forming a deep blue solution	Cu^{2+} confirmed present
(iii)To the third portion, add lead (II) nitrate solution.	White precipitate is formed	Cl^-, SO_4^{2-}, CO_3^{2-}, SO_3^{2-}, present
(iv)Use the fourth portion to carry out a test of your own choice to confirm the anion in **Y** **Test** To the fourth portion, add 2-3 drops of silver nitrate solution followed by dilute nitric acid	White precipitate insoluble in nitric acid	Cl^- confirmed present

Identify the;

Cations in **Y**: Cu^{2+} Anions in **Y**: Cl^-

Example 4

You are provided with substance **A** that contains **two cations** and **anions**. Carry out the following tests to identify the cations and anions in **A**. identify any gases the may be evolved. Record your observations and deductions in the table below.

Tests	Observations	Deductions
a) Place two spatula end-full of **A** in a test tube, add 5cm^3 of water, shake vigorously and filter. Keep both the filtrate and the residue. Divide the filtrate into 3 portions (i)To the first portion, add excess sodium hydroxide solution then heat and smell.	Partiary dissolves forming a colourless filtrate and white residue. No observable change, but a colourless gas with an irritating pungent smell is evolved. The gas turns red litmus paper blue and forms dense white fumes with conc. HCI.	Pb^{2+}, Zn^{2+}, NH_4^+, Al^{3+} probably present. NH_3 gas evolved NH_4^+ confirmed present
(ii)To the second portion, add lead (II) nitrate solution and heat	White precipitate does not dissolve on heating	Cl^- absent SO_4^{2-} present
(iii)Use the third portion to carry out a test of your choice to confirm the anion in **A** **Test** To the third portion, add 2-3 drops of Barium chloride solution followed by dilute hydrochloric acid.	White precipitate insoluble in the acid	SO_4^{2-} confirmed present
b) Wash the residue with little distilled water then divide it into two parts. (i)Strongly heat the first part until no further change occurs	White residue turns yellow when hot and then white on cooling. A colourless gas that turns blue litmus paper pink and lime water milky is evolved.	CO_2 gas evolved CO_3^{2-} present
c) To the second portion of the residue, add 3cm^3 of dilute hydrochloric acid. Divide the mixture into 2 portions. (i)To the first part of the mixture, add sodium hydroxide solution drop wise until in excess.	The residue dissolves with rapid effervescence of a colourless gas that turns damp blue litmus paper pink and lime water milky. A colourless solution is formed. A white precipitate soluble in excess $NaOH_{(aq)}$ forming a colourless solution	CO_2 gas evolved, CO_3^{2-} confirmed present Zn^{2+}, Pb^{2+}, Al^{2+}, present

(ii)To the second portion, add ammonia solution drop wise until in excess.	White precipitate soluble in excess forming a colourless solution.	Zn^{2+} confirmed present.

Identify the:

Cations in **A**: NH_4^+ and Zn^{2+}

Anions in **A**: SO_4^{2-} and CO_4^{2-}

Example 5

You are provided with a substance **T** which contains **one cation** and **one anion**. Carry out the following tests on **T** to identify the ions present. Identify any gases evolved. Record your observations and deductions in the table below.

Tests	**Observations**	**Deductions**
Note the appearance of **T**	**T** is green crystalline solid	Fe^{2+}, Cu^{2+} present NO_3^-, SO_4^{2-}, Cl^- probably present
Heat a spatula end-full of **T** in a dry test tube strongly until no further change.	Colourless vapour condenses to form a colourless liquid which turns white anhydrous copper (II) sulphate blue. Colourless gas that turns moist blue litmus paper red, gas turns acidified potassium dichromate from orange to green. Green solid turns to reddish brown.	Water of crystallization from hydrated salt or HCO_3^- or OH^- SO_2 gas evolved, SO_4^{2-} present Fe_2O_3 formed Fe^{3+} probably presents
To one spatula end-full of **T** in the test tube, add 5cm^3 of distilled water and shake. Divide the solution into 5 portions.	Dissolves forming a pale green solution	Fe^{2+}, Cu^{2+} probably present
To the first portion, add sodium hydroxide solution until in excess	Dirty green precipitate insoluble in excess and turns brown on standing.	Fe^{2+} present
To the second portion, add ammonia solution drop wise until in excess.	Dirty green precipitate insoluble in excess and turns brown on standing.	Fe^{2+} present
To the third portion, add potassium hexacyanoferrate (III).	A dark blue precipitate is formed	Fe^{2+} confirmed present
To the fourth portion, add lead (II) nitrate solution.	A white precipitate is formed	Cl^-, SO_4^{2-}, CO_4^{2-}, SO_3^{2-} present.

To the fifth portion, add Barium nitrate solution followed by nitric acid.	White precipitate insoluble in nitric acid.	SO_4^{2-} confirmed present.

Identify the;
Cation in **T**: Fe^{2+}
Anion in **T**: SO_4^{2-}

Example 6

You are provided with a substance **W** which contains **one cation** and **two anions**. Carry out the following tests on **W** to identify the ions present. Identify any gases evolved. Record your observations deductions in the table below.

Tests	**Observations**	**Deductions**
Note the appearance of **W**	**W** is a green crystalline solid	Fe^{2+}, Cu^{2+} present SO_4^{2-}, NO_3^-, Cl^-, CO_3^{2-} probably present.
Heat a spatula end-full of **W** in a dry clean test tube strongly until no further change	Colourless vapour condenses to form a colourless liquid which turns white anhydrous copper (II) sulphate blue. A colourless gas that turns moist blue litmus paper red and lime water milky is given off. Green solid turns to black.	Water of crystallization from hydrated salt, HCO_3^-, OH^- or HSO_4^- present. CO_2 gas evolved, CO_3^{2-} probably present. CuO, FeO, F_3O_4 formed Cu^{2+}, Fe^{2+}, Fe^{3+} probably present
T one spatula end-full of **W** in the test tube and $5cm^3$ of distilled water and shake. Filter and keep the residue. Divide the filtrate into 4 portions.	Partiary dissolves forming a blue filtrate and a green residue.	Cu^{2+}, Fe^{2+} probably present.
To the first portion, add sodium hydroxide solution drop wise until in excess.	A blue precipitate insoluble in excess sodium hydroxide solution	Cu^{2+} present.
To the second portion, add ammonia solution drop wise until in excess.	A blue precipitate soluble in excess forming forming a deep blue solution.	Cu^{2+} confirmed present
To the third portion, add lead (II) nitrate solution.	A white precipitate is formed.	SO_4^{2-}, Cl^-, SO_4^{2-}, CO_3^{2-}, SO_3^{2-} probably present.
To the fourth portion, add silver nitrate solution followed by nitric acid.	A white precipitate insoluble in nitric acid.	CI^- confirmed present.
Wash the residue with cold water and add nitric acid.	Residue dissolves with bubbles of a colourless gas	CO_2^{2-} gas evolved. CO_3^{2-} confirmed present.

Divide the solution into 2 portion	that turns damp blue litmus paper pink and lime water milky.	
To the first portion, add sodium hydroxide solution drop-wise until in excess.	Blue precipitate insoluble in excess.	Cu^{2+} present.
To the second portion, add ammonia solution drop-wise until in excess.	Blue precipitate soluble in excess forming a deep blue solution.	Cu^{2+} present.

Identify the;
Cation in **W**: Zn^{2+}
Anions in **W**: CO_3^{2-} and Cl^-

Example 7

You are provided with substance **M** which contains **one cation** and **one anion**. Carry out the following tests to identify the cation and anion present in **M**. Identify any gases evolved and record the observations and deductions in the table below.

Tests	**Observations**	**Deductions**
(a)Heat a spatula end-full of **M** strongly in a test tube until no further change.	A colourless gas that turns moist blue litmus paper red and lime water milky. Brown residue when hot and yellow when cold.	CO_2 gas evolved CO_3^{2-} present. Residue is PbO. Pb^{2+} present.
(b)Dissolve a spatula end-full of **M** in dilute nitric acid. Divide the solution obtained into 3 parts.	Colourless gas that turns moist blue litmus paper red and lime water milky. Colourless solution foemed.	CO_2 gas evolved CO_3^{2-} confirmed present.
(i)To the first part, add sodium hydroxide solution drop-wise until in excess.	A white precipitate soluble in excess.	Pb^{2+}, Zn^{2+}, Al^{3+} probably present.
(ii)To the second part, add dilute aqueous ammonia solution drop-wise until in excess.	A white precipitate insoluble in excess.	Al^{3+}, Pb^{2+} probably present.
(iii)Use the third part to carry out a test of your choice to confirm the cation in **M**. **Test** To the third part add potassium iodide solution.	A yellow precipitate is formed.	Pb^{2+} confirmed present.

Identify:

(i) The cation in **M**. Pb^{2+}

(ii) The anion in **M**. CO_3^{2-}

PRACTICAL SCHEDULES

Practical 1

You are provided with substance **H** which contains **one cation** and **one anion**. Carry out the following tests to identify the cation and anion in **H**. Identify any gases evolved. Record your observation and deductions in the table below.

Tests	Observations	Deductions
(a)Heat a spatula end-full of **H** in a dry test tube until there is no further change.		
(b)Dissolve two spatula end-full of **H** in $5cm^3$ of distilled water. Divide the solution into 4 equal portions.		
(i)To the first portion, add sodium hydroxide drop-wise until in excess.		
(ii)To the second portion, add ammonia solution drop-wise until in excess.		
(iii)To the third portion, add 3 drops of lead (II) nitrate solution.		

(iv)Use the fourth portion to carry out a test of your own to confirm the anion in **H**. …………………………………….. …………………………………….. …………………………………….. …………………………………….. ……………………………………..		

Identify the;

Cation in **H**………………………

Anion in **H**………………………

Practical 2

You are provided with substance **P** which contains **two cations** and **one anion**. Carry out the following tests to identify the ions in **P**. Identify any gases evolved and record your observations and deductions in the table.

Tests	**Observations**	**Deductions**
(a)Heat a spatula end-full of **P** in a dry test tube until there is no further change.		
(b)Dissolve two spatula end-full of **P** in 5cm^3 of distilled water. Filter and keep both the filtrate and the residue. Divide the solution in four equal portions.		
(i)To the first portion, add sodium hydroxide solution drop-wise until in excess.		
(ii)To the second portion, add ammonia solution drop-wise until in excess.		

(iii)To the third portion, add 3 drops lead (II) nitrate solution.		
(iv)Use the fourth portion to carry out the test of your own to confirm the anion in **P**. ………………………………… ………………………………… ………………………………… ………………………………… …………………………………		
(c)Dissolve the residue in dilute sulphuric acid and warm. Divide the resultant solution into two equal portions.		
(i)To the first portion, add sodium hydroxide solution drop-wise until in excess.		
(ii)To the second portion, add ammonia solution drop-wise until in excess.		

Identify the:

Cations in **P**………………………..

Anion in **P**…………………………

Practical 3

You are provided with substance **X** which contains **one cation** and **two anions**. Carry out the following tests to identify the cation and anions in **X**. Identify any gases that may be evolved. Record your observations and deductions in the table below.

Tests	**Observations**	**Deductions**
(a)Heat a spatula end-full of **X** in a dry test tube until there is no further change.		

(b)Dissolve the two spatula end-full of **X** in $5cm^3$ of distilled water. Filter and keep both the filtrate and the residue. Divide the solution in four equal portions.		
(i)To the first portion, add sodium hydroxide solution drop-wise until in excess.		
(i)To the second portion, add ammonia solution drop-wise until in excess.		
(ii)To the third portion, add lead ethanoate solution.		
(iii)To the fourth portion, Barium chloride solution followed by dilute hydrochloric acid.		
(c)Dissolve the residue in dilute nitric acid and warm. Divide the resultant solution in two equal portions.		
(i)To the first portion, sodium hydroxide solution drop-wise until in excess.		
(ii)To the second portion, add ammonia solution drop-wise until in excess.		

Identify the:

Cation in **X**.......................................

Anions in **X**…………………………

Practical 4

You are provided with substance **Q** which contains **two cations** and **one anion**. Carry out the following tests to identify the cations and anion in **Q**. Identify any gases evolved. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a)Heat a spatula end-full of **Q** in dry test tube until there is no further change.		
(b)Dissolve two spatula end-full of **Q** in $5cm^3$ of distilled water.		
(c)To the resultant solution, add sodium hydroxide solution drop-wise until in excess. Filter and keep both the filtrate and the residue.		
(d)Add dilute nitric acid to the filtrate until the solution becomes acid. Divide the resultant solution into three equal portions.		
(i)To the first portion, add sodium hydroxide drop-wise until in excess.		
(ii)To the second portion, add 3 drops of lead (II) nitrate solution.		

(iii)To the third portion, add barium chloride solution followed by dilute hydrochloric acid.		
(e)Dissolve the residue in dilute nitric acid and warm. Divide the resultant solution into three equal portions.		
(i)To the first portion, add sodium hydroxide solution drop-wise until in excess.		
(ii)To the second portion, add ammonia solution drop-wise until in excess.		
(iii)Use the third portion to confirm the cation in **Q**		

Identify the:

Cations in **Q**………………………….

Anion in **Q**……………………………

Practical 5

You are provided with substance **Z** which contains **one cation** and **two anions**. Carry out the following tests to identify the cation and anions in **Z**. Identify any gases evolved and record your observations and deductions in the table below.

Tests	Observations	Deductions
(a)Heat a spatula end-full of **Z** in a dry test tube gently and later strongly until there is no further change.		
(b)Dissolve two spatula end-full of **Z** in $5cm^3$ of distilled water. Divide the solution into five portions.		
(i)To the first portion, add sodium hydroxide solution drop-wise until in excess.		
(ii)To the second portion, add ammonia solution drop-wise until in excess.		
(iii)To the third portion, add 3 drops of potassium iodide solution.		
(iv)To the fourth portion, add 3 drops of lead (II) nitrate solution.		
(v)Use the fifth portion to carry out a test of your own choice to confirm the anion in **Z**. ………………………………… …………………………………		

………………………………… ………………………………… ………………………………….. …………………………………..		

Identify the:

Cations in **X**………………………….

Anion in **X**……………………………

Practical 6

You are provided with substance **T** which contains **two cations** and **two anions**. Carry out the following tests to identify the cations and anions in **T**. Identify any gases evolved. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a)Heat a spatula end-full of **T** in a dry test tube until there is no further change.		
(b)Dissolve two spatula end-full of **T** in $5cm^3$ of distilled water. Then add sodium carbonate solution. Filter and keep both the filtrate and the residue. Divide the filtrate into four equal portions.		
(i)To the first portion, add sodium hydroxide solution drop-wise until in excess.		
(ii)To the second portion, add 3 drops of lead (II) nitrate solution		

(iii)Use the third portion to carry out the test of your own choice to confirm the anion in **T**. ………………………………… ………………………………… ………………………………… ………………………………… …………………………………		
(iv)To the fourth portion, add barium chloride solution followed by dilute hydrochloric acid.		
(c)Wash the residue with distilled water and dissolve in dilute nitric acid until it dissolves. Divide the resultant solution into three equal portions.		
(i)To the first portion, add sodium hydroxide solution drop-wise until in excess.		
(ii)To the second portion, add ammonia solution drop-wise until in excess.		
(iii)To the third portion, add potassium iodide solution.		

Identify the:

Cations in **T**…………………………..

Anions in **T**…………………………..

Practical 7

You are provided with substance **Y** which contains **two cations** and **one anion**. Carry out the following tests to identify the cations and anion in **Y**. Identify any gases evolved. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a)Heat a spatula end-full of **Y** in dry test tube until there is no further change.		
(b)Dissolve two spatula end-full of **Y** in $5cm^3$ of distilled water.		
(i)To about $1cm^3$ of the solution, add 3 drops lead (II) nitrate solution.		
(ii)Use $1cm^3$ of the solution to carry out a test of your own to identify the cation in **Y**. …………………………………… …………………………………… …………………………………… …………………………………… ……………………………………		
(c)To the rest of the solution, in (b) add sodium hydroxide solution drop-wise until in excess. Filter and keep both the filtrate and the residue.		
(d)Ad dilute HCI acid drop-wise to the filtrate until it is just acidic. Divide the resultant solution into three portions.		

(i)To the first portion, add sodium hydroxide solution drop-wise until in excess.		
(ii)To the second portion, add ammonium hydroxide solution drop-wise until in excess.		
(iii)To the third portion, add potassium iodide solution.		
(e)Dissolve the residue from (c) in dilute HCI acid and divide the resultant solution into two portions.		
(i)To the first portion, add sodium hydroxide solution drop-wise until in excess.		
(ii)To the second portion, add ammonia solution drop-wise until in excess.		

Identify the:

Cations in **Y**…………………….

Anion in **Y**……………………...

Practical 8

You are provided with substance **M** that contains **one cation** and **one anion**. Carry out the following tests and identify the cation and anion in **M**. identify any gases evolved. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a)To a spatula end-full of **M,** add 5cm^3 of distilled water and shake. Divide the resultant solution into five parts.		
(i)To the first part, add sodium hydroxide solution drop-wise until in excess.		
(ii)To the second part, add ammonia solution drop-wise until in excess.		
(iii)To the third part, add lead (II) nitrate solution.		
(iv)To the fourth part of the solution, carry out the test of your own choice to confirm the anion in **M**. ……		

Identify the:

Cation in **M**………………

Anion in **M**………………

Practical 9

You are provided with substance **V** which contains **one cation** and **one anion.** Carry out the following tests to identify the cation and anion in **V**. Identify any gas(es) that may be evolved. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a)Heat a spatula end-full of **V** in a dry test tube.		
(b)Add 5cm^3 of distilled water to one spatula end-full of **V** and shake. Divide the resultant solution into five parts.		
(i)To the first part, add sodium hydroxide solution and warm.		
(ii)To the second part, add dilute ammonia solution drop-wise until in excess.		
(iii)To the third part, add lead (II) nitrate solution and warm then allow it to cool.		

(iv)To the fourth part, add silver nitrate solution followed by dilute nitric acid.		
(v)Use the fifth part to carry out a test of your own choice to confirm the anion in **V**. ………………………………….. …………………………………. …………………………………... ………………………………….. …………………………………… …………………………………… ……………………………………		

Identify the:
Cation in **V**…………….
Anion in **V**…………….

Practical 10

You are provided with substance **W** which contains **one cation** and **one anion**. Carry out the following tests on W to identify the cation and anion in **W**. Identify any gases given off. Record your observations and deductions in the table below.

Tests	**Observations**	**Deductions**
(a)Heat a spatula end-full of **W** in a dry test tube until there is no further change.		
(b)To a spatula end-full of W, add $5cm^3$ of distilled water and shake to dissolve. Divide the resulting solution into four parts.		

(i)To the first part, add sodium solution hydroxide drop-wise until in excess.		
(ii)To the second part, add ammonia solution drop-wise until in excess.		
(iii)To the third part, add lead (II) nitrate solution.		
(iv)To the fourth part, add barium nitrate solution followed by dilute nitric acid.		

Identify the:
Cation in **W**…………..
Anion in **W**…………...

Practical 11

You are provided with substance **Q** which is a mixture of ammonium chloride and copper (II) carbonate. Complete the table below by filling in the expected observation and deductions when the tests are carried out on **Q**.

Tests	Observations	Deductions
(a)Heat a spatula end-full of **Q** in a dry test tube strongly until there is no further change.		
(b)To one spatula end-full of **Q** in a test tube, add $5cm^3$ of distilled water and shake. Filter, keep both the filtrate and the residue. Divide the filtrate in 3 portions.		
(i)To the first portion, add sodium hydroxide solution drop-wise until in excess and warm.		
(ii)To the second portion, add lead (II) nitrate solution.		

(iii)To the third portion, carry out a test of your own choice to identify the anion in **Q**. ………………………………… ………………………………… ………………………………… ………………………………… …………………………………		
(c)Wash the residue with distilled water, transfer it in a test tube and add dilute nitric acid. Divide the resultant solution into two portions.		
(i)To the first portion, add sodium hydroxide solution drop-wise until in excess.		
(ii)To the second portion, add ammonia solution drop-wise until in excess.		

Cations in **Q** $NH4^{+}$ and Cu^{2+}
Anions in **Q** Cl^{-} and CO_3^{2-}

Practical 12 (UNEB PAPER 3 2019)

You are provided with substance **Q**, which contains **two cations** and **one anion**. Carry out the following tests to identify the cations and the anion present in **Q**. Identify any gas(es) that may be evolved. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a)Dissolve one spatula end-full of **Q** in about $5cm^3$ of water. Add excess sodium hydroxide solution; shake well and filter. Keep both the filtrate and the residue.		
(b)To the filtrate, add dilute nitric acid until the solution is just acid. Divide the acidic solution into five portions. (i)To the first portion of the acidified solution, add dilute sodium hydroxide drop-wise until in excess.		
(ii)To the second portion of the acidified solution, add aqueous ammonia drop-wise until in excess.		
(iii)To the third portion of the acidified solution, add potassium iodide solution.		
(iv)To the fourth portion of the acidified solution, add lead (II) nitrate solution and warm.		
(v)Use the fifth portion of the acidified solution to carry out a test of your own to confirm the anion in **Q**. ……………………………………..		

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………………………………….. ………………………………….. ………………………………….. …………………………………..		
(c)Dissolve the residue in a minimum amount of dilute sulphuric acid and divide the resultant solution into two parts. (i)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 1 small piece of zinc granules and leave the solution to stand for 5 minutes. Divide the solution into two portions and use them for part (d)		
(d) (i) To the first portion of the solution, add sodium hydroxide drop-wise until in excess.		
(ii)To the second portion of the solution, add aqueous ammonia drop-wise until in excess.		

The cations in **Q** are……………………………………

The anion in **Q** is……………………………………….

Chapter two: VOLUMETRIC ANALYSIS

Volumetric analysis is the technique of finding the concentration of the solution. In this technique the solution of the known concentration is added repeatedly to the one whose concentration is to determine until there is just enough of it to neutralize the other of the unknown concentration. This method is called titration. During titration, the volume of standard solution that completely reacts with the measured volume of the solution under the analysis is recorded. The titration is repeated to obtain consistent tires.

From consistent tires values, an average volume of the standard solution is calculated. By use of appropriate stoichiometry (reaction ratio) obtained from the balanced equation between the reacting substance in the experiment, the concentration of the solution under analysis can be calculated.

Volumetric analysis is performed using the following important apparatus. These include burette, pipette, conical flask, beakers, retort stand and clamp, volumetric flasks, weighing balance. Quantitative (volumetric) analysis requires the knowledge and application of knowledge on mole concept. Therefore the following terms are useful in volumetric analysis.

1. **Relative formula mass (RFM).**
   This is the mass of one molecule of an element or compound on a scale on which one atom of carbon-12 is exactly 12 units. It is determined by adding the atomic mass of the element in the compound.
   Relative formula mass has no units.
   E.g Calculate the relative formula mass of Na_2CO_3. (Na = 23, C = 12, O = 16)
   RFM of Na_2CO_3 = (23x2) + (12x1) + (16x3)
   = 46 + 12 + 48
   = 106
2. **Molarity of the solution (concentration in moles per litre) or molar concentration.**
   This refers to the number of moles of the compound contained in a litre ($1000cm^3$) of a solution.
   Therefore, 0.2M of HCI means $1000cm^3$ of HCI contains 0.2 moles.
3. **Concentration in grams per litre or grams per cubic decimeters.**
   This refers to the mass of the compound dissolved to make 1 litre of the solution.
   When 4g of sodium carbonate are dissolved to make 1 litre of solution, we say that the solution has a concentration of $4gl^{-1}$ or $4gdm^{-3}$ of sodium carbonate.

$$\text{From, Molarity} = \frac{\text{Concentration in grams per litre}}{\text{Relative formula mass}}$$

Therefore, Concentration in grams per litre = Molarity x Relative formula mass.

Example

53.5g of sodium chloride were dissolved to make 2000cm^3 of the solution, calculate the concentration of sodium chloride in grams per litre. (Na = 23, Cl = 35.5)

Solution

RFM of NaCl = 23 + 35.5

58.5

Therefore molar mass of NacCl = 58.5g

58.5g of NaCl contain 1 mole

1g of NaCl will contain $\frac{1}{58.5}$ moles

53.5g of NaCl will contain $\frac{1 \text{ x } 53.5}{58.5}$ moles

0.9145moles

2000cm^3 of solution contains 0.9145 moles of NaCl

1cm^3 of solution will contain $\frac{0.9145}{2000}$ moles of NaCl

1000cm^3 of solution will contain $\frac{0.91445 \text{ x } 1000}{2000}$ moles of NaCl

0.4573M

1 moles of NaCl weighs 58.5g

0.4573 moles will weigh $\frac{0.4573 \text{ x } 58.5}{1}$ g

26.75gl^{-1}

4. A standard solution.

This is a solution whose concentration is known. The concentration can be:

(i) In moles of the compound in a litre of solution (Molarity).

(ii) In grams of the compound in a litre of solution.

(iii) In grams of the compound in a given volume usually 250cm^3 or 500cm^3.

A standard solution is used to standard solutions whose concentration is not known (un-standard solution) during a process called volumetric analysis.

ACID-BASE TITRATION

Acid-base titration is the titration between an acid and an alkali. The reaction taking place in this titration is called **neutralization reaction.** The reaction is represented by the equation below.

$$H^{+}_{(aq)} + OH^{-}_{(aq)} \longrightarrow H_2O_{(l)}$$

The progress of the reaction is determined by adding an indicator to the solution in the conical flask.

At the end point, the indicator shows a sharp colour change. Students should take care when the end point is about to be reached. Add the solution from the burette drop by drop to avoid over shooting.

At this level, the indicator solutions used for titration are phenolphthalein and methyl orange indicators.

They show the following colours in acid and base media.

Indicator	Colour in acid medium	Colour in alkali medium
Phenolphthalein	Colourless	Purple
Methyl orange	Red/Pink	Yellow

Worked Examples

Example 1

You are provided with:

BA1, which is potassium hydroxide solution with unknown concentration.

BA2, which is 0.2M sulphuric acid.

You are required to determine the concentration of **BA1**

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA1** into a clean conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA2** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

Volume of pipette used.........25.0.........cm^3

Experiment	1	2	3
Final burette reading (cm^3)	15.20	17.60	21.60
Initial burette reading (cm^3)	0.00	2.00	6.00
Volume of **BA2** used (cm^3)	15.20	15.60	15.60

Titre values of **BA2** used for average

15.60cm^3 and 15.60cm^3

Average volume of **BA2** used.

$$\frac{15.60+15.60}{2}$$

$15.60cm^3$

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

$2KOH_{(aq)} + H_2SO_{4(aq)} \longrightarrow K_2SO_{4(aq)} + 2H_2O_{(l)}$

(b) Calculate the molarity of potassium hydroxide.

$1000cm^3$ of solution contains 0.2 moles H_2SO_4

$1cm^3$ of solution will contain $\frac{0.2}{1000}$ moles of H_2SO_4

$15.60cm^3$ of solution will contain $\frac{0.2 \text{x} 15.60}{1000}$ moles of H_2SO_4

0.00312 moles of H_2SO_4

From the equation,

1 mole of sulphuric acid reacts 2 moles of potassium hydroxide.

0.00312 moles of sulphuric acid will react with $\frac{2 \text{ x } 0.00312}{1}$ moles of potassium hydroxide

0.00624 moles of KOH

$25.0cm^3$ of solution contains 0.00624 moles of potassium hydroxide

$1cm^3$ of solution will contain $\frac{0.00624}{25.0}$ moles of potassium hydroxide

$1000cm^3$ of solution will contain $\frac{0.00624 \text{ x } 1000}{25.0}$ moles of potassium hydroxide

0.25M

NB: M is the same as moles per litre, moles per $1000cm^3$ and moles per dm^3

(c) Determine the concentration of KOH in grams per litre. (K = 39, O = 16, H = 1)

RFM of KOH = (39 x 1) + (16 x 1) + (1 x1)

39 + 16 + 1

56

1 mole KOH weighs 56g

0.25 moles of KOH will weigh $\frac{0.25 \text{ x } 56}{1}$ g

$14gl^{-1}$

Example 2

You are provided with:

FA1, which is a solution containing 3.7 grams per litre of a metal hydroxide $M(OH)_2$

FA2, which is 0.1M dilute hydrochloric acid

You are required to determine the atomic mass of metal M in $M(OH)_2$.

Procedure:

Pipette $25.0cm^3$ (or $20.0cm^3$) of **FA1** into a conical flask. Add 2-3 drops of methyl orange indicator and titrate with **FA2** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results

Volume of pipette used 25.0 cm^3

Experiment	1	2	3
Final burette reading(cm^3)	25.00	27.10	28.20
Initial burette reading (cm^3)	0.00	2.00	3.00
Volume of **FA2** used (cm^3)	25.00	25.10	25.20

Tire values of **FA1** used for average

$25.10cm^3$ and $25.20cm^3$

Average volume of **FA1** used

$$\frac{25.10 \text{ x } 25.20}{2}$$

$25.15cm^3$

(a) Write the equation for the reaction that took place between **FA1** and **FA2**.

$M(OH)_{2\,(aq)} + HCl_{(aq)} \longrightarrow MCl_{2\,(aq)} + 2H_2O_{(l)}$

(b) Calculate the number of moles of FA1 that reacted with FA2.

$1000cm^3$ of solution contains 0.1 moles of HCl

$1cm^3$ of solution will contain $\frac{0.1}{1000}$ moles of HCl

$25.15cm^3$ of solution will contain $\frac{0.1 \text{ x } 25.15}{1000}$ moles of HCl

0.002515moles of HCl

From the equation,

2 moles of HCl reacted with 1 mole of $M(OH)_2$

0.002515 moles of HCl will react with $\frac{1 \text{ x } 0.002515}{2}$ moles of $M(OH)_2$

0.0012575 moles of $M(OH)_2$

(c) Determine the molarity of **FA1**.

$25.0cm^3$ of solution contains 0.0012575 moles of $M(OH)_2$

$1cm^3$ of solution will contain $\frac{0.0012575}{25.0}$ moles of $M(OH)_2$

$1000cm^3$ of solution will contain $\frac{0.0012575 \times 1000}{25.0}$ moles of $M(OH)_2$

0.05M

(d) Calculate the formula mass of **FA1** and hence the relative atomic mass of metal M in $M(OH)_2$.

(H = 1, O = 16)

0.05 moles contain 3.7g $M(OH)_2$

1 mole will contain $\frac{3.7 \times 1}{0.05}$

74g

Or

Use of formula

$$RFM = \frac{\text{Conc. in } gl^{-1}}{\text{Molarity}}$$

$$= \frac{3.7}{0.05}$$

$$= 74$$

$M(OH)_2 = RFM$

$M + (16 \times 2) + (1 \times 2) = 74$

$M + 32 + 2 = 74$

$M + 34 = 74$

$M = 74 – 34$

$M = 40$

Example 3

You are provided with:

BA1, which is a solution containing 4.0g solution hydroxide dissolved to make 500cm^3 of the solution.

BA2, which is a solution containing 0.1M acid H_nX.

You are required to determine the basicity of an acid H_nX.

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA1** into a conical flask. Add 2-3 drops phenolphthalein indicator and titrate with **BA2** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results

Volume of pipette used.......25.0.........cm^3

Experiment	1	2	3
Final burette reading (cm^3)	25.40	25.00	27.00
Initial burette reading (cm^3)	0.00	0.00	2.00
Volume of **BA2** used (cm^3)	25.40	25.00	25.00

Titre values of **BA2** used for average.

25.00cm^3 and 25.00cm^3

Average volume of **BA2** used

$$\frac{25.00+25.00}{2}$$

25.00cm^3

(a) Calculate the molarity sodium hydroxide (Na = 23, O = 16, H = 1)

500cm^3 of solution contains 4.0g of NaOH

1cm^3 of solution will contain $\frac{4.0}{500}$ g of NaOH

1000cm^3 of solution will contain $\frac{4.0 \times 1000}{500}$ g NaOH

8gl$^-$

RFM of NaOH = (23 x 1) + (16 x 1) + (1 x 1)

= 23 + 16 + 1

= 40

40g of NaOH contains 1 mole

1g of NaOH will contain $\frac{1}{40}$ moles

8g of NaOH will contain $\frac{1 \times 8}{40}$ moles

0.2M

(b) Calculate the number of moles of **BA1** that reacted

1000cm^3 of solution contains 0.2 moles of NaOH

1cm^3 of solution will contain $\frac{0.2}{1000}$ moles of NaOH

25.0cm^3 of solution will $\frac{0.2 \times 25.0}{1000}$ moles of NaOH

0.005 moles of NaOH

(c) Calculate the number of moles of the acid that reacted.

1000cm^3 of solution contains 0.1 moles of the acid

1cm^3 of solution will contain $\frac{0.1}{1000}$ moles of the acid

25.00cm^3 of solution will contain $\frac{0.1 \times 25.00}{1000}$ moles of the acid

0.0025moles of the acid

(d) Determine the basicity of the acid H_nX and hence write the equation of reaction between the acid and the base.

	NaOH	:	H_nX
Number of moles	0.005	:	0.0025
Mole ratio	$\frac{0.005}{0.0025}$	:	$\frac{0.0025}{0.0025}$
	2	:	1

Therefore the basicity of the acid n is 2.

$2NaOH_{(aq)} + H_2X_{(aq)} \longrightarrow Na_2X_{(aq)} + 2H_2O_{(l)}$

Example 4

You are provided with the following;

BA1, which is a solution made by dissolving 4.8g of metal hydroxide MOH in one litre.

BA2, which is a 0.0625 moll^{-1} sulphuric acid.

You are required to determine the relative atomic mass of M in MOH

Procedure;

Pipette 25cm^3 (or 20cm^3) of **BA1** into a clean conical flask and add 2-3drops of phenolphthalein indicator. Titrate this mixture with **BA2** from the burette. Repeat the titration until you obtain consistent results.

Record your results in the table below.

Results:

Volume of pipette used.......25.0........cm^3

Final burette reading (cm^3)	24.10	48.10	24.00
Initial burette reading (cm^3)	0.00	24.10	0.00
Volume of **BA2** used (cm^3)	24.10	24.00	24.00

Volumes of **BA2** used for calculating the average

24.00cm^3 and 24.00cm^3

Average volume of **BA2** used

$$\frac{24.00+24.00}{2}$$

$$\frac{48.00}{2}$$

24.00cm^3

Questions:

(a) Calculate the;

(i) Number of moles of **BA2** that reacted,

1000cm^3 of solution contains 0.0625 moles of sulphuric acid.

1cm^3 of solution will contain $\frac{0.0625}{1000}$ moles of sulphuri aid

24.00cm^3 of solution will contain $\frac{0.0625 \text{ x } 24.00}{1000}$ moles of sulphuric aid

0.0015 moles of sulphuri acid

(ii) Number of moles of MOH in **BA1** that reacted

$2MOH_{(aq)} + H_2SO_{4\,(aq)} \longrightarrow M_2SO_{4\,(aq)} + 2H_2O_{(l)}$

From the equation;

1 mole of sulphuric acid reacted with 2 moles of MOH

0.0015 moles of sulphuric acid will react with $\frac{2 \text{ x } 0.0015}{1}$ moles of MOH

0.003 moles of MOH

(iii) Molarity of **BA1**.

25.0cm^3 of solution contains 0.003 moles of MOH.

1cm^3 of solution will contain $\frac{0.003}{25.0}$ moles of MOH

1000cm^3 of solution will contain $\frac{0.003 \text{ x } 1000}{25.0}$ moles of MOH

0.12M

(iv) Formula mass of MOH.

0.12 moles of MOH contains 4.8g

1 mole of MOH will contain $\frac{4.8}{0.12}$ g

40g

(v) Relative atomic mass of M. (O = 16, H = 1)

MOH = 40

(M x 1) + (16 x 1) + (1 x 1) = 40

M + 16 + 1 = 40

M + 17 = 40

M = 40 – 17

M = 23

Example 5

You are provided with the following:

GA1, which is a solution made by dissolving 12.6g of a monobasic acid HNO_X to make 1 litre of solution.

GA2, which is a 0.2M sodium hydroxide solution.

You are required to determine the value of x in HNO_X

Procedure:

Pipette 25cm^3 (or 20cm^3) of **GA2** into a conical flask and add 2-3 drops of phenolphthalein indicator. Titrate this mixture with **GA1** from the burette. Repeat the titration until you obtain consistent results.

Record your results in the table below.

Results:

Volume of pipette used 25.0 cm^3

Experiment	1	2	3
Final burette reading (cm^3)	25.20	25.00	25.00
Initial burette reading (cm^3)	0.00	0.00	0.00
Volume of **GA1** used (cm^3)	25.20	25.00	25.00

Volumes of **GA1** used to calculate the average

25.00cm^3 and 25.00cm^3

Average volume of **GA1** used

$\frac{25.00+25.00}{2}$

$\frac{50.00}{2}$

$25.00cm^3$

Questions:

(a) Write the ionic equation for the reaction between the acid in **GA1** and sodium hydroxide in **GA2**.

$H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$

(b) Calculate the;

(i) Moles of sodium hydroxide in **GA2** that reacted with acid.

$1000cm^3$ of solution contains 0.2 moles of sodium hydroxide

$1cm^3$ of solution will contain $\frac{0.2}{1000}$ moles of sodium hydroxide

$25.0cm^3$ of solution will contain $\frac{0.2 \times 25.0}{1000}$ moles of sodium hydroxide

0.005 moles of sodium hydroxide

(ii) Number of moles of HNO_X in **GA1** that reacted.

From the equation;

1 mole sodium hydroxide reacted with 1 mole of HNO_X

0.005 moles of sodium hydroxide will react with $\frac{1 \times 0.005}{1}$ moles of HNO_X

0.005 moles of HNO_X

(iii) Molarity of **GA1**.

$25.00cm^3$ of solution contain 0.005 moles of HNO_X

$1cm^3$ of solution will contain $\frac{0.005}{25.00}$ moles of HNO_X

$1000cm^3$ of solution will contain $\frac{0.005 \times 1000}{25.00}$ moles of HNO_X

0.2M

(iv) Formula mass of HNO_X

0.2 moles of HNO_X contain 12.6g

1 mole of HNO_X will contain $\frac{12.6}{0.2}$ g

63g

(v) Value of x. (O = 16, H = 1, N = 14)

$HNO_X = 63$

$(1 \times 1) + (14 \times 1) + (X \times 16) = 63$

$15 + 16X = 63$

$16X = 63 - 15$

$16X = 48$

$X = 3$

Example 6

You are provided with the following

BA1, which is a solution containing 10g of solid $Y.10H_2O$ in 500cm^3 of solution.

BA2, which is 0.1M hydrochloric acid solution.

(Ratio of $Y.10H_2O$: HCl is 1 : 2 and Y = 202)

You are required to determine the percentage purity of solid $Y.10H_2O$

Procedure:

Pipette 25cm^3 (or 20cm^3) of **BA1** into a clean conical flask. Then add 2-3 drops of methyl orange indicator and titrate with solution **BA2** from the burette. Repeat the titration until you obtain consistent results. Enter your results in the table below.

Results:

Volume of pipette used 25.0 cm^3

Final burette reading (cm^3)	15.40	30.90	46.30
Initial burette reading (cm^3)	0.00	15.40	30.90
Volume of **BA2** used (cm^3)	15.40	15.50	15.40

Titre values used for calculating average volume of **BA2**.

15.50cm^3 and 15.40cm^3

Average volume of **BA2**

$$\frac{15.50+15.40}{2}$$

15.45cm^3

Questions:

(a) Calculate the;

(i) Moles of hydrochloric acid in **BA2** that reacted

1000cm^3 of solution contains 0.1 moles of hydrochloric acid

1cm^3 of solution will contain $\frac{0.1}{1000}$ moles of hydrochloric acid

15.45cm^3 of solution will contain $\frac{0.1 \times 15.45}{1000}$ moles of hydrochloric acid

0.001545 moles of hydrochloric acid

(ii) Moles of Y.10H_2O in **BA1** that reacted with hydrochloric acid

From the mole ratio;

2 moles of the hydrochloric acid reacted with 1 mole of Y.10H_2O

0.001545 moles of hydrochloric acid will react with $\frac{1 \times 0.001545}{2}$ moles of Y.10H_2O

0.000772 moles of Y.10H_2O

(iii) Molarity of **BA1** and hence the percentage purity of the solid, Y.10H_2O

25.0cm^3 of solutions contain 0.000772 moles of Y.10H_2O

1cm^3 of solution will contain $\frac{0.000772}{25.0}$ moles of Y.10H_2O

1000cm^3 of solution will contain $\frac{0.000772 \times 1000}{25.0}$ moles of Y.10H_2O

0.03088M

RFM of Y.10H_2O = 202 + 180

= 382gs

1 mole of Y.10H_2O weighs 382g

0.03088 mole of Y.10H_2O weighs 382 x 0.03088

11.7gl^{-1}

Also

500cm^3 of **BA1** contain 10g of Y.10H_2O

1cm^3 of **BA1** will contain $\frac{10}{500}$ g of Y.10H_2O

1000cm^3 of **BA1** will contain $\frac{10 \times 1000}{500}$ g of Y.10H_2O

20gl^{-1}

Therefore the percentage purity of Y.10H_2O = $\frac{11.7 \times 100}{20}$ %

58.5%

NB: Percentage impurity = 100 – (percentage purity)

PRACTICAL SCHEDULES

Practical 1

You are provided with:

BA1, which is 0.1M hydrochloric acid

BA2, which is sodium hydroxide

You are required to determine the concentration of solution of **BA2** in

(i) $Moldm^{-3}$

(ii) gl^{-1}

Procedure:

Pipette $25.0cm^3$ (or $20.0cm^3$) of **BA2** in a conical flask. Add 2-3 drops of phenolphthalein indicator and titrate with **BA1** from the burette.

Repeat the procedure to obtain consistent results.

Record your results in the table below.

Results

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** used for average

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Average volume of **BA1** used

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Questions

Calculate the;

(i) Number of moles of **BA1** that reacted.

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(ii) Number of moles of **BA2** that reacted.

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(iii) Concentration of **BA2** in $Moldm^{-3}$

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(iv) Concentration **BA2** in gl^{-1}

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Practical 2

You are provided with:

BA3, which is 0.2M solution of hydrochloric acid

BA4, which is a made by dissolving 10.6g of sodium carbonate to make 1 litre if solution.

You are required to determine the concentration of **BA3** in

(i) Mold m^{-3}

(ii) gl^{-1}

Procedure:

Pipette $25.0cm^3$ (or $20.0cm^3$) of **BA4** into a conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA3** from the burette.

Repeat procedure to obtain consistent results.

Record your results in the table below.

Results:

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

Experiment	1	2	3
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of **BA3** used (cm^3)			

Titre values of **BA3** used for average

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Average volume of **BA3** used

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Questions:

(a) Calculate the;

(i) Number of moles of **BA4** that reacted (Na = 23, C = 12, O = 16)

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(ii) Number of moles of **BA3** that reacted.

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(iii) Concentration of **BA3** in $moldm^{-3}$

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(iv) Concentration of **BA3** in gl^{-1} (Cl = 35.5, H = 1)

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Practical 3

You are provided with:

BA1, which is 0.2M hydrochloric acid solution.

BA2, which is a salt solution made by dissolving 10.6g of M_2CO_3 in 1 litre of solution.

You are required to determine the relative atomic mass of metal M in M_2CO_3.

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA2** into a conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA1** from the burette.

Repeat procedure to until you obtain consistent results.

Record your observations in the table below.

Results:

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** used for average

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Average volume of **BA1** used

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Questions:

(a) Calculate the;

(i) Number of moles of **BA1** that reacted

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(ii) Write the equation reaction between **BA1** and **BA2**

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(iii) Write the mole ratio of the reaction

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(b) Calculate the number of moles **BA2** that reacted

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(c) Calculate the molarity of **BA2**

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(d) Calculate the relative formula mass of M_2CO_3

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(e) Determine the relative atomic mass of M (C = 12, O = 16)

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Practical 4

You are provided with:

BA3, which is a solution containing 1.7g of OH^- ions per litre

BA4, which is a dibasic acid H_2X containing $9.8gl^{-1}$

You are required to determine the atomic mass of X in the acid (H = 1, O = 16)

Procedure:

Pipette $25.0cm^3$ (or $20.0cm^3$) of **BA3** into a conical flask. Add 3 drops phenolphthalein indicator and titrate with **BA4** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below

Results:

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

Experiment	1	2	3
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of **BA4** used (cm^3)			

Titre values of **BA4** used for average

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Average volume of **BA4** used

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Write the ionic equation for the reaction between **BA3** and **BA4**

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Questions:

(a) Calculate the;

(i) Molarity of **BA3**

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(ii) Number of moles of **BA3** that reacted

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(iii) Number of moles **BA4** that reacted

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(iv) Molarity of **BA4**

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(v) Relative atomic mass of X in the acid

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Practical 5

You are provided with:

BA5, which is a solution containing 12.6g of dibasic acid $Y.nH_2O$ per litre of solution

BA6, which is made dissolving 8g of sodium hydroxide to make 1 litre of the solutions

You are required to determine the value of n in the salt $Y.\ nH_2O$.

(1 mole of $Y.nH_2O$ reacts 2 moles sodium hydroxide, molar mass of Y = 90)

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA6** in a conical flask. Add 3 drops of phenolphthalein indicator and titrate with **BA5** from the burette.

Repeat procedure until you obtain consistent results.

Record your results in the table below.

Results:

Volume of pipette…………………………………………cm^3

Experiment	1	2	3
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of **BA5** used (cm^3)			

Titre values of **BA5** used for average

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Average volume of **BA5** used

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Questions:

(a) Calculate,

(i) The molarity of sodium hydroxide

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(ii) The number of moles of sodium hydroxide that reacted

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(iii) The number of moles of $Y.nH_2O$ that reacted

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(iv) The molarity of $Y.nH_2O$

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(v) The value of value of **n** in $Y.nH_2O$

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Practical 6

You are provided with:

BA1, which is 0.3M sodium hydroxide solution

BA2, which is 0.2M solution of acid H_nA

You are required to determine the stoichiometry reaction between the acid H_nA and sodium hydroxide.

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA1** into conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA2** from the burette.

Repeat the procedure until you obtain consistent results

Record your results in the table below.

Results:

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 of **BA2** used for average

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Average volume of **BA2** used

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Questions:

(a) Calculate the;

(i) Number of moles of sodium hydroxide that reacted

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(ii) Number of moles of H_nA that reacted

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(b) Determine the mole ratio of the acid H_nA to sodium hydroxide

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(c) Determine the value of n in H_nA

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(d) Write the equation for reaction

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Practical 7

You are provided with:

BA1, which is 0.2 moles per litre of the acid H_nX

BA2, which is 0.5M solution of sodium hydroxide

You are required to determine the basicity, n of the acid H_nX

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA2** into a conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA1** from the burette

Repeat the procedure until you obtain consistent results

Record your results in the table below.

Results:

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** used for average

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……………………………………………………………………………………………………

Average volume of **BA1** used

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Questions:

(a) Calculate the;

(i) Number of moles of sodium hydroxide that reacted

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(ii) The number of moles of H_nX that reacted

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(b) Determine,

(i) The mole ratio of the acid H_nX to sodium hydroxide

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(ii) The basicity, n of the acid H_nX

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(c) Write an ionic equation of the reaction between the acid and the base (sodium hydroxide)

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Practical 8

You are provided with the following:

BA1, which is a solution containing $12.6gl^{-1}$ of a dibasic acid of formula $H_2C_2O_4 .xH_2O$.

BA2, which is 0.1M sodium hydroxide solution.

You are required to determine the value of x

Procedure:

Pipette $25.0cm^3$ (or $20.0cm^3$) of **BA2** into a clean conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA1** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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** used for average

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Average volume of **BA1** used

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Questions:

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(i) Number of moles of **BA2** reacted

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(ii) Number of moles of **BA1** that reacted with **BA2**

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(iii) Concentration $moll^{-1}$ of **BA1**

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(iv) The R.M.M of the acid and hence the value of x.

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Practical 9

You are provided with:

BA1, which is a solution of acid H_nX of concentration 0.625M.

BA2, which is a 0.5M sodium hydroxide solution.

You are required to determine the reaction ratio for **BA1** and **BA2**.

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA2** into a clean conical flask. Add 2-3 drops of phenolphthalein indicator and titrate with **BA1** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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** used for average

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Average volume of **BA1** used

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Questions:

Calculate the;

(i) Number of moles of **BA1** that reacted

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(ii) Number of moles of **BA2** that reacted

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(iii) The value of n (basicity of H_nX)

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(iv) The mole ratio.

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Practical 10

You are provided with:

BA1, which is a solution of an impure acid H_2X of concentration $2gdm^{-3}$.

BA2, which is a solution of sodium hydrogen carbonate made by dissolving 4.2g in $1dm^{-3}$.

You are required to determine the percentage purity of **BA1**.

Procedure:

Pipette $25.0cm^3$ (or $20.0cm^3$) of **BA2** into a clean conical flask. Add 2-3 drops methyl orange indicator and titrate with **BA1** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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** used for average

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Average volume of **BA1** used

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Questions:

(a) Calculate the;

(i) Number of moles of **BA2** that reacted

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(ii) Number of moles of **BA1** that reacted

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(iii) Molarity of BA1 (X = 88g)

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Practical 11

You are provided with the following:

BA3, which is 0.04M hydrochloric acid solution

BA4, which is a solution made by dissolving 3.6g of impure $Na_2CO_3.10H_2O$ to make 500cm^3 of a solution.

You are required to determine the percentage impurity of **BA4**.

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA4** into a conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA3** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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

Experiment	1	2	3
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of **BA3** used (cm^3)			

Titre values of **BA3** used for average

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Average volume of **BA3** used

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Questions:

(a) Write an equation for the reaction

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(b) Calculate the;

(i) Number of moles of **BA3** that reacted

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(ii) Number of moles of $Na_2CO_3.10H_2O$ in $250cm^3$ of a solution.

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(iii) Percentage purity of $Na_2CO_3.10H_2O$.

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………… (Na = 23, C = 12, O = 16, H = 1)

Practical 12

You are provided with the following:

BA3, which is a 0.2M monobasic acid.

BA4, which is a solution made by dissolving 11.6g of $Na_2CO_3.nH_2O$ to make a litre of a solution.

You are required to determine the value n

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA4** into a conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA3** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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

Experiment	1	2	3
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of **BA3** used (cm^3)			

Titre values of **BA3** used for average

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Average volume of **BA3** used

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Questions:

(a) Calculate the;

(i) Moles of **BA3** that reacted

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(ii) Moles of $Na_2CO_3.10H_2O$ in $1000cm^3$ of a solution.

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(iii) Formula mass of **BA4** and hence the value of n.

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…………………………..(Na = 23, C = 12, O = 16, H = 1)

Practical 13

You are provided with the following:

BA1, which is a solution containing 6.2g of $Y.nH_2O$ in one litre

BA2, which is 0.1M hydrochloric acid

(Y =106, 1 mole of $Y.nH_2O$ reacts with 2 moles of hydrochloric acid)

You are required to determine the number of moles of water of crystallization in **BA1**

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA1** into a clean conical flask. Add 2-3 drops of phenolphthalein indicator and titrate with **BA2** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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 of **BA2** used for average

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Average volume of **BA2** used

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Questions:

(a) Calculate the:

(i) Number of moles of **BA2** that reacted.

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(ii) Number of moles of **BA1** that reacted with the acid

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(iii) Concentration of **BA1** in moles per litre

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(iv) Value of **n** in $Y.nH_2O$.

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Practical 14

You are provided with the following:

BA1, which is a solution containing 12.5gl^{-1} of a mixture of anhydrous sodium carbonate and sodium chloride.

BA2, which is a 0.1M hydrochloric acid solution.

You are required to determine the composition of sodium chloride in **BA1**.

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA1** into a clean conical flask. Add 2-3 drops methyl orange indicator and titrate with **BA2** from the burette.

Repeat the procedure until you obtain consistent results

Record your results in the table below.

Results:

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 of **BA2** used for average

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Average volume of **BA2** used

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Questions:

(a) Calculate the;

(i) Number of moles of **BA2** that reacted.

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(ii) Number of moles of **BA1** that reacted with **BA2**.

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(iii) Concentration in moles per litre of **BA1**

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(iv) Percentage of sodium chloride in **BA1**.

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Practical 15

You are provided with:

BA1, is an aqueous solution of XCO_3 prepared by dissolving 2.65g of it in 250cm^3 of distilled water.

BA2, is an aqueous solution of hydrochloric acid prepared by dissolving 7.3g of it in a litre of distilled water.

You are required to determine the relative atomic mass of X in XCO_3.

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA1** into a clean conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA2** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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 of **BA2** used for average

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Average volume of **BA2** used

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Questions:

(a) Calculate the;

(i) Molarity of **BA2** (Cl = 35.5, H = 1)

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(ii) Number of moles of **BA2** that reacted

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(iii) Number of **BA1** that reacted (**BA1** : **BA2** = 1 : 2)

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(iv) Concentration of **BA1** in moles per litre

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(b) Determine the;

(i) Relative formula mass of XCO_3

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(ii) Value of X in XCO_3 (C = 12, O = 16)

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Procedure 16

You are provided with:

BA1, which is a sodium hydroxide solution of molarity 0.2M

BA2, which is made by dissolving 9.8g of acid H_XY per litre of solution.

You are required to determine the basicity, x of acid H_XY.

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA1** into a conical flask. Add 2-3 drops of phenolphthalein indicator and titrate with **BA2** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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 of **BA2** used for average

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Average volume of **BA2** used

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Questions:

(a) Write an equation for the reaction between the acid H_XY and sodium hydroxide.

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(b) Calculate the;

(i) Number of moles of **BA1** that reacted

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(ii) Number of moles of acid H_XY that reacted with sodium hydroxide.

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(c) Deduce the molarity **BA2**.

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(d) Determine the value x in the acid H_XY (H = 1, Y = 96)

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Practical 17

You are provided with:

BA1, which is a solution made by dissolving 3.35g of solid Na_2Y in 250cm^3 of distilled water.

BA2, which is 0.1M hydrochloric acid.

You are required to determine the ratio of reaction between Na_2Y and hydrochloric acid

(Y = 96, Na = 23)

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA1** into a conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA2** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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 of **BA2** used for average

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Average volume of **BA2** used

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Questions:

(a) Calculate the;

(i) Molarity of **BA1**

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(ii) Number of moles of Na_2Y in **BA1**

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(iii) Number of moles of hydrochloric acid in **BA2** that reacted with Na_2Y

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(b) Determine the ratio of reaction between Na_2Y and hydrochloric acid.

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Practical 18

You are provided with the following.

BA1, is a solution of sodium carbonate of molarity 0.1M

BA2, is a solution of hydrochloric acid of molarity 0.2M

You are required to determine the reaction ratio between sodium carbonate and hydrochloric acid.

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA1** into a clean conical flask. Add 2-3 drops methyl orange indicator and titrate with **BA2** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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 of **BA2** used for average

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Average volume of **BA2** used

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Questions:

(a) Determine the;

(i) Number of moles of sodium carbonate that reacted with the acid.

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(ii) Number of moles of hydrochloric acid the reacted with sodium carbonate.

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(iii) Number of moles of acid that reacted with one moles of sodium carbonate.

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Practical 19

BA3, which is a solution containing 16.0g of an impure sample of sodium carbonate -10-water, $Na_2CO_3.10H_2O$

BA4, which is a 0.1M solution of hydrochloric acid.

You are required to determine the percentage purity of sodium carbonate.

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA3** into a conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA4** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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

Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of **BA4** used (cm^3)			

Titre values of **BA4** used for average

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Average volume of **BA4** used

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Questions:

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

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(b) Calculate,

(i) The molarity of **BA3**

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(ii) The mass of sodium carbonate in one litre. (Na = 23, C = 12, O = 16, H = 1)

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(c) Determine the percentage purity of sodium carbonate in the sample.

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Practical 20

You are with the following:

BA1, which is made by dissolving 5.3g of a carbonate of the Y_2CO_3 in 1 litre of the solution.

BA2, which is 0.1M hydrochloric acid.

You are required to determine the relative atomic mass of Y

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA1** into a conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA2** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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

Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of **BA2** used (cm^3)			

Titre values of BA2 used for average

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Average volume of **BA2** used.

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Questions:

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

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(b) Calculate the;

(i) Number of moles of **BA2** that reacted

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(ii) Number of moles of Y_2CO_3 that reacted

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(iii) Molar concentration of Y_2CO_3 in **BA1**.

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(c) Determine the relative atomic mass of Y

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Practical 21

You are provided with the following

BA1, which is 0.02M hydrochloric acid

BA2, which is a solution made by dissolving 1.05g of a metal carbonate MCO_3 to make 0.5 litres of aqueous solution.

You are required to determine the relative atomic mass of metal, M in the metal carbonate.

Procedure;

Pipette 25.0cm^3 (or 20.0cm^3) of **BA2** into a conical flask. Add 3drops of phenolphthalein indicator and titrate with **BA1** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Result:

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

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

Titre values of **BA1** used for average

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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) Determine:

(i) The number of moles of **BA1** that reacted

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(ii) The number of moles metal carbonate MCO_3 that reacted.

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(iii) The concentration in moles per litre of the metal carbonate MCO_3.

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(c) Calculate the;

(i) Relative molecular mass of MCO_3

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(ii) The relative atomic mass of M in the metal carbonate MCO_3.

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Practical 22

You are provided with the following:

CA1, which is a solution of carbonate ions, CO_3^{2-}

CA2, which is a solution containing $16.1gl^{-1}$ of a metal sulphate, MSO_4.

CA3, which is a 0.2M hydrochloric acid solution.

You are required to determine the atomic mass of M in MSO_4.

The carbonate ions in solution react with an aqueous solution of the metal sulphate according to the equation.

$$CO_3^{2-}{}_{(aq)} + MSO_{4\,(aq)} \longrightarrow MCO_{3\,(s)} + SO_4^{2-}{}_{(aq)}$$

The metal carbonate produced reacts with dilute hydrochloric acid according to the equation.

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

Procedure:

(a) Pipette $25.0cm^3$ (or $20.0cm^3$) of **CA1** into a conical flask.

(b) Using a $50cm^3$ measuring cylinder, transfer $25cm^3$ of **CA2** into the conical flask in (a) .shake the contents in the conical flask and allow to stand, label the resultant mixture **CA4**.

(c) Add 3-4 drops of methyl orange indicator to the resultant mixture in **CA4** in (b) and then titrate using solution **CA3** from the burette until you reach the end point.

(d) Repeat the procedure (a) to (c) to obtain consistent results.

Record your results in the table below.

Results:

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

Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of **CA3** used (cm^3)			

Titre values of **CA3** used for average

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Average volume of **CA3** used

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Questions:

(a) Calculate the;

(i) Number of moles of hydrochloric acid in **CA3** used.

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(ii) Number of moles of MCO_3 that reacted with HCl.

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(iii) Number of moles of metal sulphate that reacted

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(iv) Mass of one mole of MSO_4 that reacted.

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(b) Determine the atomic mass of M in MSO_4. (S = 32, O = 16)

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Practical 23

You are provided with:

BA1, is an aqueous solution of XCO_3 prepared by dissolving 5.3g of it in 500cm^3 of distilled water.

BA2, is an aqueous solution of 0.2M hydrochloric acid.

You are required to determine the value of X in XCO_3.

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA1** into a conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA2** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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

Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of **BA2** used (cm^3)			

Titre values of **BA2** used for average

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Average volume of **BA2** used

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Questions:

(a) Calculate the,

(i) Number of moles of **BA2** that reacted.

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(ii) Number of moles of **BA1** that reacted (**BA1** : **BA2** = 1: 2)

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(iii) Concentration of **BA1** in moles per litre.

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(iv) Relative formula mass of XCO_3

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(v) Value of X in XCO_3

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Practical 24

You are provided with the following:

BA1, which is a solution made by dissolving 3.45g of a hydrated salt $X.nH_2O$ in 250cm^3 of water.

BA2, which is a 0.1M hydrochloric acid.

You are required to determine the value of n in the salt.

Procedure:

Pipette 25cm^3 (or 20cm^3) of **BA1** into a conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA2** from the burette.

Repeat the procedure until you obtain consistent results..

Record your results in the table below.

Results:

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

Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of **BA2** used (cm^3)			

Titre values of **BA2** used for average

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Average volume of **BA2** used

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Questions:

(a) Calculate the;

(i) Number of moles of hydrochloric acid that reacted.

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(ii) Number of moles of $X.nH_2O$ that reacted. (1 mole of $X.nH_2O$ reacts with 2 moles of hydrochloric acid).

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(iii) Number of moles of $X.nH_2O$ in $250cm^3$ of **BA1**.

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(b) Determine the value of **n** in $X.nH_2O$. (H = 1, O = 16, X = 106)

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Practical 25

You are provided with:

BA1, which is a solution containing 0.1 moles per dm^3 of a monobasic acid, Q.

BA2, which is a solution made by dissolving $5.0gl^{-1}$ of substance Y, which is an impure sodium hydroxide.

You are required to determine the percentage purity of Y.

Procedure:

Pipette $25.0cm^3$ ($20.0cm^3$) of **BA2** into a conical flask. Add 2-3 drops of methyl orange indicator and titrate with **BA1** from the burette.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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

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

Titre values of **BA1** used for average

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Average volume of **BA1** used

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Questions:

(a) Calculate the;

(i) Number of moles of sodium hydroxide that reacted

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(ii) Concentration of sodium hydroxide per litre of **BA2**.

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(iii) Mass of sodium hydroxide in one litre of **BA2**. (H = 1; O = 16; Na = 23)

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(b) Determine the percentage purity of Y.

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Practical 26

You are provided with FA1 and FA2.

FA1, is a solution made by dissolving 2.0g of sodium hydroxide to make 500cm^3 of solution.

FA2, is a solution made by dissolving 13.2g of an impure dibasic acid H_2Y per litre of solution.

You are required to find the percentage purity of the acid.

Procedure:

Pipette 20cm^3 or 25cm^3 of **FA1**, transfer it into a clean conical flask. Titrate it against **FA2** from the burette using phenolphthalein indicator.

Repeat the procedure until you obtain consistent results.

Record your results in the table below.

Results:

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

Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of **FA2** used (cm^3)			

Values of **FA2** used to calculate the average volume

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Average volume of **FA2** used

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Questions:

(a) Write equation for the reaction between **FA1** and **FA2**.

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(b) Calculate the number of moles of **FA1** that reacted with **FA2**.

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(c) Calculate the number of moles of **FA2** present in a litre of the solution.

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(d) Calculate the mass of the pure acid in the sample. Hence the percentage purity (Y = 96, H = 1)

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Practical 27

You are provided with the following solutions.

BA1, which is a solution made by dissolving 8.05g of potassium hydroxide in a little of distilled water and solution made up to 500cm^3.

BA2, which is a 0.25M solution of an acid H_nY, prepared by dissolving 15.75g of acid in 500cm^3 of solution.

You are required to determine the basicity n, of acid H_nY, and hence the value of Y

(K = 39, O = 16, H = 1)

Procedure:

Pipette 25.0cm^3 (or 20.0cm^3) of **BA1** in a conical flask. Add 2-3 drops of phenolphthalein indicator.

Titrate with **BA2** from the burette until when you obtain 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)			

Titre values used to calculate average volume of **BA2**

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Average volume of **BA2**

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Questions:

Calculate the;

(i) Molarity of **BA1**.

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(ii) Moles of **BA1** that reacted.

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(iii) Moles of **BA2** that reacted.

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(iv) Value of n in H_nY.

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(v) Value of Y in H_nY

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Practical 28

You are provided with the following.

BA1, which is a solution containing 0.1 moles of an acid H_nX per litre of solution.

BA2, which is a solution prepared by dissolving 1.95g of sodium hydroxide in 500cm^3 of distilled water.

You are required to determine the basicity of the acid (value of n in H_nX).

Procedure:

Pipette 25cm^3 (or 20cm^3) of **BA2** into a clean conical flask.

Add 2-3 drops of phenolphthalein indicator and titrate with **BA1** from the burette.

Record your results in the table below.

Repeat the titration until you obtain consistent results.

Results:

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

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

Values of used to calculate average volume of **BA1** used.

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Average volume of **BA1** used.

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Questions:

(a) Calculate the;

(i) Molarity if **BA2**. (Na = 23, O = 16, H = 1)

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(ii) Number of moles of **BA2** that reacted.

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(iii) Moles of **BA1** that reacted.

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(iv) Mole ratio of **BA1** : **BA2**; hence determine the value of n in H_nX.

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(b) Write the equation of reaction between **BA1** and **BA2**.

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Practical 29

You are provided with the following solutions.

BA1 is a solution made by dissolving 2.65g of a carbonate X_nCO_3 to make 250cm^3 of solution.

BA2 is 0.2M hydrochloric acid solution.

You are required to determine the value of **n** in the carbonate by titration.

Procedure:

Pipette 25cm^3 or 20cm^3 of **BA1** into a clean conical flask. Add 2 drops of methyl orange indicator and titrate the mixture with **BA2** from a burette. Repeat the titration and record your results in the table below.

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

Burette readings	1	2	3
Final reading (cm^3)			
Initial reading (cm^3)			
Volume of **BA2** used (cm^3)			

Titre values used for calculating average volume

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Average volume of **BA2** used

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Questions:

(a) Calculate ,

(i) The number of moles of **BA2** that reacted.

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(ii) The number of moles of X_nCO_3 in 1000cm^3 of solution. [X_nCO_3 : HCl = 1 : 2]

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(iii) Determine the;

(i) Molar mass of the carbonate

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(ii) Value of n in the carbonate X_nCO_3
(X = 27, C = 12, O = 16)

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Practical 30

You are provided with the following;

BA1 which is a solution containing 2g of sodium hydroxide in 500cm^3 of solution.

BA2 is a 0.06M solution of an unknown acid **Q**.

You are required to determine the mole ratio between the acid and sodium hydroxide.

Procedure:

Pipette 25cm^3 (or 20cm^3) of **BA1** into a conical flask. Add 2-3 drops of phenolphthalein indicator. Titrate it with **BA2** from the burette.

Repeat the titration until you obtain consistent results.

Record your results in the table below.

Results:

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

Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of **BA2** used (cm^3)			

Volumes used to determine average volume of **BA2**

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Average volume of **BA2** used.

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Questions:

(a) Calculate the number of moles of:

(i) Sodium hydroxide used. (Na = 23, O = 16, H = 1)

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(ii) Acid used.

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(b) Determine the mole ratio between acid and sodium hydroxide

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Practical 31

You are provided with the following solutions.

BA1, is a solution made by dissolving 1.8g of a metal carbonate $X_2CO_3.nH_2O$ in 250cm^3 of solution.

BA2, is 0.05M hydrochloric acid solution.

You are required to determine the number of moles of water of crystallization, n in the carbonate.

Procedure:

Pipette 25cm^3 or 20cm^3 of **BA1** into a clean titration flask, add 2 drops of methyl orange indicator and titrate with **BA2** from the burette. Repeat the titration and record your results in the table below.

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

Burette readings	1	2	3
Final reading (cm^3)			
Initial reading (cm^3)			
Volume of **BA2** used (cm^3)			

Titre values of **BA2** used for calculating average volume

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Average volume of **BA2** used.

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Questions:

(a) Calculate

(i) The number of moles of hydrochloric acid that reacted.

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(ii) The number of moles of the carbonate that reacted.

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(b) Determine the value of **n** in the carbonate $X_2CO_3.nH_2O$. [X = 23, C = 12, H = 1]

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Practical 32

You are provided with the following solutions.

BA1, which is a solution made by dissolving 2.65g of a salt M_2X in 250cm^3 of solution.

BA2, is 0.25M hydrochloric acid.

You are required to determine the formula mass of X in the salt by titration.

Procedure:

Pipette 25cm^3 or 20cm^3 of **BA1** into a conical flask, add 2 drops of methyl orange indicator and titrate with **BA2** from the burette. Repeat the titration and record your results in the table below.

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

Burette readings	1	2	3
Final burette reading (cm^3)			
Initial burette reading (cm^3)			
Volume of **BA2** used (cm^3)			

Titre values of **BA2** used for calculating average volume

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Average volume **BA2** used

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Questions:

(a) Calculate the number of moles of **BA2** that reacted.

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(b) Determine the molarity of the salt (M_2X : HCl = 1 : 2)

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(c) Determine the value of X (M = 23).

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Practical 33

You are provided with the following;

BA1, which is a 0.067M sodium hydroxide solution

BA2, which is a solution containing 4.2g of an organic acid **Q** in 500cm^3 of solution.

You are required to determine the mole ratio of reaction between sodium hydroxide and **Q.**

Procedure:

Pipette 20/25cm^3 of **BA1** into a clean conical flask then add 2-3 drops of phenolphthalein indicator.

Titrate **BA1** with **BA2** from the burette until the solution just turns colourless.

Repeat the above procdure until you obtain consistent results. Record your results in the table blelow.

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 to calculate the average volume of **BA2** used

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Average volume of **BA2** used

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Questions:

(a) Calculate the:

(i) Concentration of **BA2** in mol/dm^3

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(ii) Number of moles of acid in the average volume of **BA2** that reacted

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(iii) Number of moles of **BA1** that reacted with **BA2**.

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(b) Determine the mole ratio of reaction between sodium hydroxide and acid **Q**

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Chapter three: THERMO-CHEMISTRY

Practical experiments on thermochemistry are mainly on heat of neutralization. When an acid is added to a base, heat energy is produced. This detected by a rise in temperature which is measured by a thermometer.

When reactions take place, bonds are either formed or broken. As a result there is a change in temperature, chemical reactions result into energy changes. The heat change that occur s during a chemical reaction referred to as a enthalpy, ΔH

There are two types of reactions classified depending on heat change accompanying the reaction. These are endothermic reactions and exothermic reactions

Endothermic reactions

These are reactions which occur with absorption of heat from the surrounding. In these reactions, energy must be supplied for the reactants to be converted to products. The energy (temperature) of the products falls below that of initial energy (temperature). The enthalpy change is positive implying that energy (heat) is absorbed from the surrounding e.g. when sodium thiosulphate dissolves in water.

$Na_2S_2O_{3(s)} + (aq) \longrightarrow Na_2S_2O_{3(aq)}$, $\Delta H = +ve$

Exothermic reactions

These are reactions which occur with evolution/liberation of heat to the surrounding. The temperature (heat) rises above the initial temperature (heat). The enthalpy change accompanying the reaction is negative. This implies that heat is given out to the surrounding e.g.

$C_{(s)} + O_{2\,(g)} \longrightarrow CO_{2\,(g)}$ $\Delta H = -ve$, $\Delta H = -393Kjmol-$

-393Kjmol- implies that 393Kj of energy is liberated when 1 mole of carbon is completely burnt in oxygen to form carbon dioxide

Examples of heat changes

- **Enthalpy of neutralization**

This is the quantity of heat evolved when one mole of hydrogen ions completely reacts with one mole of hydroxyl ions to form one mole of water

$H^+_{\ (aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$ $\Delta H = -57.3Kjmol^{-1}$

Neutralization reaction is exothermic meaning that energy is given out. When a strong acid is neutralized with a strong alkali, the heat change is approximately $57.3Kjmol^{-1}$. However when the alkali or acid is weak, the enthalpy change is less than 57.3Kjmol because heat is absorbed to dissociate the weak alkali or acid.

- **Enthalpy of solution**

Heat of solution is the quantity of heat liberated or absorbed when one mole of a substance is completely dissolved in water to form an infinitely dilute solution. The quantity of heat change depends on the amount of solvent used.

$NaOH_{(s)} + (aq) \longrightarrow Na^+_{\ (aq)} + OH^-_{\ (aq)}$

❖ **Heat of precipitation/displacement.**

This is the quantity of heat liberated when one mole of a given substance is completely displaced by another substance e.g. when iron filings are added to a solution of copper (II) sulphate, a blue solution of CuSO4 turns to pale green and a brown solid is deposited at the bottom. The pale green solution is due to formation of iron (II) sulphate whereas the brown solid is due to formation of copper metal.

$CuSO4_{(aq)} + Fe_{(s)} \longrightarrow FeSO4_{(aq)} + Cu_{(s)}$

Ionically,

$Cu^{2+}_{(aq)} + Fe_{(s)} \longrightarrow Fe^{2+}_{(aq)} + Cu_{(s)}$

Note. Iron is able to displace copper from its ions because iron is higher than copper in the electrochemical series.

Activity 1

a) When $25cm^3$ of 0.2M sulphuric acid was added to $100cm^3$ of 1M sodium hydroxide solution, the temperature of the resultant solution increased by 12.6 ^0C. Write the ionic equation for the reaction that took place.

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b) Calculate the enthalpy of neutralization sodium hydroxide (S.H.C = $4.2Kjmol^{-1}\,^0C^{-1}$, density of solution = $1gcm^{-3}$)

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Activity 2

(a) $50cm^3$ of 2M hydrochloric acid and $50cm^3$ of 2M sodium hydroxide both at 22 ^0C were mixed in a plastic beaker. The mixture was stirred and maximum temperature obtained as 35 ^0C. (S.H.C = $4.2Kjmol^{-1}\,^0C^{-1}$, density of solution = $1gcm^{-3}$)

Explain why a plastic beaker was used for mixing

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(b) Calculate the heat of the reaction

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(c) Explain precisely what would happen to the value of heat of reaction calculated above if 50ml of 2M ammonia solution was used instead of sodium hydroxide.

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PRACTICAL SCHEDULES

Practical 1

- You are provided with the following:
- **BA5**, which is 2M sodium hydroxide solution.
- **BA6**, which is hydrochloric acid solution.
- Plastic cup.
- Thermometer.
- Plastic beaker.

You are required to determine the enthalpy of neutralization of hydrochloric acid by sodium hydroxide

Procedure:

(a) Measure 50cm^3 of **BA5** into the plastic cup
(b) Record the temperature, t_1 of the solution
(c) Wash the thermometer with distilled water
(d) Measure 50cm^3 of **BA6** into the plastic beaker
(e) Measure and record the temperature, t_2
(f) Now add all the 50cm^3 of **BA6** into the alkali in the plastic cup
(g) Stir the mixture carefully with the thermometer and record the highest temperature t_3

Results:

Volume of **BA5** used……………………………………………………………………
Volume of **BA6** used……………………………………………………………………
Total volume of the mixture………………………………………………………………
Temperature of **BA5**, t_1…………………………………………………………………
Temperature of **BA6**, t_2…………………………………………………………………
Average initial temperature………………………………………………………………

Final temperature, t_3…………………………………………………………………………..
Determine the temperature change……………………………………………………....

Questions:

(a) Write an equation for the reaction between **BA5** and **BA6**
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(b) Calculate the number of moles of sodium hydroxide that reacted.
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(c) Calculate the heat evolved (S.H.C = 4.2Kjmol^{-1} ^{0}c^{-1}, density of solution = 1gcm^{-3})
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(d) Calculate the molar heat of neutralization of hydrochloric acid by sodium hydroxide.
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(e) If 2M ethanoic acid was used instead of 2M HCl, what would be the heat change as compared to the value calculated above? Explain your answer.
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Practical 2

You are provided with the following,

- **BA1**, which is 2M NaOH solution
- **BA2**, which is 2M HCl solution
- Plastic cup
- Burette
- Thermometer

You are required to determine the enthalpy of neutralization of NaOH by HCl

Procedure:

a) Pipette 25cm^3 **BA1** into a clean plastic cup. Note and record the temperature, t_1
b) Note and record the temperature t_2 of solution **BA2** and put in the burette
c) Add 5cm^3 of **BA2** from the burette to **BA1**, stir and record the maximum temperature of the mixture, t_3
d) Repeat procedure (c) at 5cm^3 interval until the total of 50m^3 of **BA2** has been added
e) Record the results in the table below

Results:

Initial temperature of **BA1**, t_1…………………………………………………………………….

Initial temperature of **BA2**, t_2……………………………………………………………………

Average temperature of the mixture……………………………………………………………..

Volume of **BA2** used (cm^3)	5	10	15	20	25	30	35	40	45	50
Maximum temperature,t_3 (^{0}C)										
Temperature change $t_3 - \frac{t_1 + t_2}{2}$ (^{0}c)										

(a) Plot a graph of temperature rise against the volume of **BA2** added.
(b) Use your graph to determine the volume of **BA2** required to neutralize **BA1** from the graph

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(c) Calculate the molarity of **BA2**
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(d) Calculate the enthalpy of neutralization of **BA1** by **BA2** (S.H.C = 4.2Kjmol^{-1} ^{0}c^{-1}, density of solution = 1gcm^{-3})
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Practical 3

You are provided with the following:

DA1, which is a solution containing 54.5g of a mixture of potassium hydroxide and potassium sulphate per litre of solution.

DA2, which is a 0.5M sulphuric acid.

You are required to determine the percentage of potassium sulphate in **DA1**.

Procedure:

(a) Measure and record the temperature of **DA1**.
(b) Pipette 25.0cm^3 (or 20.0cm^3) of **DA1** into a plastic beaker.
(c) Measure 10cm^3 of **DA2** using a measuring cylinder and transfer it at once into the plastic beaker containing **DA1**. Gently stir with a thermometer and record the highest temperature attained by the mixture.
(d) Repeat procedures (b) and (c) using 15, 20, 25, 30 and 35cm^3 of **DA2.**
(e) Enter your results in the table below.

Results:

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

Volume of **DA2** used (cm^3)	0	10	15	20	25	30	35
Temperature of solution mixture (^{0}C)							

Questions:

(a) Plot a graph of temperature of solution mixture (along the vertical axis) against volume of **DA2** used (along the horizontal axis)

(b) Determine from your graph, the maximum volume of **DA2** required to react with **DA1**.

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(c) Calculate the;

i) Maximum number of moles of sulphuric acid that reacted.

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ii) Number of moles of potassium hydroxide in $20.0cm^3$ (or $25.0cm^3$) of **DA1**

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iii) Concentration of **DA1** in grams of potassium hydroxide per litre of solution. (H = 1, O = 16, K = 39)

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iv) Percentage of potassium sulphate in **DA1**.

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Practical 4

You are provided with the following:

BA1, which is a solution containing 1M sodium hydroxide solution

BA2, which is a solution containing 1M sulphuric acid

You are required to determine the enthalpy of neutralization of sulphuric acid.

Procedure:

1. Using a measuring cylinder, measure $50cm^3$ of **BA1** into a clean plastic beaker. Note and record its initial temperature $T_1{}^0C$. Wash the thermometer and dry it.
2. Using another measuring cylinder, measure $25cm^3$ of **BA2**. Note and record its initial temperature $T_1{}^0C$.
3. Transfer **BA2** into a plastic beaker containing **BA1**. Stir the mixture using a thermometer and note and record the final temperature,T of the mixture.

Results of the experiment

Initial temperature of **BA1**……………………………………………………………………….

Initial temperature of **BA2**……………………………………………………………………….

Final temperature of mixture……………………………………………………………………….

Questions:

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

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(b) Calculate the quantity of heat produced during the reaction (S.H.C = $4.2Kjmol^{-10}c^{-1}$, density of solution = $1gcm^{-3}$)

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(c) Calculate the molar heat of neutralization of the acid by sodium hydroxide

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(d) Explain why a plastic beaker is used instead of glass or metallic cup.

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(e) Explain why sodium hydroxide is used instead of ammonium hydroxide solution.

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(f) If ammonium hydroxide is used, would you expect the heat of neutralization to be greater, equal or less. Give a reason for your answer.

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Practical 5

You are provided with the following:

0.5M copper (II) sulphate

Zinc powder

(S.H.C = $4.2Kjmol^{-1o}c^{-1}$, density of solution = $1gcm^{3}$)

You are required to determine the enthalpy of displacement of copper (II) sulphate by zinc

Procedure:

a) Using a measure cylinder, transfer $50cm^3$ of 0.5M solution of copper (II) sulphate into a plastic cup. Note and record the temperature, t_1 of the solution

b) Add 2g of zinc powder and stir well but carefully with the thermometer. Note and record the highest temperature,t_2 attained by the mixture

Results:

Initial temperature of solution, t_1……………………………………………………………..

Final temperature of the mixture,t_2…………………………………………………………..

Temperature change, $t_2 – t_1$ …………………………………………………………………

Questions:

a) State what was observed

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b) Write the equation for the reaction that took place

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c) Calculate the number of moles of copper (II) sulphate solution

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d) Calculate the number of moles of zinc in 2g (Zn = 65)

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e) Calculate the number of moles of zinc that reacted

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f) Calculate the heat change that occurred in the reaction. S.H.C = 4.2Kjmol^{-10}c^{-1}, density of solution = 1gcm^{-3})

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g) Calculate the enthalpy change in Kjmol^{-1}

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h) If magnesium instead of zinc was used, would the enthalpy change for the reaction be greater, less or equal to that you have calculated in (g) above. Explain your answer.

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Practical 6

You are provided with the following:

- Plastic beaker
- Measuring cylinder
- Distilled water
- Thermometer
- 8g of **X**

You are required to determine the enthalpy of solution salt **X**

Procedure:

a) Using the measuring cylinder, measure 90cm^3 of distilled water into a plastic beaker
b) Record the temperature of the water in the beaker for every minute for 4 minutes
c) At the fourth minute, add salt **X** and stir continuously to dissolve. Record the temperature every half a minute for 3 minutes.

Record your results in the table below.

Results:

Time (min)	1.0	2.0	3.0	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5
Temp (^{0}C)											

Questions:

a) Plot a graph of temperature against time
b) Extrapolate the graph to find the change in temperature.
c) Calculate the heat of solution from the quantity of water used. (S.H.C = 4.2Kjmol^{-10}c^{-1}, density of solution = 1gcm^{-1})

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d) State whether the reaction is exothermic or endothermic, give a reason for your answer
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Practical 7

You are provided with the following
Solution **J** which is a basic solution
Solution **D** which is an acidic solution
You are required to determine:

i) the molarity of the acid
ii) The molar heat of neutralization of the acid and the base

Procedure:

(a) Using a measuring cylinder, measure 150cm^3 of **J** and transfer into a 250cm^3 beaker. Add 50cm^3 of water, mix and label this **BA1**.
(b) Transfer 100cm^3 of **D** into another 250cm^3 beaker using a measuring cylinder. Add 100cm^3 of water. Mix and label this **BA2**.
(c) Measure and record the initial temperature of **BA1**
(d) Run 25cm^3 of **BA1**from the burette into a dry plastic beaker.
(e) Using a measuring cylinder transfer at once 10cm^3 of **BA2** into a plastic beaker containing **BA1**. Stir with the thermometer and record the highest temperature attained by the mixture.
(f) Repeat the procedures (d) to (e) using 20, 30, 40 and 50cm^3 of **BA2**
(g) Record your results in the table below.

Initial temperature of **BA1**…………………………………………

Volume of **BA2** used (cm^3)	10	20	30	40	50
Highest temperature of the mixture (^{0}c)					

Questions:

(a) Plot a graph of highest temperature attained against the volume of **BA2**.

(b) From the graph determine;

(i) The volume of **BA2** required to neutralize 25.0cm^3 of **BA1**

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(i)The maximum temperature change for the reaction

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(c) Calculate the molarity of **BA2** (1 mole of the base reacts with 1 mole of the acid, Molarity of **BA1** = 1.5M

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(d) Determine the;

(i) Maximum heat evolved during the reaction (S.H.C of solution = 4.2jg^{-10}c^{-1}, density of mixture = 1gcm^{-3})

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(ii) Molar heat of reaction between the acid and the base

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Practical 8

You are provided with the following:
M which is an acidic solution
N which is an alkaline solution
You are required to determine the molarity of an acidic solution M

Procedure:

(a) Using a measuring cylinder, measure 110cm^3 of **M** and transfer into a 250cm^3 beaker, add 90cm^3 of distilled water and mix. Label this solution **BA1**
(b) Transfer 190cm^3 of **N** into another 250cm^3 beaker using a measuring cylinder. Add 10cm^3 of distilled water and mix. Label this solution **BA2**
(c) Transfer **BA1** into a burette. Run 25cm^3 of **BA1** into a plastic beaker.
(d) Add at once 10cm^3 of **BA2** from the measuring cylinder into a plastic beaker containing 25cm^3 of **BA1**. Gently stir with the thermometer and record the highest temperature attained by the mixture.
(e) Repeat the procedures (c) to (d) using 15, 20, 25, 30, 35 and 40cm^3
(f) Record your results in the table below.

Volume of **BA2** used (cm^3)	10	15	20	25	30	35	40
Temperature of the mixture (^oC)							

Questions:

(a) Plot a graph of temperature the mixture against the volume of **BA2**
(b) From the graph, determine the maximum volume of **BA2** required to react with 25cm^3 of
(c) **BA1**

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(d) Calculate the number of moles of alkali that reacted (molarity of **BA2** = 1.9M)

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(e) Calculate the number of moles of the acid that reacted (ratio of acid to alkali = 1 : 2)

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(f) Calculate the molarity of the acid

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Practical 9

You are provided with the following

BA1 which is a solution containing 50g/l of a mixture of sodium hydroxide and sodium sulphate.

Solution **D** which is 1M sulphuric acid

You are required to determine the percentage of sodium sulphate in the mixture

Procedure:

(a) Using a measuring cylinder, measure 70cm^3 of **D** and transfer into a 250cm^3 beaker. Add 70cm^3 of water, mix and label this **BA2**.

(b) Fill the burette with **BA2**.

(c) Pipette 25.0cm^3 (or 20.0cm^3) of **BA1** into a plastic beaker. Note and record its temperature, t_1.

(d) Run 5cm^3 of **BA2** from the burette into a plastic beaker containing **BA1**. Stir the mixture with a thermometer and record the highest temperature, t_2 attained.

(e) Determine the change in temperature, T for the reaction.

(f) Repeat the procedure (c) to (e) using volume 10, 15, 20, 25, 30 and 35cm^3 of **BA2**.

(g) Record your results in the table below.

Initial temperature of **BA1**…………………………………………………………………………

Experiment number	1	2	3	4	5	6	7
Volume of **BA1** used (cm^3)							
Volume of **BA2** used (cm^3)							
Temperature of **BA1**, t_1 (^{0}C)							
Temperature of the mixture, t_2 (^{0}C)							
Change in temperature, T (^{0}C)							

Questions:

(a) Plot a graph of change in temperature, T against volume of **BA2**

(b) From the graph state the highest change in temperature

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

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(d) Determine the volume of **BA1** and **BA2** that gives the highest temperature

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(e) Calculate the number of moles of:

(i) **BA2** that reacted.

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(ii) **BA1** that reacted.

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(f) Calculate the:

(i) Molarity of **BA1**

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(ii) Concentration of **BA1** in g/l

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(iii)Percentage of sodium sulphate in the mixture. (Na = 23, O = 16, S = 32, H =1)

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(g) Determine the enthalpy of neutralization during the reaction. (S.H.C of solution = 4.2jg^{-10}c^{-1}, density = 1gcm^{-3})

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Practical 10.

You are provided with the following:

BA1, which is 1.8M H_nX solution.

BA2, which is 2M sodium hydroxide solution.

You are required to determine the value of n in H_nX

Procedure:

(a) Using a measuring cylinder, measure exactly 40cm^3 of **BA2** and place it into a plastic cup or beaker.

(b) Using a burette, transfer 10cm^3 of **BA1** into another plastic cup or beaker.

(c) Place a thermometer in the cup or beaker containing **BA1** and transfer all the **BA2** in the beaker containing **BA1** while stirring carefully using the thermometer and record the maximum temperature reached.

(d) Repeat procedure (a) to (c) for volume of **BA2** 35, 30, 25, 20, 15, 10, and 5cm^3 with the corresponding volumes of **BA1** given in the table. Enter your results in the table below.

Results:

volume of sodium hydroxide /cm^3	40	35	30	25	20	15	10	5
Volume of H_nX /cm^3	10	15	20	25	30	35	40	45
% of H_nX	20	30	40	50	60	70	80	90s
Temperature /^{0}C								

(a) Plot a graph of temperature against percentage of H_nX.

(b) Calculate the volume of H_nX and sodium hydroxide that reacted to give the maximum temperature rise.

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(c) Deduce the value of **n** and X (BA1 contains 70g of H_nX per litre).

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Practical 11 (WAKISSHA PAPER 3 2013)

You are provided with the following;

BA1, which is a solution containing 3.15g of a hydrated dibasic acid $H_2X.nH_2O$, in 250cm^3 of the solution.

BA2, which is a 0.2M sodium hydroxide solution.

You are required to determine the percentage of water of crystallization, **n**, in the hydrated acid. (1 mole of acid reacts with 2 moles of sodium hydroxide)

Procedure:

(i) Pipette 25.0cm^3 (or 20.0cm^3) of **BA2** into a plastic beaker. Measure and record the initial temperature.

(ii) Fill the burette with **BA1**, then run 10cm^3 of **BA1** from the burette into the beaker containing **BA2**. Gently stir the solution using the thermometer, and record the maximum temperature attained by the mixture.

(iii)Repeat procedure (ii) above until 30cm^3 of **BA1** has been added.

(iv)Record your results in the table below.

Results:

Volume of pipette used…………………………cm^3

Volume of **BA1** added (cm^3)	0	10	15	20	25	30
Maximum temperature attained (^{0}C)						
Temperature rise (^{0}C)						

Questions:

(a) i) Plot a graph of temperature rise (along vertical axis) against volume of **BA1** added (along horizontal axis).

ii) From your graph, determine the volume of **BA1** required for complete neutralization of **BA2**.

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(b) Calculate the,

(i) Number of moles of **BA2** that reacted.

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(ii) Concentration of the hydrated acid in **BA1** in moles per dm^3

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(iii)Molar mass of the hydrated acid.

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(c) i) Determine the value of **n** in the hydrated acid (H = 1, O = 16, X = 88)

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(ii)Calculate the percentage of water of crystallization in the acid $H_2X.nH_2O$.

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Practical 12 (WAKISSHA PAPER 3 2015)

You are provided with the following,

Metal **Q** measuring about 7cm

Z which is a 0.2M solution of dilute acid, HX

You are required to determine the mass of metal **Q**

Procedure

(i) Measure and cut exactly 6cm of metal **Q** provided.

(ii) Using a measuring cylinder, measure 40cm^3 of solution **Z** and transfer it into a clean plastic beaker, note and record the initial temperature of this solution in the table provided below.

(iii) Place metal **Q** into the solution **Z** in the plastic beaker and simultaneously start the clock.

(iv) Note and record the temperature of the contents in the beaker after every 30 seconds in the table below.

Results table

Time (seconds)	0	30	60	90	120	150	180	210
Temperature (^{0}C)								

Questions:

(a) Plot a graph of temperature against time.

(b) Determine the highest temperature rise.

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(c) Calculate the amount of heat produced during the reaction. (Assume: Specific heat capacity of solution = 4.2J/g/^{0}C, density of solution = 1g/cm^3)

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(d) Given that the molar heat of reaction between metal **Q** and acid Z is 1600KJ/mol, Calculate the,

(i) Number of moles of **Q** that reacted

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(ii) Mass of **Q** used in this experiment (**Q** = 24)

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Chapter four: PRACTICAL EXPRIMENTS ON RATES OF REACTIONS

Rate of reaction

some reactions take place almost instantaneously like explosion of hydrogen in air mixture when lighted splint is inserted in it , a concept described as burning with pop sound. Other reactions are slow e.g. rusting of iron in which a noticeable change is observed after appreciable time. Some reactions show changes in colours of reactants or of products with time. For example nitrogen oxide reacts with oxygen to form nitrogen dioxide which is brown. The gradual change in colour can be measured with time, and this can indicate rate of reaction.
The change in concentration with time can be followed by titration, you will also deal with reactions in which colourless gases are evolved.
During a chemical reaction, the concentration of products increases whereas that of reactants decreases. The change in concentration with time is what is termed as rate of reaction. Therefore rate of reaction is the measure of the change in quantity of reactants or products with time.
Rate of reaction is precisely defined as speed/rate at which reactants are turned into products
In determining the rate of a chemical reaction, the amount of product formed in a given period of time or the amount of reactants consumed in a given period of time is measured.
Then the rate is expressed as amount of products formed per unit time or the amount of reactants consumed per unit time.

$$\text{Rate} = \frac{\text{amount of products formed}}{\text{Time}}$$

$$\text{Rate} = \frac{\text{amount of reactants consumed}}{\text{Time}}$$

Activities for students

Activity 1

10cm length of magnesium ribbon was cleaned with sand paper. 50cm3 of 0.1M dilute hydrochloric acid was measured into a clean conical flask and corked. A rubber cork was then removed and 10cm magnesium ribbon added, the stop watch was started and flask corked immediately. The set up was organized as shown below and gas evolved measured in the syringe in intervals of 5 seconds. The date was obtained and tabulated, use the values to answer questions.

Time (s)	Volume of gas evolved (cm^3)
0	0
5	20
10	40
15	60
20	75
25	85
30	85
35	85
40	85
45	85

(a) Plot a graph of volume of gas evolved against time
(b) Use your graph to find the rate reaction at 13 seconds
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(c) What volume of the is evolved at 16 seconds
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(d) Describe the graph you have drawn in (a) above
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(e) Explain precisely the shape of the graph
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(f) Write a balanced equation for the reaction
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Activity 2

50cm3 of hydrochloric acid was measured into the conical flask. The flask and its contents were placed on a direct weighing balance. Drop of magnesium ribbon was added to acid in flask and the timer started. Mass of the flask and its contents was taken in intervals of 5 seconds until all the magnesium ribbon was reacted.

The values were tabulated; use the table below to answer questions.

Time (s)	**Mass of flask + its contents**
0	65.50
5	65.45
10	65.35
15	65.30
20	65.27
25	65.25
30	65.25
35	65.25
40	65.25

(a) Plot a graph of volume of gas evolved against time

(b) Use your graph to find the rate of reaction at 17 seconds

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(c) What is the mass of flask and contents at 13 seconds

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(d) Describe the graph you have drawn in (a) above

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(e) Explain the shape of the graph

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(f) Write a balanced equation for the reaction

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FACTORS THAT AFFECT THE RATE OF REACTION

The major factors that affect the rate of reaction include temperature, concentration, surface area, pressure, light and catalyst. We shall pick temperature, surface area and concentration for practical purposes, however others can be taught in theory.

Effect of temperature on the rate of reaction.

The rate of reaction increases with increase in temperature. Increase in temperature increases the molecular velocities of which subsequently increase the kinetic energy of reacting particles. This increases frequency of interaction/collision of the reacting molecules to form products.

Note.

For reaction to take place, particles must collide with sufficient kinetic energy. When the temperature is increased, particles gain energy and interact with sufficient average minimum energies. This implies that activation energy of the reaction increases and so is the rate of reaction. Activation energy is the energy barrier which must be overcome by the reacting species before the reaction can proceed.

Practical A

- You are provide with the following,
- **BA1**, which is 0.16M sodium thiosulphate solution
- **BA2**, which is 2M hydrochloric acid solution
- 2 conical flasks
- 2 measuring cylinders
- Stop clock
- A sheet of white paper

You are required to determine the rate of reaction when a thiosulphate reacts with dilute hydrochloric acid.

Procedure

(i) Using a clean measuring cylinder, transfer 50cm^3 of **BA1** into a clean conical flask. Measure and record its temperature (room temperature)

(ii) Using a black or blue pen, mark a cross on the sheet of white paper.

(iii) Add 5cm^3 of **BA2** into a flask and at the same time start the stop clock, swirl the mixture and place on the sheet of white paper with the cross in the middle

(iv) Look down through the mixture at the cross and stop the clock when the cross just disappears. Record the time taken for the cross to just disappear in the middle.

(v) Measure another 50cm^3 of **BA1** into a clean conical flask, this time heat the **BA1** to a temperature of 30 ^{0}C. Add 5cm^3 of **BA2** and immediately start the stop clock, swirl the mixture and place it on a sheet of white paper with the cross in the middle. Note and record the time t, it takes for the cross to disappear.

(vi) Repeat the procedure (iii) to (v) but this time heat **BA1** to 40 ^{0}C, 50 ^{0}C, 60 ^{0}C respectively before adding **BA2**. Record your results in the table below.

Temperature (^{0}C)	**Time t, (s)**	**$^1/_t$ (s^{-1})**
Room temperature		
30		
40		
50		
60		

Questions:

(a) Plot a graph of

(i) Time against temperature

(ii) $^1/_t$ against temperature

(b) From your graph in (a) (i) determine the rate of reaction at 20 seconds

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(c) Explain the shapes of the graphs

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(d) What is your conclusion from the two graphs

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(e) State and explain how the rate of reaction varies with temperature in (a) (ii) above.

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(f) Write a balanced ionic equation for the reaction that occurred between **BA1** and **BA2**.

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Effect of concentration on the rate of reaction

The rate of reaction increases with the increase in concentration of the reactant species. When concentration of reactants increase in a given volume of the reaction vessel, the chances of collision of reacting particles consequently increase resulting into increased reaction rate.
The greater the concentration of reactants, the greater the number of interactions between reacting particles, therefore more effective collisions occur with minimum activation energy hence faster rate of reaction.
However the reverse is true for concentration of products.

Activity 3

10cm length of magnesium ribbon was cleaned with sand paper. 50cm^3 of 0.1M dilute hydrochloric acid was measured into a clean conical flask and corked. A rubber cork was then removed and 10cm magnesium ribbon added, the stop watch was started and flask corked immediately. The set up was organised as shown below and gas evolved measured in the syringe in intervals of 5 seconds. The above procedure was repeated using 0.2M hydrochloric acid. The date was obtained and tabulated, use the values to answer questions.

Time (s)	**Volume of gas evolved using 0.1M HCl**	**Volume of gas evolved using 0.3M HCl**
0	0.0	0.0
120	6.5	10.0
240	13.0	20.0
360	20.0	25.5
480	24.5	29.5
600	27.0	32.0
720	29.5	32.0
840	32.0	32.0

Questions:

(a) Plot a graph of the same axes the volume of gas liberated using 0.1M and 0.3M HCl acid against time

(b) Explain the shapes of the graphs

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(c) Find the rate of reaction for both curves at 410 seconds.

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Reaction of sodium thiosulphate and dilute hydrochloric acid

Sodium thiosulphate reacts with dilute hydrochloric acid to form a white/yellow precipitate of sulphur according to the following equation.

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

The ionic equation is,

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

The effect of changing concentration of thiosulphate on the rate of reaction by carrying out separate experiments in which the concentration of hydrogen ions (acid) is maintained constant and concentration of thiosulphate is varied. In separate experiments, the volume of the solution is kept constant. The beaker of the same size is used to mix the solutions and the beaker is placed on top of a sheet of paper marked with a black cross. Looking from above, the black cross disappears after precipitation of a specific amount of sulphur. In separate experiments the extent of reaction when the cross disappears will be the same but the time for the cross to disappear will inversely depend on the concentration of thiosulphate ions. Consequently the reciprocal of the time for the cross to disappeasr in each experiment measures the average rate of formation of the precipitate quantity per second.

A graph of concentration of sodium thiosulphate against time begins with a steep slope which gradually becomes less steep before finally flattening out towards the horizontal axis. The gradient of the curve at any point measures the rate of reaction at the time represented by the point on the graph. The shape of the graph shows that the rate of reaction decreases as the concentration of sodium thiosulphate decreases.

A graph of sodium thiosulphate against $^1/_t$ is a straight line within the limits of experimental errors. The reciprocal of the time is the measure of rate of reaction for the appropriate concentration. At a fixed temperature, the rate of reaction is directly proportional to the concentration of sodium thiosulphate solution provided that enough acid is used to react with the thiosulphate.

The effect of temperature on the rate of reaction between sodium thiosulphate and dilute hydrochloric acid can be performed by heating the solution to certain temperature before adding the acid. A graph of $^1/_t$ against temperature can be plotted. The results from such an experiment will show that the higher the temperature, the greater the rate of reaction. A fairly small rise in temperature has a large influence on the rate of reaction.

Practical B

You are provided with following:

A piece of magnesium ribbon labeled **T**

FA1, which is dilute sulphuric acid

A stop clock

You are required to determine the rate of reaction between magnesium and sulphuric acid at different concentrations.

Procedure:

(i) Cut T into 5 equal pieces of 2cm each

(ii) Using a measuring cylinder, measure $50cm^3$ of **FA1** into a clean glass beaker

(iii) Drop one piece of **T** in the beaker and simultaneously start the stop clock. Swirl the solution continuously ensuring that **T** is always inside the solution.

(iv) Note and record the time t, in seconds taken for **T** to completely dissolve.

(v) Wash the beaker and repeat the procedures (ii) to (iv) using $40cm^3$, $30cm^3$, $20cm^3$ and $10cm^3$ of **FA1** but in each case make the total volume of the solution to $5cm^3$ by adding water from the burette.

(vi) Record your results in the table below including the of $^1/_t$ for each reaction

Volume of FA1 (cm^3)	50	40	30	20	10
Volume of water added (cm^3)	0	10	20	30	40
Time, t (s)					
$^1/_t$ (s^{-1})					

Questions:

(a) Plot a graph of volume of **FA1** against $^1/_t$

(b) Write and ionic equation for the reaction

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(c) What does $^1/_t$ represent

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(d) From the graph;

(i) Determine the rate of reaction $^1/_t$ when the volume of **FA1** is 25.5cm^3

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(ii) Determine the volume of **FA1**, the rate of reaction is $4.25x10^{-2}$ s^{-1}

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(iii)What is the effect of concentration on the rate of the reaction?

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Practical C

You are provided with the following,

- **BA1** which is a solution containing 0.2M thiosulphate ions
- **BA2** which is a solution containing 2M hydrochloric acid
- Distilled water
- 2 conical flasks
- 2 measuring cylinders
- Stop clock
- Sheet of white paper

You are required to determine the rate of reaction between thiosulphate and hydrochloric acid

Procedure

a) Make a cross with a blue or black pen on the sheet of white paper provided
b) Using a measuring cylinder, measure 60ml of **BA1** into a conical flask
c) Add 10cm^3 of **BA2** into the **BA1** in the conical flask and immediately start the stop clock
d) Swirl the mixture to mix the two solutions and place it on the cross
e) Look through the solution mixture from above, record the time taken for the cross to just disappear
f) Into another clean conical flask, measure 50cm^3 of **BA1**
g) Add 10cm^3 of distilled water to it and swirl
h) Then add 10cm^3 of **BA2** to the solution, swirl and place it on the cross
i) Look from above, record the time t, taken for the cross to just disappear
j) Repeat procedures (d) – (i) but this time measure volumes of **BA1** as shown in the table below. Add a volume of distilled water to ensure that the total volume of **BA1** added to the flask remains 60cm^3
k) Record your results in the table below.

Exp no.	**Vol of BA1 (cm^3)**	**Vol of water added (cm^3)**	**Vol of BA2 (cm^3)**	**Time (s)**	**$^1/_t$ (s^{-1})**
1	60	0	10		
2	50	10	10		
3	40	20	10		
4	30	30	10		
5	20	40	10		

BA1 reacts with BA2 according to the equation.

$$S_2O_3^{2-}{}_{(aq)} + 2H^+{}_{(aq)} \longrightarrow S_{(s)} + SO_{2\,(aq)} + H_2O_{(l)}$$

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Questions:

(a) Why does the cross disappear in the experiment?

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(b) Write the balanced equation for the reaction that took place between **BA1** and **BA2**.

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(c) Plot a graph of

(i) Volume of **BA1** against time, t

(ii) Volume of **BA1** against $1/t$

(d) How does the concentration of **BA1** affect the time for the cross to disappear.

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(e) Determine the rate of reaction between **BA1** and **BA2** and state the units.

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WAKHAMWA NASSA

Practice, Continuous reading and hard work makes chemistry easier.