CHEMISTRY ASPECT OF GENERAL SCIENCE

LECTURER – ANTHONY F. ADJIVON Tel: 3650097 / 9994624
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MODULE CONTENT

THIS MODULE CONTAINS SEVEN (7) UNITS

UNIT 1

NATURE AND CHARACTER OF SCIENCE

Learning Objectives.
After studying this unit, you should know

1. What is Chemistry and what does it study?
2. The basic terms used in chemistry.

Science is the orderly search for answers to our questions about the world we live in. **Science is divided into various groups.** Science can be divided into two major groups.
One group consists of the biological sciences, which deal with the study of all living things.
The other group is made up of the physical sciences, which deal with matter, force and energy. The two main branches of physical science are **Chemistry** and **Physics**. **Physics** is the study of energy and the changes from one form of energy to another. **Chemistry** deals with the study of matter and its changes.
The term **chemistry** is very difficult to define precisely because the field is so diverse and because the practitioners perform such an incredible variety of jobs. **Chemistry** deals with solutions in which the nature of a substance is changed by altering its composition so that entirely new substances are synthesized or particular properties of existing substances are enhanced.

BASIC TERMS IN CHEMISTRY

1. A pure substance is one with constant composition. Pure substances contain compounds (combination of elements) or free elements.
2. A compound is a substance with constant composition that can be broken down into elements by chemical processes.
3. A chemical change is one in which a given substance becomes a new substance or substances with different properties or different composition.
4. Elements are substances that cannot be decomposed into simpler substances by chemical or physical means.
5. A chemical symbol identifies an element. Each element has a symbol. A symbol is a shorthand way of writing the name of the element.
6. Chemical formulae. These are used to identify compounds by showing the kind and number of atoms that are present.
7. Chemical equations. This is a better way of describing a chemical change. Such equations state what elements or compounds enter into a chemical change and what elements or compounds are produced by chemical change.
8. Solvent. A solvent is a liquid, which can be used to dissolve things.
9. Solute. A solute is a substance, which dissolves in a solvent to make a solution.
10. Matter exists in 3 states a) Solid b) liquid and c) gas
    Any substance can exist in each of these three states depending on the conditions of temperature and pressure. When a solid is heated it melts and forms a liquid. The temperature at which both solid and liquid can exist is called the melting point or freezing point. When a liquid is heated to its boiling point, it boils and forms a gas

(or vapour). Matter can be converted from one form to another by either heating or cooling and also changing the pressure.

The properties of solids, liquids and gases are summarized in the following table.

Property	Solid	Liquid	Gas
Shape	Definite shape	No definite shape, takes the shape of the container	No definite shape
Volume	Definite volume	Definite volume	No definite volume. Occupies the entire space available
Packing of particles	Packed closely to each other	Not as closely packed as in solids	Particles are far apart from each other
Movement of particles	Only vibrate about their positions	Particles slide over each other	Particles move freely
Compressibility	Cannot be compressed	Can be slightly compressed but with difficulty	Can be easily compressed

UNIT 2

Learning Objectives.

After studying this unit, you should be able to explain

1. the Atomic Theory and describe the structure of an atom
2. what isotopes are and give some examples
3. Radioactivity, types of emissions; uses and dangers associated with radioactivity and radioisotopes

ATOMIC THEORY

Dalton's Atomic Theory

In 1808 Dalton published **A new system of chemical philosophy**, in which he presented the theory of atoms. He postulated that: -

1. Each chemical element is composed of minute, indivisible particles called atoms. Atoms can be neither created nor destroyed during a chemical change.

2. All atoms of an element are alike in mass (weight) and other properties, but the atoms of one element are different from those of all other elements.

3. In each of their compounds, different elements combine in a simple numerical ratio, for example, one atom of A to one of B (AB), or one atom of A to two of B (AB_2)

The concept of atoms was clearly a good idea and this question arise; - what is an atom made of, and how do the atoms of the various elements differ?

A MODERN VIEW OF ATOMIC STRUCTURE

The simplest view of the atom is that it consists of a tiny nucleus (with a diameter of about 10^{-13} cm) and electrons that move about the nucleus with an average distance of about 10^{-8}cm from it.

The nucleus is assumed to contain protons, which have a positive charge equal in magnitude to the electron's negative, and neutrons, which have virtually the same mass as a proton but no charge.

An important question to consider is - if all atoms are composed of these components why do different atoms have different chemical properties?

The answer is - The atoms of different elements, which have different numbers of protons and electrons, show different chemical behaviour because atoms greatly affect ability to interact with other atoms.

What are isotopes?

Isotopes are atoms with the same number of protons but different numbers of neutrons, i.e. they have the same atomic number but different masses. Examples include ${}^{35}_{17}Cl$ or Chlorine -35 and ${}^{37}_{17}Cl$ or Chlorine - 37

Hydrogen has three isotopes ${}^{1}_{1}H$ or hydrogen, ${}^{2}_{1}H$ or deuterium and ${}^{3}_{1}H$ or tritium.
Since isotopes are alike chemically, no chemical method can be used to separate them. Instead, a method that depends on their differences in mass (a physical property) is used.

In general an element is represented by ${}^{A}_{Z}E$, where the atomic number Z (number of protons) is written as a subscript and the mass number A (the total number of protons and neutrons) written as a superscript. In nature most elements are mixtures of isotopes. Usually all the isotopes of an element share the same name and atomic symbol. The exception is hydrogen. The two isotopes are called deuterium (symbol D), and tritium (T).

THE NUCLEUS: This part of the atom is very small, spherical and very dense. It carries all the mass of the atom and has a positive charge. It occupies the centre of the atom. The nucleus of an atom of any element is made up of particles of two types: protons and neutrons. The only exception to this is an atom of the commonest form (isotope) of the element hydrogen. Its nucleus contains a proton only.
The proton has a positive (+ ve) charge. The mass of a proton is almost equal to the mass of a neutron. A proton is represented by the symbol **p**. In an atom, the number of protons is equal to the number of electrons. Atoms of different elements have different numbers of protons. It is the number of protons in the atom of an element that indicates which element it is and gives the element its identity.
The neutron has no electrical charge, so it is neutral. It's mass is almost the same as that of the proton. A neutron is represented by the symbol **n**.

The electron: This particle has a negative (- ve) charge, equal but opposite to the charge on a proton. The atom is electrically neutral. The atom contains equal numbers of protons and electrons therefore the numbers of positive and negative charges are equal. The symbol for the electron is **e**. Electrons occupy all the space in the atom except the part occupied by the nucleus. They are said to revolve constantly around the nucleus.
These paths are sometimes represented by a series of circles, or shell. Bohr developed this model.
When drawing the electronic configuration of an atom the following rules apply: -

1. Shells fill up in order starting with the one nearest the nucleus
2. The maximum number of electrons, which can be placed in a shell, is given by the formula $2n^2$ where n is the number of the shell. The shells are numbered in sequence with the first shell (n=1) nearest to the nucleus.

Atomic number is the special name given to the number of protons in the nucleus of a neutral atom of an element. Symbol is **Z** or proton number.
Mass number is the special name given to the mass of the atom. Mass number is equal to the number of protons plus the number of neutrons. The symbol is A.

Note that electrons take part in chemical reactions and in doing so the elements taking part do not loose their identities ie. the number of protons in each element remains the same. In nuclear reactions, the nucleus is involved and elements usually change their identities, i.e. new elements are formed.

Radioactivity

Definition: Radioactive decay:
Radioactive decay is the process in which an unstable atomic nucleus loses energy by emitting particles or electromagnetic waves. These emitted particles or electromagnetic waves are called radiation.
When a nucleus undergoes radioactive decay, it emits radiation and the nucleus is said to be radioactive. We are

exposed to small amounts of radiation all the time. Even the rocks around us emit radiation! However some elements are far more radioactive than others. Even within a single element, there may be some isotopes that are more radioactive than others simply because they contain a larger number of neutrons. These radioactive isotopes are called radioisotopes.

There are many sources of radiation. Some sources are natural and others are man-made.

- Natural sources of radiation include cosmic and terrestrial radiation.
- Man-made sources of radiation include televisions, smoke detectors, X-rays and radiation therapy.

Radiation can be emitted in different forms. There are three main types of radiation: alpha, beta and gamma radiation. The properties of alpha & beta particles, and gamma rays are summarized in the following Table:

Particle or ray/ Field	Mass number	charge	Nature	Change in element	Penetrating power	Stopped by	Electric field	Magnetic field
Alpha α-particle	4	+ 2	Helium nuclide	Yes	Low	Air Thin piece of paper	attracted towards cathode: negative pole	Away from field towards viewer
Beta β-particle	0	- 1	Electron	Yes	Medium	Thin aluminium foil	attracted towards anode: positive pole	Away from field from viewer
Gamma γ- ray	0	0	High energy photon(electromagnetic energy)	No	High	Thick concrete or lead	Unaffected	unaffected

The Dangers of Radiation

Natural radiation comes from a variety of sources such as the rocks, sun and from space. However, when we are exposed to large amounts of radiation, this can cause damage to cells. Radiation is particularly dangerous because it is able to penetrate the body, unlike α- and β- particles whose penetration power is less. Some of the dangers of radiation are listed below:

• Damage to cells:- Radiation is able to penetrate the body, and also to penetrate the membranes of the cells within our bodies, causing massive damage. *Radiation poisoning* occurs when a person is exposed to large amounts of this type of radiation. Radiation poisoning damages tissues within the body, causing symptoms such as diarrhoea, vomiting, loss of hair and convulsions.

• Genetic abnormalities:- When radiation penetrates cell membranes, it can damage chromosomes within the nucleus of the cell. The chromosomes contain all the genetic information for that person. If the chromosomes are changed, this may lead to genetic abnormalities in any children that are born to the person who has been exposed to radiation with defects such as babies born with missing limbs and abnormal growths.

• Cancer:- Small amounts of radiation can cause cancers such as leukemia (cancer of the blood)

The Uses of Radiation/ Radioisotopes

However, despite the many dangers of radiation, it does have many powerful uses, some of which are listed below:

• Medical Field: - Radioactive *chemical tracers* emitting rays can give information about a person's internal anatomy and the functioning of specific organs. The radioactive material may be injected into the patient, from where it will target specific areas such as bones or tumours. As the material decays and releases radiation, this can be seen using a special type of camera or other instrument. The radioactive material that is used for this purpose must have a short half-life so that the radiation can be detected quickly and also so that the material is quickly removed from the patient's body. Using radioactive materials for this purpose can mean that a tumour or cancer may be diagnosed long before these would have been detected using other methods such as X-rays. Radiation may also be used to sterilize medical equipment.

Radioactivity is used for

1. Preservation of food grains and seeds
2. Radio phosphorous is used for studying the rate of phosphorous assimilation by the plant.
3. It is used for finding out the faults in metal structures.
4. It is used for preparing synthetic elements (artificial transmutation)
5. In breeder reactors radiations are used to prepare the fuel / fissile material and to produce electricity in Nuclear power plants.
6. Natural radioisotopes such as C-14 can be used to determine the age of organic remains. All living organisms (e.g. trees, humans) contain carbon. Carbon is taken in by plants and trees through the process of photosynthesis in the form of carbon dioxide and is then converted into organic molecules. When animals feed on plants, they also obtain carbon through these organic compounds. Some of the carbon in carbon dioxide is the radioactive C-14, while the rest is a non-radioactive form of carbon. When an organism dies, no more carbon is taken in and the amount of C-14 in the body stops increasing. From this point onwards, C-14 begins its radioactive decay which reduces the amount of C-14 in the body. When scientists uncover remains, they are able to estimate the age of the remains by seeing how much C-14 is left in the body relative to the amount of non-radioactive carbon. The less C-14 there is, the older the remains because radioactive decay must have been taking place for a long time. Because scientists know the exact rate of decay of C-14, they can calculate a relatively accurate estimate of the age of the remains. Carbon dating has been an important tool in building up historical records.

Radioactive decay rates are normally stated in terms of their half-lifes, and the half-life of a given nuclear species is related to its radiation risk. It is defined as the time it takes a radioactive nuclide to decay to half of its original mass. The **half-life** of an element is the time it takes for half the atoms of a radioisotope to decay into other atoms.

There are 2 types of nuclear reactions:- Nuclear fission & nuclear fusion

• Nuclear fission is the splitting of an atomic nucleus into smaller fission products. Nuclear fission produces large amounts of energy, which can be used to produce nuclear power and to make nuclear weapons.

• Nuclear fusion is the joining together of the nuclei of two atoms to form a heavier nucleus. In stars, fusion reactions involve the joining of hydrogen atoms to form helium atoms. These reactions take place in the Sun.

UNIT 3
CHEMICAL BONDING

OBJECTIVES

1. To introduce basic ideas of bonding in molecules (covalent, ionic, hydrogen bonding, polar and coordinate bonding, metallic bonding)
2. To introduce the concept of intermolecular forces of attraction and explain how they affect the properties of compounds, molecules.

The forces that hold atoms together in compounds are called chemical bonds. One way that atoms can form bonds is by **sharing electrons**. These bonds are called **covalent bonds**, and the resulting collection of atoms is called a molecule.

Molecules can be represented in several different ways but the simplest method is the chemical formula, in which the symbols for the elements are used to indicate the types of atoms present and subscripts are used to indicate the relative numbers of atom, e.g. CO_2, H_2SO_4
More information about a molecule is given by its structural formula, in which individual bonds are shown. e.g. H- O-H
Water is a good example of a molecule formed by the sharing of electrons. Oxygen needs 2 electrons to complete its outer shell. Hydrogen needs one electron to complete its outer shell. The electron from each of the hydrogen atoms and the 2 electrons from the single oxygen atom are shared by the outer shells of both atoms.
Covalent bonds are usually formed when elements (usually non- metals) share outer shell electrons with each other.

A **second type** of chemical bond results from attractions among ions.
An ion is an atom or a group of atoms that has a net positive or negative charge. In other words, when the number of protons and electrons in a particle are different, then it has an overall charge which is not equal to zero.
A positive ion is called a cation e.g. Na^+, Ca^{2+}
$2Na \longrightarrow 2Na^+ + 2\ e^-$
An ion with a negative charge is called an anion e.g Cl^-
$Cl_2 + 2e^- \longrightarrow 2\ Cl^-$
Because anions and cations have opposite charges, they attract each other. **This force of attraction between oppositely charged ions is called ionic bonding.**
e.g $2Na^+ + 2Cl^- \longrightarrow 2NaCl$
An ionic bond is formed when two atoms transfer electrons. This type of bond is formed usually when a metal transfers one or more electrons from its outer shell to another element (usually non - metal).
A solid consisting of oppositely charged ions is called an ionic solid, or a salt. Ionic solids can consist of simple ions, as in sodium chloride, or in polyatomic ions, as in ammonium nitrate NH_4NO_3

Which elements make ionic compounds? Two atoms are necessary - one atom, which can easily loose one or more of its electrons and one that can accept them. The metals in group 1 and II of the periodic table have the highest tendency to lose electrons and turn into positive ions. The non-metals of groups VI and VII have the greatest affinity for electrons and readily change into negative ions.

PROPERTIES OF IONIC COMPOUNDS

1. High melting and boiling points
2. The energy needed to separate the particles is high
3. They are usually crystalline
4. Many are soluble in water
5. They do not conduct electricity when solid but are good conductors when molten or in solution.

POLAR BONDS AND ELECTRONEGATIVITIES

Hydrogen Chloride is a good example of a polar molecule. This is so because of its uneven distribution of charge. One end of the molecule has a slightly positive charge and the other a slight negative charge.

$$H^{\delta^+} - Cl^{\delta^-}$$

Note that the bond is covalent. It's small δ^- and δ^+ charges do not make it an ionic substance.
One way of predicting whether a molecule is polar is to use values of electronegativity. Electronegativity is a measure we use to tell us how an element attracts electrons in a bond. The elements - fluorine and chlorine tend to attract electrons to themselves very strongly. These elements have high values of electronegativity. On the

other hand, metals like sodium and potassium very rarely form negative ions. They tend to lose an electron to make positive ions. These have low electronegativities.
Electronegativity increases across a Period and decreases down a Group.

What is coordinate bonding? Now consider the ammonia molecule. We know this to be a slightly distorted tetrahedron, with a lone pair of electrons on the nitrogen atom. It so happens that ammonia and a hydrogen proton combine with each other. The resulting molecule has a shape resembling two tetrahedra joined together. There is an empty 1s orbital on the hydrogen (proton) atom, which could contain two electrons. It can gain them by this orbital overlapping with the lone pair on the nitrogen atom in ammonia. We say that the nitrogen donates its pair of electrons to the hydrogen atom. The name of the bond they make is a **coordinate bond**.
In some books the term **dative covalent bond** is used instead of **coordinate bonding**.

METALLIC BONDS

The nature of the metallic bond: The structure of a metallic bond is quite different from covalent and ionic bonds. In a metal bond, the valence electrons are *delocalised*, meaning that an atom's electrons do not stay around that one nucleus. In a metallic bond, the positive atomic nuclei (sometimes called the 'atomic kernels') are surrounded by a sea of delocalised electrons which are attracted to the nuclei

Definition: Metallic bond

Metallic bonding is the electrostatic attraction between the positively charged atomic nuclei of metal atoms and the delocalised electrons in the metal.

The properties of metals

Metals have several unique properties as a result of metallic bonding:

• *Thermal conductors:* Metals are good conductors of heat and are therefore used in cooking utensils such as pots and pans. Because the electrons are loosely bound and are able to move, they can transport heat energy from one part of the material to another.

• *Electrical conductors:* Metals are good conductors of electricity, and are therefore used in electrical conducting wires. The loosely bound electrons are able to move easily and to transfer charge from one part of the material to another.

• *Shiny metallic luster:* Metals have a characteristic shiny appearance and are often used to make jewellery. The loosely bound electrons are able to absorb and reflect light at all frequencies, making metals look polished and shiny.

• *Malleable and ductile:* This means that they can be bent into shape without breaking (malleable) and can be stretched into thin wires (ductile) such as copper, which can then be used to conduct electricity. Because the bonds are not fixed in a particular direction, atoms can slide easily over one another, making metals easy to shape, mould or draw into threads.

- Sonorous. Metals ring when struck with a hard object.

• *Melting point:* Metals usually have a high melting point and can therefore be used to make cooking pots and other equipment that needs to become very hot, without being damaged. The high melting point is due to the high strength of metallic bonds.

• *Density:* Metals have a high density because their atoms are packed closely together.

INTERMOLECULAR FORCES

• There are three main types of Van der Waal's forces. These are dipole-dipole, ion-dipole and London forces (momentary dipole).

• Dipole-dipole forces exist between two polar molecules, for example between two molecules of hydrogen chloride.

• Ion-dipole forces exist between ions and dipole molecules. The ion is attracted to the part of the molecule that has an opposite charge to its own. An example of this is when an ionic solid such as sodium chloride dissolves in water.

• Momentary dipole forces occur between two non-polar molecules, where at some point there is an unequal distribution of charge in the molecule. For example, there are London forces between two molecules of carbon dioxide.
• Hydrogen bonds occur between hydrogen atoms and other atoms that have a high electronegativity such as oxygen, nitrogen and fluorine. The hydrogen atom in one molecule will be attracted to the nitrogen atom in another molecule, for example. There are hydrogen bonds between water molecules and between ammonia molecules.
• Intermolecular forces affect the properties of substances. For example, the stronger the intermolecular forces, the higher the melting point of that substance, and the more likely that substance is to exist as a solid or liquid. Its boiling point will also be higher.
• In liquids, properties such as surface tension, capillarity and evaporation are the result of intermolecular forces.

SUMMARY

A hydrogen bond is made between a hydrogen atom and a highly electronegative atom such as fluorine, oxygen, chlorine or nitrogen. The hydrogen atom itself must be bonded to an atom with a high electronegativity.

Hydrogen bonds are responsible for:

1. The relatively high melting and boiling points of water and hydrogen fluoride.
2. Holding the strands of DNA together.

Intermolecular hydrogen bonds occur between different molecules, e.g. between water and alcohol molecules, or between ethanoic acid dimers.

Intermolecular hydrogen bonds occur between groups in the same molecule, e.g. in 2-nitrophenol

A coordinate bond (dative covalent bond) is a covalent between two atoms in which one of them provides both electrons. The lone pair on an ammonia molecule is often used in coordinate bonding, e.g. to a hydrogen ion as in NH_4^+

UNIT 4

ACIDS AND BASES

OBJECTIVES

1. To give different definitions of acid and bases
2. To know what is an alkali.
3. To look at simple reactions between acids and bases to give salts.
4. To know what acid - base indicators are and when they can be used.
5. To explain the term pH and its importance

The standard definition of an acid in introductory chemistry books is: -

An acid will
(I) Give hydrogen with a metal,
(ii) Neutralise a base to give a salt and water only, and
(iii) Give carbon dioxide with carbonates

This summarises a great deal of information about the properties of acids, but does not tell us anything about their chemical structures except that they contain hydrogen as one of their elements.

DEFINITIONS OF ACIDS & BASES: There are different definitions of acids and bases. These include:

- **Arrhenius definition**: Acids dissociate in water releasing H_3O^+ ions; bases dissociate in water releasing OH^- ions.
- **Brønsted-Lowry definition**: Acids are proton (H^+) donors; bases are proton acceptors. Includes the Arrhenius definition.

- **Lewis definition**: Acids are electron-pair acceptors; bases are electron-pair donors. Includes the Brønsted-Lowry definition.

BASES: These are hydroxides or oxides of metals, e.g. sodium hydroxide (NaOH) and potassium hydroxide (KOH). They are obtained from nature when some plants are burnt to ash and the ash dissolved in water.
There is a special group of bases called alkalis identified because of their solubility in water. They are the opposites of acids. They are used in homes to neutralize acids, remove greases and fats and powerful cleaning detergents contain NaOH or KOH

ACID - BASE INDICATORS: Acid - base indicators change colour in acidic, alkaline or neutral conditions. This allows them to be used to classify a substance dissolved in water as an acid, a base or a neutral substance.
Acid - base indicators can be natural or synthetic such as litmus, methyl orange and phenolphthalein.
Litmus turns **red** in any acid solution.
They are used to tell us when proper amounts of the acid or base have been added to give a neutral solution or indicates colour change to show whether a solution is acidic, basic or neutral. The procedure is known as **titration**.

Combination	Suitable indicator	Colour change	
		In acid	In alkali
Strong acid + strong base	Methyl orange	Red	Yellow
Strong acid + weak base	Methyl red / orange	Red	Yellow
Weak acid + strong base	Phenolphthalein	Colourless	Pink
Weak acid + weak base	Not suitable for titration		

Strong acids: - Hydrochloric acid, Nitric acid and Sulphuric acid
Weak acids: - Acetic acid and phosphoric acid
Strong base: - Sodium hydroxide, potassium hydroxide
Weak base: - ammonia solution

SALTS

A salt is defined as a compound made up of the positive ions of a base and the negative ions of an acid.
Acids react with bases to give salt and water only.
e.g $HCl + NaOH \longrightarrow NaCl + H_2O$
$H_2SO_4 + Ca(OH)_2 \longrightarrow CaSO_4 + 2H_2O$
Salts of sulphuric acid are called sulphates: salts of nitric acid- nitrates and hydrochloric acid - chlorides

pH scale

The pH scale is a number scale which shows the acidity or alkalinity of a solution in water. Most laboratory solutions have pH values in the range 0 -14.
The scale ranges from 0 - 14. A pH of 1, for example, shows a strong acid solution. This means a very high number of hydrogen ions present in the solution. A pH of 14 shows a strong basic solution having a very high level of hydroxide ions. Pure water is neutral and has a pH of 7.
A solution with a pH less than 7 is acidic, having an excess of hydrogen ions. With a pH greater than 7, a solution is basic, having an excess of hydroxide ions. A solution with a pH of 2 is more acidic than that with a pH of 3 and a solution with a pH of 12 is more basic than that with a pH of 10.
The pH of a solution can be found using a Hydrion paper or liquid Universal indicator. This paper or liquid changes colour when moistened with the solution. It is then compared with the colour scale. When the colours match, the pH number can be read directly from the scale. A pH meter is also used and is more accurate than the hydrion paper or Universal indicator
The approximate pH values of several common liquids are shown in the following table.

Liquid	Lemon juice	Vinegar	Soft Drinks	Orange juice	Distilled water	Fresh Cow's Milk	Pure water	Human blood	Sea water	Some Tooth-Pastes
pH	2.3	2.8 -3.1	3.5 -4.1	3.5	6.2	6.5 - 6.7	7.0	7.4	8.5	9.8

Exercise

1. A suspension of magnesium hydroxide in water is known as milk of magnesia. What is it used for and why is it used?
2. Why is the pH of toothpastes so high?

UNIT 5

TYPES OF CHEMICAL REACTIONS

Objectives

1. To introduce the term chemical reaction and study several types of chemical reactions.
2. To look at some simple chemical reactions.

A **chemical reaction** is a process that always results in the interconversion of chemical substances. The substance or substances initially involved in a chemical reaction are called reactants. Chemical reactions are usually characterized by a chemical change, and they yield one or more products which are, in general, different from the reactants. Classically, chemical reactions encompass changes that strictly involve the motion of electrons in the forming and breaking of chemical bonds, although the general concept of a chemical reaction, in particular the notion of a chemical equation, is applicable to transformations of elementary particles, as well as nuclear reactions.

Different chemical reactions are used in combinations in chemical synthesis in order to get a desired product. In order to make sense of all these reactions, we need some system for grouping reactions into classes. Although there are many different ways to do this, we will use the system most commonly used by practicing chemists.

REACTION TYPES

The large diversity of chemical reactions and approaches to their study results in the existence of several concurring, often overlapping ways of classifying them. Below are examples of widely used terms for describing common kinds of reactions.

1. **Isomerisation**, in which a chemical compound undergoes a structural rearrangement without any change in its net atomic composition.
2. **Direct combination or synthesis**, in which 2 or more chemical elements or compounds unite to form a more complex product:

   $N_2 + 3\ H_2 \rightarrow 2\ NH_3$
3. **Chemical decomposition** or **analysis**, in which a compound is decomposed into smaller compounds or elements:

   $2\ H_2O \rightarrow 2\ H_2 + O_2$
4. **Single displacement or substitution**, characterized by an element being displaced out of a compound by a more reactive element:

   $2\ Na\ (s) + 2\ HCl\ (aq) \rightarrow 2\ NaCl\ (aq) + H_2\ (g)$
5. **Metathesis or Double displacement reaction**, in which two compounds exchange ions or bonds to form different compounds:

   $NaCl\ (aq) + AgNO_3\ (aq) \rightarrow NaNO_3\ (aq) + AgCl\ (s)$

6. **Acid-base reactions**, broadly characterized as reactions between an acid and a base. An acid - base reaction is often called a neutralization reaction. When just enough base is added to react exactly with the acid in a solution, then it is said that the acid has been neutralized.

In all acid -base reactions, the following takes place.

$H^+ (aq) + OH^- (aq) \longrightarrow H_2O (l)$

e.g. $HCl + NaOH \longrightarrow NaCl + H_2O$

7. **Oxidation - Reduction reactions. Redox reactions** are reactions in which changes in oxidation numbers of atoms in involved species occur. Reactions, in which one or more electrons are transferred, are called oxidation - reduction reactions or redox reactions. The concept of oxidation states (or oxidation numbers) provides a way to keep track of electrons in oxidation reduction reactions, particularly redox reactions involving covalent substances.

In general - **oxidation is an increase in the oxidation state (loss of electrons)**
Reduction is a decrease in oxidation state (a gain of electrons)

$2Na (s) + Cl_2 \quad 2NaCl (s)$

Sodium is oxidized and chlorine is reduced. Chlorine is called the oxidizing agent (electron acceptor) and sodium is the reducing agent (electron donor)

$CH_4 (g) + 2O_2 (g) \longrightarrow CO_2 (g) + 2H_2O (g)$

i.e. Carbon is oxidized
Oxygen is reduced
CH_4 is the reducing agent
O_2 is the oxidizing agent

8. **Combustion**, a kind of redox reaction in which any combustible substance combines with an oxidizing element, usually oxygen, to generate heat and form oxidized products. The term combustion is usually used for only large-scale oxidation of whole molecules, i.e. a controlled oxidation of a single functional group is not combustion.

9. **Precipitation reactions**

When two solutions are mixed, an insoluble substance sometimes forms; that is, a solid forms and separates from the solution. Such a reaction is called a precipitation reaction, and the solid that form is called a precipitate. For example, a precipitation reaction occurs when an aqueous solution of Potassium Chromate, $K_2Cr_2O_7$ (aq), which is yellow, is added to a colourless aqueous solution containing Barium Nitrate, $Ba(NO_3)_2$ (aq), a yellow precipitate forms.

What is corrosion and how can it be prevented?

Definition: Corrosion is the slow but continuous eating away of metallic components by chemical or Electro chemical attack. It is an oxidation – reduction reaction.

Corrosion prevention processes are not able to eliminate the inevitable failure of a component by corrosion but, before this occurs, the treatment can have slowed down the corrosion process to a point where the component will have worn out or been discarded for other reasons. Most of the cost of corrosion and its prevention is related to atmospheric corrosion. When exposed to atmospheric conditions any metal becomes covered with a thin film of moisture. This moisture film is then contaminated by solids and gases dissolved in the atmosphere and these increase the rate of corrosion.

Rate of corrosion: - Marine $<$ Rural $<$ Urban $<$ Industrial $<$ chemical

Note: - rusting will not take place in dry air or in water free from dissolved air (boiled water).

CORROSION PROTECTION

Since non- ferrous metals form oxides, which protect the metals from further corrosion, the corrosion prevention methods below apply to iron and steel.

For short-term protection: - Iron and steel components may be coated with oil or grease. For long time protection this is not used. Instead methods such as

1. Electroplating – using nickel, chromium, copper

2. Galvanising – using zinc

3. Anodising – using aluminium or

4. Painting: Protection using paint is one of the most common methods. This is effective if the surface is free from corrosion and clean when the paint is applied and continues as long as it excludes air and moisture. Paint acts not only as to prevent corrosion but also provides a decorative appearance.

EXERCISE: Name three other oxidizing agents and three other reducing agents.
List three applications of redox reactions in the industry.

UNIT 6
ORGANIC COMPOUNDS

Objectives

1. To distinguish between the properties of organic and inorganic compounds
2. To explain the reason for the existence of a very large number of carbon compounds
3. To understand and define the following terms
- Saturated and unsaturated straight-chain and branched-chain hydrocarbons
- Isomers
- Fuels, Gasoline and Octane rating
4. To compare the products formed by complete and incomplete combustion of a hydrocarbon fuel
5. To study the uses of Petroleum products and natural gas.

Organic chemistry is the study of **carbon compounds** but not all carbon compounds are termed organic. The name organic chemistry originated from the fact that all the compounds initially studied were all isolated from living organisms. Nowadays, most organic compounds are synthesized.

Carbon compounds make up the structure of all living things.

The basic laws of chemistry hold both for organic and inorganic compounds. There are however, a few differences in the reactions of organic compounds compared with inorganic compounds. In general, these differences are-:

1. Most organic compounds are insoluble in water. They will however dissolve in organic liquids such as alcohol, ether, etc. Most inorganic compounds dissolve, more or less readily in water.
2. Organic compounds will decompose on heating more readily than inorganic compounds. Some even vaporize without breaking down.
3. Reactions involving organic compounds proceed at a much slower rate than do reactions between inorganic compounds.
4. Organic compounds, existing as molecules are formed from the elements by covalent bonding, i.e. sharing of electrons. Most inorganic compounds are formed as a result of ionic bonding i.e. transfer of electrons.

Types of organic compounds:- Hydrocarbons made up the largest and simplest group of organic compounds. These are compounds that are composed only of hydrogen and carbon. Other important organic groups include -: Alcohols, Aldehydes, Organic acids, Ketones, Esters, Ethers, amines, amino acids etc. These contain other elements such as oxygen and nitrogen. Compounds in each of these basic groups have similar properties and molecular structure. Other organic compounds found in foods are proteins, carbohydrates, fats, oils and vitamins.

The hydrocarbons include many important compounds. These hydrocarbons are placed into series. The simplest and most abundant series of hydrocarbons is called the alkane series. They differ from one another chiefly in the

number of links in the chain. The first compound in this series is the gas - methane (CH_4) or marsh gas, which is the main component of natural gas.
Structural formulae are used to represent organic compounds. In many organic compounds, several arrangements of atoms in a molecule are possible. For this reason, a number of carbon compounds have the same simple chemical formula. To avoid confusion, chemists often show the arrangement of atoms in a molecule by means of a structural formula.
Hydrocarbons can be saturated i.e. every carbon atom in the compound shares a single bond with another carbon atom or hydrogen atom. They are said to be unsaturated if double or triple bonds exists in the compound. In such cases more hydrogen atoms can be added to the compound.
In certain hydrocarbons, the carbon atoms are linked or bonded together in long, straight chains. However, many hydrocarbons starting with butane (C_4H_{10}) also form chains, or branched chains. The carbon atoms can be attached in either a straight chains o.r a branched chain. Carbon atom forms a branched chain bonding on to the middle carbon atom.
Isomers are compounds with the same molecular formula but are not identical. The greater the number of carbon atoms in a chain, the more isomers the compound is likely to have.
Arenes or aromatic hydrocarbons are another important group of hydrocarbon compounds which contain benzene (C_6H_6), the first member. The general formula for this series is C_nH_{2n-6}
Gasoline contains many hydrocarbons. It is a complex mixture of compounds of the alkane series. Octane is one of the important hydrocarbons in gasoline the amount and kind of isomers in gasoline affect its quality. Gasoline with branched chain hydrocarbons burns more slowly than compounds. Petrol is a mixture of gasoline and other substances to improve on its performance. Sometimes the mixture of gasoline and air burns too quickly in a car engine. This results in blows which are called **knockings** and can result in engine damage. Knocking can be prevented by
a) using a slower burning fuel and
b) by adding catalyst to the gasoline.
The ability of a gasoline to resist knocking is expressed by a rating called the **<u>octane number</u>** the higher the octane number; the more knock resistant the gasoline.

Anything that burns gives out heat. **A fuel is a substance that can be burned to produce heat at a reasonable cost**. Fuels contain potential energy that is locked within their chemical bonds.
The word **petroleum** is derived from the Latin "Petra" - rock and ' Oleum' - Oil. Crude oil is a slippery mixture with a strong odour made up of thousand of compounds. Crude oil is separated in to a large number of products by refining (fractional distillation and vacuum distillation) to give fractions such as.
Gases - used as fuel and raw material for the industry
Gasoline and naphtha – fuel as petrol and solvent
Kerosene - fuel, jet fuel and raw material for the industry
Light gas oil - diesel and light generator fuel and raw material for the industry
Heavy gas oil - to make lubricants and also as heavy fuels for furnaces and generators eg. **NAWEC**
Residue –on further processing produces
Wax- for candles,
Residual oil – heavy fuel for furnaces etc and
Asphalt – for road construction and roofing
Many homes and hotels in the Gambia use Liquefied Petroleum Gas (LPG) as a fuel for cooking and heating. This is somehow different from natural gas which is almost entirely made up of the hydrocarbon called marsh gas (methane) because it is found bubbling from the water in warm, marshy areas. In developed countries, natural gas is used and is supplied through pipes the same way as water is supplied in the Gambia. Methane is a colourless and odourless gas and therefore tiny amounts of pungent smelling substances such as ethanethiol are added to the gas by Law before delivery to consumers so that leakages can be easily detected.

Complete combustion takes place when a fuel burns with enough oxygen to support the burning process. Under this condition, carbon dioxide, water and energy are products formed. The colour of the flame is blue.

$$CH_4 + 2O_2 \rightarrow CO_2 \uparrow + 2H_2O + energy$$

When there is a shortage of oxygen, **incomplete combustion** occurs and the resulting products are carbon monoxide, water energy. Carbon monoxide is a poisonous gas. The colour of the flame is red or yellow.

$$2CH_4 + 3O_2 \rightarrow 2CO \uparrow + 4H_2O + energy$$

1. Compare the burning of natural gas to that of kerosene, charcoal and firewood.
2. Explain why kerosene lamps and candles produce smoke whereas a gas lighter does not.
3. What is Liquefied Petroleum Gas (LPG)?
4. Why is it necessary to add pungent smelling substances to methane and LPG?

UNIT 7

WATER & THE ENVIRONMENT –POLLUTION & GLOBAL WARMING

Objective:

- To explain why water is a good solvent and why it exists in a liquid phase at room temperature.
- To explain the uses of water
- To explain Global Warming and depletion of the Ozone Layer
- To explain present environmental concerns and pollution

WATER: AN EVER-PRESENT COMPOUND: Water has some remarkable properties. Pure water is a liquid that has no colour, or taste. You have seen that it exists in all three phases: solid, liquid and gas. Under normal conditions, water freezes at 0ºC and boils at 100ºC.
In many ways, water is a most remarkable compound. Almost all liquids shrink when they freeze. For instance when a beaker full of melted wax is allow to cool, a hollow will form in the center where the freezing liquid shrinks. Unlike wax, water expands when it freezes. When a tank full of water freezes, it exerts about 20 000 Newtons (N) of force on each square centimeter of the tank. A tightly sealed container filled with water may burst when the water freezes, even if it is quite strong. Water pipes and car radiators are likely to burst in winter if the water in them freezes. When water at 0°C is warmed, it shrinks until the temperature reaches 4°C. At 4°C, water reaches its greatest density. Then, as it is warmed further, the water slowly expands.
Chemically, water is a very stable compound. Thus, water does not break apart until it is heated to about 2700ºC. Water is a good solvent. Water is covalent molecule that is formed when an oxygen atom shares a pair of electrons with each of two hydrogen atoms. It has been shown that a water molecule has a bent structure. The angle of bonding, or bond angle, is 105°. Water is a polar solvent, that is, it contains small positive and negative charges caused by the slight movement of electrons in the covalent bonds.
Like all molecules, water molecules are electrically neutral. However, the hydrogen ends are somewhat positive. The oxygen atom at the opposite end is somewhat negative. A lopsided molecule of this type is called a polar molecule. The polar, covalent property of the water molecule is one of the main reasons why water is such a good solvent. Because of its polar nature, the water molecule can attract other molecules or ions of a solute, surround them, and pull them into as CO_2 (O = C = O), is a symmetrical, or nonpolar covalent molecule.

Water molecules are attracted to each other by weak forces. Water molecules are held to each other by the attraction of the positive hydrogen ends of each water molecule to negative oxygen ends of other water molecules. Thus, a weak but effective hydrogen bond is formed. Water is not simply a group of separate H_2O molecules, but rather a large number of H_2O molecules linked together. Water is a liquid at room temperature because of the formation of molecular groups by hydrogen bonding. If hydrogen bonding did not exist, water would be a gas at room temperature.

Hydrogen bonds play an important part in fixing the melting and boiling points of many substances. These bonds cause the open structure of ice crystals. This open structure accounts for the fact that ice has a lower density than water. Hydrogen also forms similar bonds with fluorine (hydrogen fluoride -HF) and with nitrogen (Ammonia-NH_3)

IMPORTANCE OF WATER IN THE INDUSTRY

Many industries use large quantities of water and are therefore situated alongside rivers or on the coast. The water may be used for different reasons. These include as:-

- As an essential ingredient in the product, soft drinks, beer etc
- For water to cool parts of the process e.g. making electricity in a oil-or coal fired power station
- As a source of energy e.g. making electricity in a hydroelectric power station
- As a raw material which is removed during the process e.g., paper making

EXERCISE: Why is carbon dioxide a nonpolar compound whereas water is polar? How does this affect the physical properties of these two compounds?

Greenhouse gases and global warming

The heating of the atmosphere: The distance of the earth from the sun is not the only reason that temperatures on earth are within a range that is suitable to support life. The composition of the atmosphere is also critically important. The earth receives electromagnetic energy from the sun in the *visible spectrum*. There are also small amounts of infrared and ultraviolet radiation in this incoming solar energy. Most of the radiation is *shortwave* radiation, and it passes easily through the atmosphere towards the earth's surface, with some being reflected before reaching the surface. At the surface, some of the energy is absorbed, and this heats up the earth's surface. But the situation is a little more complex than this.

A large amount of the sun's energy is re-radiated from the surface back into the atmosphere as infrared radiation, which is invisible. As this radiation passes through the atmosphere, some of it is absorbed by greenhouse gases such as carbon dioxide, water vapour and methane. These gases are very important because they re-emit the energy back towards the surface. By doing this, they help to warm the lower layers of the atmosphere even further. It is this 're-emission' of heat by greenhouse gases, combined with surface heating and other processes (e.g. conduction and convection) that maintain temperatures at exactly the right level to support life. Without the presence of greenhouse gases, most of the sun's energy would be lost and the Earth would be a lot colder than it is!

Many of the greenhouse gases occur naturally in small quantities in the atmosphere. However, human activities have greatly increased their concentration, and this has led to a lot of concern about the impact that this could have in *increasing* global temperatures. This phenomenon is known as global warming. Because the natural concentrations of these gases are low, even a small increase in their concentration as a result of human emissions, could have a big effect on temperature. But before we go on, let's look at where some of these human gas emissions come from.

• Carbon dioxide (CO_2)

Carbon dioxide enters the atmosphere through the burning of fossil fuels (oil, natural gas, and coal), solid waste, trees and wood products, and also as a result of other chemical reactions (e.g. the manufacture of cement, aluminium, iron etc). Carbon dioxide can also be *removed* from the atmosphere when it is absorbed by plants during photosynthesis.

• Methane (CH_4): -Methane is emitted when coal, natural gas and oil are produced and transported. Methane emissions can also come from livestock and other agricultural practices and from the decay of organic waste.

• Nitrous oxide (N_2O): -Nitrous oxide is emitted by agriculture and industry, and when fossil fuels and solid waste are burned.

• Fluorinated gases (e.g. hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride). These gases are all *synthetic*, in other words they are man-made. They are emitted from a variety of industrial processes. Fluorinated gases are sometimes used in the place of other ozone-depleting substances (e.g. CFC's). These are

very powerful greenhouse gases, and are sometimes referred to as High Global Warming Potential gases ('High GWP gases').
Overpopulation is a major problem in reducing greenhouse gas emissions, and in slowing down global warming. As populations grow, their demands on resources (e.g. energy) increase, and so does their production of greenhouse gases.
Global warming is a very controversial issue. While many people are convinced that the increase in average global temperatures is directly related to the increase in atmospheric concentrations of carbon dioxide, others argue that the climatic changes we are seeing are part of a natural pattern. One way in which scientists are able to understand what is happening at present, is to understand the earth's *past* atmosphere, and the factors that affected its temperature. One method that is used is ice core drilling.
Carbon dioxide emissions are a major problem worldwide. The Kyoto Protocol was signed in Kyoto, Japan in December 1997. Its main objective was to reduce global greenhouse gas emissions by encouraging countries to become signatories to the guidelines that had been laid out in the protocol. These guidelines set targets for the world's major producers to reduce their emissions within a certain time. After Kyoto, there have been numerous Treaties to reduce Global warming but the debate still goes on.
Recently, World leaders gathered in 2015 in Paris to find ways and means of tackling global warming.

ISSUES OF ENVIRONMENTAL CONCERN

Our environment consists of natural systems that have operated in a delicate balance for a long period of time. Although we can manipulate many natural systems, there are commonly many unforeseen consequences. Natural systems adjust to artificial changes in ways that cannot be anticipated.
ENVIRONMENTAL INTERVENTION: The forces of nature and the activities of man modifying the natural existence of the component of the eco system.
TYPES OF ENVIRONMENTAL INTERVENTION: These include:-
Natural intervention, Desert encroachment, Tectonic movement, Volcanic eruption, Earthquakes, Climate changes
MAN MADE INTERVENTION: They include: Deforestation, Pollution, Hunting, Urbanization, Farm activities & Construction
ENVIRONMENT BALANCE: This is the way of recycling matter and the flow of energy within an eco system in other to ensure continuous supply
ENVIRONMENTAL POLLUTION: Environmental pollution is the introduction of harmful pollutants into a certain environment that makes an environment unhealthy to live in. The widespread pollutants are usually chemicals, garbage, and wastewater. Environmental pollution is happening in multifold parts of Earth usually in the form of air and water pollution.
Environmental pollution is causing massive damage to the ecosystem that organisms depend upon the health of this environment to live in. Air and water pollution can cause death of myriad organisms in given ecosystem, including humans.
In many developed countries laws have been introduced to regulate multifarious types of pollution and to palliate the adverse effects of pollution. Pollution levels must be controlled at all the time if we want to keep our environment safe and healthy. Without proper pollution control, the environment soon becomes unhealthy and nothing will be able to live in it. Preventing introduction of pollutants into the environment is the best way to protect the environment from pollution. To do this it is important to develop ecological conscience of nearby communities and manage waste by recycling.
A healthy environment is prerequisite of healthy life and fighting pollution is definitely the best way to keep the environment healthy.
What is pollution? Pollution is the introduction of a contaminant into the environment. It is created mostly by human actions, but can also be a result of natural disasters. Pollution has a detrimental effect on any living organism in an environment, making it virtually impossible to sustain life.
The three main types of pollution are:

1. Land Pollution: Land pollution is pollution of the Earth's natural land surface by industrial, commercial, domestic and agricultural activities. Some of the main contributors to land pollution are: Chemical and nuclear plants, Industrial factories, Oil refineries, Human sewage, Oil and antifreeze leaking from cars, Mining, Littering, Overcrowded landfills, Deforestation & Construction debris

NUCLEAR WASTE: The uses of nuclear reactors lead to two important environmental problems. The first is that nuclear reactors produce by products that are dangerously radioactive for many years. No satisfactory way has been found for the safe storage or disposal of these nuclear wastes. The second problem is the chance of an accident at the nuclear plant. Such accidents can have awful results. There may be immediate injuries and the radioactivity may make the area around the plant unfit for people and animals for many years.

TOXIC WASTE: Toxic wastes are extremely poisonous by -products of some industrial process. Unlike pollution, these substances do not enter the environment directly but are deposited of at specific locations. Unless deposed of with care, these waste pollutes the solid around them and any water body they come in contact with. For many years toxic waste were dump with little care, and there locations where not located and this is a serious threat to health.

MINING WASTE: The waste products from mining operations include: 1. Tailing and Dumping, 2. Altered terrains, 3. Changes in the composition of the surface, and 4. Soil, liquid and gaseous waste produced by refining

SOLID WASTE: Solid wastes are disposed of in many ways, including land filling incinerating, composite, open dumping, animal feed, fertilizing and disposing in ocean. The geological consequences include changes in the surface of the land where the waste is deposited and changes in the environment (river, lake, oceans, and groundwater) where the mass of waste is concentrated. The major problems with solid waste disposal involve the disposal sites hydrological characteristic. These include the porosity and permeability of the rock in which the fill is located and whether the waste deposit intersects the water table. The altered topography associated and landfill is also critical because it can change the drainage and ground water condition.

Perhaps the most critical contamination problem is created as water passes through a landfill eg. Bakoteh dump site and other dumping sites in the country, dissolve organic and inorganic compounds, and incorporate them into the groundwater reservoirs.

2. Air Pollution: Air pollution is the accumulation of hazardous substances into the atmosphere that endanger human life and other living matter. Some of the main contributors to air pollution are: Automobile emissions, Tobacco smoke, Combustion (burning) of coal, burning of used tyres and some types of plastics, Acid rain, Noise pollution from cars and construction, Power plants, Manufacturing buildings, Large ships, Paint fumes, Aerosol sprays, Wildfires, Nuclear weapons

3. Water Pollution: Water pollution is the introduction of chemical, biological and physical matter into large bodies of water that degrade the quality of life that lives in it and consumes it. Some of the main contributors to water pollution are: Factories, Refineries, Waste treatment facilities, Mining, Pesticides, herbicides and fertilizers, Human sewage, domestic waste water, Oil spills, Failing septic systems, Soap from washing your cars, carpets, Oil and antifreeze leaking from cars, Household chemicals, Animal waste etc.