THE REPUBLIC OF UGANDA

Ministry of Education and Sports

HOME-STUDY LEARNING

SENIOR 3

CHEMISTRY

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This material has been developed as a home-study intervention for schools during the lockdown caused by the COVID-19 pandemic to support continuity of learning.

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FOREWORD

Following the outbreak of the COVID-19 pandemic, government of Uganda closed all schools and other educational institutions to minimize the spread of the coronavirus. This has affected more than 36,314 primary schools, 3129 secondary schools, 430,778 teachers and 12,777,390 learners.

The COVID-19 outbreak and subsequent closure of all has had drastically impacted on learning especially curriculum coverage, loss of interest in education and learner readiness in case schools open. This could result in massive rates of learner dropouts due to unwanted pregnancies and lack of school fees among others.

To mitigate the impact of the pandemic on the education system in Uganda, the Ministry of Education and Sports (MoES) constituted a Sector Response Taskforce (SRT) to strengthen the sector's preparedness and response measures. The SRT and National Curriculum Development Centre developed print home-study materials, radio and television scripts for some selected subjects for all learners from Pre-Primary to Advanced Level. The materials will enhance continued learning and learning for progression during this period of the lockdown, and will still be relevant when schools resume.

The materials focused on critical competences in all subjects in the curricula to enable the learners to achieve without the teachers' guidance. Therefore effort should be made for all learners to access and use these materials during the lockdown. Similarly, teachers are advised to get these materials in order to plan appropriately for further learning when schools resume, while parents/guardians need to ensure that their children access copies of these materials and use them appropriately.
I recognise the effort of National Curriculum Development Centre in responding to this emergency through appropriate guidance and the timely development of these home study materials. I recommend them for use by all learners during the lockdown.

Alex Kakooza
Permanent Secretary
Ministry of Education and Sports

ACKNOWLEDGEMENTS

National Curriculum Development Centre (NCDC) would like to express its appreciation to all those who worked tirelessly towards the production of home–study materials for Pre-Primary, Primary and Secondary Levels of Education during the COVID-19 lockdown in Uganda.

The Centre appreciates the contribution from all those who guided the development of these materials to make sure they are of quality; Development partners - SESIL, Save the Children and UNICEF; all the Panel members of the various subjects; sister institutions - UNEB and DES for their valuable contributions.

NCDC takes the responsibility for any shortcomings that might be identified in this publication and welcomes suggestions for improvement. The comments and suggestions may be communicated to NCDC through P.O. Box 7002 Kampala or email admin@ncdc.go.ug or by visiting our website at http://ncdc.go.ug/node/13.

Grace K. Baguma
Director,
National Curriculum Development Centre

ABOUT THIS BOOKLET

Dear learner, you are welcome to this home-study package. This content focuses on critical competences in the syllabus.

The content is organised into lesson units. Each unit has lesson activities, summary notes and assessment activities. Some lessons have projects that you need to carry out at home during this period. You are free to use other reference materials to get more information for specific topics.

Seek guidance from people at home who are knowledgeable to clarify in case of a challenge. The knowledge you can acquire from this content can be supplemented with other learning options that may be offered on radio, television, newspaper learning programmes. More learning materials can also be accessed by visiting our website at www.ncdc.go.ug or ncdc-go-ug.digital/. You can access the website using an internet enabled computer or mobile phone.

We encourage you to present your work to your class teacher when schools resume so that your teacher is able to know what you learned during the time you have been away from school. This will form part of your assessment. Your teacher will also assess the assignments you will have done and do corrections where you might not have done it right.

The content has been developed with full awareness of the home learning environment without direct supervision of the teacher. The methods, examples and activities used in the materials have been carefully selected to facilitate continuity of learning.

You are therefore in charge of your own learning. You need to give yourself favourable time for learning. This material can as well be used beyond the home-study situation. Keep it for reference anytime.

Develop your learning timetable to ca ter for continuity of learning and other responsibilities given to you at home.

Enjoy learning

CHEMISTRY SELF STUDY MATERIALS

SENIOR THREE

TOPIC 1: CARBON AND ITS COPOUNDS

Lesson 1.1: Different Forms of Carbon

Specific Objectives

By the end of this lesson you should be able to:

1. explain the physical properties of carbon allotropes in terms of their bonding.
2. recognize the relationship between the properties and the uses of the allotropes.

Introduction

Carbon is one of the most important elements. Carbon exists both naturally as diamond and graphite and in combined forms in many compounds. Coal, oil, natural gas, limestone and other metal carbonates are all compounds of carbon. Charcoal and the positive electrode in dry cells are all composed of carbon. In S.2 under, Atomic Structure and Periodic Table, you learnt that; Carbon is the 6th element in the Periodic Table. Hence, Atomic number = 6, Electronic configuration = 2:4

In this topic, you should be able to appreciate the importance of carbon compounds in natural environment and society.

What you need:

- ☐ wood charcoal,
- ☐ soot,
- ☐ pencil lead,
- ☐ black rod in dry cell

Activity 1.1: Identifying forms of carbon

Study the pictures below. Identify the things in the pictures.

Questions

1. Can you tell from what element the items or some of their components in the pictures are made from?
2. What is allotropy? Get the meaning from the dictionary, textbooks or the
3. internet.
4. Which elements exhibit allotropy?
5. Name two allotropes of carbon that you have identified from this activity

Occurrence of carbon

Carbon is found in the air, the sea, the rocks and all living things. It is present in every part of your body and the food you eat. Nearly all the world's energy is obtained by burning carbon and its compounds. Plastics, clothing, medicines, detergents, cosmetics, and even paper all consist mainly of carbon. So, life without carbon is unthinkable!
Because carbon forms so many compounds we have spread its chemistry over two sections. This section is about the element carbon, its oxides, carbonates and hydrogen carbonates.
Naturally, the element exists as:

(i) Diamond (ii) Graphite (iii) Amorphous carbon.

Important Terms:
Allotropy: Is existence of an element in more than one form without changing the physical state.
Allotrope: Is each of two or more different physical forms in which an element can exist.
Allotropes of carbon

a) (a)Diamond
b) (b)Graphite
   Note: These two are crystalline allotropes of carbon.
c) (c) Amorphous carbon. It is non-crystalline form of carbon which exists in
d) many forms namely:
   (i) Animal charcoal.
   (ii) (ii)Wood charcoal.
   (iii) Lampblack
   (iv) Sugar charcoal
   (v) Coke
   (vi) Soot

The 3 allotropes of carbon differ in appearance and many other physical properties.

Activity 1.2. *Comparing Hardness, Density, and Appearance of allotropes*

1. *Compare each of the following forms carbon: Wood charcoal, Soot and Black rod in dry cell or pencil lead.*
2. *Why do you think allotropes of carbon differ in their properties?*
3. *Now read the following extract about the structure of graphite and diamond and answer the questions below it.*

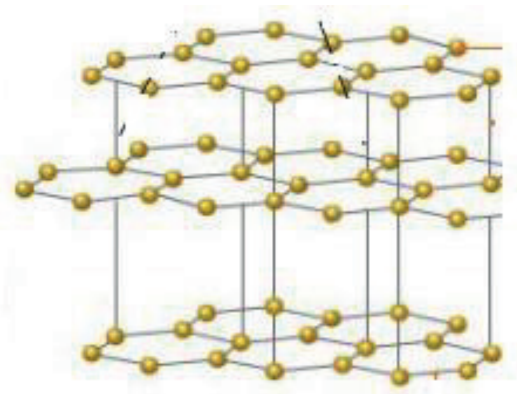
Structure of Graphite

In a graphite crystal, layers of carbon atoms form a giant structure which is in two dimensions. Each carbon atom is at the corner of a regular hexagon and is equidistant from three similar atoms.

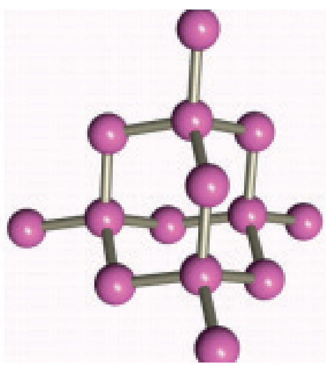
The atoms in a layer are joined by strong covalent bonds and the layers are joined to each other by weak intermolecular forces of attraction called ***Van der Waals***

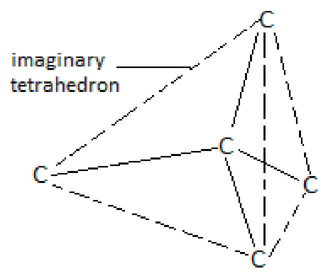
The layers are able to slide over each other easily because of the weak intermolecular forces between them. Hence graphite is slippery.

Since each carbon atom is bonded to three others, in graphite, one electron in the valency shell of each carbon atom is left mobile (delocalized) and this accounts for good electrical and heat conductivity of graphite.



Structure of Diamond





In diamond, each carbon atom is bonded to four others by strong covalent bonds and the four bonds pointing towards the corners of a regular tetrahedron. Diamonds are therefore macro-molecules and they contain millions of carbon atoms in a three-dimensional network. In this arrangement, each carbon atom uses all the valency electrons for covalent bond formation, therefore it doesn't have any mobile electrons unlike in graphite. Diamonds are transparent and sparkles in the light and are extremely hard and have a very high melting point because a large amount of energy is required to break the vast number of covalent bonds.

Now complete the table below. N/A means not applicable.

No	**Property**	**Graphite**	**Diamond**	**Use of allotrope based on property**
1	Hardness			Graphite: Used (i)to make pencils because it's soft & black (ii) Diamond: used (i) (ii)
2	**Density**	**2.3gcm^{-3}**	**3.5gcm^{-3}**	N/A
3	Appearance	It is greyish black, dull opaque and shiny.		Diamond Use: Graphite Use:
4	Conductivity of electricity and heat	It is a good conductor	Non-conductor	Graphite Use:

Amorphous carbon

Activity 1.3. ***How is each of the different forms of amorphous carbon prepared? Give one use of each.***

Summary:

- ☐ Carbon has three allotropes: graphite, diamond and amorphous carbon.
- ☐ Graphite is used as a lubricant and as an electrode.
- ☐ Diamond is for jewellery, cutting glass, and grinding and polishing other hard substances.
- ☐ Coke is used as fuel and reducing agent in extraction of metals.
- ☐ Lampblack and soot are used to make printer's ink, shoe polish and carbon paper.
- ☐ Animal charcoal is used in industry to remove brown colour in sugar.
- ☐ Wood charcoal is used as fuel and to absorb ammonia gas in toilets.

Lesson 1.2: Chemical properties of carbon and preparation of carbon dioxide

Learning Objectives

By the end of this lesson you should be able to:

1. describe the chemical reactions of carbon.
2. describe the preparation of carbon dioxide.

What you may need:

charcoal, charcoal stove or burner

Introduction

Carbon is not a very reactive element and it is insoluble in all common solvents. However, it undergoes the following reactions.

a) Combustion

When carbon is burned in air, it can form either carbon monoxide or carbon dioxide plus a lot of heat. In air with less oxygen supply, carbon monoxide is produced whereas in air with plentiful supply of oxygen, carbon dioxide is formed.

Carbon dioxide is essential to life on earth. Plants use this gas for photosynthesis. But carbon monoxide is a deadly poisonous gas. When you breathe it in, it stops your red blood cells from carrying oxygen around your body and suffocates you.

Activity 1.4. To find out what happens when carbon burns

1. *Place charcoal in a charcoal stove. Light the charcoal and let it burn. (Do this outside the house)*
2. *Observe what happens at each of the layers represented by equation during burning. Describe all the reactions that take place at each of the layers you have observed. Use the set up below to guide your description.*

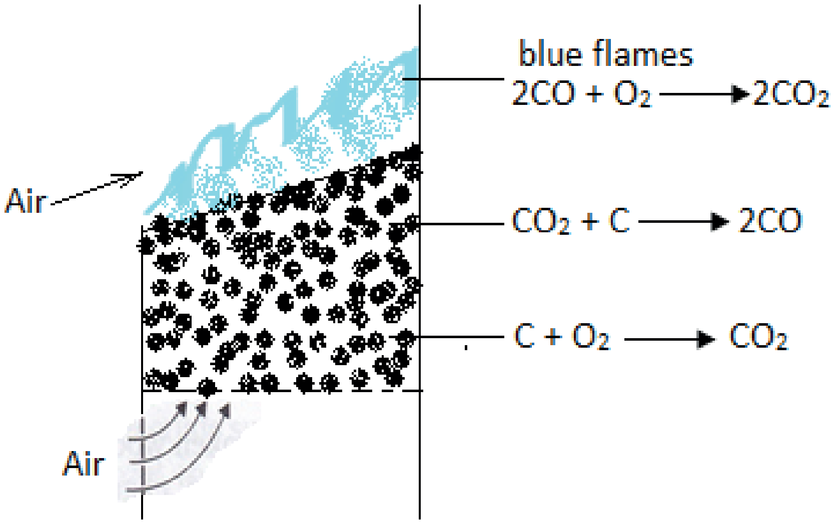


Diagram of a charcoal burner

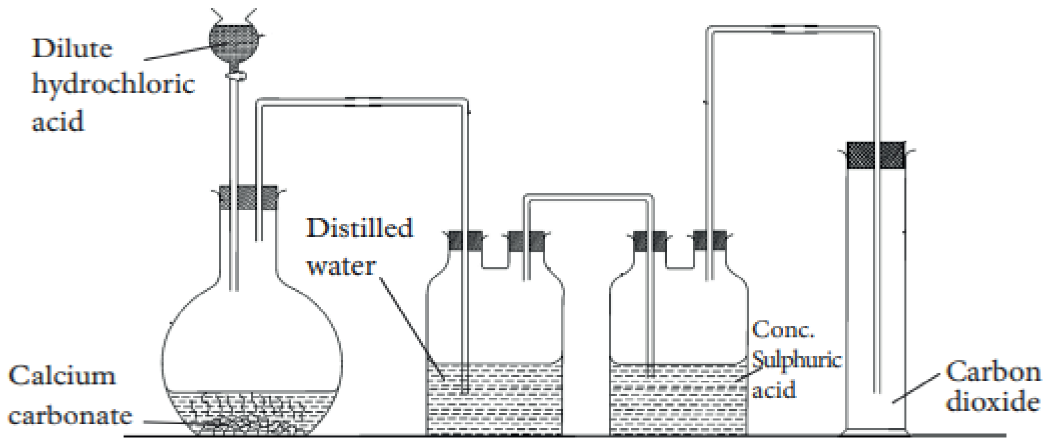
Questions

1. *Why is it advisable to carry out this activity outside the house? Clearly indicate the risk associated with carrying this activity in a space of limited air or oxygen*
2. *Use reaction for burning of carbon in oxygen/air to explain its reduction of hot oxides of zinc and metals below zinc in the reactivity series. Write equations to support your explanations*
3. *What are the industrial applications of the reduction action of carbon on metal oxides?*

Activity 1.5: Preparing carbon dioxide gas

Carbon dioxide is a gas that occurs in the air on the earth surface to the extent of about 0.03% of the volume of air. It also comes out of rocks in volcanic regions and occurs in mines as 'choke damp'. It is present in natural drinking water because of its solubility in water. The gas is of very high biological importance especially in photosynthesis. It is normally prepared in the laboratory by action of dilute hydrochloric acid on marble chips (calcium carbonate) In this activity you are going explore the laboratory preparation carbon dioxide.

1. *Study the diagram below. It is a setup of apparatus for laboratory preparation of carbon dioxide.*



2. *Use the diagram to explain how a pure dry sample of the gas can be collected.*
3. *Write equation for the reaction leading to the formation of carbon dioxide.*

Summary

- ☐ Carbon is used a fuel and as a reducing in the extraction of metals e.g.

  $2Fe_2O_3(s) + 3C(s) \longrightarrow 4Fe(s) + 3CO2\ (g)$

- ☐ In the laboratory carbon dioxide is prepared by reacting a metal carbonate with acid e.g.

  $CaCO_3(s) + 2HCl\ (aq) \longrightarrow CaCl_2\ (aq) + CO2\ (g) + H2O\ (l)$

NOTE: As you stay home due to COVID-19, do not use a charcoal stove in poorly ventilated house. (Why?)

Lesson 1.3: Hydrogen Carbonates and the Carbon Cycle

By the end of this lesson, you should be able to:

1. describe the chemical reactions of hydrogen carbonates.
2. explain dry experiment to demonstrate the physical and chemical properties of hydrogen carbonates.

What you will need:

baking powder, vinegar or lemon juice, a match box and a small pan

Introduction

Hydrogen carbonate is an acid salt. It's derived from carbonic acid in which only one of the two replaceable hydrogen atoms of carbonic acid have been replaced by a metal atom/ammonium radical. One of the important hydrogen carbonates that exist in solid form at room temperature are sodium hydrogen carbonate and potassium hydrogen carbonate. Magnesium hydrogen carbonate and calcium hydrogen carbonate are only stable in solution. The rest of the hydrogen carbonates are unstable or do not exist.

Activity 1.6: Investigating the effect of lemon juice on sodium hydrogen carbonate (baking powder)

Sodium hydrogen carbonate is locally called baking soda (powder) (bi-carbonate of soda) It is manufactured by saturating a wet mash of sodium carbonate and water with carbon dioxide. It is then washed in cold water and then dried;

$$Na_2CO_3\underline{(aq)} + H_2O\,(l) + CO_2\,(g) \longrightarrow 2NaHCO_{3(s)}$$

In this activity you are going to find out happens when lemon juice or vine gar is added on to baking powder.

1. *Put about 20cm^3 to 50 cm^3 of fresh lemon juice or vinegar into an empty-used mineral water bottle. Add half a tea spoonful of baking powder on to the lemon juice/vinegar in the bottle.*
2. *Observe what happens on addition of baking powder and immediately strike a match, hold it just at the open end of the bottle. Record your observations.*
3. *Explain the observations your observation in steps 2 above. Use equations to support your explanation.*
4. *Suggest how similar or different your observation would be if the baking powder was strongly heated instead of adding on lemon juice*

Lesson 1.4: Properties of carbon dioxide, its uses and properties of carbon monoxide

By the end of this lesson, you should be able to:
1. describe the properties and uses of carbon dioxide.
2. explain the physical and chemical properties of carbon monoxide.

What you will need:

Any fizzy drink like soda, a match stick and match box, lemon juice and baking soda or bicarbonate of soda (available in retail shops near you) and drinking straw.

Investigation 1: The physical nature of carbon dioxide gas

Did you know that fizzy drinks like soda and carbonated water are packed with carbon dioxide gas? This gas can be heard making a hissing sound as the bottle is opened.

Investigation procedure:

1. *Open a soda bottle, strike a match and hold a lit match near but just below the mouth of the open bottle.*
2. *Strike another match and hold it well above the mouth of the bottle.*
   - ☐ *What happens to the glowing match stick?*
   - ☐ *Can you suggest an explanation to your observation?*
   - ☐ *What is your conclusion about the nature of carbon dioxide gas in this experiment?*
3. *Keenly observe and sniff at the gas that escapes from your drink.*
   - ☐ *What colour was the gas that escaped from the bottle?*
   - ☐ *How does the gas smell?*

Observations.
- ☐ The gas extinguishes a glowing match stick
- ☐ It is colourless, has no smell (odourless)

Conclusion
- ☐ Carbon dioxide gas is a colourless odourless gas.
- ☐ It extinguishes a burning splint.

Investigation 2: chemical properties of carbon dioxide

Investigation Procedure

1. Put lemon juice in a plastic bottle, connect a straw through it cap, put a little water in another bottle or glass.
2. Add one spoonful of sodium carbonate to lemon juice and immediately cover the bottle. Direct the other end of straw into water as illustrated.
3. After bubbling for some time, taste the water.

Observation

Water remains colourless; however, the taste has now changed. The solution has a 'sharp' pleasant taste.

Conclusion

- ☐ In the reaction, carbon dioxide gas was evolved. The gas reacted with water to form a weak acid (carbonic acid) this is why it has a unique taste.
- ☐ Therefore, carbon dioxide reacts with water to form carbonic acid.

  The equation of reaction is

  $H_2O\ (l) + CO_2\ (g) \longrightarrow H_2CO_3\ (aq)$

Further learning points:

- ☐ Carbon dioxide reacts with water to form carbonic acid which is a weak acid which turns blue litmus paper pink.

- ☐ The best way to identify carbon dioxide is to bubble it through lime water (calcium hydroxide solution). The lime water turns milky due to the precipitation of white insoluble_calcium carbonate which settles if the mixture is allowed to stand.

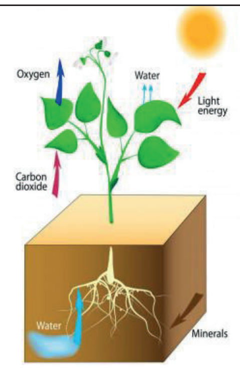
  $Ca(OH)_{2(aq)} + CO_{2(g)} \longrightarrow CaCO_{3(s)} + H_2O_{(l)}$.
- ☐ Carbon dioxide does not burn or support burning but if a piece of burning magnesium is lowered down into a jar of carbon dioxide, it continues to burn for a short time with a splintering flame and black specks of carbon are seen on the sides of the gas jar and white ash which is magnesium oxide is formed.

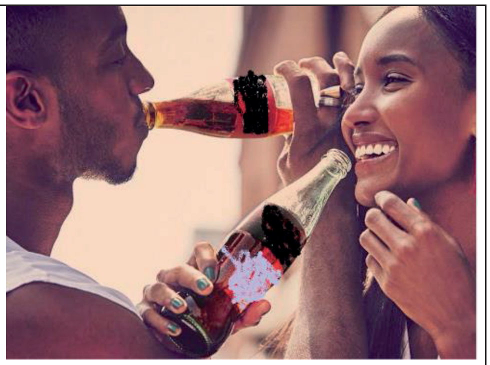
  $2Mg_{(s)} + CO_{2\ (g)} \quad 2M_gO_{(s)} + C(s)$

  This reaction is used to show that carbon dioxide is a compound of carbon and oxygen.

Uses of carbon dioxide

The pictures below show the use of carbon dioxide gas in daily life:





a) Suggest the uses of carbon dioxide basing on the pictures

b) Why is carbon dioxide used for the purpose identified in a) above?

Lesson 1.5: Carbonates

By the end of this lesson you should be able to describe the chemical reactions of carbonates.

Introduction

You earlier learnt that carbon is present in many rocks in form of metal carbonates. The table below lists some of them.

Name of rock	Carbonate present
Chalk	Calcium carbonate
Limestone	Calcium carbonate
Marble	Calcium carbonate
Magnesite	Magnesium carbonate
Calamine	Zinc carbonate
Malachite	Copper (II) carbonate

Although these substances differ in hardness, they are alike in their chemical reactions. The table below shows the important properties of common carbonates.

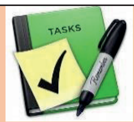
<table>
<tr><th>Element</th><th>Solubility in water</th><th>Action of heat</th><th>Action of dilute acid</th></tr>
<tr><td>K
Na</td><td>Carbonates of these are soluble in water</td><td>Carbonates of these metals are Not decomposed by heat</td><td rowspan="2">All carbonates react with dilute acid to liberate carbon dioxide gas</td></tr>
<tr><td>Ca
Mg
Al
Zn
Fe(II)
Pb
Cu</td><td>Carbonates of these elements are <u>not</u> Soluble in water</td><td>Carbonates of these metals are decomposed by heat to form oxide of the metal and carbon dioxide</td></tr>
</table>

Note: Aluminium does not form a carbonate and **iron (III) carbonate** does **not** exist. Ammonium carbonate is also **soluble** in water.

ACTION OF HEAT ON METAL CARBONATES

	Appearance	CO_2 produced	Residue	Conclusion
Calcium carbonate $CaCO_3$	WHITE SOLID	✓	WHITE SOLID	**Calcium oxide formed** (needs very strong heating)
Copper carbonate $CuCO_3$	GREEN SOLID	✓	BLACK SOLID	**Copper oxide formed**
Magnesium carbonate $MgCO_3$	WHITE SOLID	✓	WHITE SOLID	**Magnesium oxide formed**
Zinc carbonate $ZnCO_3$	WHITE SOLID	✓	YELLOW SOLID WHICH TURNS WHITE WHEN COOL	**Zinc oxide formed**

Sodium carbonate (Na_2CO_3) also decomposes on heating but it requires more heat than an ordinary bunsen burner can supply.



(a) Describe the effect of heat on each of the following carbonates. (Illustrate your answer with equation in each case)

(i) Calcium carbonate (ii) Iron (II) carbonate (iii) Lead (II) carbonate (iv) Copper (II) carbonate. **(b).** *Describe a chemical test for a carbonate ion.*

(c) State how carbonates react with dilute acids. Write a general equation that takes place.

Inquiry question. *How is sodium carbonate* made on large scale?
Solvay process. Is a process by which sodium carbonate is made on a large scale?

Raw materials in this process are: sodium chloride, ammonia gas and calcium carbonate.

Procedure: The process is carried out in a Solvay tower in which concentrated Sodium chloride (brine) is saturated with ammonia gas to form **ammoniacal brine** which is ran down the Solvay tower up which carbon dioxide is being forced.

Carbon dioxide then reacts with the mixture of ammoniacal brine to form sodium hydrogen carbonate which appears at as a white suspension since it is not very soluble in water.

$$NH_4OH_{(aq)} + NaCl_{(aq)} + CO_{2(g)} \longrightarrow NaHCO_{3(s)} + NH_4Cl_{(aq)}$$

Sodium hydrogen carbonate is filtered off and washed free of ammonia compounds. It is then heated to convert it to sodium carbonate according to the following equation.

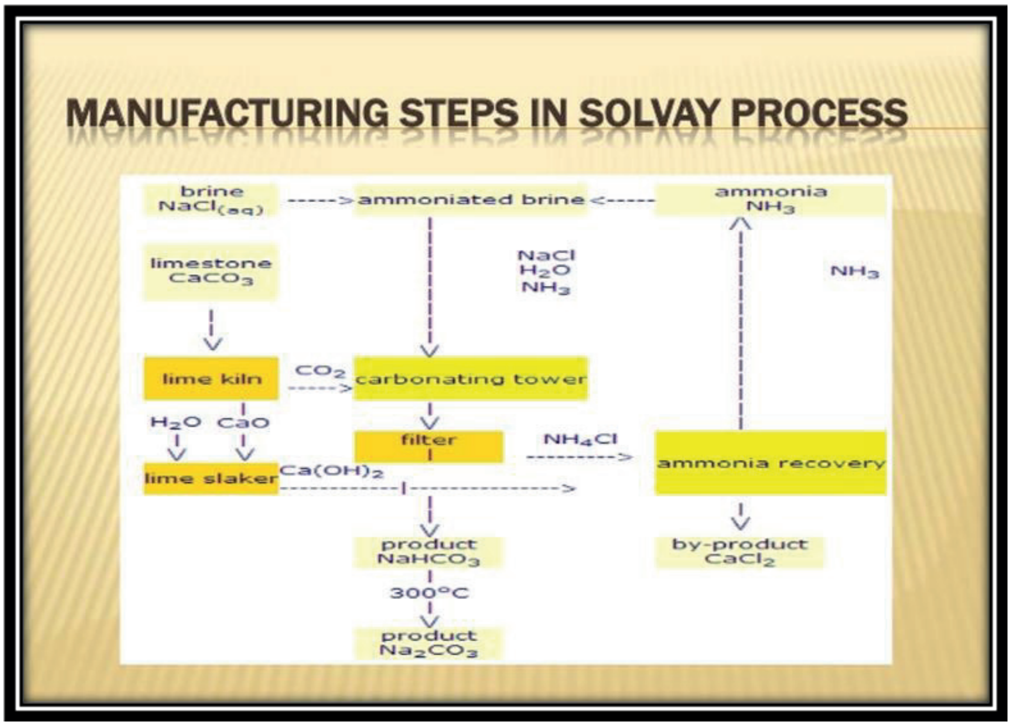
$$2NaHCO_{3(S)} \xrightarrow{heat} Na_2CO_{3(s)} + CO_{2(g)} + H_2O_{(l)}$$

Sodium carbonate produced here is anhydrous which has a wide market. It is crystallized from water to form washing soda, the 10-water hydrate.

$$NaCO_{3(s)} + 10H_2O_{(l)} \longrightarrow NaCO_3.10H_2O_{(S)}$$

Colorless/shiny/glassy crystals

Flow chart for the Solvay process



Summary

- ☐ *Metal carbonates occur in several rocks, especially chalk and limestone.*
- ☐ *When heated, most metal carbonates decompose to carbon dioxide and the metal oxide.*

Task: How useful are sodium carbonate in your daily experiences?

Activity 1.7: Exploring the carbon cycle

In this activity you will explore the carbon cycle in the natural environment

1. Read the outline below about the carbon cycle in the natural environment.

"The carbon dioxide content of the atmosphere remains practically constant at about 0.03% as a result of the carbon or carbon dioxide cycle.

Carbon dioxide is added to the atmosphere by:

i) *Combustion.* The burning in air of fuels containing carbon

ii) *Respiration*. Animals and plants breathe air, and the oxygen oxidizes sugar in their bodies to form energy as carbon dioxide is released.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + H_2O + 2800kJ$$

iii) *Making of lime*.

During the manufacture of lime, limestone is decomposed by heat to form calcium oxide and carbon dioxide.

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$$

Carbon dioxide is removed from the atmosphere by:

i) Photosynthesis. Green plants absorb carbon dioxide to make sugar.

$$6CO_2 + 6H_2O + 2800kJ \longrightarrow C_6H_{12}O_6 + 6O_2$$

ii) Hardening of mortar.
Mortar and whitewash contain calcium hydroxide, which slowly reacts with carbon dioxide to form calcium carbonate.

$$Ca(OH)_2(s) + CO_2(g) \longrightarrow CaCO_3(s) + H_2O(g)$$

iii) Solution in water. Rain dissolves carbon dioxide, and rivers, lakes, seas and oceans contain much of it".

2. *Use the outline to construct a diagrammatic representation of the carbon cycle in the natural environment.*

Hint: Encircle (or put in text box) the words/terms describing each component in the system of the carbon cycle

Summary

Hydrogen carbonates react with acids to give a salt, water and carbon dioxide.

Vinegar contains a weak acid called acetic (ethanoic) acid and baking powder is sodium hydrogen carbonate. All hydrogen carbonates liberate carbon dioxide when treated with dilute acids.

$$HCO_3^-(s) + H^+(aq) \longrightarrow CO_2(g) + H_2O(l)$$

E.g. $2NaHCO_3(s) + H_2SO_4(aq) \longrightarrow Na_2SO_{4(aq)} + 2CO_{2(g)} + 2H_2O(l)$

Hydrogen carbonate are decomposed by heat to form a carbonate, carbon dioxide and water.

$$2HCO_3^-(g) \longrightarrow CO_3^{2-}{}_{(S)} + CO_{2(g)} + H_2O_{(l)}$$

E.g. $2\ NaHCO_3(s) \xrightarrow{heat} Na_2CO_3(s) + CO_2(g) + H_2O(l)$

Note

This reaction distinguishes sodium carbonate and sodium hydrogen carbonate because sodium carbonate is not decomposed by heat.

Uses of $NaHCO_3$

Used in baking powder, fire extinguishers, making health salts, and as a quenching agent in quantitative analysis.

Topic 2: ORGANIC CHEMISTRY

Lesson 2.1: Alkanes

By the end of this lesson, you should be able to:

1. define organic chemistry.
2. define hydrocarbon and homologous series.
3. name and draw the structures of the first four alkanes.
4. define the term isomerism.
5. write all isomers of the formula C_5H_{12}

INTRODUCTION

Carbon can form covalent bonds with itself and other elements to create a number of structures. In organic chemistry, we will learn about the reactions used to synthesize important carbon-based structures, as well as the analytical methods to characterize them. Carbon forms numerous stable compounds, using a valence of four, which are far more than the compounds of all other elements in the Periodic Table put together. This is because carbon atoms can join together and form long chains for example, starch/cellulose contain chains of hundreds of carbon atoms. The bonds between the atoms are very strong and can be single, double or triple bonds.

Take a look at the pictures:

a) Name the materials
b) From which components are the materials made?

All the materials are organic materials. They are made from long chains of carbon. Because they are very many and differ in molecular structures, organic compounds are grouped in families called **homologous series**. Homologous series is a group of organic compounds of similar structure, the compounds in a homologous family share a suffix in their name.

The homologous families include:

a) Alkanes

Look at the names of the following substances

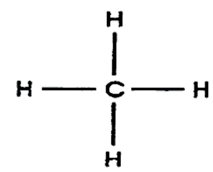
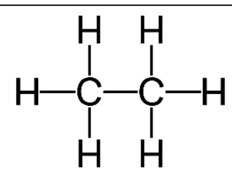
Methane	Propane	Butane

- What do you notice about the names of all these substances?
- How do their common suffixes relate to the term **ALKANE**?

Members in this homologous family:

- Share a suffix '**ANE**' at the end of their name
- Their carbon atoms have a single bond between them

Alkanes members include:

Name of alkane	Prefix in name and meaning	Suffix in the name and meaning	Structure
Methane	Meth – 1	ane	
Ethane	Eth - 2	ane	
Propane	Prop – 3	ane	
Butane	But – 4	ane	

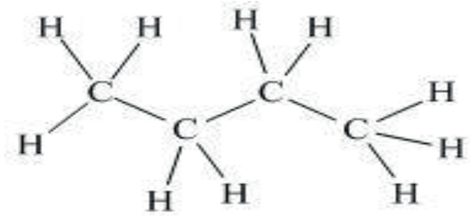
- Complete the table by writing the structures of propane and butane.
- How does one member differ from the next as you increase the carbon atoms?
- Take time and develop a formula to which the members conform.

Learning points

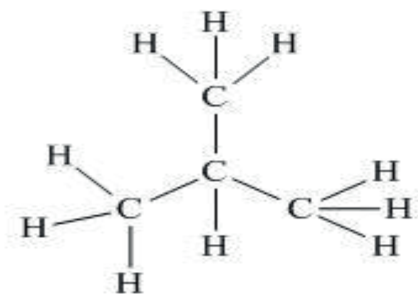
- *Hydrocarbons are organic compounds containing carbon and hydrogen only.*
- *Alkanes are saturated hydrocarbons that can be represented by the general molecular formula C_nH_{2n+2}, where n = 1,2,3,4, for example, when n = 2, the alkane has molecular formula C_2H_6.*
- *What are saturated alkanes? Read more*

Isomerism

Butane (C_4H_{10}) has the following structures;



butane



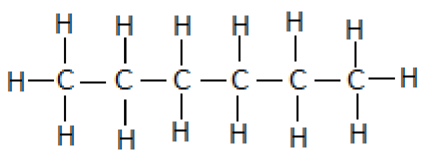
2-methylpropane

- What is common with the structure (give three ways)
- How are structures different?

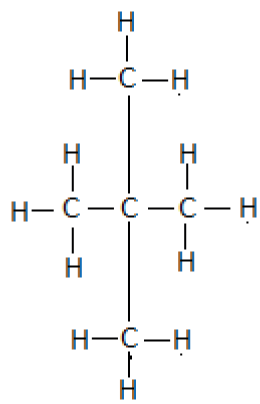
This is a phenomenon in which two or more compounds exist, having the same molecular formula but different structural formula due to the difference in the arrangement of atoms in space is called **isomerism.**

Pentane

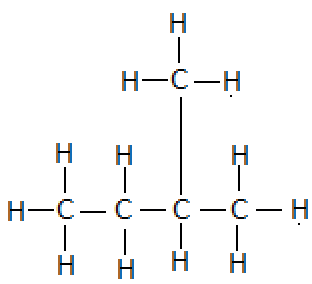
Has 5 carbon atoms, the possible isomers of pentane are:



1



2

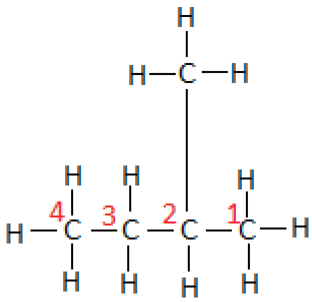


3

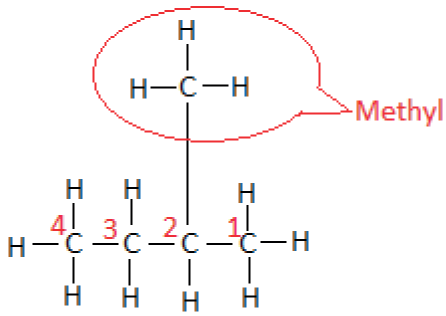
Naming the isomers.

Let us name isomer 2:

- ☐ Identify the longest carbon atom and assign a number on carbon atoms starting with the end near the branching.
  For example, pentane isomer 3:

The longest  carbon atoms have 4 atoms it is butane

- Identify the carbon atom with and name the branching (all branches have a suffix 'yl' and a prefix coding to the number of carbon atoms.
  For: 1 – carbon atom it is meth, 2 – eth, 3 – prop, 4 – but and others



- The name then becomes **2 – methyl butane.**
- From the isomers of pentane, what is the name of isomer 2 above?

Follow-up exercise:

a) What are organic compounds?
b) Identify any two characteristics of a homologous family
c) Draw the structures and name the isomers of hexane.

Lesson 2.2: Alkenes

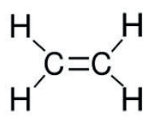
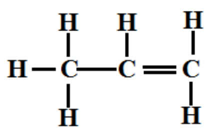
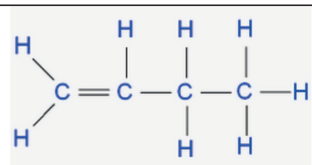
By the end of this lesson you should be able to:

1. describe the method of preparing alkenes.
2. explain the physical and chemical properties of alkenes.
3. explain the polymerisation of ethane.
4. outline environmental effect of polyethene.

Introduction

In lesson 1, you learnt that alkane is a homologous family with a number of carbon compounds characterized by a single carbon bond between their atoms. The single bond between the carbon atoms contributes to their chemical behaviour. Since the carbon atoms in alkanes use all the four bonds, they are called saturated compounds.

Just like alkanes, alkenes compounds belong to a homologous family called alkene. They are more reactive than alkanes.
Look at the structures below:

 ethene		

These are alkenes.

a) What is common with all the hydrocarbons?
b) What prefix can you attach to each compound due to the number of carbon atoms present?
c) Alkenes have a suffix ‘ene’ i.e. all their names end with ‘ene’. Name the alkenes above.
d) Develop a general formula for the alkenes

Reactions of alkenes

Alkenes are more reactive as compared to alkanes. The double bond between carbon atoms is electron seeking. Alkenes react easily with electron donating halogens like bromine and chlorine. During this reaction, the halogens are added to the compound in an addition reaction.

4. **Reaction of ethene with bromine**

   Ethene reacts with red liquid of bromine to form di bromoethane.

   $H_2C = CH_2 + Br_2 \longrightarrow CH_2BrCH_2Br$

5. Polymerization reaction of ethene

Look at the picture below,

a) Identify the materials held by the vendor
b) What are they made from?
c) What are they used for?
d) What are environmental effects of the materials?
e) How can the effects of the material be reduced?
    - The common name is **polyethene**. Their name come from 2 words; poly and ethene. Poly means many. Polyethene simply means many ethene molecules combined together to form one big material. The process of combining smaller molecules to a form a big and complex material is called Polymerisation.
    - The small units like ethene which combine together are called monomers while the larger unit formed is called a polymer.
    - Polyethene use has greatly chocked our environments due to poor disposal mechanisms.
f) Step out into a garden near you, analyse how polythene can affect soil or drainage system.
g) Given leadership opportunity in your area, how would you reduce the effects?

Polymerization is a process by which very many molecules of the same kind called monomers combine among themselves to form one giant molecule called a polymer. This is called *addition polymerization and it is undergone by alkenes.*

Polymerization of ethene to form polythene can be represented by the follow equation.

$$nH_2C = CH_2 \longrightarrow -\!\!(CH_2CH_2)\!\!-_n$$

Summary

- Alkenes are hydrocarbons with which contain a double bond between two carbon atoms.
- Alkenes are unsaturated, so other atoms can be added to their molecules.
- A polymer is a large molecule formed by joining together many small molecules called monomers.
- Alkenes can be polymerized to form products such as polythene, polystyrene and PVC**.**

TOPIC 3: ACIDS, BASES AND SALTS

Learning Objectives

By the end of this topic, you should be able to write ionic and formulae equations for specified acid-base reactions.

Lesson 3.1: Acids and Bases

By the end of this lesson, you should be able to:

1. define acids and bases.
2. recognize the difference between weak and strong acids.
3. write ionic and formulae equations for specified acid-base reactions.

Introduction

Acids and bases are some of the important substances studied in chemistry. Some of them occur naturally in our foods like fruits and vegetables or form part of the living body system. Others are industrially manufactured for different purposes.

In this lesson you are going to learn about some of the common properties of acids and bases.

Activity 3.1a): Finding definition of an acid

In this activity, you are going to find out about the definition of an acid. The definition of an acid is usually obtained from its behaviour when dissolving in water. This is because a substance behaves as an acid only when dissolved in water.

Steps

1. Carefully read result of the experimental illustration carried by students in form 3.

   The students dissolved three different samples of substances that were known to be acids. He analyzed the solutions of each of the samples. The results of the analysis proved that all the three samples produced hydrogen ions as the only positively charged ions. He then tested the **undissolved** acid to find out if hydrogen ions were present in them. He discovered that the undissolved acid had no hydrogen ions in them. He concluded that acidic property is only shown when the acid is dissolved in water.

2. From the above illustration:
   i) what substance causes an acid to produce acidic property?
   ii) What is the active ingredient produced in (i) above resulting in acidic behaviour?
3. Suggest a suitable definition for an acid.

Activity 3.1b): Finding out what a base is?

The students repeated the experiment in part A above using samples of another different group of substances called bases**.** They analyzed the solutions of each samples and proved that all the three samples produced hydroxide ions as the only negatively charged ion. The presence of the hydroxide ions characterise the substances are called alkalis.

i) Using the two activities give the difference between an acid and a base in terms of dissolving either of the substances in water.

Activity 3.1c): Demonstrating the chemical change when dissolving an acid and base

Some of the common examples of acids and bases that you need to know include the ones given in the table below.

Common name	**Chemical name**	**Formula**
Acids		
Hydrochloric acid	Hydrogen Chloride	HCl
Sulphuric acid	Hydrogen Sulphate	H_2SO_4
Nitric acid	Hydrogen Nitrate	HNO_3
Sulphorus acid	Hydrogen Sulphite	H_2SO_3
Nitrous acid	Hydrogen Nitrite	HNO_2
Bases		
Sodium Hydroxide	Sodium Hydroxide	$NaOH$
Potassium Hydroxide	Potassium Hydroxide	KOH
Calcium Hydroxide	Calcium Hydroxide	$Ca(OH)_2$
Ammonium Hydroxide	Ammonium Hydroxide	NH_4OH

In this activity you will find out the chemical change that takes place when an acid and a base dissolve in water. You will also find out how to write the equation of reaction for dissolving any acid and base in water.

Step 1

Read the guidelines below. It contains information about the chemical change that takes place and the relevant equations when an acid and a base dissolve in water.

***Guideline 1**.*
When an acid dissolve in water, the molecules of the acid dissociate to form free ions in solution (the covalent acid molecules ionize in solution)

Example 1. *When Hydrogen chloride dissolves in water, it ionizes/dissociates to form Hydrogen ions and chloride ions. The equation of reaction is represented as*

$$HCl\ (aq) \longrightarrow H^+\ (aq) + Cl^-(aq)$$

Example 2 *When Hydrogen Sulphate dissolves in water, it ionizes/dissociates to form Hydrogen ions and Sulphate ions. The equation of the reaction is represented as*

$$H_2SO_4\ (aq) \longrightarrow 2H^+\ (aq) + SO_4^{2-}(aq)$$

Guideline 2

When a base dissolve in water, the molecules of the base it dissociates to form free ions in solution.

Example1.

When Calcium Hydroxide dissolves in water, it dissociates to form Calcium ions and Hydroxide ions. The equation for the reaction is represented as

$$Ca(OH)_2(s) \longrightarrow Ca^{2+(}aq) + 2OH^-(aq)$$

Step 2

Cary out a skill building exercise

Using the guidelines 1 and 2 given above to explain process of dissolving the following acids and bases in water. Use equations to support your explanation.

- *i)* *Nitric acid*
- *ii)* *Sulphorus acid*
- *iii)* *Potassium Hydroxide*
- *iv)* *Ammonia solution.*

Lesson 3.2: Strong and Weak acids and bases

Introduction

The strength of an acid and base depends on the ease with which a given solution ionizes in water. Those that completely ionizes in water are called strong acids and bases forming Hydrogen and Hydroxide ions respectively. While those that partially ionize in water are weak acids and base. The reactions of strong acids and bases are reversible while those for weak acids and bases are irreversible.

In this lesson you will learn how to distinguish between strong acids and weak acids and strong base and weak bases.

Activity 3.2. Copying and completing the table

Substance	**Ionization in water**	**Strong acid/base**	**Weak acid/base**
Hydrochloric acid	$HCl(aq) \rightarrow H^{+}(aq) + Cl^{-}(aq)$		
Phosphoric acid	....		Weak acid
....	$H_2SO_4\ (aq) \rightarrow 2H^{+}(aq) + SO_4^{2-}(aq)$		
Ammonia solution	....		Weak base
Potassium Hydroxide	....	Strong base	
Sodium Hydroxide	....		
....	$Ca(OH)_2(s) \rightarrow Ca^{2+}(aq) + 2OH^{-}(aq)$		

(a) From the table above. List the substances which are

i) Strong acids

ii) Strong base

iii) Weak acids

iv) Weak base

(b) In each case give a reason for your answer.

Follow up activity

1.(a) State the uses of acids and bases in your daily life.

(b) Describe a chemical test you would carry out to confirm the presence of an acid or base. In each case state what is observed.

Lesson 3.3: pH of solutions

Introduction

pH is Around Us

- Substances in body involved in good digestion have different pH values
- Blood to heart and lungs contains carbon dioxide making blood slightly acidic
- Acids are used in food preservations (ethanoic acid to preserve vegetables; benzoic acid used in fruit juices, jams and oyster sauce)
- pH affects plant growth – some plants grow in acidic soil; some need alkaline soil
- When hair is cleaned with shampoo which is alkali to dissolve grease, hair can be damaged unless it's rinsed or acid conditioner is used to neutralize excess alkali

pH is the acidity or alkalinity of a substance. The pH scale ranges from 0 to 14.

Activity 3.3: Study the pH scale in fig.1below carefully

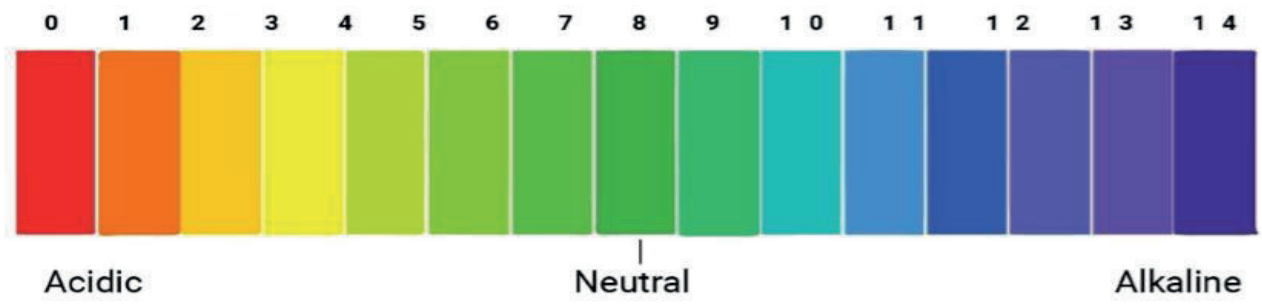


Fig.1. pH scale

Activity 3.4: Finding the pH of different solutions

The table below shows different solutions and their respective. **pH** scale values. Complete the table.

Solution	**pH scale value**	**Acid/Base**
Water	7.0	
Tooth paste	8.9	
Lemon juice	4.1	
Milk	6.5	
Soap solution	12.3	
Hydrochloric acid	1.2	
Sodium Hydroxide	13.8	

(a) From the table above. List the solutions which is/are

i) Strong acid

ii) Weak acid

iii) Strong base

iv) Weak base

v) Neutral

Conclusion

pH scale

- Is used in measuring acidity and alkalinity in aqueous solutions
- The PH scale is normally made up of pH values or numbers. pH 7 represents neutrality
- Acidity ranges from 1 to 6 and alkalinity ranges from 8 to 14
- Strength of an acid increases as the value of the numbers (pH) decreases i.e. (6<5<4<…1) hence increasing acidity
- Strength of an alkali increases as the value of the numbers increases i.e. (8>9>10>…14) hence increasing alkalinity end.

Lesson 3.4: Salts

Introduction

Salts are useful in our daily life. Common salts occur naturally in rocks, lakes such as lake Katwe in Kasese district. It is used to spice up our daily meals. In this lesson we shall learn how to prepare a given salt. Salts are categorized as soluble and insoluble salts. Do activity 3.5. below and you should be able to identify soluble and insoluble salts.

Activity 3.5: Finding out soluble and insoluble salts

What you will need:
Water, empty water bottle, common salt powder.

Steps

1. Pour about half of clean water into the empty plastic water bottle and put a small quantity of salt in it and stir the mixture. Observe?
2. Repeat the above procedure using powder.
   a) State what is observed in each case.
   b) Identify which salt is soluble or insoluble? Give a reason for your answer.

Inquiry question. What is a salt?	**A salt** is a compound formed when the replaceable ionisable hydrogen of an acid is replaced by a metal or an ammonium ion either wholly or partially.

How are soluble salts prepared?

Soluble salts are prepared by the action of an acid on a metal, metal carbonate, metal oxide, metal hydroxide or alkali

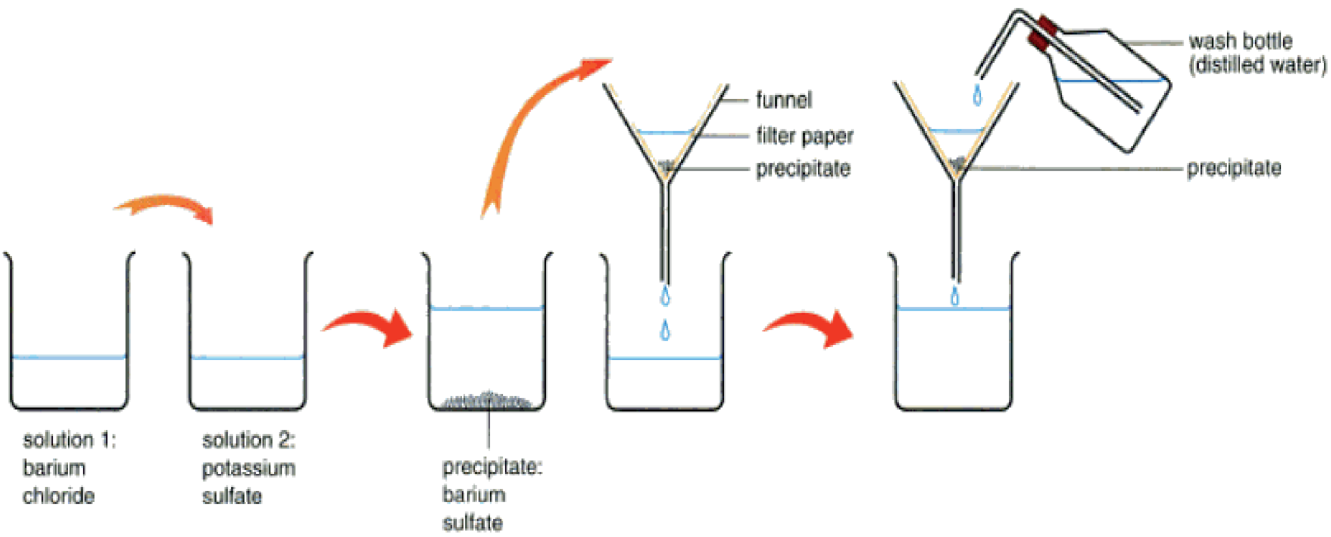
Hint:

Soluble salts of lead, copper, iron and zinc can be prepared as follows;

1. Add metal, metal oxide or metal carbonate to dilute acid until the metal is in excess and heat
2. Filter off the excess solid and concentrate the filtrate by heating
3. Cool the solution to crystallize and filter off the crystals
4. Dry the crystals to obtain a dry salt

Activity 3.6: Preparing an insoluble salt

1. Study the stages below used to prepare **an insoluble salt of Barium** sulphate. use it to describe how an insoluble salt is prepared?



TOPIC 4. MOLE CONCEPT

Learning Objective

By the end of this topic, you should be able to apply the relationship between the mole and Relative Molecular Mass (RMM) to solve related problems

LESSON 4.1: Formulae and Chemical equation

By the end of this lesson, you should be able to:

1. define the mole, molar solution and molar gas volume.
2. use the mole, molar solution and molar gas volume in defining chemical formulae and equation from both experimental results and given data.
3. represent a chemical reaction by either a full formula or ionic equation.

The mole is a concept used in measurement of amount/quantity of matter. One of the important aspects of the mole is that it relates to the number of particles present.

Activity 4.1 a): Finding out about terms that relate moles of matter to particles of matter

Step 1: Read the text/article below. It's about the scientific background to units for measurements for mole of substance and mass of particles (atoms and molecules) and their quantitative relationship. Take careful note of the examples given after the text and use them in the proceeding exercises.

"A mole is a unit that can be used by chemists to compare the number of chemical substances. This is because one mole of an element is defined/expressed by the number of atoms in it. One mole of a compound is also defined/expressed by the number of molecules of the compound. The mass of mole of a substance is known as the molar mass and it has units in grams. A single atom or molecule is far too small for its mass to be measured in any units. The example, mass of the smallest atom; hydrogen is about ***1.66×10^{-22} g*** *(much smaller than micro units of a gram). Therefore, a very big number of atoms or molecules must be present/collected together, to make up one mole that can be weighed in grams. This number is* ***6.022×10^{23}.*** *It is called the* ***Avogadro number (N_A)*** *of particles (atom or molecules).*

Mass of an atom or molecule is known as relative atomic mass or relative molecular mass respectively. This is because the value is obtained as ratio or by comparing. The scale for measurement of mass of atoms or molecules has no units. It was adopted by using the smallest atom; hydrogen as the first/beginning point with a value of 1. The mass of all other *atoms or molecules is the number of times the atom or molecules is heavier than (compared to) the mass of the smallest atom. Therefore, mass of atoms or molecules are called* ***relative masses*** *because they are obtained by comparing with (or relative to) mass of another atom.*

Carbon is the element that forms the most abundant/common compounds in nature. It's much more common and easier to store than the lightest atom; hydrogen. It was found to be the most convenient to use as a standard for comparing masses of other atoms or molecules. The mass of the lightest atom (H – atom) is $^1/_{12}$ x the mass of 1 atom of Carbon. ***(The most common isotope; carbon -12 isotope was chosen for this purpose).*** *Examples of this measurement can be expressed for some substances as follows;*

- ☐ *the atom of an element like Aluminium has relative atomic mass 27 because it is 27 times heavier than $^1/_{12}$ of mass of Carbon-12 isotope.*
- ☐ *The atom of carbon has relative atomic mass of 12 because it is 12 times heavier than $^1/_{12}$ of mass of Carbon-12 isotope.*
- ☐ *a molecule of water (H_2O) has relative molecular mass of 18 because it is 18 times heavier than $^1/_{12}$ of mass of Carbon-12 isotope.*

Therefore, the scientific standard for measuring and defining relative atomic mass and relative molecular mass is $^1/_{12}$ of mass of Carbon-12 isotope.

Relative molecular mass and molar mass are numerically the same, but differ in that molar mass has units in grams but relative atomic/molecular mass have no units."

Step 2: Questions

1. Use the information you gained from the text above and previous lessons to answer the following questions.
   a) State the definition of the following terms;
      (i) Avogadro number
      (ii) One mole
      (iii) Molar mass
      (iv) Relative atomic mass.
      (v) Relative molecular mass
   b) Explain
      (i) Why mass of an atom or molecule is known as relative atomic or molecular mass respectively.
      (ii) Why Carbon-12 is used as a standard scale for measurement of or relative molecular mass
      (iii) Why a fraction of $^1/_{12}$ of mass of Carbon-12 isotope is used as a scale.
      (iv) The similarity between molar mass and relative atomic mass.
      (v) The difference between molar mass and relative atomic mass.

c) Complete the mathematical expressions below that express/define relative atomic mass and relative molecular mass

(i) $\text{Relative atomic mass} = \frac{\dots\dots\dots\dots}{\dots\dots\dots\dots}$

(ii) $\text{Relative molecular mass} = \frac{\dots\dots\dots\dots}{\dots\dots\dots\dots}$

Activity 4.1b): How to calculate relative formula/molecular mass, molar mass and moles

In this activity you will learn about relative molecular/relative formula mass and how

to use it to calculate moles of a substance

Step 1: (i) Carefully read the information given in the brief text below and the illustrative calculations attached to the text.

"A molecule is a particle that contains two or more atoms chemically combined together. The mass of a molecule is known as its relative molecular mass. When the atoms combined together are the same, it's a molecule of an element; (examples include O_2, H_2, N_2, Cl_2). When the atoms combined together in the molecule are different then it's a molecule of a compound (H_2O, CO_2, Na_2O,). Molecules are represented by the formula of the compound. Relative molecular mass can be computed from the relative formula mass. Relative formula mass is the sum of the relative atomic masses of all the atoms represented in the formula.

Molar mass of a compound is the mass in grams of one mole of the compound. It's numerically equal to relative molecular/formula mass. It contains Avogadro number of molecules. Therefore, moles of a substance in any given mass is the ratio in grams of the substance to the molar mass of the substance. The mathematical expression for moles is given as; $\mathbf{Moles} = \frac{\mathit{Mass\ in\ grams}}{\mathit{Molar\ mass}}$ *"*

Examples to find out how relative formula/molecular mass, molar mass, percentage composition, mass and Avogadro number are related are related can be demonstrated as follows;

Example 1; To find relative formula mass, percentage composition, molar mass of sulphuric acid (H_2SO_4) and moles of 4.9 g of sulphuric acid

➢ ***Finding relative formula/molecular mass and molar mass***

Formula of sulphuric acid; H_2SO_4

Relative atomic masses of the atoms in $H_2SO_{4:}$ H = 1, S = 32, O = 16

Number of each atom in the formula H_2SO_4, and their resulting relative mass:

2 atoms of Hydrogen resulting relative mass = 2 x 1= 2

1 atom of sulphur resulting relative mass = 1 x 32= 32

4atoms of oxygen resulting relative mass = 4 x 6 = 64

Sum of relative masses (hence relative molecular/formula mass) = 2 + 32 + 64

= 98

Molar mass (mass of one mole) of sulphuric acid (with formula; H_2SO_4) is 98g

- ***Finding percentage (%) composition of element in H_2SO_4***
  The percentage of each element in a compound is given by the expression;

Percentage composition = $\left(\frac{\text{Sum of relative atomic masses of the element}}{\text{Relative molecular mass of the compound}} \times 100\right)\%$

Therefore; - *Percentage of hydrogen in sulphuric acid =* $\left(\frac{2}{98} \times 100\right)\%$

=2%

Percentage of Sulphur in sulphuric acid = $\left(\frac{32}{98} \times 100\right)\%$

=33%

Percentage of Oxygen in sulphuric acid = $\left(\frac{64}{98} \times 100\right)\%$

=65%

- ***Finding moles of sulphuric acid in 4.9g***
  Molar mass of sulphuric acid (H_2SO_4) is 98g

  98g of sulphuric acid contains has 1 mole

  1g of sulphuric acid contains has $\left(\frac{1}{98}\right)$ *moles,*

  4.9g of sulphuric acid contains has $\left(\frac{1}{98} \times 4.9\right)$ *moles,*

  Which is equal to 0.05 moles

Example 2; ***To find number of atoms of the elements in***

(a) ***5.6g of iron***
(b) ***8.0g of calcium*** *(Ca = 40, Fe = 56)*

- *56g is the mass of 1mole of iron atoms*

  5.6g is the mass of $\frac{5.6}{56}$ *moles*

  But 1 moles of iron = 6.02 x 10^{23} atoms

  $\frac{5.6}{56}$ *moles* $\left(\frac{6.02 \times 1022}{1} \times \frac{5.6}{56}\right)$ *atoms*

  <u>6.02 x 10^{22} atoms</u>

- *40g is the mass of 1 mole of calcium atoms.*

  8g is the mass of $\frac{8}{40}$ *moles.*

  But 1 mole of calcium = 6.02 x10^{23} *atoms*
  Hence, 8/40 moles = (6.02x 10^{23} *x8) ÷ 40*

  = 1.204 x 10^{23} atoms

Step 2: Use the information in the text above and the examples given to build your understanding skills by solving the exercises below

Exercise 1: Calculate the percentage composition by mass of each element in the following compounds
(a)Ammonium sulphate; $Al_2(SO_4)_3$.
(b) Sodium thiosulphate crystals $Na_2S_2O_3.5H_2O$;
(Na= 23, S=32, H=1, O=16, N = 14)

Exercise 2: Calculate the moles of
a) 4.9 g Sodium carbonate; $Na_2CO_3.5H_2O$
b) 17.2g of iron(III) sulphate; $Fe_2(SO_4)_3$

(S=32, H = 1, Fe=56, Na = 23, C= 12)

Exercise 3: Calculate the number of the following in 5.1g of aluminium oxide
a) molecules of aluminium oxide
b) atoms of aluminium

c) atoms of oxygen

(Al = 27, O= 16)

The mole is a concept used for measurement amounts of matter. One mole as a unit of measurement contains………………… Particles. The mass of a single atom is known as ………………. of the atom. Mass of one mole of atoms is known as the ……………….... of the atom

of the element.

The relative atomic mass and molar mass are similar in ……………………, but differ in that ……………………………………………..

Lesson 4.2: Converting Moles to Mass

Activity 4.1c): Changing moles to mass

1. Derive an expression for mass in a given moles using the equation;

   $$\text{Moles} = \frac{\text{Mass in grams}}{\text{Molar mass}}$$ „

2. Use the equation you have derived to a practice/build skill for calculation using first principle. This can be done by first expressing mass in 1 mole as shown in the example here below for 0.250 moles sodium;
   - The mass of 0.25 moles of sodium can be computed as;

     1 moles of sodium atoms weight 23g

     0.25 moles weigh $\frac{23}{1}$ x 0.25g

     = 5.75g

   a) 0.325moles of zinc
   b) 0.05 moles of aluminium chloride
   c) 0.05 moles of aluminium sulphate.
   d) 0.2 moles of lead(II) chloride.
   (Al = 27, Zn = 65, Cl = 35.5, S = 32, Pb = 207)

Evaluation

1. Find:

   a) Number of carbon atoms in 6 grams of carbon rod (C=12).

   b) Mass of 1.505 x 10^{23} atoms of Sulphur (S=32)

   c) (i) molecules of chlorine (ii) atoms of chlorine 3.55 g of gaseous chlorine; Cl_2? (35.5)

2. Find the moles of the following

   a) 5.3g of anhydrous sodium carbonate; Na_2CO_3 (Na=23, C=12, O=16)

   b) 15g of Aluminium oxide; Al_2O_3 (Al = 27, O =16)

3. a) How many moles of Sulphur dioxide molecules are present in 16 g of Sulphur dioxide, SO_2?

   b) What mass of magnesium (Mg=24) would contain the same number of atoms as 4 g of carbon.

c) Calculate the mole of each element present in copper(II) nitrate; $Cu(NO_3)_2$. (Cu = 64, N = 14, O =16

4. Calculate the percentage;

a) composition by mass of magnesium oxide, (Mg = 24, O = 16).

b) of water of crystallization in hydrated sodium carbonate, $Na_2CO_3.10H_2O$.

Lesson 4.3: Understanding quantitative relationship between reactants and products

Lesson Objectives

By the end of this lesson you should be able to:

1. define molar gas volume.
2. use the mole, molar gas volume in defining chemical formulae and equation from both experimental results and given data.

Step 1: Read the text below. It is an extract about the guideline used in determining quantitative relationship between reactants and products

"During a chemical reaction, the relationship between the quantities of the reactants and product can be obtained using;

- *The principle of chemical combination/reaction*
- *Avogadro's law relating volume of different gases and number of particles*
- *Gay Lussac's law of reacting volumes of gases volumes*

The principle of chemical combination/reaction This principle demonstrates that when substances react to form products, they do so in a simple relationship/ratio to one another by moles. This relationship/ratio in moles of the reactants and that of the products to one another is obtained from a balanced equation. The coefficient of the reactants and products in a balanced equation gives ratio of the quantities in moles. (The ratio of the coefficients in the balanced equation is equal to the ratio of the moles of the substances.)

When necessary, mole quantities in the balanced equation can then be converted other units of measurement like mass in grams by using the equation; mass(g) = moles x molar mass (Mr). Examples of the working can be illustrated as follows;

Example1

$2Na(s)$	+	*$2H_2O(l)$*	→	*$2NaOH(aq)$*	+	*$H_2(g)$*
2 moles		*2 moles*		*2 moles*		*1 mole*
(4 x molar mass of Na)g		*(2 x molar mass of H_2O)g*		*(2 x molar mass of NaOH)*		*(1 x Mr of H_2)*
(2 x 23)g		*(2 x 18)g*		*(2 x 40)g*		*(1 x 2)g*

Example 2

$4Al(s)$	+	*$3O_2(g)$*	→	*$2Al_2O_3(s)$*
4 moles		*3 moles*		*2 moles*
(4 x molar mass of Al) g		*(3 x molar mass of O_2)g*		*(2 x molar mass of Al_2O_3)*
= (4 x 27) g		*= (3 x 32)g*		*= (2 x 102)g*

*Avogadro's law relating volume of different gases and number of particles. This law states that equal volumes of a gas at the same temperature and pressure contain the same number of particles (hence moles). Equal moles of different gases at the same temperature pressure have the same volume. Therefore, one mole of different gases at the same temperature pressure have the same volume called **molar gas volume.** The molar gas volume at standard temperature and pressure (s.t.p.) for all gases is 22.4dm^3 (22400cm^3), at room temperature and pressure (r.t.p) is 24dm^3 (24000 cm^3)*

The volume of any gas at a given temperature and pressure can therefore be obtained by the expression; Volume = moles x molar gas volume. At s.t.p this is expressed as;

(moles x 22.4)dm^3 or (moles x 22400)cm^3. At r.t.p this is expressed as;

(moles x 24)dm^3 or (moles x 24000)cm^3

Gay Lussac's law of reacting volumes of gases volumes states that when gases react to from products that are gaseous, the volumes of reactant gases and that of products have a simple ratio to one another. Therefore, the ratio of moles gases reacting and gaseous product formed is equal to the ratio of volumes of reactants and products.

	$N_2(g)$	+	*$3H_2(g)$*	→	*$2NH_3(g)$*
	1mole		*3moles*		*2moles*
	1volume		*3volumes*		*2volumes*
Vol. at s.t.p	*(2 x 22400)cm^3*		*(3 x 22400)cm^3*		*(2 x 22400)cm^3*
Vol. at r.t.p	*(2 x 24000)cm^3*		*(3 x 24000)cm^3*		*(2 x 24000)cm^3*

*This study of the quantitative relationship between reactants and products in a balanced equation is known as **stoichiometry***

Stoichiometric calculation are used to find amounts of substances reacted or produced by using a balanced equation of a chemical reactions? The steps are;

- *Write a balanced reaction equation*
- *List the mole ratios you can derive from this balanced chemical equation.*
- *Relate the moles ratios to the relevant quantities of measurement.*

This can be done using the illustration below.

$2\,Zn(NO_3)_2(s) \rightarrow 2ZnO(s) + 4NO_2(g) + O_2(g)$

From the balanced equation, ratio of the coefficient of reactants and products are $Zn(NO_3)_2$: ZnO : $4NO_2$: O_2 = 2:2:4:1, hence the resulting mole ratio is 2 moles of $Zn(NO_3)_2$: 2 moles of ZnO : 4 moles of NO_2 : 1 moles of O_2

These ratios of moles can be converted to any required units of measurement such as mass in gram and volumes of gases using molar mass and molar gas volumes respectively"

Worked example

Find the mass of residue formed and total volume of gaseous product at s.t.p, when 10 gm of zinc nitrate completely decomposes on heating

$2\,Zn(NO_3)_2(s) \rightarrow$	$2ZnO(s)$ +	$4NO_2(g)$ +	$O_2(g)$
2 moles	2 moles	4 moles	1 mole
(2 x Mr. of $Zn(NO_3)_2$)g	(2 x Mr. of ZnO)g	(4 x 22.4)dm^3 at s.t.p	(1 x 22.4)dm^3at s.t.p

Step 1 - Calculate the amount from the equation

Amount of zinc nitrate decomposed= (2 moles x molar mass) g

= (2 x 189) g = 378g

Amount of zinc oxide(residue) formed= (2 moles x molar mass) g

= (2 x 81) g = 162g

Amount of nitrogen dioxide formed in cm^3 at s.t.p

= (4 moles x molar gas volume) cm^3

= (4 x 22,400) cm^3 = 89,600cm^3

Amount of nitrogen oxygen formed in cm^3 at s.t.p

= (1 moles x molar gas volume) cm^3

= (1 x 22400) cm^3 = 22,400cm^3

Step 2 - Calculate the amount of hydrogen required/stated in the question

- *A mount of residue; zinc oxide (ZnO);*

  from the balanced equation 378g of zinc nitrate; $Zn(NO_3)_2$ produced 162g of ZnO

  Therefore 10g of zinc nitrate; $Zn(NO_3)_2$ produced ($\frac{162}{378}$ x 10) g of zinc oxide; ZnO

- *A mount of gaseous product; there are two gaseous products; nitrogen dioxide and oxygen;*
  - ☐ *Amount of nitrogen dioxide:*
    from the balanced equation 378g of zinc nitrate; $Zn(NO_3)_2$ produced 89600cm^3 of nitrogen dioxide,
    Therefore 10g of zinc nitrate; $Zn(NO_3)_2$ produced ($\frac{89600}{378}$ x 10) cm^3 of nitrogen dioxide NO_2 = 2370.4cm^3
  - ☐ *Amount of oxygen*
    from the balanced equation 378g of zinc nitrate; $Zn(NO_3)_2$ produced 22400cm^3 of oxygen

    Therefore 10g of zinc nitrate; $Zn(NO_3)_2$ produced ($\frac{22400}{378}$ x 10) cm^3 of oxygen; O_2 = 592.6cm^3

  - ☐ *Total volume of gaseous products = (2370.4 + 592.6) cm^3*
    =2963cm^3

1. Use the information you have gained from the text and examples illustrated to find solutions to the following exercises

Exercise 1 4.6 g of sodium reacts completely with excess water:

$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

Calculate the:

a) Mass of water used
b) volume of hydrogen produced. (Na = 23, molar volume = 24 dm^3)

Exercise 2
Calcium carbonate decomposes to form calcium oxide and carbon dioxide when it is heated:

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Calculate the
a) the mass of residue left.

b) *volume of carbon dioxide produced from completely decomposing 1.0 g of calcium carbonate. (M_r of $CaCO_3$ = 100, molar volume = 24,000 cm^3)*

Lesson 4.4.: The Mole in Solution

By the end of this lesson, you should be able to:

1. define molar solution, standard solution, concentration and molarity.
2. use the mole, molar solution and molar gas volume in defining chemical formulae and equation from both experimental results and given data.
3. represent a chemical reaction by either a full formula or ionic equation.

Introduction

The amount of solute in per unit amount of solution is called concentration ***(How much solute is present in one unit of the solute)***.

Mathematically concentration can be expressed as the ratio of amount of solute to amount of solution. Concentration can be expressed in many terms depending on units used to measure amount solute and amount of solution. In this lesson you going to find out about some the terms used to express concentration

Activity 4.2: Finding out how to express the concentration of solutions of salt dissolved in water

What you need

- calculator
- common salt
- clean water
- small weighing scale or small spoon
- cups
- stirrer
- any container you can use to estimate volume'

Steps

1. Weigh any three different portions of salt (for example 20g, 40g and 60g.) You can estimate the masses/weight of the salts arbitrarily using a small spoon
2. Measure equal volume of water (for example 500ml/half a litre into the separate cups. Label them as cup A, cup B and cup C.
3. Add one of the portions into one cup, another portion into the next cup and the third portion into the third cup. Stir each of the mixtures until the salts dissolve into a uniform solution. Taste each of the solution and describe the difference in taste. This is how difference in concentration feels.
4. Carry out the following calculations on the solution in each cup.
   (i) Find the amount of salt in grams present in one centimetre cubed in each cup and give the units

Hint: You use the methods bellow:

Mass of salt in 1cm^3 = ($\frac{Mass\ in\ grams}{Volume\ in\ cm3}$)

OR (Use first principle)

500 cm^3 of solution dissolved 30g,

1 cm^3 of solution dissolved ....

(ii) Change the masses salt dissolve into moles and find the amount of salt in moles present in one centimetre cubed. Give the units (Na= 23, Cl=35.5)

(iii) Convert the volume of solution into decimetres cubed/litres and find the amount of salt in grams present in one decimetre cubed/litres. Give the units

(iv) Find the amount of salt in moles present in one decimetre cubed/litre. Give the units. This concentration on moles per decimetre cubed or per litre is also known as ***MOLARITY.*** The unit for molarity molar and abbreviated as M.

Compare the values of the molarity with strength of taste you felt for each solution.

1. Use the knowledge you have gained from step 4 above to answer the following questions
   a) What does the term molarity mean?
   b) Calculate
      (i) the morality of the following solution prepared by dissolving 16.8g of sodium hydrogen carbonate in 500cm^3 of a solution containing.

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

      (ii) the mass of solute dissolved in 500 cm^3 to make a 0.5M sodium carbonate solution (C=12, O =16, Na =23)

      (iii) moles of nitric acid 50cm^3 of a 0.1 M.

Activity 4.3: Finding out how to use a standard solution for standardization and quantitative analysis

A standard solution is one whose concentration is accurately known. It is used as a reference for analysis of other solutions. The procedure involves use of known volume of one of the solutions to find the volume of the other solution. This procedure is known as volumetric analysis or titrimetry.

A molar solution contains 1 mole of the dissolved substance per litre of solution. Thus solutions are referred to as:

1M means one mole in a litre, 2M means two moles per litre, 0.1M means………

Note: 1 litre of solution = 1dm^3 =1000cm^3

This technique is used in quantitative analysis involving standardization, determining basicity of an acid, determining relative atomic mass/percentage purity/water of crystallization.

Examples of calculation using results obtained from experiments of the above listed techniques include;

Example 1

Calculate the morality of hydrochloric acid if 25cm^3 of 0.1M sodium hydroxide solution required 20cm^3 of the acid for complete neutralization.

Solution

1000cm^3 of solution contains 0.1 moles of sodium hydroxide.

25cm^3 of solution contains $\frac{0.1\ x25}{1000}$ moles of sodium hydroxide

$NaOH_{(}ag) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

1 mole of sodium hydroxide neutralizes 1 mole of HCl acid.

$\left(\frac{0.1\ x25}{1000}\right)$ moles of hydroxide neutralizes $\left(\frac{0.1x25}{100}\right)$ moles of acid.

- 20cm^3 of HCl acid contained $\frac{0.1\ x\ 25}{1000}$
- 1000cm^3 of HCl acid contained $\frac{0.1\ x\ 25}{1000}$ x $\frac{1000}{20}$

Hence molarity of acid is 0.125M

Example 2.

What volume of a 0.2M hydrochloric acid is required to react completely with 20cm^3 of a 0.1 M sodium carbonate solution?

Solution

1000cm^3 of solution contains 0.1moles of sodium carbonate.

20cm^3 of solution contains $\left(\frac{0.1}{1000}\ x\ 20\right)$ moles of sodium carbonate.

$Na_2CO_{3(aq)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

1 mole of Na_2CO_3 neutralizes 2 moles of acid.

$\left(\frac{0.1 \, x \, 20}{1000}\right)$ moles of Na_2CO_3 neutralises $\left(\frac{2 \, x \, 0.1x20}{1000}\right)$ moles of acid.

But 0.2 moles of acid are in $1000cm^3$ of solution.

$\left(\frac{2x0.1x20}{1000}\right)$ moles of acid are in $\left(\frac{1000}{0.2} \, x \, \frac{2 \, x \, 0.1 \, x \, 20}{1000}\right)$ cm^3

Volume of acid required is $20cm^3$.

Example 3.

Find the volume of 0.25M dibasic acid required to completely react with $25cm^3$ of 0.5M sodium hydroxide solution.

Solution

$1000cm^3$ of the solution contains 0.5moles of sodium hydroxide.

$25cm^3$ of the solution contains $\left(\frac{0.5 \, x \, 25}{1000}\right)$ moles of sodium hydroxide.

$2NaOH(aq) + H_2A(aq) \rightarrow Na_2A(aq) + 2H_2O(l)$

2moles of sodium hydroxide neutralized 1 mole of acid.

$\left(\frac{0.5 \, x \, 25}{1000}\right)$moles of sodium hydroxide neutralize $\left(\frac{1}{2} \, x \, \frac{0.5 \, x \, 25}{1000}\right)$moles of acid.

But 0.25moles of dibasic acid are in $1000cm^3$ of solution.

$\left(\frac{0.5 \, x \, 25}{2 \, x \, 1000}\right)$ moles of acid are in $\left(\frac{1000}{0.25} \, x \, \frac{0.5 \, x \, 25}{2 \, x \, 1000}\right)$

Required volume of acid is $25cm^3$.

Example 4

$25cm^3$ of a 0.02M sodium hydroxide solution neutralized completely $10cm^3$ of a 0.025M acid. The basicity of the acid is:

Solution:

$1000cm^3$ of sodium hydroxide solution contains 0.02 moles

$25cm^3$ of solution contains $\left(\frac{0.02 \, x \, 25}{1000}\right)$ moles of sodium hydroxide.

= 0.0005 moles of sodium hydroxide.

$1000cm^3$ of acid solution contains 0.025 moles of acid

$10cm^3$ of acid solution contains $\left(\frac{0.025 \, x \, 10}{1000}\right)$ moles of acid

= **0.00025 moles of acid.**

	Acid	:	NaOH
No. of moles	0.00025	:	0.0005
Ration of moles	0.00025	:	0.0005
	0.00025	:	0.00025
Mole ratio	1	:	2

.: Mole ration of acid: NaOH = 1:2

HnX(aq) + n NaOH(aq) → NanX(aq) +n H_2O(L)

1: n

.: Basicity of acid is 2

Example 5

15cm^3 of solution containing 39.2g dm^{-3} of acid H_2A neutralized 30cm^3 of 0.4m sodium hydroxide solution. Determine the formula mass of A. (H = 1).

<u>Solution:</u>

1000cm^3 of alkali solution contains 0.4 moles of NaOH.

30cm^3 of alkali solution contains $\frac{0.4}{1000}$ x 30 moles

=0.012 moles of NaOH.

2NaOH(aq) + H_2A(aq) → Na_2A(aq) + 2H_2O(L)

.: 0.012 moles of alkali neutralize $\frac{1}{2}$ x .012 moles of acid.

- 15cm^3 of acid solution contained 0.006 moles of acid.

.: 1000cm^3 of acid solution contained $\frac{0.006 X\ 1000}{15}$

= 0.4 moldm^{-3}

- 0.4 moles of acid H_2A weigh 39.2g

.: 1 mole of acid H_2A weighs $\frac{39.2}{0.4}$ = 98g

REM acid H_2A = 98

(1x2) + A = 98

A = 96

Example 6

6.30g of hydrated oxalic acid /Ethane dioic acid, $H_2C_2O_4$. nH_2O was made up to 1dm^3 of solution. 20cm^3 of this solution required 25cm^3 of 0.08m potassium hydroxide for complete neutralization.

Determine the value of n. (H =1, C = 12, 0 = 16).

Solution:

1000cm^3 of alkali solution contain 0.08 moles of KOH 25cm^3 of alkali solution contains($\frac{0.08\,x25}{1000}$) moles of KOH

$2KOH\,(aq) + H_2C_2O_4\,(aq) \rightarrow K_2C_2O_4(aq) + 2H_2O(l)$

2 moles of KOH neutralize 1 mole of acid.

($\frac{0.08x25}{1000}$) moles of KOH neutralize ($\frac{0.08\,x25}{2x\,100}$) moles of acid

- 20cm^3 of acid solution contains $\frac{0.08\,x25}{2\,x1000}$ moles of acid.

1000cm^3 of acid solution contained $\frac{0.08x25x100}{2\,x1000x20}$ moles of acid

Concentration of acid solution is 0.05mol dm^{-3}.

- 0.05 moles of $H_2C_2O_4.NH_2O$ weigh 6.30g

.: 1 mole of $H_2C_2O_4.nH_2O$ weighs $\frac{6.30}{0.05}$ g

= 126g

RFM of $H_2C_2O_4.nH_2O$ = 126

(1X2) + (12X2) + (16X4) + n (12) +16) = 126

90 +48n = 126

18n = 36

N = 2

2 Using the examples given above, try out the following exercises

Exercise 1

30cm^3 of 0.4M potassium hydroxide neutralized completely Vcm^3 of a 0.2M dibasic acid H_2B. Find the value of V. (Answer = 30cm^3)

Exercise 2

18.75cm^3 of a 0.2M sodium hydroxide solution neutralized 25cm^3 of a 0.05M solution of acid X. The molar ratio in which the acid reacts with sodium hydroxide is;

Mole ratio of acid: NaOH = 1:3

Exercise 3

A carbonate of metal M reacts with hydrochloric acid according to the following equation.

$$M_2CO_3(aq) + 2HCl(aq) \rightarrow 2MCl(aq) + CO_2(g) + H_2O(l)$$

If 20cm^3 of 0.2m hydrochloric acid reacts completely with 20cm^3 of a solution containing 21.2gdm^{-3} of a solution containing 21.2gdm^{-3} of carbonate, determine the atomic mass of metal M (C= 12, 0 = 16) (Answer atomic mass of m is 76)

Exercise 4

3.575g of hydrated sodium carbonate, Na_2CO_3. XH_2O was made up to 250cm^3 of this solution required 22.7cm^3 of a 0.11m hydrochloric acid for complete reaction. Determine the value of x. (Na =23, C =12, 0 = 16, H =1)

Solution x = 10

Exercise 5

7.0g of impure sodium hydroxide was dissolved in water to make 1dm^3 of solution. 20 cm^3 of this solution required 25cm^3 of 0.1M hydrochloric acid for complete reaction. Calculate the percentage purity of the sodium hydroxide. (Na =23, O=16, H= 1)

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