UNIT 1: INTRODUCTION TO CHEMISTRY

By the end of this chapter students will be able to show an understanding of appropriate uses of scientific methods, techniques and materials to solve problems in their daily lives.

Chemistry is the study of the nature, composition, structure and behavior of matter and the changes it undergoes.

Branches of chemistry

There are six branches of chemistry

1. **Physical chemistry**
2. **Environmental**
3. **Chemistry**
4. **Analytical chemistry**
5. **Industrial chemistry**
6. **Organic chemistry**
7. **Inorganic chemistry**

PHYSICAL CHEMITRY

Physical chemistry is the study of how and why a chemical system behaves as it does.

It shows how chemical compounds and their constituents react and interact with each other.

Physical chemistry shows how atoms are joined together to form molecules which further relates the structure of molecules in a substance to its physical properties like melting and boiling points.

ENVIRONMENTAL CHEMISTRY

Environmental chemistry is the study of water, air, soil and the impacts of human activities on the environment.

It involves the study of the impacts of pollutants and the reduction of these pollutants and how the environment can be managed.

ANALYTICAL CHEMISTRY

Analytical chemistry is the study of finding out the chemical nature and quantity of each of the substances present in the mixture.

It involves the separation, identification and quantification of the chemical components of the materials present in the mixture.

INDUSTRIAL CHEMISTRY

Industrial chemistry is the study of the application of physical and chemical processes which convert raw materials into finished products.

It involves the processes of industrial designing and manufacturing processes in an industry, for example manufacturing of pain killers like panado.

ORGANIC CHEMISTRY

Organic chemistry is the study of the carbon containing compounds except oxides and carbonates.

It involves the study of substances which are formed by carbon and hydrogen atoms linking together. These substances include fuels such as oils and natural gas.

INORGANIC CHEMISTRY

Inorganic chemistry is the study of the structure and properties of substances made up of non living things.

Note that inorganic compounds do not contain carbon and hydrogen atoms linking together.

IMPORTANCE OR APPLICATIONS OF CHEMISTRY IN EVERYDAY LIFE

Chemistry is applied in many areas. The following are the applications of chemistry in the everyday life:

1. Water treatment: Dirty water is treated with a chemical called **flocculant** which makes the solid particles to settle down and to be bound together to form sediments. The clean water is then treated with chlorine to kill germs to make it safe for consumption.

2. Making a cup of tea: When making tea, firstly the water is boiled and then tea leaves and milk are added to the boiled water which makes the boiled water to change the colour. The taste of a complete made tea differs from the taste of its components which are water, tea leaves, sugar and milk.

3. **Cooking nsima:** When cooking nsima, water is boiled in a pot and then maize flour is added to the boiled water alongside stirring the contents with a cooking stick until thick porridge forms which is nsima ready to be served.

4. **Soap making:** The process of making soap follows chemistry procedures.

5. **Pharmaceutical:** All the processes which are considered to make medicine are chemistry procedures.

6. **Pesticides:**All the pesticides which are made to get rid of pests are made from the chemicals

7. **Food industries:** In food industry the fertilizer used to grow crop is a chemical. Food additives are chemicals. This is all done with the help of chemistry procedures.

AREAS WHERE CHEMISTRY IS APPLIED

The following are the areas where chemistry is applied:

Schools and colleges: in schools and colleges chemistry processes are taken in laboratories when chemistry experiments are handled.

Hospitals and pharmacies: in hospitals and pharmacies, drugs and chemicals are made and mixed in the right quantities which are then given to patients orally or by injection.

Water boards: in water boards, chemicals are added to water to kill germs.

CAREERS IN CHEMISTRY

The followingare the careers in chemistry and their importance:

Biochemists: these chemists study the chemical processes in living things. They help in understanding the factors that help in the growth of living things and diagnosing the diseases.

Teacher chemists: these chemists teach chemistry in schools and colleges. They help in spreading the knowledge of chemistry and its importance in the world

Geochemists: these chemists study the mechanisms behind major geological systems like earth crust and oceans. They help in predicting earthquakes and volcanic eruptions.

Pharmacists: these chemists are healthcare professionals and practice pharmacy. These help to multiply the presence of medical shops for people to get drugs at the right time.

Environmental chemists: these study the physical and biochemical properties of soil, water and air. These chemists help in understanding the factors that affect the environment.

Food chemists: these chemists study the chemicals present in the food products. These help in identifying whether the food supplied in the market is good for human consumption

Quality control and assurance personnels: these chemists study the products made in their organizations to determine the chemical components included in the products. These help in determining the chemicals that a product contains.

Photo chemists: these chemists study the chemical effects of light.

These help in understanding the properties of light and photosynthesis

THE LABORATORY

The importance of the laboratory in the study of chemistry

i. A laboratory is a place where the manufacture of essential materials that the society needs is done, e.g. drugs, cement, paint, dyes, soft drinks etc

ii. Diagnosis of the micro organisms like bacteria and viruses are done in the laboratory.

Importance of maintaining cleanliness in the laboratory

Maintaining cleanliness in the laboratory is very important in the following ways:

i. It helps to minimize unnecessary accidents in the laboratory. Pieces of broken glasses may cut learners conducting experiments in the laboratory if not taken care of.

ii. It helps the laboratory to look conducive, cleanand ready for other students who will come next for the other laboratory session.

GENERAL LABORATORY SAFETY RULES

Laboratory safety rules are safety guidelines to be observed by the user in order to stay safe and minimize accidents while in the laboratory.

The following are some of the laboratory safety rules:

- Do not enter the laboratory without the teacher's permission
- Enter the laboratory in an orderly manner
- Do not rush as you enter in the laboratory or scramble for the front bench
- Avoid unnecessary movements in the laboratory
- Do not perform unauthorized experiments in the laboratory
- Do not taste any chemical in the laboratory
- Do not tamper with electrical, gas or water fittings
- Do not smell gases directly
- Read the label on the reagents before you start using them
- If the chemicals get in contact with your skin, eyes or clothes, wash the affected part with plenty of water
- Avoid entering the laboratory bare -footed
- All experiments that produce dangerous gases should be performed in a fume chamber or open space
- Always clean all the apparatus and bench tops after use
- Wash your hands after each laboratory session.
- Do not move anything out of the laboratory unless authorized

INTERPRETING HAZARD SYMBOLS

Hazard symbols are used for the labeling hazardous substances according to the Ordinance on Hazardous Substances.

The following are the hazard symbols and their meanings and their interpretation.

a) Flammable substance

Meaning : the substance catches fire easily hence they should not be brought

near fire.

b) Poisonous or toxic substance

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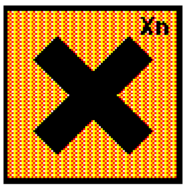
Meaning: they can cause death hence avoid direct contact

c) Harmful substance



Meaning: they can cause harm hence avoid direct contact

d) Harmful to the environment

Meaning: they can kill destroy the environment hence a void careless disposal

e) Corrosive substance

Meaning : these chemical burn the skin hence avoid direct contact

COMMON UNITS OF MEASUREMENTS AND THEIR SYMBOLS

In chemistry there are five basic units of measurements:

i.Mass
ii.Length
iii.Time
iv.Volume
v.temperature

MASS

Mass is defined as the quantity of matter in an object. The SI unit of mass is the kilogram symbolized as**kg**. Note that mass can also be measured in grams,**g**.

Note that **1000g = 1 kg**

Mass is measured by an instrument called a **triple beam balance**. It can also be measured by a **digital balance**. The following are the diagrams for the triple beam balance and the digital balance respectively

The triple beam balance

The digital balance

LENGTH

Length is defined as the distance between two points. The SI unit of length is the metre symbolized as **m**. Length is measured by a**tape measure** or a **metre ruler**. The following are the diagram for a tape measure

The tape measure

TIME

Time is defined as the measure of the duration of an event. The SI unit of time is the second symbolized as **s.** It is measured by an instrument called a **stop watch.** The following is a diagram of the stop watch.

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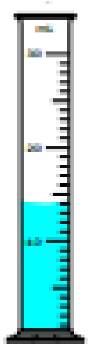
The stop watch

VOLUME

Volume is defined as the measure of the extent of an object. In simple terms, volume is defined as the amount of space occupied by an object. The SI unit of volume is the cubic metre symbolized as **m^3**

Volume is measured by an instrument called a **measuring cylinder**. The following is a diagram of a measuring cylinder



TEMPERATURE

Temperature is defined as the degree of hotness and coldness of a substance. The SI unit of temperature is the degrees Celsius symbolized as ℃**.** It is measured by an instrument called a **thermometer.**The following is the diagram for a thermometer

THE IMPORTANCE OF UNITS OF MEASUREMENTS TO THE STUDY OF CHEMISTRY

The units of measurements are important in the following ways:

i. Units make the numbers meaningful by giving a sense of numerical data
ii. They help to prevent accidents by giving the right chemicals to be mixed
iii. They help to come up with right quantities of materials that should be mixed.

THE SI PREFIXES

Depending on the magnitude of the quantity, measurements have units of different prefixes. The table below shows some SI unit prefixes, their symbols and their meanings

prefix	symbol	Meaning or conversion factor
Tera-	T	1,000,000,000,000 or 10^{12}
Giga-	G	1,000,000,000 or 10^{9}
Mega-	M	1,000,000 or 10^{6}
Kilo-	K	1,000 or 10^{3}
Deci-	D	$^{1}/10$ 0r 10^{-1}
Centi-	C	$^{1}/100$ or 10^{-2}
Milli-	m	$^{1}/1,000$ or 10^{-3}
Micro-	μ	$^{1}/1,000,000$ or 10^{-6}
Nano-	N	$^{1}/1,000,000,000$ or 10^{-9}
Pico-	p	$^{1}/1,000,000,000,000$ or 10^{-12}

CONVERTING TIME

Time can be converted from one form of time measurement to the other form of time measurement. Consider the following relationships when converting time;

60 seconds =1 minute

60 minutes = 1 hour

24 hours = 1 day

7 days = 1 week

52 weeks = 1 year

Example 1

Convert 3 hours to seconds.

Solution

When tackling this problem, you need to go up the ladder by starting from hours, then to minutes and then to seconds

Note that,**1hr= 60 mins**

$\therefore$ **3 hrs = ? (more)**

$\therefore \frac{\mathbf{3hrs}}{\mathbf{1hr}} \times$ **60 mins** $= 3 \times \mathbf{60mins} = \mathbf{180mins}$

Then you convert 180 minutes to seconds,

1 min = 60 sec

$\therefore$ **180 mins = ? (more)**

$\therefore \frac{\mathbf{180mins}}{\mathbf{1min}} \times \mathbf{60sec}$**= 180** $\times \mathbf{60sec}$

$= \mathbf{10,800seconds}$

Example 2

Convert 30240 minutes to weeks.

Solution

When tackling this problem, you need to go down the ladder by starting from minutes, and then to hours and then to days and finally to weeks as follows:

You know that, 60mins = 1 hr

$\therefore$ **30240 mins = ? (more)**

$\frac{\mathbf{30240mins}}{\mathbf{60mins}} \times \mathbf{1hr} =$ **504 hrs**

Then convert 504 hrs to days,

You know that,24hrs = 1 day

∴ 504 hrs = ?(more)

∴ $\frac{\mathbf{504hrs}}{\mathbf{24hrs}} \times \mathbf{1day}$ **= 21 days**

Lastly you convert 21 days to weeks,

7 days = 1 week

∴ 21 days =? (more)

$\frac{\mathbf{21days}}{\mathbf{7days}} \times$ **1 wk = 3 weeks**

CONVERTING MASS

In order to convert mass from one unit to the other, the following conversion relationship is used:

10 milligrams = 1 centigram

10 centigrams = 1 decigram

10 decigrams = 1 gram

10 grams = 1 decagram

10 decagrams = 1 hectograms

10 hectograms = 1 kilogram

Example 1

Convert 3500 grams (g) to milligrams (mg).

Solution

When tackling this problem, firstly count how many tens are above the grams. You will see that there are 3 tens that are aabove the grams.

Then multiply these 3 tens as follows, $\mathbf{10 \times 10 \times 10 = 1000}$

Which means, 1000 milligrams = 1 gram

But take note that in the question, we have been given grams; therefore, the above equation is written in such a way that the grams should start.

$$\therefore \textbf{1 gram = 1000 milligram}$$

If 1g = 1000 mg

$$\therefore \textbf{3500 g = ? (more)}$$

$$\therefore \frac{\mathbf{3500g}}{\mathbf{1g}} \times \mathbf{1000mg} = \mathbf{3500,000mg}$$

Example 2

Convert 20 decigrams (dg) to decagrams (dag).

Solution

Firstly, you will see that from decigrams to decagrams there are only 2 tens that are above the decagrams.

Then, multiply these 2 tens as follows: $\mathbf{10 \times 10 = 100}$

Which means, 100 dg = 1 dag.

In the question, we have been given decigrams; therefore, there is no need of reversing the equation because the decigram has already started.

If 100dg = 1 dag

$$\therefore \textbf{20 dg = ? (more)}$$

$$\therefore \frac{\mathbf{20dg}}{\mathbf{100dg}} \times \mathbf{1dag} = \mathbf{0 \cdot 2dag}$$

CONVERTING VOLUME

Inorder to convert volume, the following conversion relationship is used

1000 mm^3 = 1 cm^3

1000 cm^2 = 1 dm^3

1000 dm^3 = 1 m^3

1000 m^3 = 1 dam^3

1000 dam^3 = 1 hm^3

1000 hm^3 = 1 km^3

Example1.

Convert 40000 dm^3 to hm^3,

Solution

Note that from dm^3 to hm^3, there are three one thousands a above the hm^3.

In total there are

$\mathbf{1000 \times 1000 \times 1000}$**= 1,000,000,000 dm^3**

$\therefore$ **1,000,000,000dm^3 = 1 hm^3**

$\therefore$**if 1,000,000,000 dm^3 = 1 hm^3**

$\therefore$ **4000 dm^3= ?(less)**

$\therefore \frac{\mathbf{40000dm^3}}{\mathbf{1,000,000,000dm^3}} \times \mathbf{1hm^3}$ **= 0.00004 hm^3**

BASIC AND DERIVED UNITS OF MEASUREMENTS

Basic units of measurements

The basic units of measurements provide a reference that is used to formulate all the derived units of measurements.

The following are the examples of the basic units of measurement:

i. Mass
ii. Temperature
iii. Electric current
iv. Length
v. Time
vi. Force

Derived units of measurement

Derived units of measurements are the products of the basic units and are used as measures of the derived quantities.

The following are the examples of the derived quantities;

i. Area
ii. Volume
iii. Speed
iv. Density
v. acceleration

AREA

Area is derived from the dimension of length. The dimension of area is derived by multiplying the fundamental dimension of length and width.

Area = length $\times$ width

Since the SI unit of length is the metre, therefore the SI unit of area is the square metre, m^2

VOLUME

Volume is a three dimensional quantity that is derived by multiplying length by width by height.

Therefore, volume = length $\times$ width $\times$ height.

If all these three dimensions are in metres, then the derived unit of volume is thus in cubic metres, m^3

SPEED

Speed is defined as the distance travelled per unit time. Speed is derived from the SI unit of length and time.

In mathematical terms,

Speed = $\frac{\text{distance}}{\text{time}}$.

Note that if distance is in metres and if time is in seconds, then the derived unit of speed is in metres per second, m/s.

DENSITY

Density is defined as the mass per unit volume of substance. The SI unit of density is derived from the SI unit of mass and the SI unit of volume.

Mathematically,

Density = $\frac{\text{mass}}{\text{volume}}$

If mass is in kg and if volume is in m^3, then the derived unit of density is in kg/m^3.

ACCELERATION

Acceleration is defined as the rate of change of speed. The SI unit of acceleration is derived from the SI unit peed and the SI unit of time.

Mathematically:

Acceleration = $\frac{\text{speed}}{\text{time}}$

If speed is in m/s and if time in seconds, then the derived SI unit of acceleration is in metres per second squared, m/s^2.

THE SCIENTIFIC METHOD OF INVESTIGATION.

Scientists try to explain what is happening in the world around us. They explain their investigations very carefully. They try to enquire and relate these findings to come up with a solid conclusion.

The following are the steps in the scientific enquiry:

1. ask a question
2. do background research
3. construct a hypothesis
4. test the hypothesis with an experiment
5. analyze data and then draw conclusions

Ask a question

The scientific method starts with asking a question about something that you observe. The question must be about something that you can measure, preferably with a number and a unit of measurement. The following questions are used: how, what, when, who, which, why or where?

Do a back ground research

This involves reviewing scientific literature using the library to help you find the best way to do things and ensure that you do not repeat the same mistakes from the past.

Construct a hypothesis

A hypothesis is an educated guess about how things work. The hypothesis is stated in such a way that you can easily measure and the hypothesis should be constructed in such a way that the question should be answered correctly.

Test the hypothesis with an experiment

Your experiment tests whether your hypothesis is true or not. Note that your experiment should be affair test by making that you change only factor while keeping other factors the same. The experiment should be repeated four or five times to make sure that that the first result was not just an accident or an error.

Analyze data and draw conclusions

Once the experiment is completed, you can collect your measurements and then analyze them to see if they support your hypothesis or not.

FORMULATION OF LAWS AND THEORIES

Note that the scientific enquiry leads to the formulation of laws and theories. This is done through experiments. If the results of the experiment are corrected and consistent they can be used to formulate a theory or a law.

UNIT 2: ESSENTIAL MATHEMATICAL SKILLS FOR CHEMISTRY.

Expressing numbers in standard form and scientific notation.

Scientific notation refers to expressing a number as a product of any number between 1 and 10 to the 10th power. Scientific notation is mostly used when dealing with large quantities or numbers containing many digits since it shortens the notation.

To write a number in scientific notation consider the following steps:

Step 1 : If the number is in decimal notation, move the decimal point to the right of its original position and place it after the first non-zero digit. The exponent of 10 will be the number of places the original decimal point was moved, and it will be *negative* since it was moved to the right.

Example

Write 0.00089 in scientific notation

Solution

We need to move the decimal point to the right 4 places up to number 8 which is the first non zero digit. Then we multiply the result by 10^{-4} and eliminate the meaningless zeros on the left.

The answer will be:

8.9×10^{-4}

Step 2: If the number to be changed to scientific notation is a whole number greater than 10, move the decimal point to the left of its original position and place it after the first digit. The exponent of 10 will be the number of places the original decimal point was moved, and it will be *positive* since it was moved to the left.

Example

Write 125,000 in scientific notation

We need to move five steps to the right up to 1 which is the first digit and then multiply the result by 10^5.

The answer will be:

1.25×10^5

To write a number from scientific notation to standard notation consider the steps below:

Step 1: Move the decimal point the same number of places as the exponent of 10. Move it to the right if the exponent is positive; move it to the left if the exponent is negative. (Add zeros as necessary.)

Step 2: Eliminate the multiplication sign and power of 10.

Step 3: To multiply two numbers in scientific notation, multiply the coefficients and then add the powers of 10.
Step 4: To divide in scientific notation, we divide the coefficients and then subtract the powers of 10.

Example
Write 1.206×10^9 in standard notation:
Solution
Because the exponent is 9, we move the decimal point 9 places to the right.

$1.206 \times 10^9 = 1.206000000 = 1,206,000,000$

Example
Write 3.05×10^{-7} in standard notation
Solution
Because the exponent is -7, we must move the decimal point 7 places to the left.
$3.05 \times 10^{-7} = .000000305 = 0.000000305$

Practice questions
Rewrite each number in scientific notation:
1. Number of pounds of advertising mail received by Americans in one year: 3,650,000,000 pounds
2. A red blood cell count is typically about 5,000,000/mm^3 blood. Express this count in scientific notation.
3. The average human brain is believed to have about 100 billion nerve cells.

Express this in scientific notation.
4. 0.0000720.008
5. Time needed to compress a deuterium pellet by laser light: 0.000000001 second
6. Size of a DNA molecule: 0.00000217 millimeter

Rewrite each number in standard notation:
7. Energy given off by a hurricane: 5.0×10^{22} ergs
8. Number of gallons of water used by Americans daily: 4.5×10^{11} gallons
9. The pH value of a certain chemical is 1.0×10^{-2}
10. Number of seconds in the month of January: 2.6784×10^6 seconds
11. An x-ray has a wavelength of 1×10^{-10}

Compute and express your answers in scientific notation:

12. $(1.24 \times 10^{-13}) \div (6.2 \times 10^{20})$
13. $(1.24 \times 10^{-23}) \times (0.08 \times 10^{2})$
14. $(0.02) \times (0.000000078)$
15. $(5.6 \times 10^{18}) \div (2.8 \times 10^{18})$
16. $(1.2 \times 10^{-13}) \times (24000000)$

Significant figures

There are three rules on determining how many significant figures are in a number:

1. **Non-zero digits are always significant.**
2. **Any zeros between two significant digits are significant.**
3. **A final zero or trailing zeros in the decimal portion ONLY are significant.**

Rule 1: Non-zero digits are always significant.

Hence a number like 26.38 would have four significant figures and 7.94 would have three. The problem comes with numbers like 0.00980 or 28.09.

Rule 2: Any zeros between two significant digits are significant.

Suppose you had a number like 406. By the first rule, the 4 and the 6 are significant. However, to make a measurement decision on the 4 (in the hundred's place) and the 6 (in the unit's place), you HAD to have made a decision on the ten's place.

Rule 3: A final zero or trailing zeros in the decimal portion ONLY are significant.

For example the final zeros below are significant
0.005**00**
0.0304**0**

Note the following a bout zeros

a) **Space holding zeros on numbers less than one are not significant**

Here are the first two numbers from just above with the digits that are NOT significant in boldface:

0.**00**500
0.**0**3040

These zeros serve only as space holders. They are there to put the decimal point in its correct location. They DO NOT involve measurement decisions.

b) **The zero to the left of the decimal point on numbers less than one is not significant**

When a number like 0.00500 is written, the very first zero (to the left of the decimal point) is put there by convention. Its sole function is to communicate unambiguously that the decimal point is a decimal point.

c) **Trailing zeros in a whole number are not significant.**

200 is considered to have only ONE significant figure while 25,000 has two.

This is based on the way each number is written. When whole number are written as above, the zeros, BY DEFINITION, did not require a measurement decision, thus they are not significant.

Addition and Subtraction of significant figures

When computing addition and subtraction of significant figures, consider the following:

1) Count the number of significant figures in the decimal portion of each number in the problem. (The digits to the left of the decimal place are not used to determine the number of decimal places in the final answer.)

2) Add or subtract in the normal fashion.

3) Round the answer to the LEAST number of places in the decimal portion of any number in the problem.

Multiplication and Division of significant figures

The following rule applies for multiplication and division:

The LEAST number of significant figures in any number of the problem determines the number of significant figures in the answer.

This means you MUST know how to recognize significant figures in order to use this rule.

Example #1

How many significant figures will the answer to 3.10 x 4.520 have?

You may have said two. This is too few. A common error is for the student to look at a number like 3.10 and think it has two significant figures. The zero in the hundedth's place is not recognized as significant when, in fact, it is. 3.10 has three significant figures.

Three is the correct answer. 14.0 has three significant figures. Note that the zero in the tenth's place is considered significant. All trailing zeros in the decimal portion are considered significant.

Example #2:

2.33 x 6.085 x 2.1. How many significant figures in the answer?

Answer - two.

Which number decides this?

Answer - the 2.1.

Why?

It has the least number of significant figures in the problem. It is, therefore, the least precise measurement.

Accuracy and Precision in Measurements

Accuracy is how close a measured value is to the actual value

It shows the agreement between an experimental value, or the average of several Determinations of the value,with an accepted or theoretical ("true") value for a quantity.
Accuracy is usually expressed as a percent difference:

$$\% \text{ difference} = \frac{(\text{measured value} - \text{true value}) \times 100\%}{\text{true value}}$$

Precision is defined as how close two measured values are to one another.

UNIT 3: COMPOSITION AND CLASSIFICATION OF MATTER

By the end of this chapter students will be able to appreciate the composition and properties of various natural and synthetic substances which form their environment.

MATTER

Matter is anything around us which has mass and occupies space. Everything that we see around us is matter. The following are some of the examples of matter:

i. Chalk
ii. Stone
iii. Duster
iv. Water
v. Paraffin
vi. Cooking oil
vii. Air

COMPOSITION OF MATTER

Matter is made up of small particles called **atoms**. These atoms are microscopic which cannot be seen by our naked eyes. The combinations of these atoms form molecules.

An atom is defined as the smallest particle of an element. Each substance is made up of individual particles called atoms. The combination of millions and millions of atoms form matter.

THE STATES OF MATTER

Matter is classified into three phases commonly known as the three states of matter. Generally there are three states of matter:

1. **Solids**
2. **Liquids**
3. **Gases**

SOLIDS

In solids the particles are closely packed and are held by strong attractive forces which make solids to **have fixed volume, fixed shape, and fixed size** at a given temperature. All solids do not flow.

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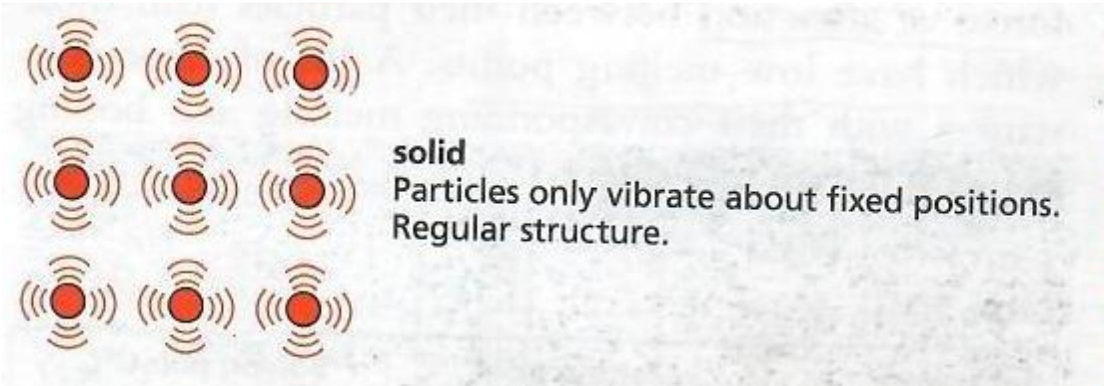
These particles form a three dimensional structure and form an orderly arrangement called lattice.



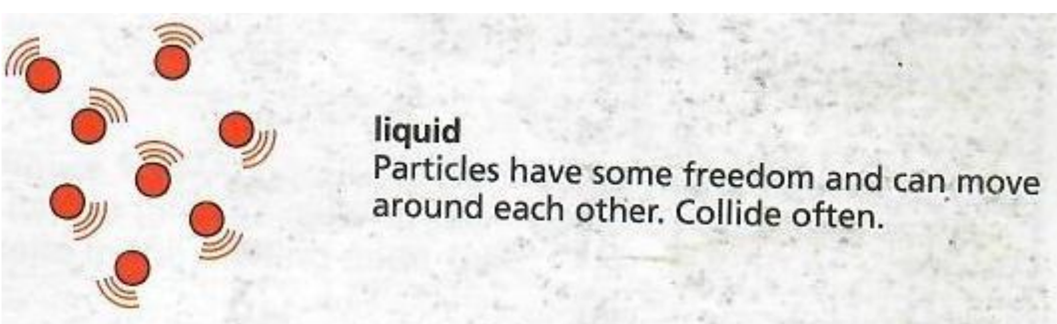
The particles in solids **have no freedom of movement from place to place but rather they can just vibrate to and fro within their fixed positions when they gain enough kinetic energy.**

LIQUIDS

In liquids the particles **are fairly close together but not very tightly packed as compared to solids.**

All liquids have fixed volume, but they take the shape of their containers in which they are put. All liquids do flow.

Particles in liquids are **held by fairly strong forces of attraction which are not as strong as compared to the attractive forces in solids.**

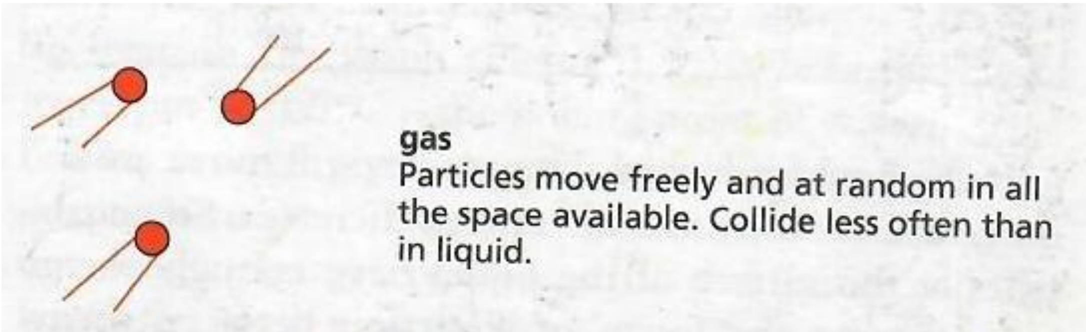


There are some small spaces in between the adjacent particles in liquids**which makes these particles to have little freedom of movement. Therefore the particles in liquids can slightly move around each other by sliding.**

GASES

In gases the particles are far apart from one another. All gases have no fixed volume, no fixed shape. Gases do flow.

These particles **are free to move randomly in all directions, in straight lines.**



The intermolecular forces in gases are negligible (almost zero) which makes these particles to travel freely at high speeds in all directions and in straight lines.

EVIDENCE THAT MATTER IS MADE UP SMALL PARTICLES

The following are the evidence which shows that matter is made up of small particles:

i. Diffusion of substances in the air
ii. Dissolving of substances in water

Diffusion of substances in air

Diffusion is defined as the movement of particles from a region of high concentration to a region of low concentration.

When you put paraffin at one corner of the room, you will see that after a few minutes you will feel the smell of paraffin. This means that the paraffin molecules have moved all over the room. This is diffusion. This further indicates that paraffin is made up of small microscopic particles.

Dissolving of substances in water

When you put blue potassium permanganate crystals in water, the colour of water gradually changes to blue until all the water in beaker take the colour of potassium permanganate.

This means that the particles of potassium permanganate have spread evenly into the water molecules.

ELEMENTS AND COMPOUNDS

ELEMENTS

Elements **are molecules which are made up of the same kind of atoms.**

The following are examples of elements:

i. **Oxygen gas molecule, O_2**, is made up of two oxygen atoms only
ii. **Nitrogen gas molecule, N_2**, is made up of two nitrogen atoms only
iii. **Chlorine gas molecule, Cl_2**, is made up of two chlorine atoms only

COMPOUNDS

Compounds are molecules which are made up of different kinds of atoms.

The following are examples of compounds:

i. **Water molecule, H_2O**, is formed by combining two hydrogen atoms and one oxygen atom together.
ii. **Carbon dioxide gas molecule, CO_2**, is made by combining one carbon atom and two oxygen atoms together.

DIFFERENCES BETWEEN ELEMNTS AND COMPOUNDS

The following are the differences between elements and compounds

i. Elements are substances that have only one type of atoms while compounds are substances that are made up of more than one type of the atoms.
ii. Elements cannot be broken down into simpler substances by chemical means while compounds can be broken down into individual elements using reactions

CHEMICAL SYMBOLS OF THE ATOMS OF THE ELEMENTS

Elements and compounds are made by joining two or more atoms together.

The following table shows the names of the first twenty atoms of the elements. Note carefully each atom and its corresponding symbol.

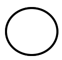
NAME OF THE ATOM	SYMBOL
Hydrogen	H
Helium	He
Lithium	Li
Beryllium	Be
Boron	B
Carbon	C
Nitrogen	N
Oxygen	O
Fluorine	F
Neon	Ne
Sodium	Na
Magnesium	Mg
Aluminium	Al
Silicon	Si
Phosphorus	P
Sulphur	S
Chlorine	Cl
Argon	Ar
Potassium	K
Calcium	Ca

FORMATION OF DIFFERENT MOLECULES USING MODELS OR DIAGRAMS

Formation of molecules of substances can be depicted using the molecular models or diagrams. These models or diagrams represent the atom of the substance.

Note the following key:

 Represents oxygen atom

 Represents carbon atom.

 Represents hydrogen atom

Example 1

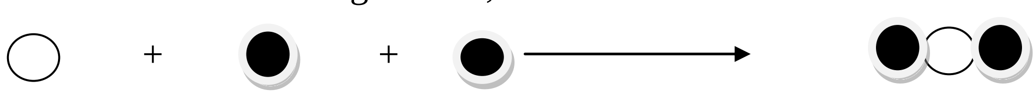
Draw the molecular models for the formation of carbon dioxide, CO_2.

Solution

Note that carbon dioxide is made from combining one carbon atom and two oxygen atoms together.

∴ Carbon + oxygen + oxygen $\longrightarrow$ carbon dioxide

This is shown as follows using models,



Example 2

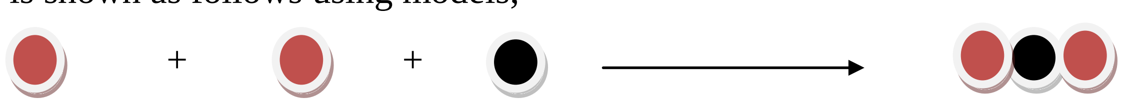
Draw the molecular models for the formation of water, H_2O.

Solution

Note that water is formed from the combination of two hydrogen atoms and one oxygen atom together,

∴Hydrogen + hydrogen + oxygen $\longrightarrow$ water

This is shown as follows using models,



NAMING SUBSTANCES GIVEN THEIR CHEMICAL FORMULAE

Different substances have different chemical formulae hence they also possess different names.

The following are rules which are followed when naming these substances:

Rule 1: when two different elements combine to form a molecule, the name of the molecule usually ends with **–ide.**

Note that when the combining elements are a metal and anon metal, the name of the metal starts and the name of the non metal is written last with an **–ide** at the end.

Rule 2: When the non metal elements only are combining, the name of the elements with smaller atomic number always comes first and those with larger atomic numbers are written last with an **–ide** at the end.

Rule 3: when two identical elements combine the name does not change. The name of the element remains the same.

Example 1

Write the name of the molecules formed between the combination ofSodium and chlorine

Solution

Note that sodium is a metal; therefore its name will not change and will be written first.

Chlorine is a non metal, therefore its name will be written last and the **–ine** part from chlorine will be replaced by **–ide**. Therefore, the name of the molecule is **sodium chloride**

Example 2

Write the name of the molecule formed from the combination of hydrogen and bromine

Solution

Both hydrogen and bromine are non metals and hydrogen has a smaller atomic number, therefore, its name will not change and will be written first.

The name of bromine atom will be written last with an **–ine** part replaced by **–ide**

Therefore the name of the molecule is **hydrogen bromide**

Example 3

Write the name of the molecule formed from the combination of two oxygen atoms.

Solution

Note that these two oxygen atoms are identical; therefore the name of the molecule is **oxygen**

DETERMINING THE TYPE AND NUMBER OF ATOMS IN A GIVEN FORMULAE OF A SUBSTANCE

In any formula of the substance it is possible to determine the number and type of the atoms present in the chemical formula.

Example 1

Determine the number and type of atoms present in water molecule, H_2O.

Solution

Water molecule is made by combining two hydrogen atoms and one oxygen atom.

Therefore **water molecule has 3 atoms in total.**

Example 2

Determine the type and number of atoms present in ammonium nitrate, NH_4NO_3.

Solution

Ammonium nitrate is formed from the combination of two nitrogen atoms, four hydrogen atoms and three oxygen atoms.

In total there **are nine atoms in ammonium nitrate.**

PURE SUBSTANCE AND MIXTURES

PURE SUBSTANCES

A pure substance **is a substance that is made up of only one kind of atoms or molecules.**

All elements and compounds are examples of pure substances because they contain only one kind of particles.

Therefore all elements like **hydrogen, oxygen, chlorine, sulphur are examples of elements.**

Likewise all compounds like **water, sugar, carbon dioxide, sodium hydroxide, hydrochloric acid, and silicon dioxide are examples of pure substances.**

Note that a pure substance not be separated into simpler substances by physical processes like filtering or distillation.

MIXTURES

A mixture is a substance which consists of two or more elements or compounds not chemically combined together.

A mixture can be separated into pure substances by physical processes like filtering and distillation. The following are examples of mixtures,

- Air
- Gun powder
- Brass
- Salt solution (brine)
- Sugar solution

TYPES OF MIXTURES

There are two main types of mixtures:

a) **Homogeneous mixtures**
b) **Heterogeneous mixtures**

HOMOGENEOUS MIXTURE

Homogeneous mixture is a mixture in which the particles are evenly distributed and cannot be distinguished from one another.

Examples of homogeneous mixtures are:

- Salt solution (brine)
- Sugar solution
- Sea water
- Alcohol
- Soft drinks
- Lemonade

HETEROGENEOUS MIXTURE

Heterogeneous mixture is a mixture in which the particles are not evenly distributed and can be distinguished from one another.

Examples of heterogeneous mixtures are:

- A mixture of salt and sand
- Polluted air
- Gun powder
- Ink
- Paint

Differences between a homogeneous and a heterogeneous mixture

i. A homogeneous mixture has uniform composition throughout its mass while a heterogeneous mixture does not have a uniform composition throughout its mass.

ii. A homogeneous mixture has no boundaries of separation while a heterogeneous mixture has boundaries of separation

SOLUTES, SOLVENTS AND SOLUTIONS

SOLUTES

A solute is a substance that dissolves into another substance.

Examples of solutes are:

- Sugar
- Salt
- Ammonium chloride
- Urea
- Copper sulphate

SOLVENTS

A solvent is a substance that dissolves other substances.

Examples of solvents are:

- Water
- Alcohol
- Acetone
- benzene

SOLUTIONS

A solution is homogeneous mixture of two or more substances. It consists of a solute and its solvent.

Examples of solutions are:

- Salt solution (brine)
- Alcohol
- Soft drinks
- Lemonade
- Sugar solution

TYPES OF SOLUTIONS

There are five main types of solutions:

1. Solid in solid solution
2. Liquid in liquid solution
3. Solid in liquid solution
4. Gas in liquid solution
5. Gas in gas solution

SOLID IN SOLID SOLUTION

A Solid in solid solutionis a solution that is formed usually when two different metals are molten and then mixed together to form a different complex metal after cooling.

The metal produced in this way is called an alloy.

Examples of solid in solid mixtures are:

- **Brass;** this is formed after mixing molten zinc and copper metals
- **Bronze;** this is formed after mixing molten tin and copper metals

LIQUID IN LIQUID SOLUTION

Liquid in liquid solution is a solution that is formed by mixing one liquid into another liquid.

Liquid in liquid solutions can be **miscible** or **immiscible.**

Miscible liquids are liquids that can mix completely to form solutions.

The particles of each liquid are spread uniformly into each other to form solutions.

Examples of miscible liquids are:

- A solution of ethanol in water (alcohol)
- A solution of kerosene in oil

Immiscible liquids are liquids that do not mix completely to form solutions. The particles in these liquids do not mix completely into each other. Immiscible liquids usually form two layers

Examples of immiscible liquids are:

- A solution of paraffin in water
- A solution of kerosene in water

Note that all of the above examples are examples of liquid in liquid solutions.

SOLID IN LIQUID SOLUTIONS

A solid in liquid solution is formed when a solid is mixed into a given liquid. Usually this is the common type of solution.

Note that a solid in liquid solution may be in **pure solution** form or **a suspension**.

In Apure solution form, the particles of a solid are spread evenly throughout the whole solution. Examples of these solutions are **sugar solution** and **salt solution.**

In a suspension, some particles eventually settle at the bottom of the beaker while some particles are just suspended all over the solution without settling down. These suspended particles make the mixture to look cloudy, for example, muddy water.

GAS IN LIQUID SOLUTION

A gas in liquid solution is a solution that is formed when a gas is dissolved in a liquid.

Examples of gas in liquid solution are.

- Dissolved oxygen in water used by aquatic animals
- Dissolved carbon dioxide in fizzy drinks like coca cola

GAS IN GAS SOLUTION

This is a solution in which one gas is dissolved into another gas. Air is a solution of gases like oxygen, argon carbon dioxide, and nitrogen. Note that nitrogen is a solvent in air and all other gases are solutes.

SATURATED AND UNSATURATED SOLUTIONS

SATURATED SOLUTION

Saturated solution is a solution in which no more solute can be dissolved at a given temperature. It contains a maximum amount of a solute that will dissolve at a given temperature.

A saturated solution is formed by adding a maximum amount of a solute until the solute cannot dissolve anymore making the solute particles settle at the bottom.

UNSATURATED SOLUTION

An unsaturated solution is a solution in which more quantity of a solute can dissolve at a given temperature. It contains less solute than it has the capacity to dissolve

SOLUBILITY

Solubility is a measure of the ability of a solute to dissolve in a given volume of solvent at a specific temperature. It shows how much of a solute dissolves in a certain amount of a solvent.

MAIN FACTORS THAT AFFECT SOLUBILITY:

Nature of the solute and solvent –The amount of solute that dissolves depends on what type of solute it is. While only 1 gram of lead (II) chloride can be dissolved in 100 grams of water at room temperature, 200 grams of zinc chloride can be dissolved. This means that a greater amount of zinc chloride can be dissolved in the same amount of waterthan lead II chloride.

Temperature -- Generally, an increase in the temperature of the solution increases the solubility of a solid solute. For example, a greater amount of sugar will dissolve in warm water than in cold water. A few solid solutes, however, are less soluble in warmer solutions. For all gases, solubility decreases as the temperature of the solution rises. An example of this is Soda. The solubility of the carbon dioxide gas decreases when a soda is warm, making the soda flat.

Pressure -- For solid and liquid solutes, changes in pressure have practically no effect on solubility. For gaseous solutes, an increase in pressure increases solubility and a decrease in pressure decreases solubility. Example: When the cap on a bottle of soda pop is removed, pressure is released, and the gaseous solute bubbles out of solution. This escape of a gas from solution is called **effervescence**.

FACTORS THAT AFFECT THE RATE OF SOLUTION:

The **rate of solution** is a measure of how fast a substance dissolves.

Size of the particles -- When a solute dissolves, the action takes place only at the surface of each particle. When the total surface area of the solute particles is increased, the solute dissolves more rapidly. *Breaking a solute into smaller pieces increases its surface area and increases its rate of solution.*

Stirring -- With liquid and solid solutes, stirring brings fresh portions of the solvent in contact with the solute. Stirring, therefore, allows the solute to dissolve faster.

Amount of solute already dissolved –When you have very little solute in the solution, dissolving takes place quickly. When you have a lot of solute in the solution, dissolving takes place more slowly.

temperature-- For liquids and solid solutes, increasing the temperature not only increases the amount of solute that will dissolve but also increases the rate at which the solute will dissolve. For gases, the reverse is true. An increase in temperature decreases both solubility and rate of solution.

METHODS OF SEPERATING MIXTURES

The following are the methods of separating mixtures

1. Distillation
2. Filtration
3. Decantation
4. Evaporation
5. Chromatography
6. magnetism

DISTILLATION

Distillation is method of separating mixtures of immiscible liquids of different boiling points. It involves heating a liquid to form vapour and then cooling the vapour to get back the liquid. There are two types of distillation:

i. Simple distillation
ii. Fractional distillation

Simple distillation

Simple distillation is used to separate two liquids of different of different boiling points.

Simple distillation is used to separate the mixture of ethanol and water, the mixture of salt and water etc.

In simple distillation, evaporation and condensation take place at the same time but at different parts of the apparatus.

The diagram below shows the simple distillation apparatus, for the separation of ethanol and water.

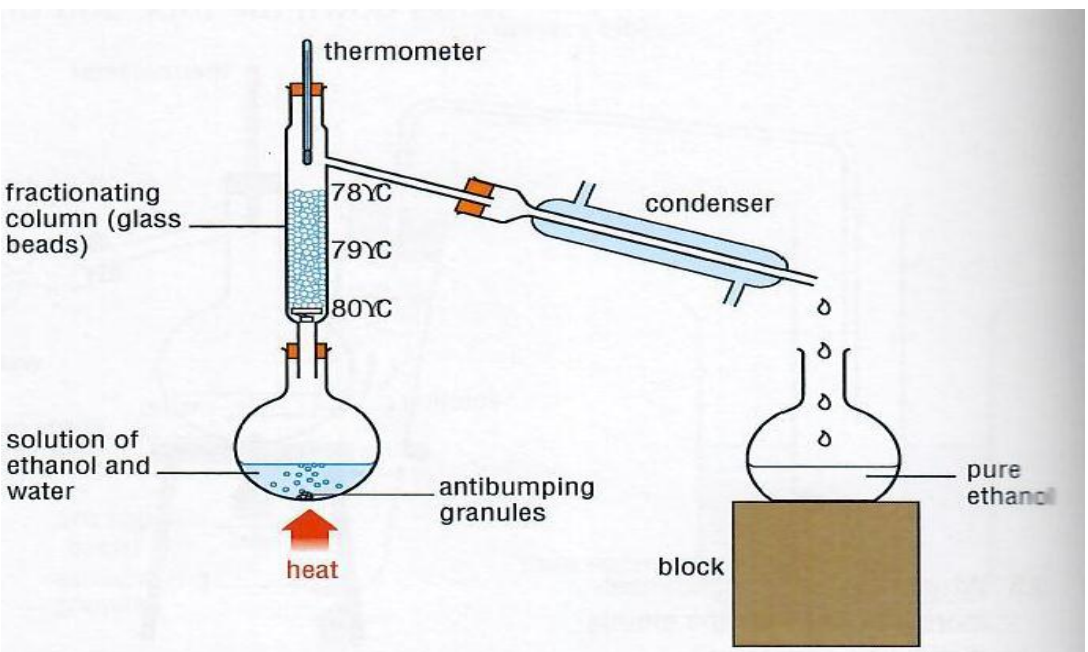


Figure 2.26 The distillation of ethanol.

Firstly, the mixture of ethanol and water is boiled and evaporated in the distillation flask. The boiling point of water is 100℃ and the boiling point of ethanol is 78℃. This means that when the mixture is heated ethanol will start to evaporate because it has low boiling point.

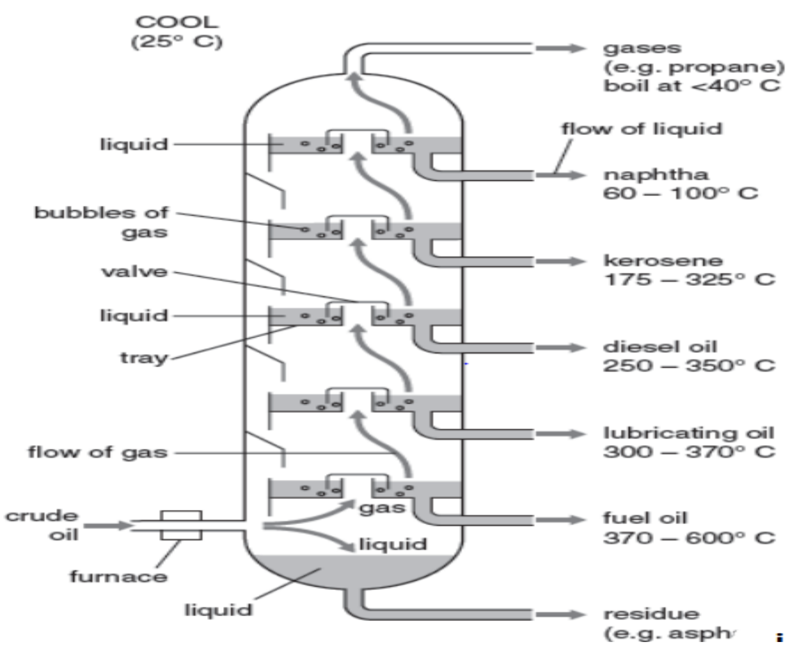
This ethanol vapor is condensed by passing it through a condenser, which is cooled by water. This condensed ethanol is transferred into a container. The pure ethanol collected is called a distillate.

When the thermometer reads just above 78℃ all the ethanol is gone and what remains is water

Fractional distillation

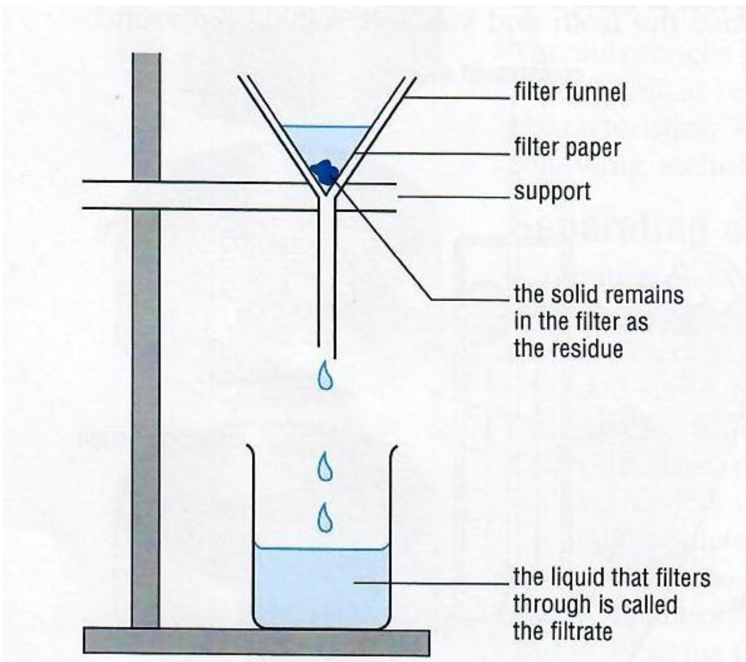
Fractional distillation is used to separate more than two liquids of different boiling points. An example of fractional distillation is the separation of water, ethanol and nitrobenzene.

Note that water has a boiling point of 100℃, ethanol has a boiling point of 78℃ and nitrobenzene has a boiling point of 210℃. When this mixture is heated, the liquids will come out in their order of their boiling points. The liquid with the lowest boiling point will come out first and the liquid with the highest boiling point will be the last to come out.



FILTRATION

Filtration is a method used to separate a mixture of a liquid and an insoluble solid using a filter. For example sand and water can be separated by filtration. The diagram below shows an apparatus used to separate the mixture of sand and water.



In the diagram above, when the mixture of sand and water is put on the filter, water runs through the filter and is collected in the collecting bottle, sand remain on the filter as the residue.

DECANTATION

Decantation is a method of separating mixture of immiscible liquids such as the mixture of water and paraffin. This involves pouring off the top layer of the mixture into another container.

Decantation can also be used to separate the mixture of a liquid from an in soluble solid which has a density greater than water. For example, when lime is mixed with water, it does not dissolve but it settles down at the bottom of the container. Then water if poured off at the top and lime remain behind.

EVAPORATION

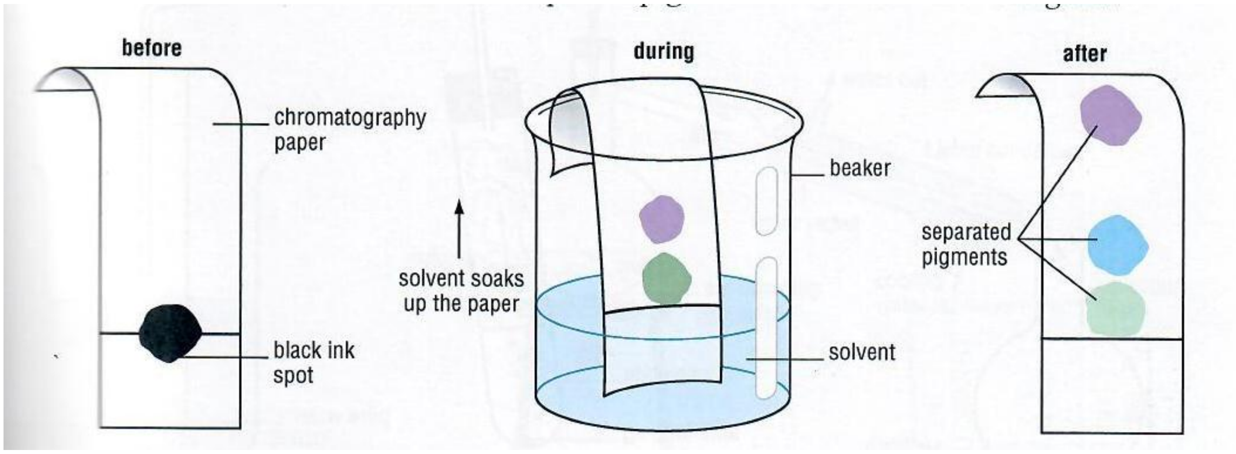
Evaporation is a method of obtaining a soluble solid from a solvent.

This is done by heating the mixture so that the solvent evaporates completely leaving behind the solute.

CHROMATOGRAPHY

Chromatography is a method of separating mixtures of colours. This is done by taking advantage of the colours different rate of movement over the absorbent paper.

This is done by putting a spot of the ink on the piece of the chromatography paper called chromatogram.



The chromatogram is then dipped into a suitable solvent ink, as the solvent moves up the paper, the dyes are carried with it and begin to separate. They separate because the substances have different solubilities in the solvent and are absorbed to different degrees by the chromatogram.

MAGNETISM

Magnetism is amethod of separating mixtures of magnetic and non magnetic materials. This is done by bringing the magnet closer to the mixture. Then the magnet attracts magnetic materials leaving behind non magnetic materials.

UNIT 4 : ATOMIC STRUCTURE

By the end of this chapter, students will be able to appreciate properties of various inorganic compounds, their uses in the manufacturing industry and the dangers they pose on the environment.

COMPOSITON OF AN ATOM

An atom is a smallest particle of an element that makes up molecules.

It consists of the following:

- Protons
- Electrons
- Neutrons
- Nucleus
- Shells

Protons

Protons are positively charged particles which are found inside the nucleus of an atom.

Electrons

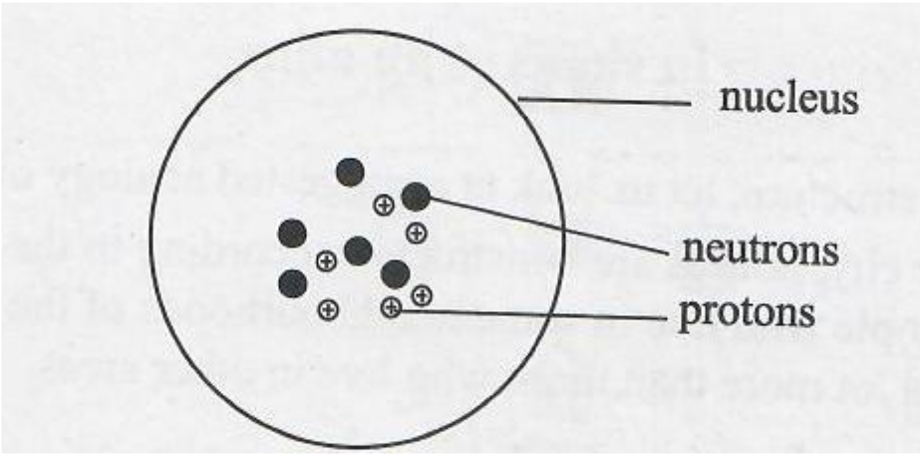
Electrons are negatively charged particles which are found outside the nucleus of an atom in the shells or orbits.

Note that in any electrically neutral atom, the number of electrons is exactly equal to the number of protons. In real sense, any neutral atom has an overall charge of zero.

Neutrons

Neutrons are found inside the nucleus of an atom. It possesses no charge at all.

THE STRUCTURE OF AN ATOM



ATOMIC NUMBER

Atomic number is the number of protons in the nucleus of an atom. It is denoted by capital letter Z.

MASS NUMBER

Mass number is the total number of neutrons plus protons. It is denoted by capital A.

POSITION OF THE MASS NUMBER AND ATOMIC NUMBER ON AN ATOM

Mass number is placed on the top left of any atom while atomic number is put on the bottom left of any atom.

Let's consider that the symbol of the atom is X, then the positioning of mass and atomic numbers will be as follows:

$$^{A}_{Z}\mathbf{X}$$

Given that,

Z represents number of protons

N represents number of neutrons

Then from the definition,

Mass number = number of protons + number of neutrons

Using the symbols we have:

A = Z + N

Example 1

Given that atom X has 17 protons, 20 neutrons and 17 electrons.

a) Find the charge of the atom
b) Find the atomic number, Z
c) Find the mass number, A
d) Write the nuclide symbol of element X

Solution

a) The overall charge of the atom is **zero** because the number of protons and neutrons is the same.
b) From the question, **Z = 17**, the number of protons

c) From the equation, **A = Z + N**
Z =20, and N = 20
∴ A = 17 + 20

∴ A = 37

∴ Mass number of element X is 37

d) Therefore the nuclide symbol, for element X is as follows

$$^{37}_{17}\mathbf{X}$$

THE MASS OF APROTON, A NEUTRON AND AN ELECTRON

The proton

The mass of a proton is always 1. Therefore the symbol of a proton is as shown below:

$$^{1}_{1}\mathbf{P}$$

This means that a proton has a mass number of 1 and an atomic number of 1. Remember also that the charge of a proton is +1.

The neutron

The mass number of a neutron is 1and the symbol for a neutron is as shown below:

$$\mathbf{{}^{1}_{0}n}$$

This means that the neutron has a mass number of 1 and an atomic number of 0. The overall charge of a neutron is 0.

The electron

The mass number of an electron is -1 and its symbol is as shown below:

$$\mathbf{{}^{0}_{-1}e}$$

This shows that an electron has a mass number of 0 and an atomic number of -1. The overall charge of an electron is -1.

ISOTOPES

Isotopes are atoms of the same element with the same `atomic numbers but different mass numbers. This difference in mass numbers is due to the difference in the number of neutrons in their nuclei.

EXAMPLES OF ISOTOPES

Isotopes of carbon

There are three well known isotopes of carbon

1. Carbon-12
   The nuclide symbol for carbon-12 is ${}^{12}_{6}C$. This means that carbon-12 has a mass number of 12 and an atomic number of 6. There are 6 neutrons in carbon-12.
2. Carbon-13
   The nuclide symbol for carbon-13 is ${}^{13}_{6}C$. This means that carbon-13 has a mass number of 13 and an atomic number of 6. There are 7 neutrons in carbon-13
3. Carbon-14
   The nuclide symbol for carbon-14 is ${}^{14}_{6}C$. This means that carbon-14 has a mass number of 14 and an atomic number of 6. Therefore carbon-14 has 8 neutrons.
   You will note that all the three isotopes of carbon have the same atomic number of 6 but they have different mass numbers and number of neutrons
   Isotopes of chlorine

There are two well known isotopes of chlorine

1. Chlorine-35
   Chlorine-35 has the nuclide symbol of $^{35}_{17}Cl$. This means that chlorine-35 has an atomic number of 17 and a mass number of 35. Therefore, chlorine-35 has 18 neutrons.
2. Chlorine-37
3. The nuclide symbol for chlorine-37 is $^{37}_{17}Cl$. This means that chlorine-37 has an atomic number of 17 and a mass number of 37. Therefore chlorine-35 has 20 neutrons.
   You will note that all these two isotopes of chlorine have the same atomic number of 17 but they have different mass numbers and number of neutrons.

CALCULATING THE AVERAGE MASS OF AN ELEMENT GIVEN THE MASSES OF THE ISOTOPES

Relative atomic mass is the average mass of the isotopes of an element related to the mass of carbon-12.

Inorderto calculate the relative atomic masses of the isotopes we use the percentage abundances or ratios of the isotopes.

$$\text{Relative atomic mass} = \frac{\text{average mass of isotopes in amu}}{\frac{1}{12}\times\text{mass of carbon}-12\text{ in amu}}$$

Note that in the formula, the denominator is always 1 hence in most cases the denominator is not included to shorten our calculations.

Calculating relative atomic masses of elements using percentage abundances

Example 1

Calculate the relative atomic mass of chlorine if the percentages aabundances of the isotopes of chlorine in nature are 75% for chlorine-35 and 25% for chlorine-37.

Solution

$$\text{Ar of chlorine} = \frac{\text{average mass of chlorine isotopes}}{\frac{1}{12}\times\text{mass of carbon}-12}$$

$$\text{Ar of chlorine} = \frac{\frac{(35\times75)+(37\times25)}{100}}{\frac{1}{12}\times12}$$

Note that the denominator is 1; hence it will be left out for simplicity sake.

Arof chlorine = $\frac{2625+925}{100}$

Ar of chlorine = $\frac{3550}{100} = 35.5$

Calculating relative atomic masses of elements using ratios

Example 2

Chlorine consists of two isotopes, chlorine-35 and chlorine-37 in the ratios of 3:1 respectively. Calculate the relative atomic mass of chlorine

Solution

Average mass of chlorine = $\frac{\text{total mass of all atoms}}{\text{total number of atoms in the ratio}}$

Average mass of chlorine = $\frac{(3 \times 35) + (1 \times 37)}{4}$

Ar of chlorine = $\frac{105+37}{4} = \frac{142}{4}$

Ar of chlorine = 35.5

UNIT 5 : THE PERIODIC TABLE

The periodic table is a chart that shows the arrangement of elements in order of increasing atomic numbers.

MAIN FEATURES OF THE PERIODIC TABLE

Generally the periodic table has two main features:

- Groups or families
- Periods or series

GROUPS OR FAMILIES

Groups or families are the vertical columns while periods or series are horizontal rows.

There are 8 groups of the periodic table. The following is the periodic table that shows the first twenty elements arranged in order of increasing atomic numbers.

V VIII

$^{1}_{1}H$	II	III	IV	V	VI	VII	$^{4}_{2}He$
$^{7}_{3}Li$	$^{9}_{4}Be$	$^{11}_{5}B$	$^{12}_{6}C$	$^{14}_{7}N$	$^{16}_{8}O$	$^{19}_{9}F$	$^{20}_{10}Ne$
$^{23}_{11}Na$	$^{24}_{12}Mg$	$^{27}_{13}Al$	$^{28}_{14}Si$	$^{31}_{15}P$	$^{32}_{16}S$	$^{35.5}_{17}Cl$	$^{40}_{18}Ar$
$^{39}_{19}K$	$^{40}_{20}Ca$						

THE GENERAL DISTRIBUTION OF THE ELEMENTS IN THE PERIODIC TABLE

In the periodic table, elements of groups 1, 2 and 3 are metals while elements of 4, 5, 6, 7 and 8 are non metals.

ELECTRON CONFIGURATION OF THE FIRST TWENTY ELEMENTS

Electron configuration is the number and arrangement of electrons in the shells of an atom.

Note that the electrons live in the shells of an atom. Each particular shell has the maximum number of electrons that should be filled in at a time.

The following formula helps to fine the maximum number of electrons that should be filled in at a time:

$\mathbf{2n^2}$ Where n stands for the number of shells or energy levels.

For example,

- Shell 1 is filled up to $2(1)^2$ electrons = up to 2 electrons
- Shell 2 is filled up to $2(2)^2$ electrons = up to 8 electrons
- Shell 3 is filled up to $2(3)^2$ electrons = up to 18 electrons and so on

Note that, when we say shell 2 is filled up to 8 electrons, it does not mean that shell 2 should be filled by exactly 8 electrons always, but it simply means that the maximum number of electrons in shell 2 should not exceed 8.

The following table shows the electron configuration of the first 20 elements.

ELEMENT	SYMBOL	ELECTRON CONFIGURATION
Hydrogen	H	1
Helium	He	2
lithium	Li	2,1
beryllium	Be	2,2
Boron	B	2,3
Carbon	C	2,4
Nitrogen	N	2,5
Oxygen	O	2,6
Fluorine	F	2,7
Neon	N	2,8
Sodium	Na	2,8,1
Magnesium	Mg	2,8,2
Aluminium	Al	2,8,3
Silicon	Si	2,8,4
Phosphorus	P	2,8,5
Sulphur	S	2,8,6
Chlorine	Cl	2,8,7
Argon	Ar	2,8,8
Potassium	K	2,8,8,1
Calcium	Ca	2,8,8,2

THE RELATIONSHIP BETWEEN NUMBER OF ELECTRONS IN THE OUTERMOST SHELL AND THE GROUP NUMBER.

The group in which a particular element belongs tells the number of valence electrons (outermost electrons) of that particular element.

For example, lithium is in group hence it has 1 outer most electron only

Carbon is in group 4 hence it has 4 outermost electrons

Argon is in group 8 hence it has 8 outer most electrons

Note that all group 8 elements have 8 outer most electrons except helium which has two valence electrons.

Note that hydrogen is a non-metal element but it is placed on top of group one elements for convenience sake. It is not a group one element.

THE RELATIONSHIP BETWEEN THE NUMBER OF PERIODS AND THE SHELLS OF AN ELEMENT.

The period number of a particular atom indicates the number of shells of that particular atom.

For example,

- All elements in period number 2 have two shells
- All elements in period number 3 have three shells and so on.

FAMILY NAMES OF SOME ELEMENTS IN THE PERIODIC TABLE

Some groups in the periodic table have been given special names.

Alkali metals

All group 1 elements are called alkali metals. These elements are

- Lithium
- Sodium
- Potassium
- Rubidium
- cesium

Alkali earth metals

All group 2 elements are called alkali earth metals. These elements are:

- Beryllium
- Magnesium
- Calcium
- Strontium
- Barium

Halogens

All group 7 elements are known as halogens. These elements are:

- Fluorine
- Chlorine
- Bromine
- Iodine
- Astatine

Noble gases or inert gases

All group 8 elements are known as noble gases or inert gases. These elements are:

- Helium
- Neon
- Argon
- Krypton
- Xenon
- Radon

UNIT 6: PHYSICAL AND CHEMICAL CHANGES

By the end of this chapter students will be able to demonstrate an understanding of reaction dynamics and chemical energies essential for the advancement for the chemical and manufacturing industry.

PHYSICAL CHANGES

A physical change is a reversible change in which a substance undergoes a change in its physical properties. A physical change is also known as a temporary change.

Examples of physical changes

i. Melting of substances
ii. Boiling of substances
iii. Freezing of substances
iv. Condensing of substances
v. Dissolving of substances

CHARACTERISTICS OF PHYSICAL CHANGES

The following are the characteristics of physical changes:

i. No new substances are formed
ii. The change is temporary and can always be reversed
iii. The mass of the substance remains unchanged
iv. No energy change occurs

CHEMICAL CHANGES

A chemical change is an irreversible change in which complete new substances with different properties are formed. A chemical change is also known as a permanent change.

Examples of chemical changes

i. Burning of wood
ii. Mixing of two solutions forming a precipitate
iii. Rusting of iron
iv. Decomposition of food
v. Grinding maize into maize flour

CHARACTERISTICS OF CHEMICAL CHANGES

i. New substances are formed
ii. The change is permanent
iii. Mass of substances changes
iv. Energy change is involved

DIFFERENCES BETWEEN A PHYSICAL CHANGE AND A CHEMICAL CHANGE

i. In a physical change no new substances are formed while in a chemical change complete new substances are formed.
ii. A physical change is reversible while a chemical change is irreversible
iii. In physical change, intermolecular forces are just weakened while in a chemical change bonds are broken down
iv. Physical changes involve no energy changes while chemical changes involve energy changes.

CHEMICAL REACTIONS

A chemical reaction is a chemical process in which new substances with new properties are formed.

A chemical reaction involves the rearrangement of atoms between reacting substances forming new substances. It consists of two things:

- Reactants
- products

Reactants are substances that take part in a chemical reaction.

Products are new substances formed as a result of the chemical reaction

EXPRESSING CHEMICAL REACTIONS

Note that chemical reactions are expressed using word and chemical equations.

A very good example of a chemical reaction is the burning of magnesium ribbon in air to produce magnesium oxide.

In word equation, this can be represented as follows.

Magnesium + oxygen $\longrightarrow$ magnesium oxide,

In symbols this can be represented as follows:

$Mg + O_2 \longrightarrow MgO$

Balancing simple chemical equations

i. The following are the rules for balancing simplechemical equations
ii. Write the equation using the correct formula for the reactants and products
iii. Count the number of atoms of each element in the reactant and the product sides.
iv. Balance the equation by writing the coefficients of reactants and products on either side.
v. Insert the correct state symbols for each substance

UNIT 7: ORGANIC COMPOUNDS

Organic compounds are compounds of the hydrocarbon and their derivatives. They occur in all living organism like microorganisms, plants, animals and human beings.

NATURAL SOURCES OF HYDROCARBONS

The following are the natural sources of organic compounds:

a) **Plants and animals**
   These organisms synthesize many organic compounds; these include sugar, starch, fats, dyes, drugs etc
b) **Petroleum**
   Petroleum is a fossil fuel that originates from dead organisms that have undergone chemical changes over a million years.
c) **Natural gas**
   Natural gas is found underground on top of the crude oil deposits. It is also found under the sea
d) **Coal**
   Coal is a fossil fuel that is formed from decayed plant materials that have been subjected to heat and pressure over many years. When the dead plant and animals are buried and compressed by sediments so that they are embedded in rocks they are called fuels.

FUELS

A fuel is any substance which when burnt in plenty of oxygen it produces heat or any other form of energy.

TYPES OF FUELS

There are two main types of fuels:

1. **Bio fuels**
2. **Fossil fuels**

BIO FUELS

Bio fuels are fuels whose energy is obtained through the process of biological carbon fixation. These are mainly fuels from living organisms. The following are the examples of bio fuels.

i. **Biogas**
ii. **Ethanol**

iii. **Biodiesel**

BIOGAS

Biogas is a gas that is produced by the breaking down of organic matter in the absence of oxygen. It is a product of anaerobic digestion of sewage, animal by-products, agricultural wastes, industrial wastes and municipal wastes. This anaerobic digestion can take place in swamps, landfills or biomass digesters.

USES OF BIOGAS

Biogas is used as a fuel in the following ways:

i. To generate electricity
ii. To illuminate domestic and street lights
iii. For running tube-well engines and water pump set engines.
iv. For cooking and heating
v. For cooling in absorption refrigerators
vi. As a fuel for vehicles

ETHANOL

Ethanol is the alcohol that is produced by the fermentation of sugars by the help of enzymes in the yeast cells.

USES OF ETHANOL

i. Used in the manufacturing of dyes and acetic acid
ii. Used as a fuel in the cars
iii. Used in thermometers
iv. Used to make paints and spirit

BIODIESEL

This is the fuel that is produced from vegetable oils and animal fats. This fuel is produced when vegetable oil and animal fats are chemically reacted with alcohol to produce the biodiesel.

USES OF BIODIESEL

i. To power diesel railway engines in blend with other fuels.
ii. Used as fuels in aircrafts

FOSSIL FUELS

Fossil fuel is a fuel that is produced by the anaerobic decomposition of buried plants and animals million of years ago. They are found in sedimentary rocks.

The remains of the dead plants form coal while the remains of the dead animals form petroleum and natural gas.

EXAMPLES OF FOSSIL FUELS

The following are the examples of fossil fuels:

COAL

Coal is a fuel that is found in sedimentary rocks consisting of water, carbon and volatile gases.

USES OF COAL

i. Producing electricity
ii. Manufacturing of gaseous fuels and cement
iii. Production of steel

PETROLEUM OR CRUDE OIL

Petroleum is hydrocarbon oil found in the rock strata. It is a naturally occurring complex mixture made up of carbon and hydrogen compounds.

USES OF PETROLEUM OR CRUDE OIL

i. Manufacturing of plastics
ii. Manufacturing of plastic and oil based paints
iii. Manufacturing of wax

NATURAL GAS

Natural gas is a naturally occurring mixture of methane, ethane, propane, and butane gases which are produced by the remains of dead animals.

USES OF NATURAL GAS

i. As a domestic and industrial fuel
ii. Used to prepare black carbon
iii. Used in the manufacture of fertilizers

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COMPOSITION OF PETROLEUM

Petroleum is composed of hydrocarbons in which some are gaseous while some are liquids. It is also known as crude oil because it is in a non refined state and cannot be used in that state.

Generally petroleum is composed of the mixture of the following hydrocarbons:

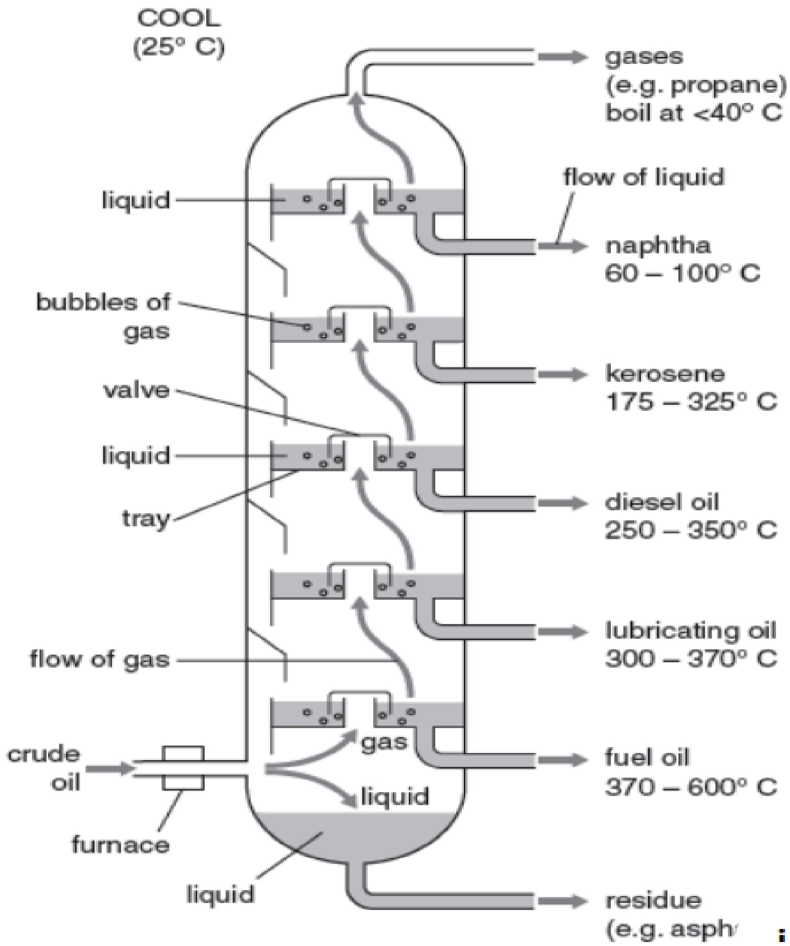
i. Paraffin
ii. Petrol
iii. Diesel
iv. Grease
v. Wax
vi. Oil
vii. Benzene
viii. Kerosene
ix. Bitumen

Note that these substances that form a composition of petroleum are known as petroleum fractions.

SEPERATION OF PETROLEUM FRACTIONS INTO USEFUL PRODUCTS BY FRACTIONAL DISTILLATION.

Fractional distillation is the process of separating fractions of petroleum basing on their boiling points.

The components of petroleum have different sizes, weights and boiling points. In order to use these components there is need to separate them and this is only done by fractional distillation.



In order to separate petroleum into its useful fractions, firstly it is heated and the components with the lowest boiling points will boil off first. it is cooled upon rising and then condenses when it reaches the condensation points. It is then passed into collecting tanks as a liquid. The other components will do the same in order of increasing boiling points.

USES OF PETROLEUM FRACTIONS

PETROL

- It is mostly used as a fuel in vehicles. Petrol is commonly known as Gasoline.

DIESEL

- It is mostly used a as fuel for heavy vehicles like Lorries, trucks and buses.

BITUMEN

- It is used to surface the roads
- It is also used to repair leaked roofs

PARAFFIN

- It is used as a fuel in the homes for cooking and lighting

LUBRICANTS

- It is used to reduce friction in moving parts of machines to a void wearing out of the machine parts.

UNIT 8: ELEMENTS AND THE PERIODIC TABLE

By the end of this chapter students will be able to appreciate the properties of various inorganic compounds their uses in the manufacturing industry and the dangers they pose on the environment.

BLOCKS OF ELEMENTS IN THE PERIODIC TABLE

Elements of the periodic table are classified intothreeblocks:

- **metals**
- **Non metals**
- **Metalloids**

METALS

Generally elements of groups 1,2 and 3 are metals. These elements are good conductors of heat and electricity.

NON METALS

Non metals are elements of group 4,5,6,7 and 8 of the periodic table. These do not conduct heat and electricity.

METALLOIDS

Metalloids are elements which behave as metals and non metals. These have the properties of both metals and non metals. They are usually called semi metals.

Examples of metalloids are

- Boron
- Silicon
- Germanium

TRENDS IN THE PROPERTIES OF ELEMENTS IN THE PERIODIC TABLE

The properties of the elements in the periodic table exhibit trends or periodicity across the periodic table.

The following are the trends or patterns of elements in the periodic table

- **Atomic radii**
- **Ionization energy**
- **Electron affinity**

- **Electro negativity**

Atomic radii

Atomic radius is the distance from the centre of the nucleus of an atom to the outer most shell.

Atomic radius decreases when we move across the period from left to right of the periodic table because when we move from left to right the effective nuclear charge increases which pulls the shells inwards thereby decreasing the size of the atoms.

Atomic radii increases when we move down the group this is because moving down the group the number of shells increases thereby increasing the sizes of the atoms

Ionization energy

Ionization energy is the energy needed to remove an electron from a gaseous atom.

The closer and more tightly bound an electron is to the nucleus the more difficult it will be to remove it from the atom thereby increasing its ionization energy.

When moving from left to right across the periods of the periodic table the ionization energy increases because moving from left to right the sizes of the atoms decrease making the outermost electrons to be tightly bound to the nucleus making it difficult to remove them.

When going down the group, the ionization energy decreases because going down the group the number of shells increases making the outer most electrons to be further away from the nucleus making it loosely bound to the nucleus, hence it becomes easier to remove.

Electron affinity

Electron affinity is the ability of an atom to accept electrons. It is the energy change that occurs when an electron is added to the gaseous atom. Atoms with greater effective nuclear charges have greaterelectronaffinities.

The electron affinity of metals is almost zero since they don't accept electrons. Non metals generally have grater electron affinities.

Moving from left to right across the periods the electron affinity increases.

Moving down the groups the electron affinity decreases.

Electro negativity

Electro negativity is the ability of an atom to attract shared electrons in a bond. Electronegatity increases as we go along the periods.

Electronegativity is closely related to the ionization energies. Atoms with low ionization energies have low Electronegativities because their nuclei do not exert a strong attractive force on the electrons. Elements with high ionization energies have high electro negativities due to the strong pull exerted on the electrons by the nucleus.

THE PHYSICAL AND CHEMICAL PROPERTIES OF ALKALI METALS

Remember that alkali metals are group 1 elements of the periodic table.

PHYSICAL PROPERTIES OF GROUP 1 ELEMENTS

- They are good conductors of heat of electricity
- They are soft metals
- They are metals with low densities
- They have shinny surfaces when freshly cut with a knife
- They have low melting and boiling points
- They are malleable and ductile

TRENDS IN THE PHYSICAL PROPERTIES OF GROUP 1 ELEMENTS.

Going down the group 1 elements:

- The density increases due to the increase in size and mass of the molecules which increases the mass to volume ratio.
- The boiling and melting points decreases due to the increase in the size of the atoms hence decreased attractive forces between the nucleus and the valence electrons thus less energy is needed to remove electrons from such atoms.
- Electronegativity decreases due to increase in the size of the atoms

CHEMICAL PROPERTIES OF GROUP 1 ELEMENTS

- They burn in oxygen or air with characteristic flame colours to form white solid oxides.
  For example,
  Lithium + water $\longrightarrow$ lithium oxide

  $$\mathbf{4Li_{(s)} + O_{2\,(g)} \longrightarrow 2Li_2O_{(s)}}$$

- They react vigorously with water to form alkaline solutions of the metal hydroxide as well as producing hydrogen gas.

  For example,
  Sodium + water $\longrightarrow$ sodium hydroxide + hydrogen gas

  $$\mathbf{2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}}$$

- They react vigorously with halogens to form metal halides.

  For example,
  Sodium + chlorine $\longrightarrow$ sodium chloride

  $$\mathbf{2Na_{(g)} + Cl_{2\,(g)} \longrightarrow 2NaCl_{(s)}}$$

TRENDS IN THE REACTIVITY OF GROUP 1 ELEMENTS

The reactivity of group 1 elements depends on the ease with which the outer most electron is lost. The easier the removal of an electron from the outer most shell of an element, the more reactive the element is.

The harder the removal of an electron from the outer most shell of an element, the less reactive the element becomes.

The reactivity of group 1 elements increases as we go down the group because going down the group, the size of the atoms increases making the outer most electron to be further away from the nucleus and becomes loosely held, thus requiring less energy and becomes much easier to be removed.

This means that lithium is least reactive of all the alkali metals and potassium is more reactive than lithium and sodium.

USES OF GROUP 1 ELEMENTS

USES OF LITHIUM METAL

- Lithium is used in deoxidizing copper and copper alloys
- It is used to produce lubricating greases
- It is also used in the manufacture of batteries for cell phones and computers
- It is also used in special glasses and ceramics

USES OF SODIUM METAL

- Sodium is used in lamps for street lighting
- Sodium chloride is added to food to increase the taste and flavour
- Sodium carbonate is used for softening water hardness
- Sodium hydroxide and sodium chloride are used in the manufacture of soaps and detergents

USES OF POTASSIUM METAL

- Potassium nitrate is used as a food preservative
- Potassium chloride is used in the manufacture of fertilizer
- potassium hydroxide is used in the manufacture detergents
- Potassium chromate is used in the tanning of leather and in the manufacture of inks, gun powder, and dyes among others

PHYSICAL PROPERTIES OF ALKALINE EARTH METALS

Note that alkaline earth metals are group 2 elements of the periodic table.

The following are the physical properties of group 2 elements:

- They are harder than alkali metals
- They are silvery grey in colour when pure and clean, however they tarnish quickly when left in air.
- They are good conductors of heat and electricity
- They are malleable and ductile
- They have relatively high melting and boiling points than alkali metals
- They are denser than alkali metals

CHEMICAL PROPERTIES OF GROUP 2 ELEMENTS.

The following are the chemical properties of group 2 elements:

- They burn in air to produce white solid oxides

  For example,

  Magnesium + oxygen $\longrightarrow$ Magnesium oxide

  $\mathbf{2Mg_{(s)} + O_{2\,(g)} \longrightarrow 2MgO_{(s)}}$

- They react with water to produce alkaline solutions of the metal hydroxide and hydrogen gas but they do so much less vigorously than the elements in group 1.

  For example,

  Calcium + water $\longrightarrow$ calcium hydroxide + hydrogen gas

  $$\mathbf{Ca_{(s)} + 2H_2O_{(l)} \longrightarrow Ca(OH)_{2\,(aq)} + H_{2(g)}}$$

  USES OF ALKALINE EARTH METALS

  USES OF BERYLLIUM
- It is used in the nuclear reactors as a reflector and moderator
- It is also used in the transmission of X-rays
- Alloys of beryllium are used as structural materials for aircrafts, missiles, space craft, and communication satellites.

USES OF MAGNESIUM

- It is used as a reducing agent in the production of uranium and other metals from their salts
- Magnesium sulphate is used as abrick liner in furnaces
- It is used in computers for radio frequency shielding
- Magnesium hydroxide, magnesium chloride, and magnesium sulphate are used in the manufacture of medicine
- Magnesium is required in the formation of chlorophyll the plants
- Magnesium alloys are used in the construction of aircraft

USES OF CALCIUM

- Calcium is used to remove oxygen, sulphur and carbon from alloys
- It is used as a reducing agent in the extraction of other metals
- Calcium carbonate is used in the manufacturing of cement
- Calcium carbonate is also used in the formation of anti acids

PHYSICAL PROPERTIES OF HALOGENS

Note that halogens are group 7 elements of the period table.

The following are the physical properties of halogens

- These elements are coloured and darken going down the group
- They exist as diatomic molecules
- They show a gradual change from chlorine gas through bromine liquid to solid iodine
- They form molecular compounds with other non metallic elements
- They have low melting and boiling points
- They have a chocking smell
- They are slightly soluble in water

CHEMICAL PROPERTIES OF HALOGENS

They react with hydrogen to produce hydrogen halides which dissolve in water to form acidic solutions.

For example,

Chlorine + hydrogen $\longrightarrow$ hydrogen chloride

$\mathbf{Cl_{2(g)} + H_{2(g)} \longrightarrow 2HCl_{(g)}}$

They react with metals to produce metal halides

For example,

Lithium + bromine $\longrightarrow$ lithium bromide

$2Li_{(s)} + Br_{2(g)} \longrightarrow 2LiBr_{(s)}$

TREND IN THE REACTIVITY OF GROUP 7 ELEMENTS

The reactivity of all group 7 elements depends on the strength of the attractive force that is used to pull the incoming electron. The greater the attractive force, the more reactive an element is. The less the attractive force, the less reactive an element is.

The reactivity of group 7 elements decreases as we go down the group, because as we go down the group, the sizes of the atoms increases hence the nucleus exerts a less force of attraction to the incoming electron thereby decreasing the reactivity.

Fluorine is more reactive halogen because the incoming electron is being more strongly attracted into the outer energy level.

USES OF HALOGENS

USES OF FLUORINE

- It is used in the manufacture of plastics
- It is used inform of fluorides in drinking water and tooth paste because it reduces tooth decay

USES OF CHLORINE

- It is used to make PVC plastics
- It is also used as a disinfectant in drinking water
- It is also used in to manufacture salts

USES OF BROMINE

- It is used to make disinfectants
- Used to make fire retardants
- It is also used as a photographic chemical
- Used in the manufacture of medicines

USES OF IODINE

- It is used as a disinfectant
- Used as a photographic chemical
- Used in the manufacture of plastics
- It is used as an antiseptic in hospitals
- It is added to salt to prevent goiter

PHYSICAL PROPERTIES OF NOBLE GASES OR INERT GASES

Note that noble gases or inert gases are the group 8 elements of the periodic table.

- They are colourless gases
- They exist as individual atoms
- They are poor conductors of heat and electricity
- They have relatively low melting and boiling points because they are molecular compounds
- They are usually less dense
- They are non reactive elements

USES OF GROUP 8 ELEMENTS OF THE PERIODIC TABLE

USES OF HELIUM

- Used to provide an inert atmosphere for welding
- Used as a coolant in nuclear reactors
- Used to inflate tyres in large air crafts

USES OF NEON

- used to make neon advertising signs
- used to make high voltage indicators
- liquid neon is a refrigerant

USES OF ARGON

- used in electric light bulbs
- it provides an inert atmosphere for welding
- used to fill fluorescent tube for lighting

UNIT 9: CHEMICAL COMPOSITION OF MATTER

By the end of this chapter students will be able to appreciate the composition and properties of various natural and synthetic substances which form their environment.

CHEMICAL BONDING

A chemical bond is defined as the combination of atoms to attain stability. A chemical bond holds atoms together in elements and compounds.

TYPES OF CHEMICAL BONDING

There are three main types of chemical bonds:

- Ionic bonding
- Covalent bonding
- Metallic bonding

IONIC BONDING

An ionic bond is an electrostatic force of attraction between the oppositely charged ions.

An ionic bond can also be defined as an electrostatic force of attraction between cations and anions. The ionic bond occurs between metal elements and non metal elements only.

The metal elements lose their valence electrons to attain a noble gas electron configuration. Non metal elements gain the valence electrons to attain a noble gas electron configuration.

CATIONS AND ANIONS

A cation is a positively charged ion. It is formed when metal elements lose their valence electrons. The following are the examples of cations:

- **Lithium ion, Li^+,** +1 charge on lithium atom means that lithium has lost one valence electron.
- **Magnesium ion, Mg^{+2},** +2 charge on magnesium means that magnesium has lost 2 valence electrons.
- **Aluminium ion, Al^{+3},** +3 charge on aluminium means that aluminium has lost 3 valence electrons.

An anion is a negatively charged ion. It is formed when non metal elements gain the valence electrons. The following are the examples of anions:

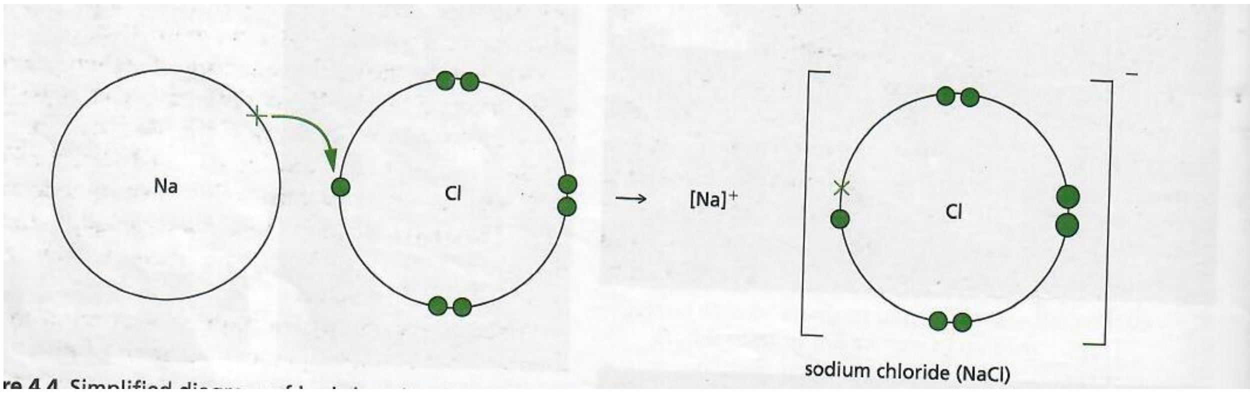
Chloride anion, Cl^{-1}, this simply means that chlorine has gained one valence electron.

DOT AND CROSS DIAGRAMS FOR IONIC BONDING

A dot and cross diagram is a diagram that shows the transfer or sharing of electrons between the atoms. It uses crosses (x) and dotsto represent electrons.

Note that an ionic bond occurs between metal elements and non metal elements. These metal elements lose their valence electrons to become positively charged anions while these non metal elements gain the valence electrons become negatively charged anions.

THE FORMATION OF SODIUM CHLORIDE, NaCl

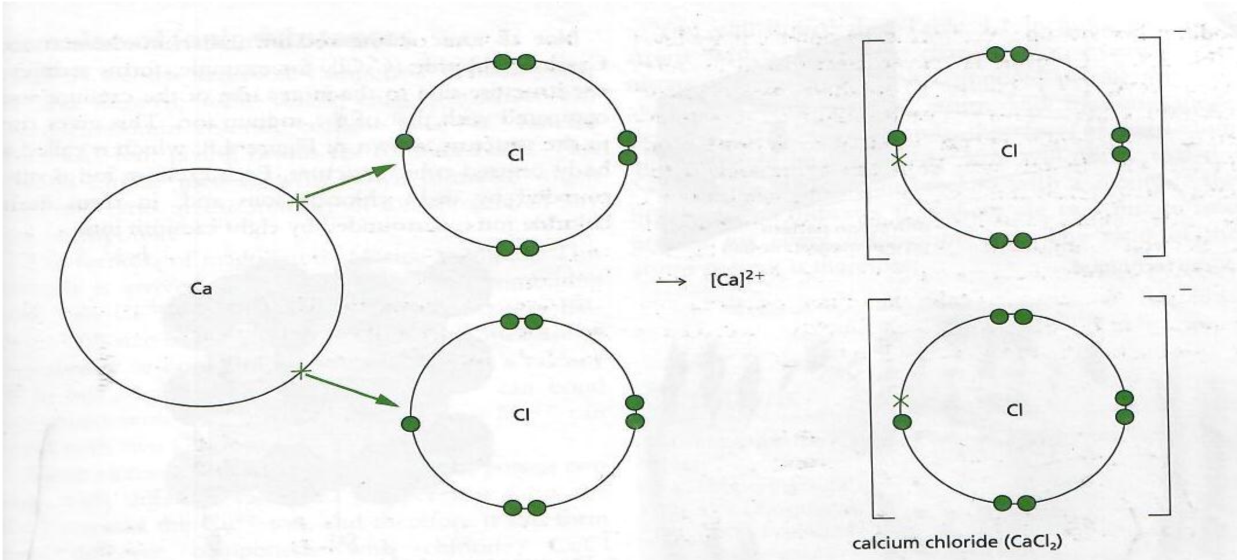


Sodium chloride is formed from the ionic bonding of lithium and chlorine. Lithium loses its valence electron and chlorine accepts this valence electron to attain a noble gas electron configuration

THE FORMATION OF MAGNESIUM CHLORIDE, $CaCl_2$

Magnesium chloride is formed from the ionic bonding of magnesium and chlorine. Note that magnesium belongs to group 2, this means that calcium should lose all the two electrons to attain an electron configuration of its nearest noble gas. Chlorine belongs to group 7, this means that chlorine should gain one more electron to attain an electron configuration of its nearest noble gas.

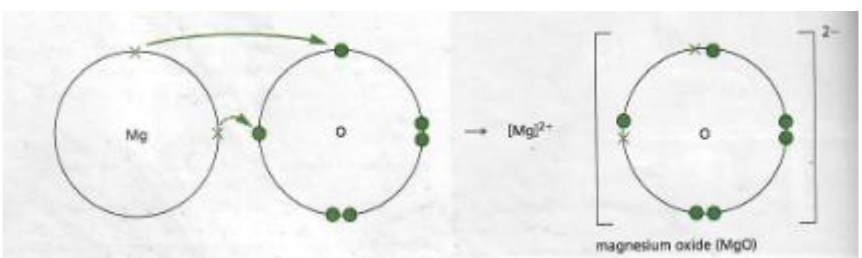
The following is the dot and cross diagram for the formation of calcium chloride.



THE FORMATION OF MAGNESIUM OXIDE, MgO

Magnesium oxide is formed from the ionic bonding of magnesium and oxygen. magnesium belongs to group; hence it should lose its two valence electrons to attain its nearest noble gas electron configuration. Oxygen is in group 6, hence it should gain two valence electrons to attain its nearest noble gas electron configuration.

The following is the dot and cross diagram for the formation of magnesium oxide.



IONIC COMPOUNDS

Ionic compounds are compounds formed from the ionic bonding. The following are examples of ionic compounds.

- Magnesium chloride, $MgCl_2$
- Sodium chloride, NaCl
- Calcium oxide, CaO

WRITING THE FORMULA OF IONIC COMPOUNDS GIVEN VALENCIES

Valency is defined as the number of electrons, an atom can lose or gain or share in order to attain stability. It shows the number of electrons an atom of the element uses to combine with atoms of other elements.

The valency of metal elements is equal to their group number.

For example,

- Group 1 elements have a valency of 1
- Group 2 elements have a valency of 2
- Group 3 elements have a valency of 3

The valency of non metal element is found by subtracting the group number of the element from group 8.

For example,

- Nitrogen is in group 5, therefore, its valency is 8-5 = 3
- Oxygen is in group 6, therefore its valency is 8-6 = 2
- Chlorine is in group 7, therefore its valency is 8-7 = 1

Note that the valency of all group 8 elements is 0 because they are already stable.

The following are the steps that should be considered when writing the formula of ionic compounds:

i. In the formula, the metal element should always come first
ii. Write the correct valency of an element on the top right hand sideof the symbols
iii. Exchange the valencies by writing them below as subscripts using arrows.
iv. Write the symbols close together.

Example 1

Given that the valency of magnesium is 2 and the valency of chlorine 1. Write the formula of the compound.

Solution

Magnesium is a metal, thus it is written first. Then the formula will represented as below including their valencies

$Mg^2\ Cl^1$

Then these valencies are exchanged,

$$Mg^2 \times Cl^1$$

Therefore the formula of magnesium chloride is $MgCl_2$.

Take note that when valencies are all even numbers, divide by their highest common factor to reduce the formula in its lowest terms. Consider the example below.

Example 2

Write the formula of the compound formed between calcium and oxygen.

Solution

Note that calcium is in group 2 and is a metal; hence its valency is 2. Oxygen is in group 6 and is a non metal, hence its valency is 8-6 = 2

We have, $Ca^2 \quad O^2$

Then these valencies are exchanged,

$$Ca^2 \times O^2$$

This will reduce to Ca_2O_2.

Note that in the formula, all the subscripts are even numbers. Hence their common factor is 2. After dividing, these numbers will reduce to 1. Therefore the formula is just CaO.

COVALENTBONDING

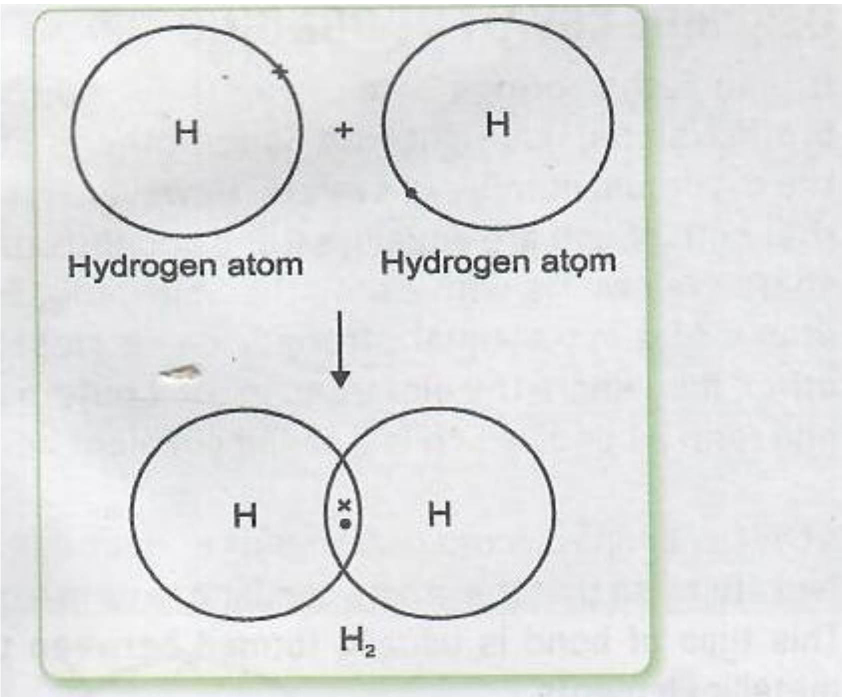
A covalent bond is chemical bond that is formed by the sharing of one or more pairs of electrons between two non metal atoms.

Note that a covalent bond occurs between non metal elements only. Non metal elements attain stability by gaining the electrons.

THE FORMATION OF HYDROGEN MOLECULE

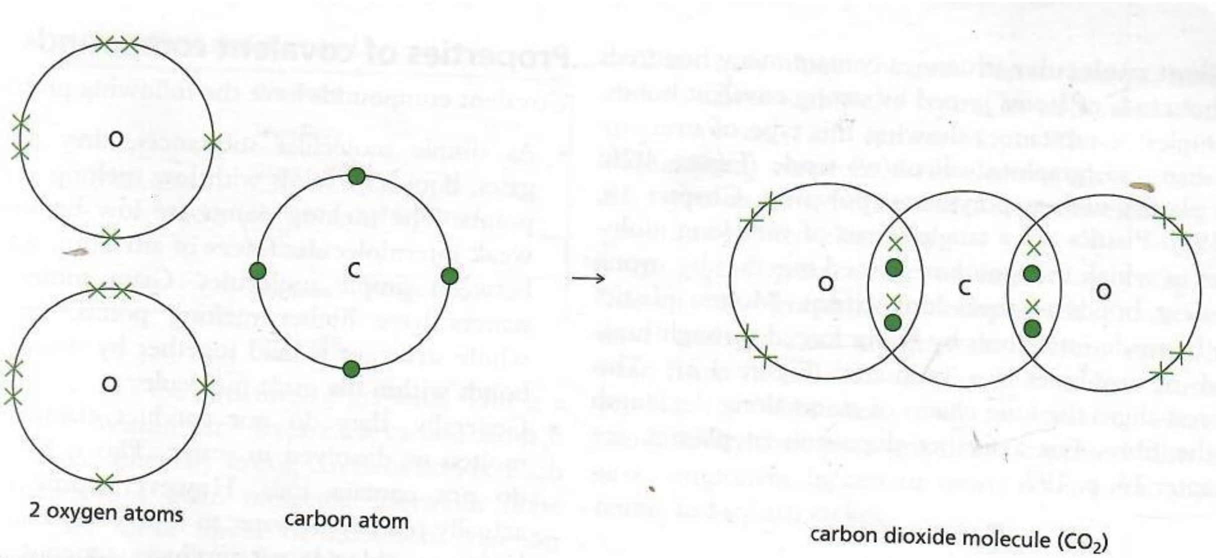
Each hydrogen atom, has only one outer most electron, for it to be stable, it have one more electron to have a total of two electrons. These two hydrogen atoms will just share for them to attain stability.

The following is the dot and cross diagram for the formation hydrogen molecule



THE FORMATION OF CARBON DIOXIDE MOLECULE

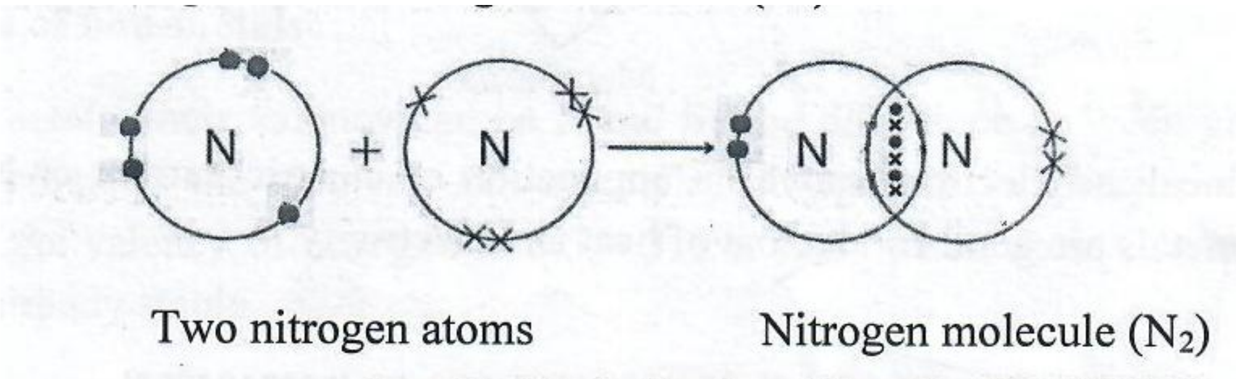
Carbon dioxide molecule comes from the combination of two atoms and one carbon. Oxygen is a group 6 element hence its needs two more electrons to attain stability. Carbon is in group 4 and needs four electrons to attain stability.



THE FORMATION ON NITROGEN MOLECULE

Nitrogen molecule comes from the combination of two nitrogen molecules. Nitrogen is a group 5 element hence it needs three more electrons to attain stability.

The following is the dot and cross diagram for the formation of nitrogen molecule.



TYPES OF COVALENT BONDS

There are three types of covalent bonds depending on the number of shared electron pairs.

- Single covalent bond
- Double covalent bond
- Triple covalent bond

SINGLE COVALENT BOND

A single covalent bond is a bond that is formed when one electron pair is shared between two atoms. A single covalent bond is represented by one horizontal line between the elements.

EXAMPLES SINGLE COVALENT BONDS

- The bond hydrogen molecule, H_2.
- The bond chlorine molecule, Cl_2

DOUBLE COVALENT BOND

A double covalent bond is a bond that is formed when two electron pairs are shared between two atoms. A double covalent bond is represented by two horizontal lines between the elements.

EXAMPLES OF DOUBLE COVALENT BONDS

- The bond in oxygen gas, O_2

- The bond in carbon dioxide molecule, CO_2

TRIPLE COVALENT BOND

A triple covalent bond is a bond that is formed when three electron pairs are shared between two atoms. A triple covalent bond is represented by three horizontal lines between the elements.

EXAMPLES OF TRIPLE COVALENT BONDS

- The bond in nitrogen molecule, N_2

COVALENT COMPOUNDS

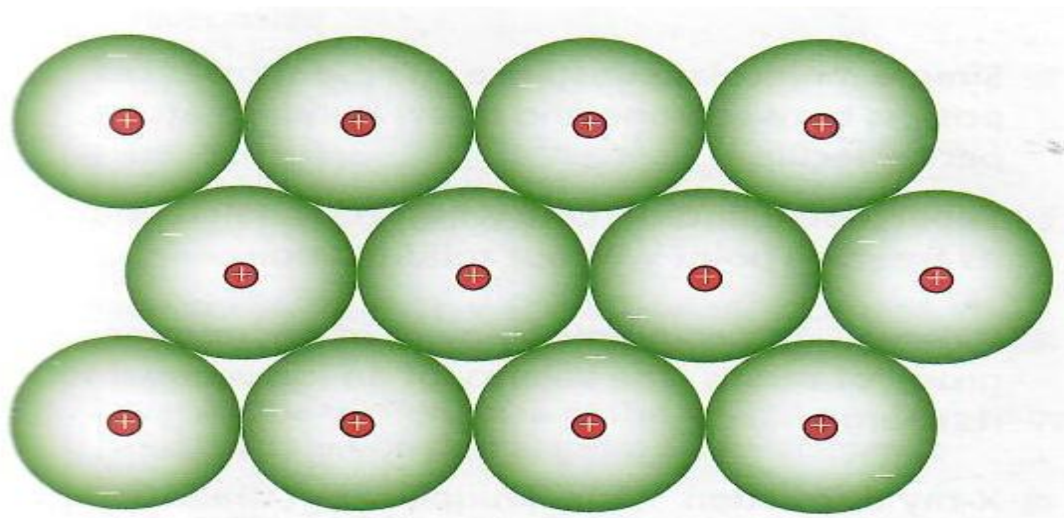
Covalent compounds are compounds that are formed from covalent bonding. The following are the examples of covalent bonding.

- Hydrogen molecule, H_2
- Water molecule, H_2O
- methane molecule , CH_4

METALLIC BONDING

A metallic bond is an electrostatic force of attraction between the delocalized sea of electrons and the static positive metal ions.

The following is the diagram of a metallic bonding.



UNIT 10 : ACIDS AND BASES

ACIDS

An acid is substance that dissociates in water to give hydrogen ions. The following are examples of acids.

- Sulphuric acid
- Phosphoric acid
- Nitric acid
- Hydrochloric acid

Properties of acids

- Acids have sour taste
- They turn blue litmus paper to red
- They have a PH of less than 7
- They conduct electricity (they are electrolytes)
- They react with bases to form salt and water
- They react with metals to form their salts and hydrogen gas
- Acids are corrosive in nature; they corrode and damage a metal container

BASES

A base is a substance that dissociates in water to give hydroxide ions. They are slippery or soapy to touch.

The following are examples of bases:

- Sodium hydroxide
- Magnesium oxide
- Calcium carbonate

Properties of bases

- Bases have a bitter taste
- They turn red litmus paper to blue
- They conduct electricity (they are electrolytes)
- They have a PH of greater than 7

PREPARATION OF ACID – BASE INDICATORS FROM LOCALLY PROCESSED MATERIALS

Acid- base Indicators are substances which distinguish an acid from abase using colour changes. Locally made indicators can be prepared from selected leaves and flowers such as tomato leaves, hibiscus leavesand acacia leaves.

The following are steps that are followed when preparing acid- base indicators from locally processed materials:

- Collect the coloured flowers or leaves
- Crush them in a mortar using a pestle
- Add a small amount of ethanol
- Grind the mixture until you get enough extract of the flower
- Filter the liquid into a clean beaker
- The solution is an acid- base indicator

THE UNIVERSAL INDICATOR CHART

A universal indicator is a solution of many other indicators which gives different colours at different PH of solutions. The strength of an acid or a base is measured oa scale of numbers called the PH scale. The PH scale has the numbers ranging from 0-14. The colour shown by the universal indicator in an acid or base is matched against the PH scale to gets its PH value. The PH value shows the acidity or Basicity of solutions.

Any solution with a PH of less than 7 is an acid,while a solution with a PH more than 7 in alkaline solutions.

A Typical pH Scale

Colour	Dark Red	Red	Orange	Light Orange	Light Green	Green	Greenish Blue	Light Blue	Dark Blue	Violet	Purple
pH Value	0 – 1	2	3 – 4	5	6	7	8	9	10	11 – 12	13 - 14

← Increase acidity

Increasing basicity →

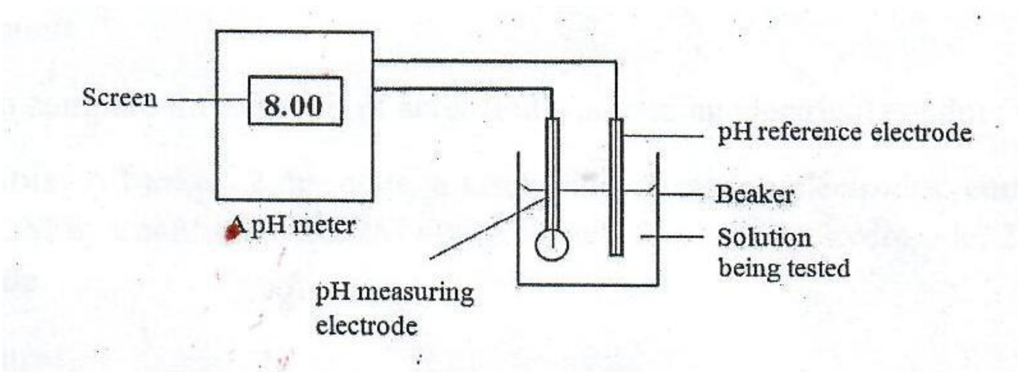
Neutral

DETERMINING THE STRENGTH OF AN ACID OR A BASE

a) USING A pH METER

A pH meter is an instrument that measures the pH of a solution. It measures the pH of a solution by measuring the voltage between two electrodes submerged in the solution. The pH value is shown on the screen of the pH meter and it indicates the strength of the acid or base. Stronger acids have lower pH values while stronger bases have higher pH values.

pH Measurement Circuit



In the above diagram, the solution being tested is a weak base (pH = 8.00)

b) USING UNIVERSAL INDICAATOR

A universal indicator is a mixture of many indicators. It gives different colours depending on the strength of the acid or base. A pH scale is a band of colours with corresponding pH values. The pH scale has values ranging from 0 to 14. The colour shown by the universal indicator in an acid or base is matched against a pH scale to get the pH value. The pH value shows the strength of the acid or base. For example, if the colour changes to dark red, the pH scale shows that the acid has a pH of 1 hence it is a strong acid.

A Typical pH Scale

Colour	Dark Red	Red	Orange	Light Orange	Light Green	Green	Greenish Blue	Light Blue	Dark Blue	Violet	Purple
pH Value	0 – 1	2	3 – 4	5	6	7	8	9	10	11 – 12	13 - 14

Increase acidity

Increasing basicity

Neutral

Any solution with a pH less than 7 is acidic and any solution with a pH greater than 7 is alkaline. Any solution with a pH equal to 7 is neutral. Substances with a pH of 1 are strongest acids and substances with a pH of 14 are the strongest bases.

c) **USING ELECTRICAL CONDUCTIVITY**

Acids and bases conduct electricity in aqueous form. However, the degree of conductivity depends on the strength of the acid and base strong acids and bases produce more ions in aqueous form hence their solutions are good conductors of electricity. On the other hand, weak acids and bases produce few ions in solutions hence their solutions form weak electrolytes. The few ions released by the weak acids and bases results in poor electrical conductivity.

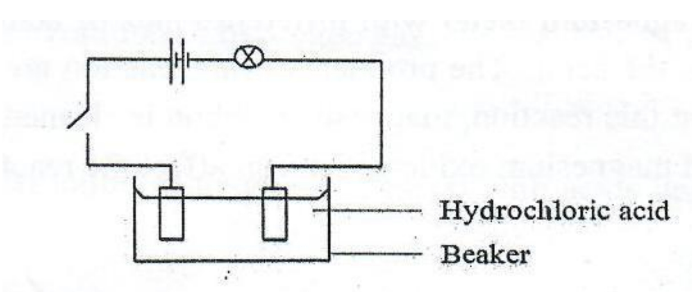
Experiment

Aim: To compare the strength of acids and bases using electrical conductivity.

Apparatus: A breaker, 2 dry cells, a torch bulb, 2 carbon electrodes, connecting wires, switch, 2m hydrochloric acid, 2m ethanol acid, 2m sodium hydroxide, 2m ammonium hydroxide.

Procedure:

a. Set up the apparatus as shown below



b. Close the switch and observe the brightness of the bulb.
c. Replace the hydrochloric acid with ethanoic acid and observe the brightness of the bulb.
d. Compare the conductivity of hydrochloric acid and ethanoic acid.
e. Repeat steps (b) to (d) with sodium hydroxide and ammonium hydroxide.
f. Record your observations in a table of results.
g. Compare your results with the ones shown in the table below.

Table of Results

SOLUTION	BRIGHTNESS OF THE BULB (bright or faint)	CONCLUSION
2M Hydrochloric acid	Bright Light	Strong acid
2M Ethanoic acid	Faint Light	Weak acid
2M Sodium hydroxide	Bright Light	Strong base
2M Ammonium hydroxide	Faint Light	Weak base

Discussions

When acids and bases are dissolved in water, they dissociate to form ions which conduct electricity. The degree of electrical conductivity depends on the amount of ions present in the solution. When there are more ions in the solution, electrical conductivity is high.

Strong bases and acids have higher electrical conductivity as compared to weak acids and bases. This is because strong acids and bases ionize completely thereby releasing all the ions which conduct electricity when dissolved in water. This is because they do not ionize completely in aqueous form and therefore release few ions to conduct electricity.

Conclusion

Solutions of strong acids and bases have greater electrical conductivity than solutions of weak acids and bases.

COMPARING THE STRENGTH OF ACIDS OF THE SAME CONCETRATIONS BY REACTING WITH MAGNESIUM ROBBON (MAGNESIUM METAL)

The reaction of magnesium metal with different kinds of acids is used to measure the relative strength of acids. The products of this reaction are a salt and hydrogen gas. Before carrying out this reaction, magnesium ribbon is cleaned first to remove a coating on the metal called magnesium oxide which can affect the reaction.

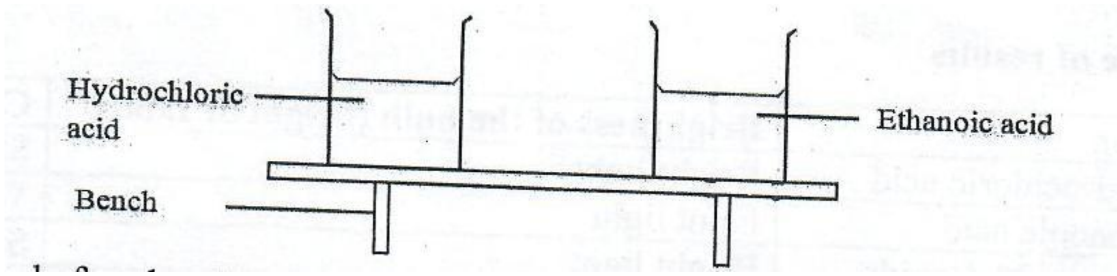
Experiment

Aim: To compare strengths of acids of the same concentrations by reacting them with magnesium ribbon.

Apparatus: 0.1M hydrochloric acids, 0.1M ethanoic acid, forceps, magnesium ribbon and 2 breakers.

Procedure:

1. Set up the apparatus as shown below,



2. Pour 10ml of each acid into a separate beaker and label the beakers.
3. Clean 2 pieces of magnesium ribbons, each 1cm long.
4. Using the forceps, place the 1cm magnesium ribbons in each beaker at the same time.
5. Observe the rate of evolution of hydrogen gas to indicate the relative strength of each acid.

Observation

The reaction of magnesium metal with the 0.1M hydrochloric acid is much faster than the reaction of magnesium metal with the 0.1M ethanoic acid.

Discussion

When magnesium ribbon reacts with strong acids such as hydrochloric acid, the reaction is more vigorous with rapid evolution of hydrogen gas. Hydrochloric acid reacts faster because it contains more hydrogen ions. The equation for this reaction is given below;

$$Mg\ (s) + 2HCl\ (aq) \longrightarrow MgCl_2\ (s) + H_2\ (g)$$

However, when magnesium reacts with weak acids like ethanoic acid, the reaction is less vigorous with less evolution of hydrogen gas.

Conclusion

Therefore, the rate of reaction of magnesium metal with acids depends on the strength of the acid.

THE DIFFERENCE BETWEEN CONCENTRATION AND STRENGTH OF AN ACID

The strength of an acid relates to the degree to which an acid ionizes in water while concentration refers to how much of the acid is present in a given volume of water. A strong acid completely dissociates in water while a weak acid partially dissociates in water. A concentrated acid contains more acid in a given volume of solution while a dilute acid contains a small amount of acid in a given volume of solution.

USES OF ACIDS AND BASES

a. Uses of Acids

- Hydrochloric acid is used in the digestive system.
- Hydrochloric acid is used to clean or remove stains from metals.
- Sulphuric acid is used in car batteries as an electrolyte.
- Sulphuric acid is also used to make detergents, fertilizers and polymers.
- Carbonic acid is used to make carbonated drinks.
- Acids are used to make esters.
- Acids are used to manufacture salts.
- Nitric acid and sulphuric acid are used in the manufacture of dyes, paints, drugs and explosives.
- Phosphoric acid is used to make detergents, fertilizers and soft drinks.

b. Uses of Bases

- Sodium hydroxide is used in the manufacture of soap.
- Bases are used to neutralize acidic soils.
- Ammonia is used in the production of fertilizer
- Sodium hydrogen carbonate (soda) is used in cooking okra and baking cakes.
- Calcium hydroxide is used in the manufacture of bleaching powder.
- Potassium hydroxide is used in the manufacture of alkaline batteries.
- Calcium hydroxide is used to neutralize acidic soils.
- Calcium hydroxide is used in the manufacture of fungicides.
- Magnesium hydroxide is used as an antacid in treatment of heart burn and indigestion.
- Magnesium hydroxide and soda help in relieving pain from ulcers.

NEUTRALISATION REACTION

Neutralization reaction is a chemical reaction between an acid and a base to form salt and water. The reaction is called neutralization because the reaction between an acid and a base produces salt and water which are neutral compounds. Therefore, the products of a neutralization reaction have a pH of 7. The summary of this reaction is as follows;

Acid + Base $\longrightarrow$ Salt + Water

An example of a neutralization reaction is given below;

$$HCl\ (aq) + NaOH\ (aq) \longrightarrow NaCl\ (aq) + H_2O\ (l)$$

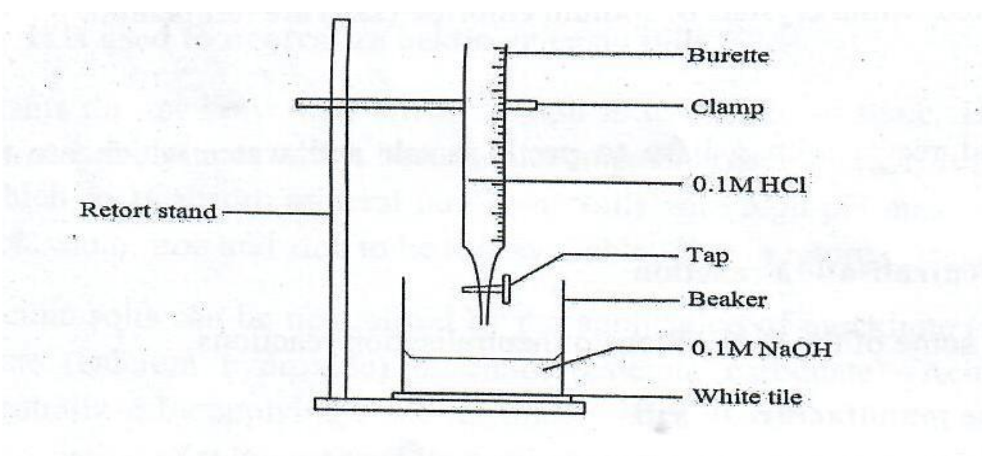
Experiment

Aim: To demonstrate neutralization reaction.

Apparatus: Phenolphthalein indicator, funnel, clamp, clamp stand, conical flask, evaporating dish, wire gauze, Bunsen burner, measuring cylinder, tripod stand, white tile or paper, 0.1M NaOH and 0.1MHCl.

Procedure:

1. Set up the apparatus as shown below:



2. Using the funnel, fill the burette with hydrochloric acid to the zero mark.
3. Pour 10ml of the 0.1M NaOH into the beaker or conical flask.
4. Add 2 drops of phenolphthalein indicator to the sodium hydroxide in the beaker. Observe the colour change.
5. Slowly add the 0.1M HCl to the 0.1M NaOH while shaking the beaker.
6. Continue adding the acid to the base until the pink colour disappears.
7. Record the reading on the burette at this point in the table of results.

Initial Volume of HCl (ml)	Final Volume of HCl (ml)	Volume of HCl used (ml)

8. Having known the volume of the acid used to neutralize the base, repeat steps 2 to 7 without using an indicator.
9. Evaporate the resulting solutions to crystallization point.
10. Record your observations.

The reaction is repeated without an indicator because the indicator would make the salt impure. The solution from the beaker is heated to let the water evaporate. After the water has evaporated, white crystals of sodium chloride (salt) are left behind.

Conclusion

Therefore, an acid reacts with a base to produce salt and water which are neutral substances.

APPLICATION OF NEUTRALIZATION REACTION

The following are some of the applications of neutralization reactions.

a. **It is used in the manufacture of salts**

The products of neutralization reaction are salt and water. The salt can be obtained by boiling the mixture and in the process all the water will evaporate while the salt will remain in the container. The salt can be used for various purposes. The type of salt produced depends on the type of acid used. For example, carbonic acid will produce carbonic salts, sulphuric acid will produce Sulphate salts, nitric acid will produce nitrate salts and hydrochloric acid will produce chloride salts.

b. **It is also used to treat indigestion**

Sometimes the stomach generates excess hydrochloric acid, leading to indigestion or heartburn. Therefore, people suffering from indigestion are advised by doctors to take antacids such as milk of magnesia and sodium bicarbonate (soda), which neutralizes excess hydrochloric acid in the stomach. This helps to treat indigestion.

c. **It is used to neutralize insect bites**

An insect bite can either be acidic or basic in nature depending on the nature of the insect. For example, wasp sting is basic in nature hence applying vinegar to the sting neutralizes the sting as vinegar is acidic in nature. However, be sting contains methanoic acid which causes itching, pain and swelling. The acid can be neutralized by applying a base like baking soda. This relieves the pain from the bite site.

d. It is used to prevent tooth decay

Most food particles are acidic in nature. Such foods produce acid in our mouth which reacts with the enamel leading to cavities. At the same time, bacteria feed on the food remains in the mouth and they produce acids. These act on the enamel and make it weak thereby causing tooth decay. Toothpaste for brushing teeth is basic in nature and it neutralizes the acid which causes tooth decay. This helps to prevent tooth decay.

e. It is used to neutralize acidic or basic soil

Plants do not grow well when the soil is too acidic or basic. High acidity in the soil reduces the rate at which bacteria decompose organic matter. It also reduces the rate at which roots absorb mineral nutrients. Soils with high pH make some minerals such as potassium, iron and zinc to be less available. This in return affects plant growth.

Acidic soils can be neutralized by the application of quicklime (calcium oxide), slaked lime (calcium hydroxide) or chalk (calcium carbonate). Acidic soils can also be neutralized by applying basic fertilizers. High alkalinity in the soils can be lowered by application of sulphur or acidic fertilizers such as ammonium Sulphate ($(NH_4)_2SO_4$).

f. It helps in relieving pain from ulcers

Excess accumulation of hydrochloric acid in the stomach damages the wall of the stomach thereby leading to stomach ulcers. Therefore, people with ulcers are advised by the doctors to take antacids such as milk of magnesia and sodium bicarbonate (soda), which neutralizes excess hydrochloric acid in the stomach. This helps in relieving the pain caused by the ulcers.

End of unit exercise

1. Study the diagram below and answer the questions that follow.

Solution	O	P	Q	R	S
pH value	14	7	1	8	6

a. Which solution is:
   i. A strong acid ii. A weak acid iii. A strong base iv. A weak base v. Neutral

b. In which of these solutions will phenolphthalein indicator:
   i. Turn pink ii. Remain colourless
c. In which solutions will the bulb give a brighter light in an electrical conductivity test?

2. Briefly describe how you can determine the strength of an acid using.
   a. Reactivity b. Electrical conductivity

3. What is the difference between concentration and strength of an acid?

4. a. Define a neutralization reaction
   b. Briefly describe five applications of neutralization reaction.

UNIT 11: ORGANIC CHEMISTRY

By the end of this chapter students will be able to demonstrate creative use of knowledge and skills on the position and reactivity of organic compounds for safe and efficient utilization of resources around them.

CLASSIFICATION OF ORGANIC COMPOUNDS

Organic compounds are classified into two groups:

- Hydrocarbons
- Oxy carbons

HYDROCARBONS

Hydrocarbons are organic compounds which contain carbon and hydrogen atoms only in their structure. Examples of hydrocarbons are:

- Alkanes
- Alkenes

OXYCARBONS

Oxycarbons are organic compounds which contain hydrogen, carbon and oxygen atoms in their structure.

The following are the examples of oxy carbons:

- Alkanols
- Alkanoic acids
- Alkanals
- Alkanones
- Alkanoates

HOMOLOGOUS SERIES

Homologous series is the collection of organic compounds with related formula and structure. There are two homologous series of hydrocarbons:

- Alkanes
- Alkenes

ALKANES

Alkanes are hydrocarbons which contain hydrogen and carbon atoms only in their structure.

FUNCTIONAL GROUP OF ALKANES

Generally alkanes do not contain a functional group. Hence they are considered to be non reactive.

GENERAL FORMULA OF ALKANES

The general formula of alkanes is given by:

$\mathbf{C_nH_{2n+2}}$ where n stands for the number of carbon atoms.

Note that the general formula is used to come up with the molecular formula of any alkane given the number of carbon atoms.

For example,

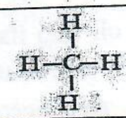
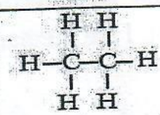
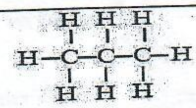
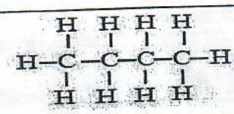
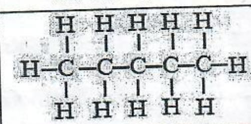
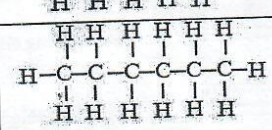
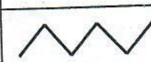
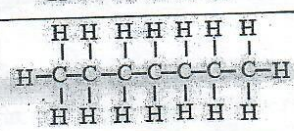
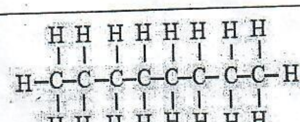
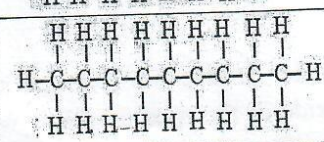
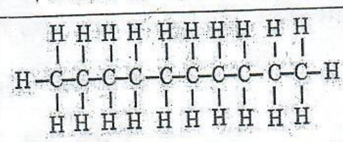
- When n = 1, then the formula will be $C_1H_{2(1)+2} = CH_4$
- When n = 2, then the formula will be $C_2H_{2(2)+2} = C_2H_6$
- When n = 3, then the formula will be $C_3H_{2(3)+2} = C_3H_8$

NAMING ALKANES

The system of naming alkanes end up with **–ane.** Therefore the first ten alkanes are as follows:

- Methane
- Ethane
- Propane
- Butane
- Pentane
- Hexane
- Heptane
- Octane
- Nonane
- Decane

Summary of the formulae of the first ten straight chain alkanes

Name	Molecular formula	Structural formula	Condensed formula	Skeletal formula
Methane	CH_4		CH_4	
Ethane	C_2H_6		CH_3CH_3	
Propane	C_3H_8		$CH_3CH_2CH_3$	
Butane	C_4H_{10}		$CH_3CH_2CH_2CH_3$	
Pentane	C_5H_{12}		$CH_3(CH_2)_3CH_3$	
Hexane	C_6H_{14}		$CH_3(CH_2)_4CH_3$	
Heptane	C_7H_{16}		$CH_3(CH_2)_5CH_3$	
Octane	C_8H_{18}		$CH_3(CH_2)_6CH_3$	
Nonane	C_9H_{10}		$CH_3(CH_2)_7CH_3$	
Decane	$C_{10}H_{22}$		$CH_3(CH_2)_8CH_3$	

SOURCES OF ALKANES

The following are the sources of alkanes:

Crude oil or petroleum

Crude oil or petroleum is the main source of alkanes which is separated into its components by fractional distillation. Examples of alkanes that are found in crude oil are methane, ethane and propane.

Natural gas

Natural gas is found underground on top of the crude oil deposits. It is also found under the sea. Natural gas contains methane, ethane, propane and butane.

Living things

The fermentation of organic matter produces methane gas.

Preparation in the laboratory

Alkanes can be prepared in the laboratory by heating a mixture of sodium alkanoate and sodium hydroxide to form an alkane and sodium carbonate.

For instance, sodium ethanoate can be heated together with sodium hydroxide to produce methane gas and sodium .

Sodium ethanoate + sodium hydroxide $\rightarrow$ methane gas + sodium carbonate

$$\mathbf{CH_3COONa_{(s)} + NaOH_{(s)} \longrightarrow CH_{4\,(g)} + Na_2CO_{3(s)}}$$

THE PHYSICAL PROPERTIES OF ALKANES

The following are the physical properties of alkanes

a) Solubility in water

Generally are insoluble in water, that is, they do not dissolve in water. They only dissolve in some other organic solvents.

b) Melting and boiling points

Alkanes have generally low melting and boiling points. The melting and boiling points of alkanes increase as the sizes and masses of the molecules increase. This is so because as the molecular masses increase the intermolecular forces also increases, as a result more energy is needed to weaken and break these forces.

c) Density

The density of alkanes increases as the sizes and masses of the molecules increase.

This is so because as the molecular masses increase, the intermolecular forces increases as well which pulls the whole structure to occupy a smaller volume thereby increasing the mass to volume ratio.

d) Viscosity

Viscosity is defined as the measure of the ability of a substance to flow steadily. A liquid of high viscosity does not flow steadily while a liquid of low viscosity flows steadily. The longer the carbon chain the more viscous an alkane becomes because of the increase in the strength of intermolecular forces which increases the resistance to flow of a liquid

e) Electrical conductivity

All alkanes do not conduct electricity. Because they are covalent compounds and they don't have free ions.

CHEMICAL PROPERTIES OF ALKANES

Alkanes are generally non reactive as compared to alkenes because they don't have the functional group and the alkane molecules contain single bonds which are strong enough and require a lot of energy for them to break. Under certain conditions, alkanes do react. There are two main reactions which alkanes undergo:

A. Combustion reactions
B. Substitution reactions

COMBUSTION OF ALKANES

Combustion reaction is the reaction in which a substance burns in air and releases heat energy to produce a flame.

There are two types of combustion of alkanes.

i. Complete combustion
ii. Incomplete combustion

Complete combustion

This is a combustion reaction in which an alkane is burnt in plentiful supply of oxygen to produce carbon dioxide and water. More energy is released when an alkane undergoes a complete combustion.

The following is an example of a complete combustion, Methane + oxygen $\longrightarrow$ carbon dioxide + water

$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(l)}$

Note that in complete combustion, more energy is released.

Incomplete combustion

An incomplete combustion is a reaction in which an alkane is burnt in limited or insufficient supply of air to produce carbon monoxide and water or just carbon and water.

For example,

Methane + insufficient oxygen $\longrightarrow$ carbon monoxide + water

$2CH_{4(g)} + 3O_{2\,(g)} \longrightarrow 2CO_{(g)} + 4H_2O_{(l)}$

Methane + limited oxygen $\longrightarrow$ carbon black + water

$CH_{4(g)} + O_{2\,(g)} \longrightarrow 2C_{(g)} + 2H_2O_{(l)}$

Note that in incomplete combustion, less energy is released.

SUBSTITUTION REACTIONS OF ALKANES

Alkanes undergo substitution reactions with halogens in the presence of ultra violet light.

In substitution reactions of alkanes, one hydrogen atom is replaced by a halogen to produce haloalkanes and hydrogen halides.

The following are examples of substitution reactions of alkanes.

Methane reacts with chlorine to produce chloromethane and hydrogen chloride.

$CH_{2(g)} + Cl_{2(g)} \xrightarrow{\text{U.VLight}} CH_3Cl_{(g)} + HCl_{(g)}$

Ethane reacts with bromine to produce bromoethane and hydrogen bromide

$C_2H_{6(g)} + Br_{2(l)} \xrightarrow{\text{U.V Light}} C_2H_5Br_{(g)} + HBr_{(g)}$

USES OF ALKANES

i. The first four alkanes are used in heating, cooking and electricity generation.
ii. They are also used as fuels.
iii. Alkanes are used as lubricants.

iv. Incomplete combustion of alkanes produces carbon black that is used to manufacture printing ink, black pigment and shoe polish.
v. They are used as a source of hydrogen.

ALKENES

Alkenes are in the same homologous series with alkanes. They also contain hydrogen and carbon atoms only in their structure.

FUNCTIONAL GROUP OF ALKANES

Alkenes have a carbon to carbon double bond functional group. The presence of this functional group makes these alkenes to more reactive than alkanes.

Functional

GENERAL FORMULA OF ALKANES

The general formula of alkanes is C_nH_{2n}. where n stands for the number of carbon atoms.

Note that the general formula is used to come up with the molecular formula of any alkene given the number of carbon atoms.

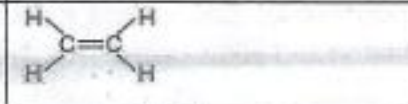
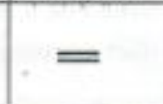
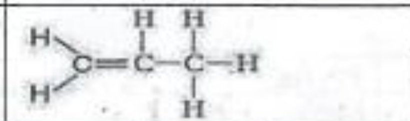
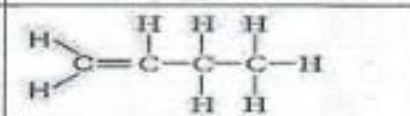
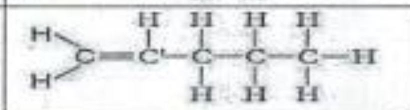
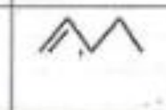
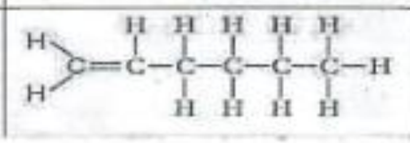
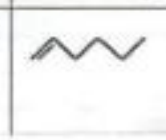
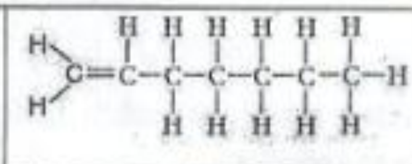
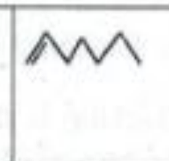
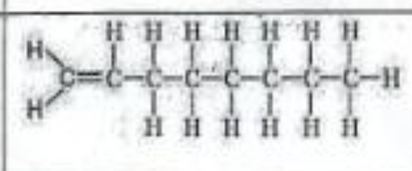
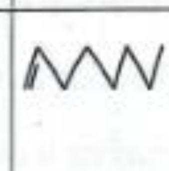
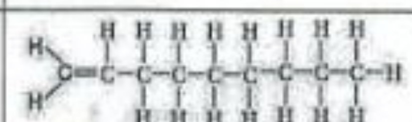
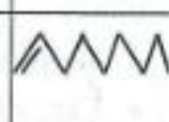
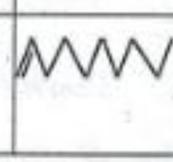
For example, if n = 2, we have $C_2H_{2(2)} = C_2H_4$

NAMING ALKENES

The system of naming alkenes end up with –ene. The following are the nine alkenes:

- Ethene
- Propene
- Butene
- Pentene
- Hexene
- Heptene
- Octene
- Nonene
- Decene

THE STRUCTURE OF THE FIRST NINE ALKENES

Name	Molecular formula	Structural formula	Condensed formula	Skeletal formula
Ethene	C_2H_4		$CH_2{=}CH_2$	
Propene	C_3H_6		$CH_2{=}CHCH_3$	
Butene	C_4H_8		$CH_2{=}CHCH_2CH_3$	
Pentene	C_5H_{10}		$CH_2{=}CH(CH_2)_2CH_3$	
Hexene	C_6H_{12}		$CH_2{=}CH(CH_2)_3CH_3$	
Heptene	C_7H_{14}		$CH_2{=}CH(CH_2)_4CH_3$	
Octene	C_8H_{14}		$CH_2{=}CH(CH_2)_5CH_3$	
Nonene	C_9H_{18}		$CH_2{=}CH(CH_2)_6CH_3$	
Decene	$C_{10}H_{20}$		$CH_2{=}CH(CH_2)_7CH_3$	

SOURCES OF ALKENES

There are two main sources of alkanes

- **Dehydration of alcohols**
- **Cracking of alkenes**

DEHYDRATION OF ALCOHOLS

Dehydration is defined as the removal of water from a compound. In the dehydration of alcohols , the alcohol is heated in the presence of concerated sulphuric acid to produce an alkene plus water,

In general:

$$\textbf{Alcohol} \xrightarrow[\text{Heat}]{\text{Conc.acid}} \textbf{Alkene + water}$$

$$CH_3CH_4OH \xrightarrow[\text{heat}]{\text{Conc. acid}} C_2H_4 + H_2O$$

CRACKING OF ALKENES

Cracking is the process where single covalent bonds in long chain alkanes are broken down to release smaller alkanes and alkenes. This is done by heating a long chain alkane to release at high temperature to weaken and break the strong covalent bonds

For example,

$$\textbf{Hexane} \xrightarrow{700℃} \textbf{butane + ethane}$$

$$C_6H_{14} \xrightarrow{700℃} C_4H_{10} + C_2H_4$$

PHYSICAL PROPERTIES OF ALKENES

a) **Solubility in water**

Generally alkenes are insoluble in water, that is, they do not dissolve in water. They only dissolve in some other organic solvents.

b) **Melting and boiling points**

The melting and boiling points of alkenes increase as the sizes and masses of the molecules increase. This is so because as the molecular masses increase the intermolecular forces also increases, as a result more energy is needed to weaken and break these forces.

c) Density

The density of alkenes increases as the sizes and masses of the molecules increase. This is so because as the molecular masses increase, the intermolecular forces increases as well which pulls the whole structure to occupy a smaller volume thereby increasing the mass to volume ratio.

d) Viscosity

The presence of the double bond in alkenes causes them to have higher viscosity than the single bonded alkanes. A liquid of high viscosity does not flow steadily while a liquid of low viscosity flows steadily. The longer the carbon chain the more viscous an alkene becomes because of the increase in the strength of intermolecular forces which increases the resistance to flow of a liquid.

e) Electrical conductivity

All alkenes do not conduct electricity. Because they are covalent compounds and they don’t have free ions.

CHEMICAL PROPERTIES OF ALKENES

Alkenes are more reactive than alkanes because of the presence of the carbon to carbon double bond functional group.

There are two main types of reactions which alkenes undergo.

1. **Combustion reactions**
2. **Addition reactions**

COMBUSTION OF ALKENES

Like alkanes there are two main types of combustion of alkanes. There are two types of combustion of alkenes.

- **Complete combustion**
- **Incomplete combustion**

Complete combustion

This is a combustion reaction in which an alkene is burnt in plentiful supply of oxygen or air to produce carbon dioxide and water. More energy is released when an alkene undergoes a complete combustion.

The following are examples of complete combustion of alkanes.

$$C_2H_{4\,(g)} + 3O_{2(g)} \longrightarrow 2CO_{2\,(g)} + 2H_2O_{(l)}$$

$$C_6H_{12(g)} + 9O_{2(g)} \longrightarrow 6CO_{2\,(g)} + 6H_2O_{(l)}$$

Incomplete combustion

An incomplete combustion is a reaction in which an alkene is burnt in limited or insufficient supply of air to produce carbon monoxide and water or just carbon black and water.

For example,

Methane + insufficient oxygen ⟶ carbon monoxide + water

$$C_2H_{4\,(g)} + 4O_{2\,(g)} \longrightarrow 2CO_{(g)} + 2H_2O_{(l)}$$

Methane + limited oxygen ⟶ carbon black + water

$$C_2H_{4\,(g)} + O_{2\,(g)} \longrightarrow 2C_{(g)} + 2H_2O_{(l)}$$

ADDITION REACTIONS OF ALKENES

An addition reaction is the reaction which takes place with molecules where two carbon atoms have a double bond or a triple bond. In the addition reaction of alkenes the double bond is broken and is used to connect other atoms to the molecule.

There are three types of addition reactions of alkenes:

- **Bromination**
- **Catalytic hydrogenation**
- **hydration**

BROMIATION OF ALKENES

In bromination of alkenes, bromine atom is added to the double bond of an alkene to form a haloalkane. The following are the examples of bromination of alkenes:

Alkene + bromine ⟶ dibromoalkanes

Ethene + bromine ⟶ dibromoethane

$$C_2H_{4\,(g)} + Br_{2(l)} \longrightarrow C_2H_4Br_{2(l)}$$

Ethene + chlorine ⟶ dichloroalkanes

$$C_2H_{4\,(g)} + Cl_{2(g)} \longrightarrow C_2H_4Cl_{2(g)}$$

CATALYTIC HYDROGENATION

In catalytic hydrogenation, ethene reacts with hydrogen in the presence of nickel catalyst and heat to produce ethane.

In general,

Ethene + hydrogen $\xrightarrow{\text{nickel catalyst}}$ ethane

150 ℃

$$C_2H_{4\,(g)} + H_{2(g)} \xrightarrow[\mathbf{150\ ^\circ C}]{\textbf{Ni}} C_2H_{6(g)}$$

HYDRATION OF ALKENES

A hydration reaction is a chemical reaction in which water is added to an alkene to form an alcohol in the presence of warmth.

Ethene + water $\xrightarrow{\text{warmth}}$ ethanol

$$C_2H_{4\,(g)} + H_2O_{(g)} \xrightarrow{\textbf{warmth}} C_2H_5OH_{(l)}$$

USES OF ALKENES

The following are the uses of alkenes:

- Alkenes are used in the manufacture of plastics
- They are used in the artificial ripening of fruits
- They are used in flower maturation
- Alkenes are also used in seed germination
- They are used in the production of alkanols and alkanes

UNIT 12 : ENVIRONMENTAL CHEMISTRY

DEFINITION OF AIR

Air is the general name for the mixture of gases that makes up the earth's atmosphere. Therefore, air can simply be defined as mixture of gases.

COMPONENTS OF DRY AIR

Dry air is a theoretical sample of air that does not contain water vapour. The major components of dry air are nitrogen, oxygen and argon. The rest of the gases present in air are known as trace gases. Trace gases are those present in the atmosphere other than nitrogen, oxygen and argon. Examples of trace gases include carbon dioxide, helium, neon and hydrogen.

PERCENTAGE COMPOSITION OF DRY AIR

COMPONENT OF DRY AIR	PERCENTAGE COMPOSITION BY VOLUME (%)
Nitrogen	78
Oxygen	21
Argon	0.93
Carbon dioxide	0.3
Neon	0.0018
Helium	0.00052
Krypton	0.00011

SEPARATING COMPONENTS OF DRY AIR BY FRACTIONAL DISTILLATION

Air is a mixture of gases such as nitrogen, oxygen, carbon dioxide, noble gases and water vapour. These gases can be obtained by fractional distillation of liquid air.

Fractional distillation is a process by which components in a chemical mixture are separated according to their different boiling points.

STAGE FOLLOWED IN THE FRACTIONAL DISTILLATION OF LIQUID AIR

Step 1

Air is purified by passing it through filters

Step 2

Carbon dioxide gas is removed by passing the air through concentrated sodium hydroxide solution.

Step 3

The remaining air is cooled to about -25^{o}C to remove water vapour which solidifies as ice.

Note: Carbon dioxide and water vapour are removed because they solidify at low temperatures and this would block the flow of liquid air through the pumps and pipes

Step 4

The dry air free of carbon dioxide is then compressed to about 200 atmospheres causing it to become very hot. The warmed air is passed through a heat exchanger to cool it down. The cooled compressed air is then allowed to expand rapidly. The process is repeated several times until the temperature of the air reaches about -200^{o}C. At this temperature, most of the gases become liquids except neon and helium which remain as gases. The two gases are then removed.

Step 5

The liquefied air is then passed into a fractionating column containing various compartments. Each compartment is slightly at a higher temperature than the one above it. In the fractional column, the air is gradually warmed up and the components of the liquid air then separate according to their boiling points. Nitrogen distills off first because it has a lower boiling point of about -196^{o}C followed by argon at -186^{o}C and finally oxygen at -183^{o}C.

USES OF GASES FOUND IN AIR

We will discuss the use of nitrogen, carbon dioxide and the noble gases

i.Nitrogen

- It used in the production of ammonia gas, which is used to produce nitric acid
- Nitrogen is also used in freezing liquid in damaged pipes while they are being repaired.
- It is used in oil tankers to prevent fires because of its inertness.
- Liquid nitrogen is used in shrink fitting.

- It is also used in food packaging to keep the food fresh.
- It is also used in the manufacture of dyes, explosive and fertilizers.
- Liquid nitrogen is used as a refrigerant. Its low temperature makes it useful for freezing food quickly.

ii.Carbon dioxide

- It is used in fire extinguishers since carbon dioxide does not support burning.
- It is used to make carbonated soft drinks and sod water.
- It is used by green plant to make their own food in the process of photosynthesis.
- Carbon dioxide is used to remove caffeine from coffee.
- Carbon dioxide gas is used for transferring heat in some nuclear power stations.

iii.Helium

- It is used as a shielding gas in are welding processes.
- It is also use as a protective gas in growing silicon and germanium crystals.
- It is used to inflate tyres of large aircrafts.
- It is used in pressuring in rocket fuels to liquids.
- It is used to fill airships and weather balloons.
- It is used as a coolant in nuclear reactors.
- Helium at low temperatures is used in cryogenics.

iv.Neon

- Neon is often used in brightly lit advertising signs.
- Neon and helium are used in making gas lasers.
- It is also to make high voltage indicators.
- Liquid neon is used as a cryogenic refrigerant.
- It is used in television tubes.

v.Argon

- It is used to fill electric light bulbs and fluorescent light bulbs.
- Used as an inert gas shield for arc welding and cutting.
- It is used as a protective atmosphere for growing silicon and germanium.

vi.Krypton

- It is use in certain photographic flash lamps for high – speed photography.

- It is also use d sterilization of fluids.
- It is also used to treat certain eye problems and to remove birth marks.
- It is use as a filling gas for energy saving fluorescent lights and as an inert filling gas in incandescent bulbs.

vii.Xenon

- It is used in plasma display panels and ultraviolet lasers.
- It is used in high efficiency incandescent bulbs for automotive and stage light uses
- It is also used in medicine as a general anesthetic and medical imaging.

PHYSICAL AND CHEMICAL PROPERTIES OF OXYGEN

PHYSICAL PROPERTIES OF OXYGEN

- It is a colourless gas
- It is an ordourless gas
- It is slightly soluble in water
- It is a poor conductor of heat and electricity
- It is slightly denser than air

CHEMICAL PROPERTIES OF OXYGEN

- Oxygen relights a glowing split.
- It aids corrosion.
- Oxygen is neutral to indicator. It is neither acidic nor basic.
- Oxygen supports combustion but does not burn.
- Oxygen reacts with metals to form metal oxides. All metal oxides are basic in nature.
- Oxygen reacts with non-metals to form non-metal oxides are acidic in nature e.g. sulphur dioxide (so_2) while others are neutral e.g. carbon monoxide (co) and water (H_2o).

REACTIONS OF OXYGEN WITH METALS AND NON-METALS

a. Reactions of oxygen with metals

Oxygen reacts with metal to form oxides which are basic in nature. Basic oxides are oxides which produce a basic solution when dissolved in water. Examples of reactions of oxygen with metals as followings:

i.Lithium + oxygen $\longrightarrow$ lithium oxide

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$4Li(s) + O_2(g) \rightarrow 2Li_20(s)$

ii.Calcium reacts quickly with oxygen to form calcium oxide

Calcium + Oxygen $\rightarrow$ Calcium Oxide

2Ca (s) + O2(g) $\rightarrow$ 2CaO (s)

iii.Aluminium reacts quickly with oxygen to form Aluminium Oxide

Aluminium + Oxygen $\rightarrow$ Aluminium Oxide

$4Al (s) + 3O_2 (g) \rightarrow 2MgO (s)$

iv.Magnesium on heating reacts with oxygen to form magnesium oxide.

Magnesium + Oxygen $\rightarrow$ Magnesium oxide

$2Mg(s) + O_2 (g) \rightarrow 2MgO(s)$

b. Reactions oxygen with non-metals

When non-metal react with oxygen are as follows:

a. Sulphur reacts with oxygen to form Sulphur dioxide is acidic in nature.

Sulphur + oxygen $\rightarrow$ Sulphur dioxide

$S (s) + O_2(s) \rightarrow SO_2(g)$

b. Carbon reacts with oxygen to form carbon dioxide. Carbon dioxide is a neutral oxide.

Carbon + Oxygen $\rightarrow$ Carbon dioxide

$C (s) + O_2 (g) \rightarrow Co_2 (g)$

c. Nitrogen reacts with oxygen to form nitrogen monoxide. Nitrogen monoxide is a neutral oxide.

Nitrogen + Oxygen $\rightarrow$ Nitrogen monoxide

$N (g) + O_2 (g) \rightarrow 2 NO (g)$

TEST FOR OXYGEN

Oxygen is a colourless gas that support burning. To test for the presence of oxygen, follow the following steps:

i.Light a wooden splint

ii. Allow it to burn for a few seconds and the blow it out by mouth or by shaking.

iii. Place the glowing end the splint into tube containing a sample of a gas.
iv. If the glowing splint relights or reignites, then the gas in the test tube is oxygen.

USES OF OXYGEN

- It also used to burn hydrogen and kerosene fuels in space rockets.
- It is used in hospitals to help patients with breathing problems.
- Human beings and animals need oxygen for respiration.
- It is used in industries to convert pig iron into steel.
- Oxygen is also used in the treatment of sewage.
- It is also used in the purification of steel.

AIR POLLUTION

Air pollution is defined as the addition of harmful substances into the air. When harmful substances are added to air, the air is known as polluted air. Pollute air is harmful to people, animals and the environment.

COMMON POLLUTANTS

Air pollutants are the harmful substances that are added into air. They come in the form of gases and finely divided solid and liquid aerosols. These can either be primary or secondary pollutants.

A primary pollutant is an air pollution that is emitted or released directly from a source. Examples of primary pollutants include:

- Carbon monoxide (CO)
- Sulphur dioxide (SO_2)
- Nitrogen oxides
- Ammonia (NH_3)
- Unburned hydrocarbons

A secondary pollutant is an air pollutant that is formed when primary pollutants react in the atmosphere. Examples of secondary pollutant include:

- Acid rain
- Nitrogen dioxide (NO_2)
- Sulphur dioxide (SO_3)
- Ground level ozone
- Smog (mixture of smoke and fog)

SOURCES OF AIR POLLUTANTS

Air pollutants can either be indoor or outdoor.

a. INDOOR AIR POLLUTANTS

These are air pollutants that make the air inside homes and building harmful to human health. Indoor air pollution can being within the building or be drawn in from outdoors. Indoor air pollution affects the quality of air in an enclosed space.

Sources of indoor pollution include the following

i. **Pesticides**
ii. Pesticides are chemical substances that are used to kill pest and other unwanted organism. Exposure to pesticides may lead to eye, nose and throat irritation, headache, dizziness and nausea. It may also lead to damage of the central nervous system and may increase risk of cancer. Chronic exposure to some pesticides may result in damage to the liver, kidney, endocrine and nervous system.
iii. **Tobacco Smoke**

Smoking tobacco in any form within the confines of a house is a major source of household air pollution. Cigarette smoke contains different chemical compounds such as carbon monoxide, formaldehyde, volatile organic compounds (VOCs), nicotine and particulate matter. Large amounts of these pollutant indoor consequently reduce the quality of indoor air. Tobacco smoke exposes people to serious health risks such as cardiovascular diseases, lung cancer, bronchial asthma and other respiratory problems.

iv. Biological Pollutants

Biological pollutants are substance which come from living organisms and can affect our health. Biological pollutants can travel through the air are often invisible.

Sources of common indoor biological pollutants

- Pollens, which originate from plants
- Viruses, which are transmitted by people and animals.
- Molds, mildews, mites and fungi.
- Bacteria, which are carried by people , animals , soil
- Household pests, which are sources of saliva and skin flakes.
- Dropping and body parts from rodents, cockroaches and other pests or insects.
- The protein in urine from rats and mice is a potent allergen (a substance that can cause an allergy). When it dries it becomes airborne.
- Poorly maintained air conditioners.

Biological pollutants cause allergies, asthma, fever, digestive problems, dizziness, headaches, colds, flu and pneumonia. They may also cause irritation of the eyes, nose and throat.

v. Formaldehyde

Formaldehyde is a pungent gas mainly comes from carpets, particle boards and insulation form. It causes irrigation to the eyes, nose and throat and may cause allergies in some people. It may also cause headaches, nausea, coughing and may lead to cancer.

vi. Asbestos

Asbestos is a natural mineral fibre that is resistant to heat and is used in various building materials. Sources of asbestos include damaged or deteriorating ceiling, pipe insulation and floor tiles. Asbestos can cause lung disorders, lung cancer and asbestosis. Asbestosis is a serious medical condition caused by breathing threads of asbestos into the lungs.

vii. Radon

Radon is a natural radioactive gas without odour, colour or taste. It comes from radioactive decay of uranium or radium. Sources of radon include rocks, soil, concrete and bricks. Radon gas enters the house through cracks in concrete floors and walls, through gaps between floor and floor and slab, and around drains and pipes, and small pores of hollow-block walls. The main danger of from high radon exposure is increased risk of lung cancer.

viii. Carbon Monoxide (CO)

Carbon monoxide is produced by incomplete combustion of all fuels. Sources include gas stoves and heaters, wood or coal stoves, charcoal burners, chimneys and tobacco smoke among others. When there are low levels of carbon monoxide in the air, it can lead to nausea, headaches, dizziness and unconsciousness. Exposure to too much carbon monoxide can lead to death since it is poisoners.

b. OUTDOOR AIR POLLUTANTS

These are air pollutants that make the air outside homes and buildings harmful to human health and the environment. Outdoor air if often referred to as ambient air.

The most common sources of outdoor pollution include:

i. Smoke From Bushfires

Smoke from bushfires consists of a complex mixture of particle and gases, and has signification impacts on air quality, visibility and human health. Emissions from bush fires can travel long distance and produce effects far away from the fire location. These emission include particulate matter, carbon monoxide, atmospheric, mercury, ozone forming chemicals and volatile organic compounds.

Smoke from bush fire can cause itchy or watering eyes and a runny nose. It also affects the respiratory system thereby causing irritations of the throat, coughing and lung conditions such as asthma.

ii. **Particulate Matter**

Particular matter is an air pollutant made up of small particles, some of which can penetrate deeply into the lungs. Particulate matter includes dust and metal particles found in air. Sources of particulate matter include power plants and industry, motor vehicles, domestic coal burning and natural sources such as volcanoes and dust storms.

Exposure to particulate matter has been associate with a wide range of human health effects such as irritation of the eye, nose and throat. It can also cause wheezing, coughing and shortness of breath. In extreme cases, it can cause asthma and lung cancer.

iii. Ozone (O_3)

Ozone is a complex from of oxygen. It is a gas that is formed in the atmosphere when three atoms of oxygen are chemically combined. The presence of ozone in the air we breathe is harmful to our health.

The following are some of the health effects caused by ozone:

- Headaches
- Coughing
- Throat irritation
- Pain, burning or discomfort in the chest when taking a deep breath.
- Increases the frequency of asthma attacks.
- Cause wheezing and shortness of breath.

However, the presence of ozone at a height of 12-50km (upper atmosphere) is essential to living things on earth. It shields the earth and all living things from the harmful effects of ultraviolet (UV) radiation emitted by the sun.

iv. **Nitrogen dioxide (NO_2)**

The main source of nitrogen dioxide resulting from human activities is the combustion of fossil fuel especially fuel used in car engines. It is also produced from making nitric acid and refining of petrol and metals. It is also produced from natural processes, for example, lightning and biological processes that occur in plants and animals.

Nitrogen dioxide is not usually released directly into the air. At high temperatures inside a car engine, nitrogen and oxygen in the air react to produce nitrogen monoxide.

Nitrogen + Oxygen $\longrightarrow$ Nitrogen monoxide

$N_2(g) + O_2(g) \longrightarrow 2NO(g)$

The nitrogen monoxide in the engine is discharged along with other combustion products and enters the atmosphere as a primary pollutant. In the atmosphere, nitrogen monoxide reacts with oxygen to produce nitrogen dioxide.

Nitrogen monoxide + Oxygen $\longrightarrow$ Nitrogen dioxide

$2NO(g) + 20_2(g) \longrightarrow 2NO_2(g)$

Nitrogen dioxide causes irritation of eyes and lungs when inhaled. It also promotes respiratory diseases and can cause brain damages when inhaled. It also dissolve in rain water thereby forming acid which damages crops, buildings and attacks metals.

v. **Carbon monoxide (CO)**

Carbon monoxide is a colourless and ordourless gas produced by incomplete combustion of carbon fuels. Carbon monoxide causes headaches, dizziness, and impairment of human respiration among others. Very high levels of carbon monoxide can cause death.

vi. **Sulphur dioxide (SO_2)**

The main sources of sulphur dioxide in the air is industrial activities that burn fossil fuels containing sulphur. Some mineral ores also contain sulphur and sulphur dioxide is released when they are processed.

Sulphur dioxide affects human health when it is breathed in. it irritates the nose, throat and airways to cause coughing, wheezing and shortness of breath among others. In addition, sulphur dioxide dissolves in rain water to form acid rain which damages crops, forests and it speeds up the decay of building, statues and sculptures.

Reaction of the Common Atmospheric Pollutants

- Nitrogen and oxygen molecules in the air react at very high temperatures to form nitric oxide (NO). Nitric oxide is a colourless gas which irritates the lungs when inhaled.
- Nitrogen dioxide reacts with rain water to produce nitric. The acid produced causes rain water to be acidic. The rain is known as acid rain.

- Sulphur dioxide if formed when coal and petroleum are burned. It is a primary air pollutant that enters the air. Sulphur dioxide (SO_2) present in the air then reacts with oxygen to form sulphur trioxide (SO_3).

- Sulphur trioxide dissolve in water droplets of the atmosphere to produce sulphuric acid. Sulphur acid is a secondary pollutant and is a major component of acid rain.

- Carbon dioxide reacts with rain water to produce carbonic acid.

<u>Effects of Pollutants on Health and the Environment</u>

1. Effects of pollutants on health.

Air pollution is harmful to human health. People exposed to high levels of certain pollutants may experience some of the following problems.

- Increased risk of lung cancer
- Wheezing, coughing, chest tightness and breathing difficulties.
- Increased risk of heart attacks.
- Worsening of existing lung and heart problems such as asthma.
- Irritation of eyes, nose and throat.
- Death due to continuous exposure to some pollutants such as carbon monoxide.
- Loss of memory and even brain damage due to inhalation of pollutants such as lead (Pb).

In addition, long-term exposure to air pollution can cause cancer and damage to the immune, neurological, reproductive, and respiratory systems.in extreme cases, it may even cause death.

2. Effects of pollutants on the environment

Besides causing harm to human health, air pollutants cause several environmental effects. Some of them have been described below.

Formation of acid rain

Sulphur dioxide and nitrogen oxides react with water in the atmosphere producing sulphuric acid and nitric acid respectively. These acids come down along with the rain. This rain is known as acid rain.

In the environment, acid rain causes respiratory and skin disorders, affects productivity of plants by damaging the leaves, enters the soil and affects the soil pH and causes leaching of nutrients, enters the ground and rive water which causes harm to aquatic life. Furthermore, acid rain also speeds up the decay of building, statues and sculptures.

Depletion of ozone layer

The stratosphere of the atmosphere has ozone (O_3). Ozone is known to absorb ultraviolet (UV) rays present in the radiations of the sun and protects us from the harmful effects of the UV rays. However, chemical such as chlorofluorocarbons (CFCs) destroy the ozone molecules which deplete the ozone layer. Ozone holes have been detected in the atmosphere which permits the UV rays to reach the surface of the earth. The harmful effects of UV radiation include skin cancer and eye problems.

Global climate change

Due to excessive burning of fossil fuels and extensive changes in the land cover by deforesting large areas to make space for cities or farms, immense quantities of greenhouse gases such as carbon dioxide are released into the air. Greenhouse gases are air components whose accumulation in the atmosphere causes rise in global temperature. Greenhouse gases facilitate an increase in global temperatures by trapping the heat in the atmosphere, and their ever-increasing concentrations have radially started to change the climate of the earth. Climate change results in increased temperature, melting of ice caps, rise in sea water levels, more frequent drought's, floods, heat related disease and extinction of plant and animal species.

Eutrophication

Eutrophication is a condition in a water body where high concentrations of nutrients such as nitrogen stimulate excessive plant growth. Eutrophication can cause death of fish and loss of plant and animal diversity. Although eutrophication is a natural process, human activities can greatly accelerate eutrophication by increasing the rate at which nutrients enter aquatic ecosystems. Air emission nitrogen oxides from power plant, cars and other sources contribute the amount of nitrogen entering aquatic ecosystems.

Effects on world life

Animals are exposed to air pollutants through inhalation of gases or small particle, ingestion of particle suspend in food or water and absorption of gases through the skin. The absorption of pollutants through the skin affect only soft – bodied invertebrates like earthworms and animals with thin, moist skin. Just like humans animals can experience health problems if they are exposed to sufficient concentration of air pollutants over time. The most common health effects on animals are respiratory problem. At the same time, air pollutants affect the quality of the environment or habitat in which animals live and the quality of food that animals eat.

Haze

Haze is an atmospheric phenomenon where visibility of the sky is reduced due to the high presence of smoke, dust and other airborne particles. Haze is produced when sunlight hits concentrated particle of airborne pollutants such as sulphur dioxide and nitrogen oxide. There pollutants are emitted from power plants, industrial facilities, and automobiles or produced by the smoke from wildfires. Haze decreases visibility. It obscures the clarity, texture and form of what you see. Short-term exposure to haze particles can lead to development of medical condition such as bronchitis. It also increases the risk of lung cancer and death by cardiovascular Diseases.

Ways of reducing atmospheric pollution

- There is need to introduce better and more efficient filter systems in industries.
- There is need to introduce better processing of fuels to make them free from sulphur compounds.
- There is need to introduce smokeless fuels like hydrogen.
- There are is need to improve combustion of fuels in petrol and diesel engines.
- There is need to promote the use of renewable energy sources such as solar energy, wind energy, geothermal energy and hydroelectric energy.
- Plant more tree since trees release fresh air.

End of topic exercise

1. What is meaning of fractional distillation?
2. In the separation of air into its components,
   i. Why is carbon dioxide and water vapour removed?
   ii. How is carbon dioxide removed?
   iii. Why is nitrogen obtained before oxygen?
3. Explain why a mixture of methane gas and oxygen burn better than a mixture of methane and air
4. Why is carbon dioxide used in fire extinguishers?
5. Describe any two effects of pollutants on:
   i. health
   ii. Environment
6. Suggest three ways of reducing atmospheric pollution.
7. With the aid of a flow diagram, describe how nitrogen, oxygen and argon are obtained during fractional distillation of air.

UNIT 13 : SOIL

Definition of soil
Soil is the thin layer of organic and inorganic materials that covers the surface of the earth.
Components of soil
Soil is composed of inorganic matter, organic matter, air and water.

a. Inorganic Matter

Inorganic matter forms a larger percentage of most soils. It is derived from weathered rocks and is compose of minerals such as potassium, copper and magnesium which influence the properties of soil. Inorganic materials take the form of sand, silt and clay.

Sand is mainly made up of the mineral called silica (SiO_2).sand particles are chemically inactive and insoluble in most natural acids. The amount of silt particle present in the soil determines the soil structure and the distribution of pores in the soil. Clay retains water much longer than silt or sand. Soil nutrients are not easily leached through clay soil.

b. Organic Matter

Organic matter come from the decomposition of parts of plants animal wasted and the remains of deal plant and animals. Bacteria are responsible for the decomposition of these material to for humus. These bacteria play vital role in increasing soil fertility. Organic matter help in binding the soil particles together and increases the water holding capacity of soil.

c. Air (Soil Air)

The spaces or pores in the soil are occupied by air from the atmosphere. Soil air is needed by microorganisms that release plant nutrients. The air fills the soil pores as water drains or is removed from the soil pore by evaporation or root absorption. Therefore, soil aeration is affected by an increase in soil water content.

d. Water

The pores in between soil particles are occupied by water when it is treated with water. It is usually called soil water or soil moisture. Soil water dissolves various mineral salts which are necessary for plant growth. Presence of too much water in the soil causes waterlogging in the soil. Waterlogging interferes with the free circulation of air in the soil, thereby reducing the amount of oxygen necessary for bacteria and plants. When the bacteria activity in the soil is interfered with, less

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humus will be formed thereby leading to low soil fertility. In addition, waterlogging promotes leaching of soil nutrients beyond the root zone.

CHEMICAL PROPERTIES OF SOIL

a. Cation Exchange Capacity

Cation Exchange Capacity is the ability of the soil to exchange cations at a given pH. It is a measure of the ability of the soil to hold and release nutrients for plant use. By definition, cations are positively charged ions while anions are negatively charged ions.

Examples of Cations and Anions Found in the Soil

CATIONS ***(positively charged ions)***	**ANIONS** ***(negatively charged ions)***
Calcium ions (Ca^{2+})	Chloride ions (Cl^{-})
Potassium ions (K^{+})	Nitrates ions (NO^{-}_{3})
Magnesium ions (Mg^{2+})	Sulphate ions (SO^{2-}_{4})
Ammonium ions (NH^{+}_{4})	Phosphate ions (PO^{3-}_{4})

Cations hold on to soil particles and are not easily leached while anions do not hold on to soil particles. The anions are found in solution form in the soil hence they are easily leached. Fertile soils have very high cation exchange capacity. However, a soil with low cation exchange capacity is less fertile because it is unable to hold too many nutrients. Cation exchange capacity depends on the amount of organic matter and clay in the soil. The higher the organic matter and clay content, the higher the cation exchange capacity.

b. Soil Salinity

Soil salinity is the amount of salt present in the soil. Soils which have a high concentration of soluble salts are known as saline soils. Soil salinity is caused by some of the following;

- Poor drainage
- Low rainfall where there is high rate of evaporation
- Excessive use of artificial fertilizers
- Releasing of salts into the soil by the parent material
- Irrigating the soil with poor quality water

Effects of salt accumulation

- Excess salt in the soil increase soil alkalinity which makes the soil toxic to some crop .
- It also affects seed germination and plant growth.
- Some nutrients such as potassium, boron and iron become unavailable to plants in saline soils.

c. **Organic matter**

Organic matter are remains of dead animals and plants which become part of the soil. It's the main component of top soil. It accounts for many properties of soil such as moisture content, texture, PH, ion exchange capacity and nutrient content.

d. **Soil pH**

Soil pH is the degree of acidity or alkalinity of a soil solution. Soil pH is as a result of the concentration of hydrogen ions (H^+) and hydroxyl ions (OH^-) in the soil. An increases in concentration of hydrogen ions in soil causes the soil to be more acidic. Similarly, an increase in the concentration of hydroxyl ions in the soil causes the soil to be more alkaline. However when the concentration of hydrogen ions and hydroxyl ions are equal, the soil tends to be neutral.

The pH scale is used to determine the degree of acidity or alkaline of soil .pH scale has values ranging from 0 to 14. All soils of pH more than 7 are alkaline while all soils with a pH less than 7 are acidic. A pH of 7 indicates a neutral soil. The pH is important because it influence the availability of essential nutrients necessary from plant growth.

Effects of high soil acidity and alkalinity

a. Effects of High Soil Acidity

- Acidic in soil reduces the rate at which bacteria decompose organic matter.
- It also reduces in rate at which roots absorb mineral nutrients.
- Acidic soils results in an increase of aluminum ions which are toxic to plants.

b. Effects of High Soil Alkalinity

- Soils with high pH (alkaline soils) make some minerals such as iron zinc less available.
- Soils with high pH also affect activities of microorganisms.

Controlling Acidity and Basicity of Soil

- The acidity in the soil can be lowered by application of lime or basic fertilizer.
- High alkalinity in the soils can be lowered by application of sulphur or acidic fertilizer such as ammonium Sulphate ($(NH_4)_2SO_4$)

Importance of controlling acidity of soil

Soil acidity has negative impacts on soil fertility, biological activity and plant productivity. Soil that is highly acidic kills the micro-organisms that are present in the soil. The micro-organisms are an essential part of the soil, helping in the decomposition of organic matter thereby providing nutrients for plant growth. Soil acidity also reduces the rate at which roots absorb mineral salts thereby interfering with plant growth. Therefore, it is essential to the acidity of soil.

SOIL POLLUTION

Soil pollution is the release of harmful substance in the soil by human activities which affects plant growth and animal health.

Sources of Soil Pollutants and Their Effects

Human activities are the major cause of soil pollution. Some of the main sources of soil pollutants are described below:

A. Excessive Use of Agrochemicals.

Agrochemicals are the various chemicals that are used in agriculture. There include chemical fertilizers, herbicides, insecticides, pesticides and fungicides. They contaminate the soil by changing its physical and chemical properties. Pesticides that contaminate the soil seep lower down the soil layer and contaminate ground water that is used for domestic purpose. In addition, chemicals from agricultural practices harm the survival of a number of a number of essential soil microorganisms. These microorganisms help in the formation of humus. Any disturbance on their activities reduces soil fertility.

B.Radioactive Pollutants

Radioactive pollutants arise from human activities such as nuclear weapon testing, nuclear power plants and poor disposal of radioactive wastes. Radioactive elements that are released into the air also enter the soil as radio nuclides with rain water. When soil is contaminated by radioactive substances, the harmful substances are transferred into the plants growing on it. This leads to genetic mutation within the plant thereby affecting the normal functioning and growth of the plant. Some plant may die after exposure to radioactive substances while others may develop weak seeds. Radioactive elements can also be absorbed by the soil particles thereby causing harm to soil microorganisms**.**

C. Deforestation

Deforestation is destruction of forests in order to make land available for other uses. As trees are cut down, the exposed soil is easily carried away during soil erosion. With the soil taken away, the land is left unable to support vegetation.

D. Acid Rain

Acid rain occurs when pollutants in the air such as sulphur dioxide and nitrogen oxides mix with rain. When acid rain enters the soil, it affects soil pH thereby affecting plant growth and activities of activities of microorganisms. Acid rain also causes leaching of mineral nutrients leading to decrease in soil fertility.

E. Petroleum Products

Petroleum products are the refined products of crude oil such as kerosene, diesel, naphtha, fuel oils and gasoline. Many of these products can cause problems when present in the soil. For example, some petroleum products can be very thick and sticky. When these types of petroleum products get spilled on the soil, they can clog the soil thereby reducing the amount of water reaching plant roots, resulting in drought-like conditions. They also affect soil aeration which causes soil microorganisms to get insufficient oxygen from the soil.

F. Dumping of Soil Wastes

Solid wastes come from households and industries. Some solid wastes are biodegradable while others are non-biodegradable. Uncollected solid wastes increase the risk of injury and infection. Solid wastes deposited near water sources results in contamination of water bodies. In addition, solid wastes affect soil aeration and this affects plant growth and activity of microorganisms.

EFFECTS OF SOIL POLLUTION

- Decrease in soil fertility
- Loss of soil nutrients present in the soil
- Reduction in nitrogen fixation caused by reduction in microbial activities
- Increase in soil salinity which affects plant growth
- Alteration in soil structure causes death of many essential soil organisms
- Disturbance in balance of flora and fauna residing in the soil

- Contamination of ground water used for domestic purposes as pesticides that contaminate the soil seep lower down the soil layer
- Barrenness of soil due to excessive use of chemicals

WATYA OF PREVENTING SOIL POLLUTION

- Recycling paper, plastics and other materials.
- Over tiling of the land must be avoided to avoid soil erosion and soil compaction.
- Reducing the use of chemical fertilizer and pesticides and replacing them with organic ones
- Avoid deforestation and promote planting of trees where the land is bare.
- Biodegradable wastes which are combustible can be burnt in incinerators.
- Promote suitable and safe disposal of domestic and industrial wastes.
- Proper maintenance of sewage systems.
- Promoting pollution awareness programs.

<u>END OF UNIT EXERCISE</u>

1. Describe the main components of soil.
2. Describe the chemical properties of soil.
3. Why is it important to regulate soil pH?
4. What is the meaning of the term soil salinity?
5. State any four causes of soil salinity.
6. Briefly describe the sources of soil pollutants and their effects.
7. Explain any two effects of acidic soils on plant growth.
8. Briefly describe three effects of soil pollution.
9. Explain ways of preventing soil pollution.