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# STRUCTURE OF ATOM

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It was John Dalton who first enunciated matter to be composed of indivisible particles having an independent existence and called them Atoms (meaning uncut). But towards the end of the 19th century, modern atomic theory, mostly from the works of Thomson, Rutherford, Chadwick, Milliken, Bohr, de Broglie proved that atom is divisible and made up of three fundamental sub-atomic particles namely electron, proton and neutron. Atoms are very reactive and do not exist in the free state, except the atoms of noble gases.

## Constituents of Atom

An atom consists of three fundamental particles:

(i) **Electron:** The presence of electrons was discovered by J.J. Thomson. Electrons are negatively charged particles revolving around the nucleus in orbits of fixed energy.

(ii) **Proton:** The proton was observed by Goldstein in 1896. Protons are positively charged particles residing in the nucleus.

(iii) **Neutron:** Neutron was identified by James Chadwick in 1932. These are neutral particles (no charge) residing in the nucleus with protons.

In addition to the above fundamental particles, some uncommon sub-atomic particles have also been postulated:

(i) **Positrons:** These are the positive counterpart of the electrons. These were discovered by Anderson in 1932. These are highly unstable and combine with electrons producing $\gamma$-rays (energy radiations).

(ii) **Neutrinos and Antineutrinos:** These are the particles of small mass and zero charge. These were postulated by Fermi in 1934.

(iii) **Pi-mesons (Pions) and $\mu$-mesons (muones) :** These particles have a mass intermediate between that of the electron and the proton. The positively and negatively charged mesons were postulated by Yukawa in 1935. Neutral mesons ($\pi$) were postulated by Kemmer to account for the binding forces between the nucleons.

Therefore, an atom, on the whole, is neutral because the no. of protons is equal to the no. of electrons. Almost the entire mass of atom is concentrated in a very small part of its total size. This part is called the nucleus and all the protons and neutrons are embedded in it. Radius of the nucleus is approx. $10^{-13}$ cm and that of the atom is near about $10^{-8}$ cm.

## Rutherford's Experiment - Atomic Model

In 1911, Lord Rutherford bombarded a gold foil with a beam of $\alpha$-particles (an $\alpha$-particle is a positively charged helium ion - $He^{2+}$).

He observed that:

(i) Most of the $\alpha$-particles passed straight through the foil.

(ii) Some were deflected away from the path near the centre.

(iii) A few were reflected back.

On the basis of the results of alpha -Scattering experiment, Rutherford proposed that

(i) Atom is spherical.

(ii) Most part of the atom is empty.

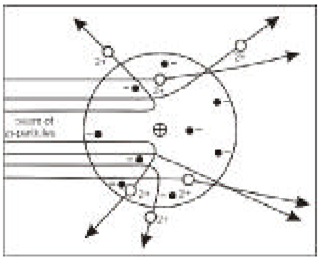
(iii) Mass and positive charge of the atom are located at the centre of the atom i.e. in the nucleus.

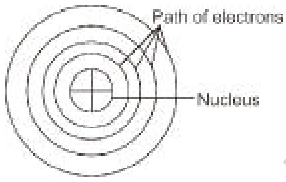
(iv) Electrons move around the nucleus in circular paths.

| Particle mass | Symbol | Position | Relative | Absolute charge | Relative mass charge | Absolute w.r.t proton) |
|---|---|---|---|---|---|---|
| Electron | e | around the nucleus | – 1 | $-1.60 \times 10^{-19}$ coulomb | $\frac{1}{1840}$ | $9.1 \times 10^{-28}$gm |
| Proton | p | Nucleus | +1 | $+1.60 \times 10^{-19}$ coulomb | 1 | $1.67 \times 10^{-24}$ gm |
| Neutron | n | Nucleus | 0 | 0 | 1 | $1.68 \times 10^{-24}$ gm |

(v) The attractive force between the positively charged nucleus and negatively charged electron is balanced by the centrifugal force.

The diagram of the experiment is shown below:






## Bohr model of an atom

Rutherford's model, however, fails to explain the stability of atoms and the line spectrum of hydrogen. To overcome the drawbacks of Rutherford's model, in 1913 Neil Bohr proposed a new model of the atom. This can be stated as:

(i) Atom is spherical.

(ii) Most part of the atom is empty.

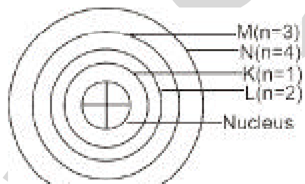
(iii) Protons and neutrons are located in the nucleus.

(iv) Electrons move around the nucleus in an atom in orbits known as energy levels having fixed energy.

(v) The energy levels are either designated as K, L, M, N etc. or numbered as n = 1, 2, 3, 4, etc.

(vi) The absorption or emission of energy can occur only by transition of electrons from lower to the higher energy level, or vice-versa.

Thus, as long as electrons continue to revolve in the same energy level, they neither lose nor gain energy and the atom remains stable.




**Different energy levels in an atom**

## Distribution of Electrons in Different Energy Levels

According to the Bohr-Bury scheme, the maximum number of electrons in any energy level is $2n^2$ where n is the number of that energy level. The energy levels are also known as shells.

K - Shell (n = 1) = $2n^2 = 2 \times 1^2 = 2$ electrons

L - Shell (n = 2 ) = $2n^2 = 2 \times 2^2 = 8$ electrons

M - Shell (n = 3 ) = $2n^2 = 2 \times 3^2 = 18$ electrons

N - Shell (n = 4 ) = $2n^2 = 2 \times 4^2 = 32$ electrons

The electrons firstly occupy the lowest energy shell. This systematic distribution of electrons is called electron configuration of the atom.

## Dual Nature of Electron

de-Broglie pointed out in 1924 that the electron have photon (lightparticles) like particles, behaving both as a material particle and as a wave, i.e. the electron has a dual character. The de-Broglie wavelength of material particle is given: by $\lambda = \frac{h}{mv} = \frac{h}{p}$

$\lambda$ = wavelength

h = Plank's Constant

m = mass

v = velocity

p = momentum

The wave character of electrons was experimentally proved by x-ray diffraction studies.

## Heisenberg's Uncertainty Principle

It is not possible to determine exactly both position and velocity (momentum) simultaneously of a particle having wave nature. In other words, the product of uncertainty in momentum ($\triangle p$)and that in position ($\triangle x$) almost remains constant.

$\triangle x . \triangle p \geq \frac{h}{4\pi}$

The Heisenberg's concept introduces the concept of probability of locating the electrons in the space about the nucleus.

## Atomic Number

It is defined as the number of unit positive charges on the nucleus (nuclear charge) of the atom of that element. It is denoted by z. It is basically the number of protons and this number is also equal to the number of electrons in a neutral atom.

Atomic number = number of protons = number of electrons.

## Mass Number

The sum of the protons and neutrons present in the nucleus of the atom is known as the mass number of the atom.

## Valence Electron

An electron in one of the outer shells of an atom that takes part in forming chemical bonds is known as the valence shell.

## Valency (Valence)

It is the combining power of an atom equal to the number of hydrogen atoms that the atom could combine with or displace in a chemical compound (hydrogen has a valency of 1). It is equal to the ionic charge in ionic compounds, for example, in $Na_2S$, Sodium has a valency of 1 ($Na^+$) and Sulphur a valency of 2 ($S^{2-}$).

## Atomic Mass

Atomic mass of an isotope = mass of neutrons + mass of protons.

**Isotope :** The name isotope was first introduced by Soddy. Different kinds of atoms of the same element which have the same atomic no. but different mass nos. or atomic mass (or atomic weights) are called isotopes of that element. In other words, it can also be defined as different atoms of the same element which have same no. of protons but different no. of neutrons in their respective nuclei. Isotopes have identical chemical properties and differ slightly in their physical properties like densities, melting and boiling points.

## Symbolic Representation of Isotopes

In the representation of an isotope of a given element, the mass number (A) is shown as the superscript at the head of the symbol of the element while the atomic no. (Z) is shown as the subscript at its bottom. The symbolic representation of an isotope of an element 'X' has been shown below:

A $\rightarrow$ Mass number (protons + neutrons)

X $\rightarrow$ Symbol of the element

Z $\rightarrow$ Atomic number = Protons = electrons

e.g. ${}_8O^{16}$

O is symbol of oxygen atom

8 is atomic no. of oxygen atom

16 is mass no. of oxygen atom

## Examples of Isotopes

1. There are three isotopes of hydrogen (atomic no. Z=1) with mass no. (A) 1, 2, 3. These are:
   i. Protium – ${}_1H^1$ - Ordinary hydrogen
   ii. Deuterium – ${}_1H^2$ - or D-heavy hydrogen
   iii. Tritium – ${}_1H^3$ & T
2. Isotopes of oxygen- ${}_8O^{16}$, ${}_8O^{17}$, ${}_8O^{18}$
3. Isotopes of chlorine - ${}_{17}Cl^{35}$, ${}_{17}Cl^{37}$
4. Isotopes of carbon - ${}_6C^{12}$, ${}_6C^{14}$

## Isobars

The atoms of different elements which have the same mass no. but different atomic number are called isobars. These can also be defined as atoms of different elements which have the same sum of protons and neutrons in the nucleus of each of these atoms but different atomic number.

As for example ${}_{18}Ar^{40}$, ${}_{19}K^{40}$, ${}_{20}Ca^{40}$ etc.

## Isotones

The atoms of different elements which have the same no. of neutrons but different atomic numbers are called isotones.

Example – ${}_6C^{14}$, ${}_7N^{15}$, ${}_8O^{16}$

Since mass no. = Protons + Neutrons

$\therefore$ For ${}_6C^{14}$

14 = 6 + n

n = 14 - 6 = 8

for ${}_7N^{15}$

15 = 7 + n

n = 15 - 7 = 8

For ${}_8O^{16}$

16 = 8 + n

n = 16 - 8 = 8

Hence the no. of neutrons of all ${}_6C^{14}$, ${}_7N^{15}$, ${}_8O^{16}$ is the same as 8 but their atomic no. is different.

## Quantum Numbers

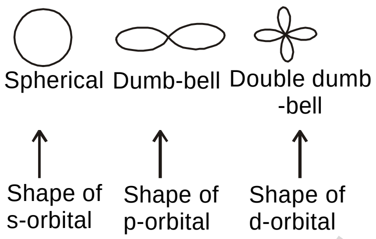
The electronic structure of an atom refers to the way in which the electrons are arranged about the nucleus and in particular the energy levels that they occupy. Each electron can be characterized by a set of four quantum numbers as follows :

(i) **Principal Quantum Number:** It is denoted by n. It gives the main energy level and has values 1, 2, 3, etc. (the higher the number, the further the electron from the nucleus). Traditionally these levels or the orbits corresponding to them are referred to as shells and are denoted by letters K, L, M etc. Hence it gives information about the energy of an electron in an orbit, the distance of the electron from the nucleus (size of an atom) etc.

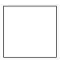
(ii) **Azimuthal Quantum Number:** It is denoted by *l*. It gives orbitals and the shape of orbitals. The values of l depend on the values of n and range from 0 to n -1 for a particular value of n. Thus for n = 2, the value of l is 0 and 1, for n = 3, there are three values of l (0, 1, 2)

$l$ = 0, 1, 2, 3

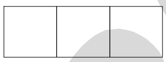
orbital = s p d f




(iii) **Magnetic Quantum Number:** It is denoted by m. It's value depends on the values of *l*. For a particular values of *l*, the values of m range from +*l* to -*l* including zero. Thus if *l* = 3, the value of m are +3, +2, +1, 0, -1, -2, -3. This quantum number indicates the orientation of the orbitals in the magnetic field.

s-orbital — 

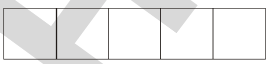
$l = 0, m = 0$

p-orbital — 

$p_x$ $p_y$ $p_z$

l = 0, m = +1 0 -1

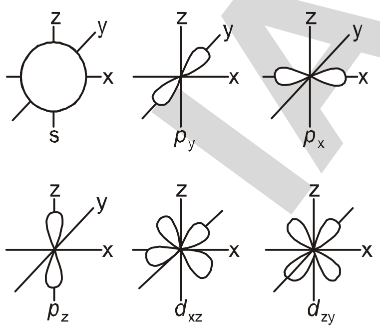
d-orbital

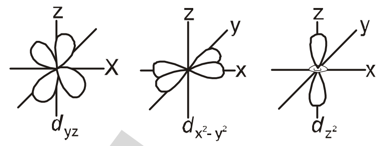
l = 2— 

$d_{xy}$ $d_{zx}$ $d_{yz}$ $d_{x^2-y^2}$ $d_{z^2}$

m = +2 +1 0 -1 -2

**Orientation of different orbitals are shown in the figure given below :**




(iv) **Spin Quantum Number:** It is denoted by s. It indicates the spin of the electron around its own axis. The spin can be either clockwise or anticlockwise. For clockwise spin

$$s = +\frac{1}{2}$$

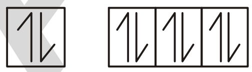
for anticlockwise spin

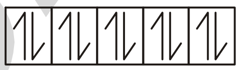
$$s = -\frac{1}{2}$$

**Pauli Exclusion Principle :** No two electrons in the atom can have the same set of quantum numbers.

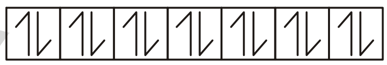
## Aufbau Principle

It gives the order in which orbitals are filled in successive elements in the periodic table. The order of filling is 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d. This is according to the increasing order of energy. Maximum capacity of the s-orbital is 2 electrons, of the p-orbital is 6 electrons of the d orbital is 10 electrons and of the f orbital is 14 electrons i.e.

s-orbital  p-orbital

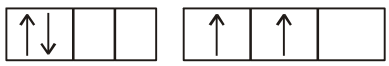
d-orbital 

f-orbital



## Hund's Rule

When electron filling occurs in an orbital, each orientation of the orbital is first singly occupied and only after this pairing occurs. The filling of two electrons in the p-orbital can be shown as:



+1 0 -1 +1 0 -1

**(A)** **(B)**

In (A), electron pairing occurs leaving empty orientation, hence this distribution is not valid according to Hund's rule. In B, single occupancy of orientation occurs and this is valid distribution of electrons according to Hund's rule.

# COMPOSITION OF MATTER

## Matter and its Nature

Entire universe is made up of only two types of entities – matter and energy. Matter occupies space and has mass. It can be seen, tested, smelt or felt, but energy can only be experienced, like light and heat.

Two types of change take place in matter:

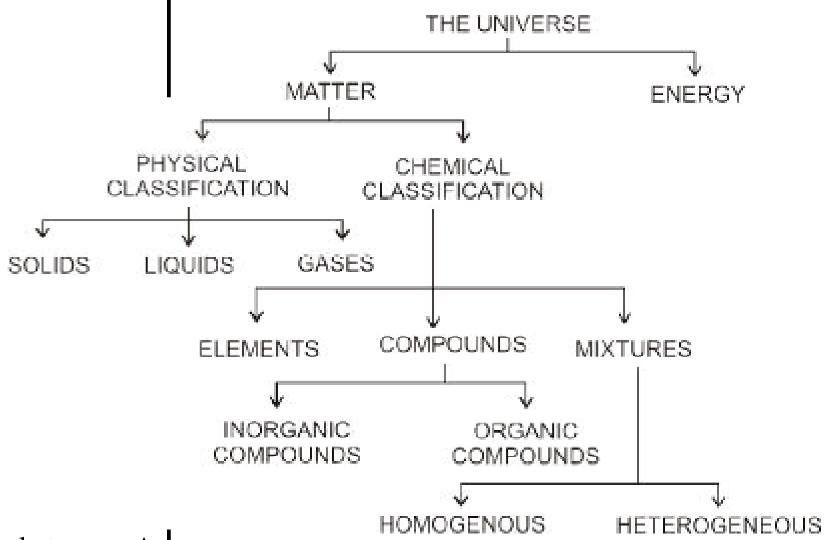
(A) **Physical Change :** It is a temporary change and does not involve any change in the composition of matter. For example – conversion of water into ice, stretching a spring, evaporation of water etc. This change is reversible, it means that matter can be brought back to its original form on removing the factors governing the change.

(B) **Chemical Change :** It is a permanent change in which the composition and properties are changed. This change is irreversible (original substance can not be reobtained , even after removing the factors governing the change.) For example, burning i.e. Combustion, rusting of iron, respiration, cooking food, etc.

Matter is made up of different kinds of substances. A substance is a material of which all parts are chemically identical and of same composition.

## Elements, Compounds and Mixtures

1. An element may be defined as the simplest form of matter which can neither be broken into, nor built from two or more simple substances by any physical or chemical method.
2. An element is a substance made up of atoms.
3. There are about 109 elements known to man. It is a remarkable fact that the entire universe consists of about 100 elements only, of which, 92 are found in nature and the rest are man – made.
4. Some examples of elements are Carbon, Nitrogen, Helium, Potassium, Iron, Gold, Platinum, etc.
5. Elements are found in all forms of matter i.e. solid, liquid and gaseous form.
6. Some elements like nitrogen, oxygen, noble gases and gold occur in the free state or the native state, while most other elements occur in the combined state.
7. Elements are represented by the symbol e.g. Mercury is represented by Hg, Bromine is represented by Br. etc.
8. Some elements like Technetium, Promethium, Astatine, Francium and all the elements with atomic number above 92 are found either in very slight traces or not at all in nature.




## Compounds

1. A compound may be defined as a substance formed by the combination of elements in a fixed proportion by weights.
2. It can be decomposed into two or more elements by any suitable method.
3. Formation and decomposition of compounds can be understood by taking an example i.e. Hydrogen and Oxygen combine to form water and conversely water is decomposed into Hydrogen and Oxygen by passing the electric current through it.

Hydrogen + Oxygen $\rightleftharpoons$ Water

(Elements) (Compound)

### FORMS OF ELEMENTS

| Elements in liquid form | Elements in gaseous form | Elements in solid form |
|---|---|---|
| Mercury (Hg)<br>Bromine (Br)<br><br>Francium (Fr) | Hydrogen (H)<br>Nitrogen (N)<br>Oxygen (O)<br>Fluorine (F)<br>Chlorine (Cl)<br>and noble gases like<br>Helium (He)<br>Neon (Ne),<br>Argon (Ar) | Rest elements like Carbon (C)<br>Sodium (Na)<br>Potassium (K)<br>Calcium (Ca)<br>Barium (Ba)<br>etc. |

$$\text{Water} \underset{\text{Current}}{\overset{\text{Electric}}{\rightleftharpoons}} \text{Hydrogen} + \text{Oxygen}$$

4. Compounds, unlike mixture, cannot be separated by physical means.
5. The composition of a particular compound does not depend upon the source. For example, water obtained from rain, wells, oceans, rivers or mountains has the same composition ($H_2O$).
6. A compound is represented by a chemical formula indicating the presence of elements and their relative number of atoms. For example, chemical formula of water is represented by $H_2O$ which includes two Hydrogen and one Oxygen atoms.

## Mixtures

1. Mixture is obtained by mixing of two or more substances (elements or compounds) in any proportion.
2. Components retain their individual chemical properties.
3. It can be separated by suitable physical means.
4. Soil, stone, wood, air, water, milk, kerosene, etc. are examples of mixtures.
5. Its properties depend on the nature and amount of the constituents.
6. There are two types of mixtures :
   - i. Homogeneous mixture; and
   - ii. Heterogeneous mixture.

### Difference Between Mixtures

| | Homogeneous Mixture | Heterogeneous Mixture |
|---|---|---|
| 1. | Composition is uniform throughout. | Different components are not present uniformly. |
| 2. | Exist in one phase either solid or liquid or gas.<br>**Examples:**<br>Air - Oxygen + Nitrogen + other gases<br>**Salt Solution -** Sodium Chloride in water<br>**Sugar Solution -** Sugar + Water<br>**Carbonated Water** - $CO_2$ + Water | Exist in different phases.<br><br>**Examples:** Smoke (mixture of air and Carbon particles), Milk, mixture of iron filings and Sulphur. |

## Separation of Mixtures

**Some methods for the separation of mixtures are described as below :**

1. **Sublimation:** A direct change of state from solid to gas is called sublimation. In this process gaseous subtances on cooling give back the original substance. This phenomenon is only applicable when the vapour pressure of the solid phase is high. It can be used for substances which form sublimates in their separation from non-sublimate materials. Naphthalene, iodine and ammonium chloride are sublimable.

   $$\text{Solid} \rightleftharpoons \text{Gas}$$

2. **Distillation:** On heating, a liquid is converted into vapour which converts into the liquid on cooling. This process is called distillation. In this process both vapourisation and condensation take place. It is used to purify liquids and to separate liquid mixtures.

- **Fractional Distillation:** When the boiling points of various components are far apart, then simple distillation method is used to separate the mixtures. But if boiling points are closely related with each other, then fractional distillation is used. In this process a fractionating column is used to separate two or more volatile liquids. It is applied extensively in petroleum refining, separation of Oxygen, $N_2$, inert gases and Carbon dioxide from liquid air, manufacture of spirits such as – whisky, gin, rum and brandy.
- **Steam Distillation:** It is a method of distilling liquids that are immiscible with water by bubbling steam through them. It is essential that the vapour pressure (and hence the boiling point) of the mixture of the two immiscible liquids should be lower than the vapour pressure of either, pure liquid. This method gives results, almost equivalent to those obtained from simple distillation.

3. **Sedimentation and Decantation:** This method is applicable when one component is liquid and another component is an insoluble solid (heavier than the liquid). If muddy water is kept undisturbed for some time in a beaker, the particles of earth (clay and sand) settle at the bottom leaving a clear liquid

at the top. This process is called sedimentation. The clear liquid (water in this case) can be gently transferred into another beaker. This process is known as decantation.

4. **Filtration:** Separating the solid particles through a filter is called filtration. The filter is made up of a porous material (such as paper or fine glass wool) which prevents solid particles from passing through. There are some applications of this method which are useful in our daily life such as -

- purification of the domestic water supply by filtering river water through a layer of sand.
- removal of solid particles in engine oil in car engines by air filters.
- filtration of tea from tea leaves in the preparation of tea, etc.

Gas filtration involves removal of solids (called dust) from a gas-solid mixture. Liquid filtration is used for a liquid-solid separation in the manufacture of chemicals, polymer products, medicines, beverages and foods, in mineral processing, in water purification, in sewage disposal, in the operation of machines such as internal combustion engines.

5. **Crystallization:** This process involves the formation of crystals from a liquid or gas. Separation and purification of solid substances is done by this method. During this process, firstly mixture is heated with a suitable solvent to its boiling point and then the hot solution is filtered. The filtrate is slowly cooled down to room temperature. Thus pure solid crystallizes out. This is separated from the filtrate by filtration and dried. In fractional crystallization the components of the mixture crystallize out at different intervals of time.

6. **Chromatography:** This is a technique for analysing or separating mixtures of gases, liquids or dissolved substances. The components of a mixture move differently on an adsorbent material (filter paper), blotting paper, solid surface of Silica, etc. when the liquid moves through them. They travel to different extents through the adsorbent material and thus get separated. Separation of coloured materials from green vegetables, ink are common examples.

## States of Matter

There are three states (or phases) of matter i.e. solids, liquids and gases. Sometimes plasma is also considered a fourth state of matter which is a highly ionisable gas.

1. **Solids:** It is a state of matter which has a three-dimensional regularity of structure, resulting from the proximity of the component atoms, ions or molecules and the strength of the forces between them . In this closely packed structure molecules vibrate about fixed positions, solids are incompressible and all its atoms are in a state of perpetual motion. True solids are crystalline. If a crystalline solid is heated, the kinetic energy increases. At the melting point the binding forces between the components break down and the solid becomes a liquid.

2. **Crystalline Solids:** It has a regular internal arrangement of atoms, ions or molecules. Crystalline materials need not necessarily exist as crystals, for example, all metals are crystalline although they are not usually seen as regular geometric crystals.

3. **Amorphous Solids:** Some liquids do not solidify on cooling into true solids. Internal structure of this solid is haphazard and thus these solids are shapeless or amorphous. Glass is a common example.

4. **Liquids:** In a liquid, atomic (or ionic or molecular) regularity of the solid is absent. There is a short range structural regularity extending over several molecular diameters. These bundles of ordered atoms, molecules or ions are free to wonder about, enabling liquids to have almost fixed volumes which adopt the shape of their containers.

5. **Gases:** It is a fluid of which volume is not fixed. There are very weak bonds between the molecules of a gas, so the molecules are free to move.

## Change of State

Solid, liquid and gas are converted into each other through the melting, boiling, condensation and solidifying processes. At melting point any change involves the loss or gain of a certain amount of heat and this heat is called latent heat. Some impure and non-crystalline substances like glass, butter, etc. do not have definite melting points. Volume of substances expand upon melting and shrinks upon solidifying but water expands on freezing. An additional amount of heat energy called the heat of vapourization is required to turn a liquid, such as water at $100^0$ C into steam at that same temperature. Properties like boiling and melting depend on pressure. At less than normal pressure, melting and boiling points are generally lower. On increasing the pressure, the boiling point and melting point generally increase but melting point of water decreases on increasing of pressure.

## Atomic Theory of Matter

1. Matter is made up of indivisible particles called atoms.
2. Atoms of a particular element are all alike but differ from atoms of another element. So different elements behave differently but different samples of the same element show the same behaviour.
3. A fixed quantity of an element (which must contain a fixed no. of atoms) has a fixed mass.
4. Atoms can neither be created nor destroyed.

| Percentage of ions in Sea-water | | | | | | | |
|---|---|---|---|---|---|---|---|
| Solute | Chloride $Cl^-$ | Sodium $Na^+$ | Sulphate $So_4^{2-}$ | Magnesium $Mg^{2+1}$ | Calcium $Ca^{2+}$ | Potassium $K^+$ | Bromide Br– |
| Percentage | 55.05 | 30.61 | 7.68 | 3.69 | 1.16 | 1.10 | 0.19 |

| % by wt. of Major Elements in the Lithosphere | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Symbol of element | O | Si | Al | Fe | Ca | N | K | Mg | Ti | H | P | Mn |
| | 43.6 | 27.7 | 8.1 | 5.0 | 3.6 | 2.8 | 2.6 | 2.1 | 0.44 | 0.14 | 0.2 | 0.1 |

But according to the modern atomic concept atoms are divisible i.e. made up of electrons, protons and neutrons.

## Laws of Chemical Combination

There are three important laws of chemical combination based on the Daltonian atomic concept as below:

1. **Law of Conservation of Matter (or Mass):** According to this law "Matter can neither be created nor destroyed in a chemical reaction". Thus there is no change in mass in a chemical reaction. For example, the reaction between Sodium Chloride and water can be written as :

   $NaCl + H_2O \rightarrow NaOH + HCl$

   We see that the total no. of atoms before and after the reaction remains the same. Hence mass or matter is conserved in this reaction.
2. **Law of Constant Composition or Law of Definite Proportion:** This law states that "the composition of a pure compound is always the same." Compound is always made up of the same elements in the same percentage. This law can also be explained on the basis of Daltonian theory : "The no. and kind of atoms in a given compound is fixed." $H_2O$ molecule always contains 2 atoms of hydrogen and 1 atom of Oxygen.
3. **Law of Multiple Proportion :** This law states that when two elements combine to form two or more than two compounds, a simple ratio of weight of both elements is maintained. For example, consider the formation of Carbon dioxide ($CO_2$. and Carbon monoxide (CO) by the combination of Carbon and Oxygen atoms.

   In Carbon dioxide one Carbon atom combines with two Oxygen atoms. In Carbon monoxide (CO) one Carbon atom combines with one Oxygen atom. Hence the ratio of Oxygen combining with the fixed amount of Carbon is 2 : 1 between $CO_2$ and CO. This is also the ratio of their weights.

## Kinetic Theory of Matter

1. All matter is made up of atoms or molecules of independent existence.
2. These constituent particles of each substance are distinct and have certain properties which are different from those of atoms or molecules of all other substances.
3. Molecules of the same substance are identical in all respects.
4. There are empty spaces between molecules, which increase as in the following order:

   solid < liquid < gas
5. Forces of attraction being exerted between molecules are in the following decreasing order :
   solid > liquid > gas
6. Molecules possess kinetic energy to move freely through the bulk or volume of liquid or gas. Increasing order of kinetic energy is as below:

   solid < liquid < gas
7. The molecules of a gas are in continuous random motion and exert pressure on the walls of the container.
8. The kinetic energy increases on increasing the temperature.

| Gaseous Composition of the Air | | | | | |
|---|---|---|---|---|---|
| Gas | Nitrogen | Oxygen | Argon | Carbon dioxide | Xenon, Neon, Krypton, Water Vapour |
| Percentage (%) | 78 | 21 | 1 (just-Under) | 0.04 | Very Small amounts |

## Molecules

It is one of the fundamental units to form a chemical compound that can take part in a chemical reaction. Molecules can be classified into two types:

**Homoatomic Molecules**

- Made up of similar atoms.
- Mostly elementary gases are homoatomic, for example, Hydrogen gas consists of two atoms of hydrogen i.e. $H_2$. Oxygen gas consists of two Oxygen atoms but they are diatomic. Hence it may be diatomic, etc.

**Heteroatomic Molecules**

- Made up of different atoms.
- Mostly ionic compounds are heteroatomic. It may be in any state of matter. It also may be diatomic, triatomic, etc. Sulphur dioxide is a triatomic molecule in which two atoms of Oxygen and one Sulphur atom are combined together as $SO_2$.

## Atomicity

The total no. of atoms in a molecule is called atomicity. For example atomicity of hydrogen molecule ($H_2$) is 2, of hydrogen chloride (HCl) is 2 (H=1, Cl=1) and of Benzene ($C_6H_6$) is 12 (C=6, H=6).

## Avogadro's Hypothesis

Equal volumes of all gases contain equal numbers of molecules at the same pressure and temperature. This statement is called Avogadro's hypothesis. It is true only for ideal gases. The actual no. of molecules in a gram molecule is known as Avogadro's number and its value is $6.023 \times 10^{23}$ molecules.

## Atomic Mass

It is the average relative mass of an atom. It is calculated by how many times an atom is heavier than $\frac{1}{12}$th weight of Carbon-12 isotope. For example, Atomic mass of Nitrogen is 14 i.e. Nitrogen is 14 times heavier than $\frac{1}{12}$th of a Carbon-12.

## Molecular Mass

It is the mass of a molecule i.e. number of times a molecule is heavier than $\frac{1}{12}$th weight of the C-12 atom.

Molecular mass = Sum of the masses of all atoms in a molecule.

For example, molecular mass of $CO_2$ is 12 + 2 x 16 = 12 + 32 = 44. Therefore, molecular mass of $CO_2$ is 44 a.m.u. The molecular mass of the compound is expressed in grams known as gram molecular weight. Gram molecular weight of Carbon dioxide ($CO_2$) is 44 gm.

## Mole

Mole is a unit which represents $6.023 \times 10^{23}$ particles (atoms, molecules or ions etc) irrespective of their nature. The number $6.023 \times 10^{23}$ is called Avogadro's number.

1 mole of atoms = $6.023 \times 10^{23}$ atoms

1 mole of molecules = $6.023 \times 10^{23}$ molecules

**A mole of any substance is related to :**

a) mass of a substance,

b) number of particles,

c) volume of a gaseous substance

One mole of all the gases at STP (Standard Temperature and Pressure i.e. $0^0$ C and 760 mm of Hg) occupy a volume of 22.4 litres or 22400 cc.

# GASEOUS BEHAVIOUR

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## Kinetic Theory of Gases

1. Gaseous particles are in motion. Particles are made up of molecules and as such molecules are in motion. The moving molecule theory of gases is known as the kinetic theory of gases.
2. Actual volume of a gas is negligible as compared to the empty space between molecules.
3. Molecules experience attractive forces and therefore these are in rapid, random (Zig-Zag) motion.
4. Molecules collide each other but there is no loss of kinetic energy.

## Boyle's Law

Volume of a fixed mass of a gas at constant temperature is inversely proportional to the pressure of the gas. It can be shown as:

$V \propto \frac{1}{P}$ at constant T and n

P = Pressure, V = Volume, T = Absolute temperature, n = no. of moles of gas.

## Charles' Law

The volume of a given mass of gas at constant pressure varies directly with absolute temperature. Mathematically it can be seen as:

$V \propto T$ at constant P and n

## Avogadro's Hypothesis

At constant temperature and pressure, volume of a gas varies directly with no. of moles of the gas. Mathematically it can be seen as :

$V \propto n$ at constant T and P.

## Equation of State or Ideal Gas Equation

It is a combined gas law and is established with the help of Boyle's law, Charle's law and Avogadro's hypothesis. i.e.

PV = nRT where R is gas constant and is equal to 8.314 $JK^{-1}$ $mol^{-1}$

Relation between different values of P,V,T for a gas can be established as : $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

## Real and Ideal Gas

Gases which obey Boyle's law, Charle's law, Avogadro's law and equation of state are called ideal, or perfect gases and those which show deviations from these laws are called non-ideal or real gases. Almost all gases show deviation from these laws and hence almost all gases are non-ideal, or real gases.

## Vander Waal Equation

Since none of the gases is known to behave according to the ideal gas equation, these gases are called as real gases. Their behaviour is explainable on the basis of Vander Waal's equation as represented below :

$$\left(P + \frac{an^2}{V^2}\right)(V-nb) = nRT \text{ (for n mole of the gas.)}$$

It is the modification of the ideal gas equation PV = nRT where pressure correction 'a' as well as volume correction 'b' have been applied; a and b are Vander Waal's constants whose values depend on the nature of the gas.

## Liquefaction of Gases

When gases are compressed and cooled (i.e. subjected to high pressure and low temperature), they are converted to liquid. The process of gas $\rightarrow$ liquid is known as liquifaction and the temperature at which a gas is converted to liquid is known as the liquifaction temperature. At high pressure and low temperature, attractive forces between gaseous molecules is high and molecules are drawn together to form a liquid. The liquifaction of gases is indicative of the attractive forces between the gaseous molecules.

## Critical Temperature

The temperature at which a gas can be liquified is called liquifaction temperature and this liquifaction temperature is also called critical temperature because above this temperature, the gas cannot be liquified no matter how high the pressure is. Thus above the critical temperature gaseous state exists, at the critical temperature liquifaction occurs and below critical temperature liquid state exists. Critical temperature depends on the attractive forces present in the gaseous molecule. Thus attractive forces in HCl ($H^{+d}$ – $Cl^{-d}$) is greater than that in $CO_2$ $\left(O^{-\delta} \leftarrow C^{+\delta+\delta} \rightarrow O^{-\delta}\right)$ and so critical, temperature of HCl is higher than that of $CO_2$ i.e., HCl is liquified at a higher temperature than $CO_2$.

## Deviation from Ideal Gas Behaviour

Gas behaves like ideal gas at high temperature and low pressure. If gases behave like ideal gas through obeying PV=nRT gas equation, it means that at high temperature – high pressure, PV = nRT is valid but at

(i) low temperature – high pressure and

(ii) low temperature – low pressure, there is deviation.

Deviation from ideal gas behaviour is less at high temperature and greater at low temperature.

## Inversion Temperature

It is the temperature at which the gas neither shows heating effect nor shows cooling effect on expansion.

## Diffusion

Inter mixing of gases irrespective of the force of gravity is known as diffusion. It refers to the flow of molecules from a region of high concentration to a region of low concentration.

## Effusion

The passage of gases through a small aperture under pressure is known as effusion. Graham's law of diffusion is also applicable to effusion.

## Graham's Law of Diffusion

Under similar conditions of temperature and pressure, the rates of diffusion of gases are inversely proportional to the square roots of their molecular masses or their densities or directly proportional, to their pressures.

$$r_{\text{diffusion}} \ \alpha \sqrt{\frac{1}{m}} \ \text{or} \sqrt{\frac{1}{d}} \quad r_{\text{diffusion}} \ \alpha \ p$$

Where r = Rate of diffusion

p = Pressure

m = Molecular weight

d = Density

For two different gases

$$\frac{r_1}{r_2} = \frac{P_1}{P_2}\sqrt{\frac{M_2}{M_1}}$$

$r_1$ = Rate of diffusion of one gas

$r_2$ = Rate of diffusion of another gas

$P_1$ = Pressure of one gas

$P_2$ = Pressure of another gas

$M_1$ = Molecular weight of one gas

$M_2$ = Molecular weight of another gas

## Different Types of Velocities

The three different types of velocities possessed by gas molecules are :

**Most Probable Velocity (Cm):** It is the velocity possessed by the maximum fraction of the molecules of the gas at a particular temperature. $C_m = \sqrt{\frac{2RT}{M}}$

R = gas constant

T = temperature (273 + t°C)

M = molecular weight

**Average Velocity ($C_a$):** It is the arithmetic mean of the different velocities of the molecules of the gas at a particular temperature. $C_a = \sqrt{\frac{8RT}{\pi M}}$

**Root Mean Square Velocity ($\bar{C}$):** It is the square root of the average of the squares of the different velocities of molecules at particular conditions. $\bar{C} = \sqrt{\frac{3RT}{M}}$

M = molecular weight of the gas.

●●●

# SOLUTION

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A solution is a homogeneous mixture of two or more substances whose properties vary continuously with varying proportion of the components. Several types of solutions are possible because components of a solution can be in any state of aggregation (i.e. solid, liquid or gas). They are solid – solid, solid – gas, liquid – liquid, liquid – gas and gas – gas.

## Solvents and Solutes

In a solution, the substance which dissolves is called the solute. In salt water solution salt is the solute. The liquid that the solute dissolves in is called the solvent. In salt water solution water is the solvent. If sugar is dissolved in water, then a solution is obtained in which sugar is the solute and water is the solvent.

Mostly chemical reactions take place through the solvent system. Water is universal solvent due to its high dielectric constant, thus it dissolves a large no. of different substances. Generally solvent is in an excess quantity.

Some alloys are solid solutions of one metal in another. Ionic solids also form solid solution (e.g. NaCl, and KCl). Gas dissolves in liquids as well as solids. A solution of ammonia in water is familiar as a cleaning solution in homes. Oxygen is also sufficiently soluble in water to permit survival of aquatic life in lakes, rivers and oceans. Both examples are from the gas-liquid type. An example of a gas dissolving in solids is the solubility of gaseous Hydrogen in Palladium or Platinum when water evaporates in the air; the water is the solute and the air is the solvent, thus it is an example of gas-gas solution.

## Saturated Solution

In a dilute solution, a small amount of solute is dissolved in a large quantity of solvent. In a concentrated solution a large amount of solute is dissolved. When a solvent has dissolved as much solute as is possible, the solution is called as saturated solution. At this point there can be no further addition of solute to solvent. Supersaturated solutions have a greater proportion of solute than is contained in the saturated solutions.

## Miscible and Immiscible Liquids

Liquids which mix with each other are called miscible, e.g. water and ethanol can mix with each other. Liquids which do not mix with each other are called immiscible. e.g. oil, and water do not mix with each other.

### Distinctions Between Acid and Base

| Acid | Base |
|---|---|
| • It is sour in taste. It turns blue litmus paper into red. | • It turns red litmus paper blue. |
| • Methyl orange turns red in colour. | • Methyl orange turns yellow in colour. |
| • It is ionized in aqueous solution to give $H^+$ ions (hydrogen lions). It contains hydrogen. | • It contains hydroxyl groups and form hydroxy lions ($OH^-$) in an aqueous solution. |
| • It donates protons in solution. | • It accepts protons. |
| • Hydrochloric acid (HCl), Sulphuric acid ($H_2SO_4$), Acetic acid ($CH_3COOH$) etc. are the examples. etc. | • Sodium hydroxide (NaOH), Ammonium hydroxide ($NH_4OH$), Potassium hydroxide (KOH) are the examples. |
| • According to the modern concept (Lewis concept), it accepts a lone pair of electrons. | • It donates a lone pair of electrons. |
| • Electron deficient compounds such as $ZnCl_2$, $AlCl_3$, $BF_3$, $FeCl_3$, etc. are acids. | • Compounds having a lone pair of electrons such as HOH, : $NH_3$, HF etc. are bases. |

## Emulsion

When we add cooking oil to water, the oil floats on the water. Oil and water are immiscible. But on shaking vigourously the oil and water, a milky-looking liquid is obtained, this is called an emulsion. This milky liquid is due to the presence of tiny droplets of oil. Milk is an emulsion. It is made up of tiny droplets of fat floating in water.

## Importance of Solution in Human Body

Human body is about 70% water. In water several important reactions which are necessary for keeping alive, take place. For instance, respiration is a chemical reaction which releases energy from food. It happens in every cell in human body. These chemical reactions will happen only if the substances taking part in the reaction – the reactants – are in solution. Cells are jelly – like solutions of many different substances in water. If the water was not there, the chemical reactions would not take place. It would then result into death.

## Solubility

Solubility is a measure of how much of a substance will dissolve. At saturation, the amount of solute in a given solvent at a specified temperature is known as the solubility of the solute. It can also be defined as the no. of grams of solute that will dissolve in 100 gms of solvent at a given temperature. For example, the solubility of table salt is 35.7 grams in 100 grams of water at solvent—temperature of $0^0$ C. It is 39.8 grams at $100^0$ Celsius.

Solubility of solids increases with increasing temperature and solubility of gases decreases with increasing temperature. We take an example of gaseous solubility such as in a pond on a cool day there is usually plenty of Oxygen dissolved in the water because solubility of gas increases at low temperature. But on a hot day, the hot, fast – moving Oxygen molecules can escape from the water into the air. Less Oxygen remains in solution in the water because solubility of gases decreases with increase in the temperature. Fishes then may get short supply of Oxygen and have to come to the surface to get air.

## Colligative Properties

Colligative properties of solutions are those properties which depend on the number of solute and solvent particles (molecules or ions) but not on the nature of the solute. Examples of such properties are :

i. lowering of vapour pressure.

ii. elevation of boiling points.

iii. the depression of freezing point.

iv. the osmotic pressure.

## Boiling and Freezing Points of Solution

Boiling point of a solution is higher than that of the pure solvent and freezing point of a solution is lower than that of the solvent. For running the car in subzero weather when its radiator is full of water, an antifreeze material, ethylene, glycol or alcohol, is added to lower the freezing point of the liquid in the radiator.

## Osmosis

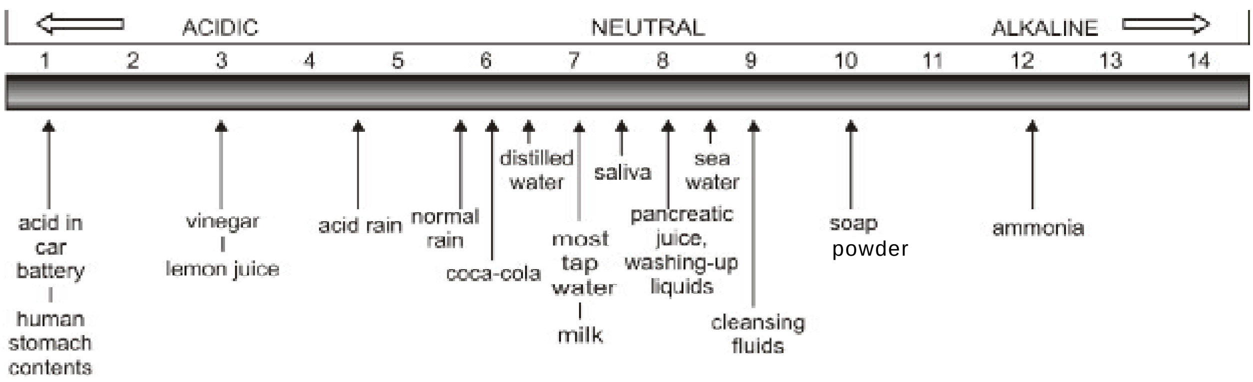
Osmosis is the phenomenon where solvent molecules flow from a dilute solution to a more concentrated solution through a semipermeable membrane. There are two types of osmosis:

i. **Exosmosis:** It is the outward flow of water from a cell containing an aqueous solution through a semipermeable membrane e.g. grape in NaCl solution.

ii. **Endosmosis:** It is the inward flow of water from a cell containing an aqueous solution through a semipermeable membrane e.g., grape in water.

## Osmotic Pressure

Osmotic pressure is the pressure which just prevents the passage of pure solvent into the solution



The Universal indicator colour range

through a semipermeable membrane. It may be the equilibrium hydrostatic pressure of the column set up as a result of osmosis or minimum of excess pressure to be applied in the solution to prevent the entry of the solvent molecules into the solution through a semipermeable membrane.

i. **Hypotonic Solution :** A solution is called hypotonic if its osmotic pressure is lower than that of the solution separating it by a semipermeable membrane. In such a system, the flow of solvent due to osmosis, will be from the hypotonic solution into the other solution across the semipermeable membrane.

ii. **Hypertonic Solution:** A solution is called hypertonic if its osmotic pressure is higher than that of the solution separating it by a semipermeable membrane. In such a system, the flow of solvent due to osmosis will be from the solution across the semipermeable membrane into the hypertonic solution.

iii. **Isotonic Solution:** Two solutions are called isotonic if they exert the same osmotic pressure. In such a system, no osmosis occurs and hence there will not be a flow of solvent from either of the solutions separated by a semipermeable membrane.

**Plasmolysis**: When a plant cell is placed in a hypertonic solution, the fluid from the plant cell comes out and the cell shrinks. This phenomenon is called plasmolysis and this is due to osmosis.

**Reverse Osmosis:** When external pressure applied on the solution is more than the osmotic pressure, the solvent will start flowing from the solution to the pure solvent. It is called reverse osmosis. It is used in the desalination of sea water to obtain pure water.

**Importance of Osmosis for Living Beings:** We already know that all living beings are made up of cells. In each cell there is a semipermeable membrane around the cellular materials. Cell draws water, oxygen and nutritive substances from outside the liquid through the semipermeable membrane. Wastes are taken out through the semipermeable membrane into the surrounding liquid. These processes take place by osmosis. A very delicate balance in osmotic; pressure must be maintained in the case of cells.

## Molar and Normal Solutions

The word 'molar' and 'normal' indicates the concentration of solution. If one litre of a solution contains one gram molecular weight or one mole of a solute, it is called a molar solution.

The gram molecular weight of Nitric acid is $HNO_3$ = 1 + 14 + (3 X 16) = 15 + 48 = 63 grams

One molar solution (1M) of Nitric acid would therefore contain 63 grams of the acid in one litre of solution.

One litre of such solution which contains 1 gm. equivalent of solute is called a normal solution denoted by N. A gram equivalent weight is the molecular weight divided by the no. of active hydrogen atoms or — OH groups in a molecule of the substance. In the case of Sulphuric acid, the gram equivalent weight is 98 divided by 2 or 49 grams. A normal solution (1N) of Sulphuric acid would, therefore, contain 49 grams of the acid in one litre of solution.

## Alkalies

All bases are not soluble in water. Bases which are soluble in water are called alkalies.

## Amphoteric

A compound which can act as both an acid and a base is called amphoteric. For instance, Aluminium hydroxide $Al(OH)_3$ and Zinc hydroxide are amphoteric.

## Salts

Salt is an ionic compound containing a positive ion (cation) and a negative ion (anion). It is formed by the neutralization reaction of an acid with a base. Some common examples of salts are table salt or Sodium Chloride, Sodium Sulphate, Ammonium Chloride, etc.

## Importance of Acids, Bases and Salts

There are a huge (number of) uses of acids, bases and salts in our daily life. Sulphuric acid is used in the

| Property | True solution | Colloidal solution | Suspension |
|---|---|---|---|
| Particle size | Less than 1 nm. | Between 1 - 100 nm. | More than 100 nm. |
| Appearance | Clear and transparent | Translucent | Opaque |
| Settling | Do not settle | Do not settle under gravity, but can be made to settle under centrifugation | Settle on standing under gravity |
| Filterability | Filterable through filter paper, parchment membrane | Pass through filter paper non filterable though parchment membrane | Not filterable at all |
| Diffusible | Diffuse quickly | Diffuse slowly | Do not diffuse |
| Tyndall effect | No Tyndall effect | Shows Tyndall Effect | Very little or no Tyndall effect |

manufacture of explosives, dyestuffs, drugs, fertilizers and also in oil and sugar refining. Hydrochloric acid is used in the manufacture of glue, gelatin, dextrose, and polyvinyl chloride (PVC) and it is also used in cleaning metals. Nitric acid is used as a solvent in gold ornament industry, as a solvent for many other metals. Nitric acid is also used for the manufacture of fertilizers and explosives such as dynamites, picric acid and trinitrotoluene (T.N.T). Acetic acid is used as a solvent for many organic compounds and for the formation of cellulose acetate. Hydrofluoric acid is used in making refrigerants and certain plastics.

Bases also play a vital role in our day to day life. Sodium hydroxide is used in the rayon, soap, paper and petroleum industries. Calcium hydroxide is used to raise the Ph of soils and to make insecticides.

Uses of salts are also well-known. Sodium chloride is used in food, to increase taste, purifying water and in many plastics. Potash alum and calomel are medicinally used. Hypo or Sodium Thiosulphate ($Na_2S_2O_3 . 5H_2O$) is used in photography as a fixing agent sodium bicarbonate ($NaHCO_3$) is used as baking powder. Magnesium Chloride ($MgCl_2 . 6H_2O$) Solution is also used in cotton industry for increasing the strength of threads and used as a cement for joining broken tooth. Plaster of paris ($CaSO_4$ 2 $H_2O$) is used for making surgical bandages and in plastering of walls. Potassium nitrate ($KNO_3$) is used in the production of gunpowder. Potassium iodide (KI) is used in photography.

## pH System

It is a negative logarithmic scale for expressing the acidity or alkalinity or basicity of a solution. It is expressed as pH = - log $[H^{+1}]$

$[H^+]$ is molar concentration of $H^+$ in the solution. A pH below 7 indicates an acid solution, one above 7 indicates an alkaline or basic solution. pH value depends on concentration of the hydrogen ion. The range of pH is 0 to 14. The PH of blood, milk and saliva is 7.35, 6.6 and 6.3 respectively.

There are various ways for determining the pH of a solution. One of the simplest ways is using the indicators. When an indicator comes into contact with an acidic or a basic solution, it changes colour at different points on the pH Scale.

Some natural colouring materials from red cabbage, raddish skin, beet root and rose petals are used as indicators.

| Indicator | Colour in Strong Acid | Colour in Strong Base |
|---|---|---|
| Litmus | Red | Blue |
| Methyl orange | Red | Yellow |
| Phenolphthalein | Colourless | Red |
| Bromophenol blue | Yellow | Blue |

## Titration

By this method we can determine the amount of acid or base in a solution or strength of a solution.

**Buffer Solution:** Buffer solution is a solution which resists change in PH when an acid or alkali is added or when the solution is diluted. There are two types of buffer solutions : (a) acidic buffer; and (b) basic buffer.

a. **Acidic Buffer :** These are formed by mixing solutions of a weak acid and its salt such as $CH_3COOH$ and $CH_3COONa$.

b. **Basic Buffer:** These are made up by mixing solutions of a weak base and its salt such as $NH_4OH$ and $NH_4Cl$.

| | Dispersed Phase | Dispersion Medium | Designation | Examples |
|---|---|---|---|---|
| 1. | Gas | Liquid | Foam | Whipped cream, soap- suds. |
| 2. | Gas | Solid | Solid foam | Pumice stone, bread, foam rubber, styrene foam. |
| 3. | Liquid | Gas | Aerosol | Clouds, mists, fogs. |
| 4. | Liquid | Liquid | Emulsion | Milk, creams and other emulsions. |
| 5. | Liquid | Solid | Gel | Cheese, jellies, curd, boot polish. |
| 6. | Solid | Gas | Solid foam | Smoke, volcanic dust, dust storm. |
| 7. | Solid | Liquid | Liquid sol | White of an egg, mud. |
| 8. | Solid | Solid | Solid sol | Coloured glass, precious stones, alloys, minerals, pearls. |

There is a great importance of buffers for us. For example, in the laboratory, buffers are used to prepare solutions of known stable PH. Natural buffers occur in living organisms, where the biochemical reactions are very sensitive to change in pH. The main natural buffers are $H_2CO_3$, $HCO_3^-$ and $H_2PO_4^-$-$HPO_4^{2-}$ Buffer solutions are also used in medicine (e.g. in intravenous injections), in agriculture and in dyeing, fermentation processes and the food industry. Buffer solutions are widely used in electroplating and also in processed food and drinks to prevent excessive acidity.

## Colloidal Solution

Colloidal solution is a homogeneous system of two immiscible phases. It means that colloids are now regarded as systems in which there are two or more phases, with one (is called the dispersed phase) distributed in the other (the continuous phase).

There are various types of colloidal solutions. Sol is called a colloidal solution. Sols are of two types:

i. **Lyophobic Sols:** In these sols there is no affinity between the dispersed phase and the liquid.

ii. **Lyophilic Sols:** These are more like true solutions in which the solute molecules are large and have an affinity.

**Applications of Colloidal Solution:**

1. **In Medicine:** Oral medicines are taken in colloidal form because they are more effective in this state. Colloidal gold, colloidal silver, colloidal calcium, colloidal manganese, etc. are used to increase the vitality of our body. Colloidal sulphur is used as a germicide.
2. **Cleansing of Clothes:** Soaps and detergents are used to clean dirty clothes. They remove dirt by converting and precipitating them as colloidal particles.
3. **Use of Gas Masks:** Use of gas masks depends on the absorption property of charcoal.
4. In making of inks, dyes and paints etc. ink, dyes and paints are colloidal substances.
5. **Purification of Water:** When potash alum is added to muddy water, the colloidal muddy particles get coagulated and they precipitate out and settle down at the bottom making water clean and pure.
6. **Smoke Precipitation:** Smoke is a colloidal solution of carbon in air. They are charged particles and hence they can be precipitated on charged metal plates.
7. **Sewage Disposal:** Disposal of sewage is based on the phenomenon of cataphoresis.

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# CHEMICAL THERMODYNAMICS



## Introduction

Thermodynamics is the study of the laws that govern the conversion of energy from one form to another, the direction in which heat will flow and the availability of energy to do work. Chemical thermodynamics is the branch of thermodynamics which deals with the study of processes involving chemical energy only.

**System:** It is a part of the universe which is selected for thermodynamic investigation.

**Surroundings:** Except for the system the rest of the universe is the surrounding. A gas enclosed in a cylinder is the system, cylinder is the surrounding and cylinder + gas is the universe in thermodynamic sense.

On the basis of exchange of mass and energy, the system may be:

i. **Isolated System:** For thermodynamics, system is defined as quantity of matter enclosed by a boundary surface from the rest of the universe i.e. the surrounding. If the boundary of the system neither allows heat flow nor allows matter flow, it is called an isolated system.

ii. **Open System:** If boundary of the system allows heat flow or matter flow through it, the system is called an open system.

**Example of Open System:** Evaporation of water kept in beaker is example of an open system. Water vapour escapes into surroundings and heat required for evaporation flows from the surroundings to the beaker. Thus, both matter and energy flow through the system.

iii. **Closed System:** If the boundary of the system allows only heat flow but not matter flow it is called closed system.

**Example of Isolated System:** If water in a sealed bottle is insulated, heat transfer from the surrounding to the bottle is prevented. Thus water in a sealed bottle and bottle covered with insulator is an example of an isolated system. Water kept in thermos flask represents an isolated system.

## First Law of Thermodynamics

This statement is equivalent to the law of conservation of energy. Heat added to a system is equal to the change in internal energy and work done by the system. Mathematically it can be expressed as :

$q = dE + W$

where

$q$ = heat absorbed by the system

$dE$ = change in internal energy

$W$ = work done by the system

## Principles of Conservation of Energy

i. Different forms of energy are interchangeable, but when a quantity of one kind of energy disappears an equivalent amount of energy appears.

ii. Energy cannot be annihilated nor can it be created from nothing.

iii. Changes and transformations in energy may occur, but the total energy of the universe is constant.

## Isothermal Process

It is one in which temperature of the system remains constant ($\triangle T = 0$); change of state (freezing, melting, evaporation, etc.) is an isothermal process.

## Isobaric Process

It is one in which the pressure of the system remains constant ($\triangle P = 0$).

## Isochoric Process

It is one in which the volume of the system remains constant ($\triangle V = 0$).

## Adiabatic Process

It is one in which the system does not exchange heat with the surroundings i.e. no heat enters or leaves the system ($\triangle q = 0$).

## Reversible Process

It is one in which direction may be reversed at any stage. Such a process is carried out extremely slowly in equilibrium conditions. The reversible process takes infinite time to occur. For a process to be reversible, friction, resistance, etc. should be absent and secondly there should be thermodynamic equilibrium.

## Irreversible Process

This process occurs suddenly or spontaneously without the restriction of occurring in stages. There is no thermodynamic equilibrium during the change. The system does not change to its initial stage by itself after the change. The heat change and work in opposite directions are unequal. All natural processes are irreversible.

## Heat Capacity at Constant Pressure (Cp)

The amount of heat required to raise the temperature of one mole of a substance by one degree at constant pressure is called molar heat capacity at constant pressure and is denoted by (Cp).

## Heat Capacity at Constant Volume (Cv)

Heat required to raise the temperature of one mole of a substance by one degree at constant volume is called heat capacity at constant volume and is denoted by (Cv).

## Relation between Cp and Cv

$C_p$ - Cv = R , R = Gas constant

$\frac{C_p}{C_v}$ = l, l = Specific heat ratio.

## Conversion of Heat into Work (Carnot Engine)

Heat engine is a machine used for the conversion of heat into work. Carnot gave an imaginary reversible cycle which demonstrates the maximum conversion of heat into work. Here, the system consists of one mole of an ideal gas enclosed in a cylinder fitted with a frictionless piston. The heat engine takes heat from the reservoir at high temperature (called the source), converts some heat into work and returns the remaining heat to another reservoir at low temperature (called the sink). Steam engine is one common example.

Efficiency of heat engine (h) = $\frac{W}{Q_2}$

$$= \frac{Q_2 - Q_1}{Q_2} = \frac{T_2 - T_1}{T_2} = 1 - \frac{T_1}{T_2}$$

W = work done

$Q_2$ = Heat absorbed from the source

$Q_1$ = Heat returned to the sink respectively

$T_2$ = Temperature of the source

$T_1$ = Temperature of the sink

## Second Law of Thermodynamics

The first law of thermodynamics does not help us to predict the direction of the change. This problem is overcome by the second law of thermodynamics. This is developed in terms of the entropy criterion:. According to this law, it is impossible to transfer heat from cold to a hot reservoir without doing some work. In other words, it is impossible to convert all the heat taken from source to work, without losing some of it to the colder reservoir.

## Entropy

Entropy can be interpreted as a measure of a system's disorder or randomness, the higher the entropy the greater the disorder. The change in entropy during the process is mathematically given by the ratio of heat absorbed by the system (q) in the reversible manner to the temperature (T) at which it is absorbed.

$$D\,S = S_2 - S_1 = \frac{q_{rev}}{T}$$

## Spontaneous Process

The physical, or chemical, process which occurs in a particular set of conditions either of its own or after proper initiation. All natural processes are spontaneous processes. Spontaneous processes cannot reverse on their own. In a spontaneous process there is an increase of entropy.

The conversion of solid into liquid and liquid into gas (solid $\rightarrow$ liquid $\rightarrow$ gas) is accompanied with increased random distribution of molecules and also increased entropy. Similarly, spontaneous diffusion of one gas into another involves increase of entropy and the molecules of the two gases get mixed in a more random manner.

The concept of entropy as a measure of randomness or lack of order has a great physical significance. For example, when ice melts to water at $0^0$C, $\triangle$S is 5.26 cal.deg$^{-1}$ mole$^{-1}$ but when solid benzene melts, $\triangle$S = 8.27 cal. deg$^{1}$ mole$^{-1}$. This means that there is greater order in water than in liquid benzene which may be due to hydrogen bonded structure in water.

## Entropy Change for Irreversible process

Entropy change for an irreversible process is positive hence entropy increases. Since all natural processes are occuring spontaneously i.e. irreversibly, the entropy of the universe is increasing continuously.

Now-a-days, different types of pollution are occurring in our atmosphere. Hence, greater disorder is occuring around our lives, thus entropy is continuously increasing. The entropy of the universe tends towards a maximum.

**Entropy Change in a Reversible Process :** The total entropy change of the system and the surrounding in the reversible process is equal to zero.

**Entropy Change during Freezing and Condensation:** Freezing of a liquid and condensation of gases are examples for which the entropy is decreased.

## Importance of Thermodynamics

Since thermodynamics is concerned with energy change therefore we assimilate a complete knowledge of various forms of energy i.e. kinetic energy, potential energy, electrical, energy, radiant energy, mass energy, nuclear energy and chemical energy from its study. These energies play a vital role in our lives.

The concepts of thermodynamics are applied in studying the phenomena involving light, heat or electric and magnetic fields. It also helps in predicting the maximum efficiency of various types of heat engines and maximum work obtainable from a given fuel, i.e. in the problems of combustion and power. For example, refrigerator is based on this principle.

# CHEMICAL REACTIONS

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## Chemical Reactions

Chemical reaction is a process in which one or more substances (called reactants) react together to form one or more new substances (called products) or a compound decomposes into two or more new compounds. In the chemical reaction, bond breaking and bond formation take place. In other words, we can say that there is a rearrangement of the energy distribution in the chemical reaction.

Chemical reaction is represented by a chemical equation. A chemical equation includes the chemical formulae of a compound representing the symbols of elements. Or in other words, a chemical equation is a brief method of expressing a chemical reaction with the help of symbols and formulae. For example, sodium (Na) reacts with water ($H_2O$) to form sodium hydroxide (NaOH) and hydrogen gas ($H_2$). This chemical reaction represented by a chemical equation would be written as :

$2Na + 2H_2O \rightarrow 2NaOH + H_2$

## Balancing Equations

According to the law of mass conservation, in chemical reactions the amount and constituents of reactants are accountable in the form of products. Consider the reaction of nitric oxide (NO) with $O_2$ producing $NO_2$ as given below :

$NO + O_2 \rightarrow NO_2$

This is evidently not a balanced equation as no. of O atoms on the left hand side of the equation do not equal those on the right hand side. Simple algebra is used to balance without disturbing the molecular formula of the reactants and products. Hence balanced equation can be written as

$2NO + O_2 \rightarrow 2\,NO_2$

No. of Nitrogen (N) – atoms

= 2(L.H.S. = R.H.S)

No. of oxygen (O) – atoms

= 4 (L.H.S. = R.H.S.)

Where

L.H.S. = Left hand side

R.H.S. = Right hand side

There are large no. of varieties of chemical reactions. Some of these may be explained as below:

1. **Combination Reactions:** In this type, combining of an element with a compound and another element or a compound results to form a new compound.

   $4Na + O_2 \rightarrow 2Na_2O$

2. **Decomposition Reactions:** It is just a reverse of the combination reaction. In this type of reaction, a compound decomposes into simpler substances.

   $2NaHCO_3 \xrightarrow{Heat} Na_2CO_3 + CO_2 + H_2O$

   Explosions are violent decomposition reactions that release large amounts of energy.

3. **Displacement Reactions :** It is also known as substitution reaction. In this type of reaction replacement takes place in which a substrate of reactant replaces another substrate of reactant to form a product. For example,

   $2Na + 2H_2O \rightarrow 2NaOH + H_2$

   In the above reaction, sodium (Na) displaces hydrogen of water molecule and combines with hydroxyl ($OH^-$) group to form sodium hydroxide. (NaOH)

   $Na_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2NaOH$

   Sodium Carbonate displaces $OH^-$ from $Ca(OH)_2$ and combines to form NaOH and Ca displaces $CO_3$ from $Na_2CO_3$ then combines to form $CaCO_3$

4. **Isomerisation Reaction :** In this type of reaction, a new compound is formed after rearrangement of atoms.

   $NH_4CNO \rightarrow H_2NCONH_2$

   Ammoniumcyanate (Urea)

## Chemical Formula

Chemical formula represents exact figure of the constituents in a compound. It denotes how many atoms are combined in a molecule. For example, $H_2O$ is the chemical formula for the water molecule, in which two atoms of hydrogen and one atom of oxygen are present. Sometimes elements exist as molecules that are combinations of like atoms. Thus hydrogen or oxygen gas is diatomic as $H_2$ or $O_2$. Some can be polyatomic, for instance, $S_8$ or $P_4$.

## Oxidation and Reduction

**Oxidation is a chemical process which involves :**

i. combination with oxygen or other electronegative elements (electron attractor elements).

ii. removal of hydrogen or any other electropositive element (electron donor elements) from a compound.

iii. increase in valency of metal atom in a compound.

iv. increase in the proportion of an electronegative element or group and decrease in the proportion of electropositive element in a compound.

v. increase in oxidation no. (the no. of charges) of an element.

vi. loss of electrons.

Electronegative elements $\rightarrow$ S, Cl, Br, I, N, O, etc.

Electropositive elements $\rightarrow$ Fe, Cu, Na, K, etc.

**Examples of oxidation :**

i. $2Cu + O_2 \rightarrow 2CuO$

ii. $2Mg + O_2 \rightarrow 2MgO$

iii. $Mg + Cl_2 \rightarrow MgCl_2$

iv. $4HCl + MnO_2 \rightarrow 2H_2O + MnCl_2 + Cl_2$

v. $2SO_2 + O_2 \rightarrow 2SO_3$

vi. $2Mg + O_2 \rightarrow 2MgO$

In the above reactions (i) and (ii) Cu, Mg are combined with oxygen. Hence they have undergone oxidation and oxygen is the oxidizing agent. In (iii) reaction Mg is combined with electronegative element $Cl_2$. Hence Mg has undergone oxidation. In (vi) reaction H has been removed from HCl to obtain $Cl_2$ hence HCl has undergone oxidation and $MnO_2$ is the oxidizing agent. In (v) reaction oxidation number of S is +4 in $SO_2$ which has increased to +6 in $SO_3$ . Hence $SO_2$ has undergone oxidation and $O_2$ is the oxidizing agent. In (vi) reaction each Mg atom has lost 2 electrons to form $Mg^{++}$ ion during the process of oxidation of Mg to $Mg^{++}O^{-}$.

**Oxidizing Agents:** An oxidizing agent oxidizes other substances. It is a substance which can supply oxygen or any other electronegative element and can remove hydrogen or an electropositive element from a compound. Modern definition of an oxidizing agent is a substance which has the capacity to gain electrons.

i. $F + e \rightarrow F^-$

F is an oxidizing agent

ii. $O + 2e^- \rightarrow O^{--}$

O is an oxidizing agent

**Following types of elements and compounds are oxidizing agents :**

1. Most of the non-metals except C, H and P.
2. All ic-salts of metals – $FeCl_3$, $Fe_2(SO_4)_3$, $CuSO_4\,5H_2O$, $CuCl_2$, $HgCl_2$, $HgSO_4$
3. Oxides and higher oxides of metals – CuO, $Fe_2O_3$, $NaO_2$
4. $KMnO_4$, HClO, $HClO_2$, $HClO_3$, $HClO_4$, $HNO_3$, $K_2Cr_2O_7$

**Reduction: It is a chemical process which involves:**

i. combination of an element with hydrogen or with any other electropositive element.

ii. removal of oxygen or any other electronegative element from a compound.

iii. decrease in valency of a metal atom in a compound.

iv. increase in the proportion of an electropositive element and decrease in the proportion of an electronegative element or group in a compound.

v. decrease in oxidation number of an element.

vi. gain of electrons by a substance.

***Examples:***

i. $S + 2Na \rightarrow Na_2S$

S has undergone reduction

ii. $CuO + C \rightarrow Cu + CO$

CuO has undergone reduction to Cu

iii. $2Fe^{+3}Cl^{-1}_3 + S^{+4}O^{-2}_2 + 2H^{+1}_2O^{-2} \rightarrow 2Fe^{+2}Cl^{-1}_2 + H^{+1}_2S^{+6}O^{-2}_4 + 2H^{+1}Cl^{-1}$

Oxidation number (no. of charges) of Fe has decreased from +3 in $FeCl_3$ to +2 in $FeCl_2$. Hence $FeCl_3$ has undergone reduction.

ii. $2FeCl_3 + H_2S \rightarrow FeCl_2 + 2HCl + S$

$FeCl_3 \xrightarrow{H_2O} Fe^{+++} + 3Cl^-$

$FeCl_2 \xrightarrow{H_2O} Fe^{++} + 2Cl^-$

$Fe^{+++} + e^- \rightarrow Fe^{++}$

Each $Fe^{+++}$ ion of $FeCl_3$ gains an electron and is reduced to $Fe^{++}$ which is present in $FeCl_2$

$\therefore$ Reduction involves gain of electrons.

**Reducing Agents:** A substance which has the capacity to supply hydrogen or any other electropositive element and remove oxygen or any other electro-negative element from a compound is called a reducing agent.

Modern definition of a reducing agent is that it has the capacity to loose electrons.

$Na \rightarrow Na^+ + e^-$

$\therefore$ Na is a reducing agent.

**Following substances are reducing agents:**

All metals, carbon, hydrogen, phosphorus, $FeCl_2$, $FeSO_4$, $SnCl_2$, $Hg_2Cl_2$, NaH, $LiAlH_4$, $CaH_2$, $NH_3$, $H_2S$, HBr, HI, HCl, $H_2S$, $H_2Se$ and $H_2Te$, Aldehydes, formic acid, oxalic acid, Na – oxalate, sodium formate, sulphides, bisulphide, sulphite and nitrite are reducing agents.

**Redox Reaction:** There is no such reaction known in which only oxidation or only reduction occurs. In all oxidation-reduction reactions, which are called redox-reactions if one substance is oxidized, there is another substance which is reduced. In other words, it can be said that in redox reactions oxidising agent is reduced and reducing agent is oxidized.

To find out which substance is oxidized and which is reduced, oxidation numbers of all atoms on the left hand side and right hand side of a redox-reaction are calculated. A reactant whose oxidation number increases as a result of the reaction gets oxidized and a reactant whose oxidation number decreases as a result of the reaction gets reduced.

***Examples :*** $S^{+4}O^{-2}_2 + 2^{+1}H_2S^{-2}$ à $2^{+1}H_2O^{-2} + 3S^0$

The oxidation number of all atoms are written at the top of the reactants and the products in the equation. It can be seen that oxidation number of S decreases from +4 in $SO_2$ to zero in elemental sulphur. $SO_2$ is reduced to S.

$\therefore$ $SO_2$ is an oxidizing agent. Oxidation no. of S in $H_2S$ is –2 which increases to zero in elemental S. Hence, $H_2S$ is oxidized and hence it is a reducing agent.

**Importance of Oxidation-Reduction:** Oxidation-reduction is closely related with our lives. Various reactions taking place in our body are redox reactions. For examples, digestion, respiration, etc. are related with redox reactions. Following are important examples:

i. **Combustion of Fuels:** When a fuel burns, it gains oxygen. It is oxidized. Natural gas is a good example. Natural gas is methane, $CH_4$.

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

ii. **Respiration:** Respiration is the release of energy from food in living cells. Glucose from food reacts with oxygen. The carbon in glucose is oxidized.

Glucose + oxygen $\rightarrow$ Carbon dioxide + water

$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O\,(l)$

(aq – aqueous),

g = gas

l = liquid

So we get energy from our food by a redox reaction.

iii. **Corrosion of Metals:** Many metals corrode or rust in air. Iron is a good example. The iron combines with oxygen. It is oxidized.

Iron + oxygen $\rightarrow$ Iron oxide (rust)

$4Fe + 3O_2(g) \rightarrow 2Fe^{3+}{}_2O^{2-}{}_3(S)$

The iron loses electrons, so it is oxidized. The oxygen gains electrons, so it is reduced. Rusting is a redox reaction.

iv. **Formation of Power Cells of Quartz Watches:** By using the redox reactions, scientists can create tiny power cells for quartz watches, control the rusting of iron and explain the role of oxygen in keeping them alive.

v. **Extraction of Metals from Ores:** Iron is extracted from iron ore in a blast furnace. The iron combines with hot carbon monoxide gas.

Iron ore + Carbon monoxide $\rightarrow$ Iron + Carbon dioxide

$Fe_2O_3(S) + 3CO(g) \rightarrow 2Fe(S) + 3CO_2(g)$

The iron ore loses oxygen, so it is reduced. The carbon monoxide gains oxygen, hence it is oxidized. Extracting of metal from ore is a redox reaction.

vi. **Reaction of Photosynthesis:**

Light energy absorbed

$$6CO_2 + 12H_2O \xrightarrow[\text{By Chlorophyll}]{\text{Light energy absorbed}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

Oxygen is set free after water molecules are broken out. The hydrogen from the water molecules combines with Carbon dioxide to form glucose. Hence, oxidation and reduction takes place.

vii. **Electrolysis :** At anode oxidation takes place and at cathode reduction takes place. Electrolysis plays an important role in the metal industry. Besides production of many metals, it is also used in the production of heavy water ($D_2O$).

# THERMO CHEMISTRY



It is well known that the system naturally tends towards greater stability. This stability results from lowering the energy because a lower energy state is more stable than a high energy state. This drives a chemical reaction in which the products would have lower energy than the reactants, after going through either evolution or absorption of heat. All these things are dealt with by thermochemistry.

## Exothermic Reaction

Chemical reaction in which heat is evolved is called an exothermic reaction and is expressed as : $A + B \rightarrow C + D + Q$ where Q is heat evolved, A and B = reactants and C and D = products.

## Endothermic Reaction

Chemical reaction in which heat is absorbed is called an endothermic reaction and is expressed as $A + B + Q \rightarrow C + D$ or $A + B \rightarrow C + D - Q$ where Q is heat absorbed, A and B = reactants and C and D = products.

## Bond Dissociation Energy and Bond Energy

Bond dissociation energy is the energy required to break a particular type of bond in one mole of gaseous molecules.

The energy released in the formation of one mole of bonds is known as bond energy.

For example, the bond dissociation energy of hydrogen molecules is 435.6 KJ per mole. This means, 435.6 KJ $mol^{-1}$ of energy is required to break the H – H bonds in one mole of hydrogen molecules. This may be expressed as

$$\underset{\text{1 mole of hydrogen molecule.}}{H_2} + \underset{\text{Energy absorbed}}{435.6\ KJmol^{-1}} \xrightarrow[\text{Breaking}]{\text{Bond}} 2H(g)$$

or 435.6 KJ/mol of heat energy is given out during the formation of one mole of hydrogen gas molecules.

## Enthalpy

It is denoted by H. A thermodynamic property of a system is defined by H = U + PV, where H is the enthalpy. U is the internal energy of the system, P is its pressure and V is its volume. For an exothermic reaction $\triangle H$ is taken to be negative and for an endothermic reaction $\triangle H$ is taken to be positive. Enthalpy is also known as heat content.

## Heat of Formation

Heat absorbed or released in the formation of one mole of a substance from its elements is called heat of formation and $\triangle H_f$ is called enthalpy change of formation.

$$\frac{1}{2} H_2(g) + \frac{1}{2} Cl_2(g) \rightarrow HCl(g) + 22KCal$$

Heat of formation $Q_f$ = 22KCal

$\triangle H_f$ = -22KCal

## Heat of Combustion

Heat released in complete combustion of one gram-atom of an element or one gram-mole of a compound is called heat of combustion and $\triangle H$ is called enthalpy change of combustion.

$C(s) + O_2(g) \rightarrow CO_2(g) + 94\ KCal$

Heat of combustion of C = Q

= 94 KCal

$\triangle H$ combustion of C = -94 KCal

This is the same reaction that we observe when we burn charcoal in stoves and ovens in the kitchen.

## Heat of Fusion

Heat absorbed in the conversion of one mole of a solid to liquid is called heat of fusion and DH is called enthalpy change of fusion.

$$\underset{\text{Ice}}{H_2O(s)} \rightarrow \underset{\text{water}}{H_2O(l)} - 1.44\ KCal$$

Q = -1.44 KCal

$\triangle H_{fusion}$ = + 1.44 KCal

## Photochemical Reaction

It is a chemical reaction caused by light or ultraviolet radiation. The incident photons are absorbed by reactant molecules to give excited molecules or free radicals which undergo further reaction. Photosynthesis in presence of sunlight, expands dissociation of $I_2$ molecule into two iodine atoms upon absorption of light. Photography in which photographic film is coated with silver bromide which is sensitive to light and is chemically affected by light and hence the photographic image is obtained by developing the film in the dark are examples of photochemical reactions. In a photochemical reaction light is required.

## Electrochemistry

The study of chemical properties and reactions involving ions in solution, including electrolysis and electric cells is called electrochemistry.

**Chemiluminiscent Reaction:** Light is evolved.

**Electrolytic Reaction:** Electricity is required.

**Electrochemical Reaction:** Electricity is produced.

**Respiration:** It is the process of release of energy; it is an exothermic reaction.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2} \rightarrow \underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O}$$

## Metallic Corrosion

Many metals react with air or the environment to form undesirable compounds on their surfaces. This process is called corrosion. Mostly metals, except like least active metals platinum, gold undergo corrosion. Iron corrosion is called rusting. In contact with air, iron forms red or orange materials. This material is the hydrated form of ferric oxide ($Fe_2O_3\, xH_2O$).

The reaction may be written as :

$$\underset{\text{Iron}}{8Fe} + \underset{\text{Oxygen (fromair)}}{6O_2} + \underset{\text{Water}}{6H_2O} \longrightarrow \underset{\text{Iron Oxide}}{2Fe_2O_3} + \underset{\text{Iron Hydroxide}}{4F_3(OH)_3}$$

$$Fe_2O_3 + xH_2O \rightarrow \underset{\text{Rust}}{Fe_2O_3xH_2O}$$

Iron rusting is not possible in dry air and vacuum. It is prevented by coating the iron with Zinc. Zinc forms zinc compounds with humid air and forms a protective cover over the iron thus protecting it from rusting. This coated iron is known as galvanized iron or G.I.

## Chemical Reactions

**The chemical reactions are primarily classified as :**

i. irreversible; and

ii. reversible reactions.

**i. Irreversible Reactions :** These are chemical reactions in which the products do not react back to give the reactants.

For example, $2KClO_3 \rightarrow 2KCl + 3O_2$

$AgNO_3 + HCl \rightarrow AgCl + HNO_3$

ii. **Reversible Reactions:** These are chemical reactions in which the products also react to give back the reactants. Such reactions can be made to occur in either direction by suitable variations in the conditions. If the reaction is carried out in a closed vessel, it is found that the reaction does not go to completion.

For example,

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

$3Fe(S) + 4H_2O(g) \rightleftharpoons Fe_3O_4(S)_3 + 4H_2(g)$

## Equilibrium State

When a reversible reaction is carried out in a closed vessel, then it is observed that a constancy in properties like intensity of colour, pressure, concentration, etc., is achieved under a given set of conditions. Such a state is referred to as an equilibrium state. A chemical equilibrium is a state at which the composition of the chemical system becomes constant under a given set of conditions. It must be noted that at equilibrium, the chemical reaction does not stop but instead both the forward as well as the backward reactions take place at the same rate.

## Chemical Equilibrium

When two reactants are mixed, they react to form the product as:

$A + B \rightarrow C + D$

A and B are reactants and C and D are products. At time 0, the concentration of the products is 0 and as time progresses, concentration of the reactants decreases and the concentration of the products increases. As the concentration of the products increases, they may also react according to the reaction.

$C + D \rightarrow A + B$

Thus there is competition between

$A + B \rightarrow C + D$

$C + D \rightarrow A + B$

And backward $C + D \rightarrow A + B$ reactions

At a particular instant (time), the concentration of the reactants no more decreases and there is no increase in the concentration of the products i.e. at a particular instant the concentration of both the reactants and the products are constant. This state is called equilibrium state and is represented by

$A + B \rightleftharpoons C + D$

($\rightleftharpoons$ sign of equilibrium)

The state of equilibrium continues indefinitely until it is disturbed by external factors like variation of concentration, temperature, pressure, etc. A catalyst does not affect the final state of the equilibrium.

## Law of Mass Action

Rate of a reaction is proportional to the product of the active mass of reactants. Active mass of a substance is approximately equal to its molar concentration.

This is the law of mass action. For the reaction aA + bB $\rightarrow$ cC + dD, the rate of reaction is given as : rate = $K[A]^a[B]^b$

where K is called rate constant, [A] is molar concentration of A and [B] is molar concentration of B.

**Equilibrium Constant :** In the equilibrium state the rate of forward reaction is equal to the rate of backward reaction and the reaction is given as :

$aA + bB \rightleftharpoons cC + dD$

In this aA + bB $\rightarrow$ cC + dD is forward reaction and cC + dD $\rightarrow$ aA + bB is backward reaction

$r_f$ = Rate for the forward reaction = $K_f[A]^a[B]^b$

$r_l$ = Rate for the backward reaction = $K_b[C]^c[D]^d$

at equilibrium $r_f = r_b$

$\therefore \quad K_f [A]^a[B]^b = k_b [C]^c[D]^d$

or, $$\frac{[C]^c[D]^d}{[A]^a[B]^b} = \frac{K_f}{K_b} = K_e$$

[A], [B], [C] and [D] is the molar concentration of A, B, C, and D respectively.

## Le Chatelier's Principle

If any kind of stress (such as change in concentration, temperature or pressure) is applied on equilibrium, it shifts in a direction that tends to undo the effect of the stress. For example:

i. Decrease in the concentration of any of the products or increase in the concentration of any of the reactants pushes the equilibrium in the forward direction.

ii. In an endothermic reaction, an increase in temperature favours the forward reaction, while a decrease in temperature favours the backward reaction. In an exothermic reaction, low temperature favours the forward reaction and a high temperature favours the backward reaction.

iii. Increase of pressure pushes the equilibrium towards the side in which number of gaseous moles decreases.

iv. **Effect of Inert Gas :** For a reaction at constant volume i.e., when the no. of moles of the reactants are equal to the no. of moles of the products the addition of inert gas has no effect. When an inert gas is added to the equilibrium system at constant pressure, the equilibrium will shift in a direction in which there is an increase in the no. of moles of gases.

v. A catalyst increases the rate of forward and backward reactions to the same extent.

## Applications of Le Chatelier's Principle in Everyday Life

i. **Transport of Oxygen by Haemoglobin in Blood :** The haemoglobin of RBCs of our blood combines with oxygen to form oxyhaemoglobin as below:

$$\underset{\text{Haemoglobin}}{Hb(s)} + \underset{\text{Oxygen}}{O_2(g)} \rightleftharpoons \underset{\text{Oxyhaemoglobin}}{HbO_2(s)}$$

When oxyhaemoglobin reaches into the tissues, the partial pressure of oxygen becomes low so equilibrium shifts towards the left, giving up oxygen. When the blood returns to the lungs, the partial pressure of oxygen becomes higher and the equilibrium favours the formation of more oxyhaemoglobin.

ii. **Removal of Carbon Dioxide by Blood :** Blood gives up $CO_2$ from the tissues according to the equilibrium

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

Due to the high partial pressure of $CO_2$, $CO_2$ is dissolved in the blood in the tissues and due to low partial pressure of $CO_2$ in the lungs, $CO_2$ is released from the blood.

iii. **Sweet Substances Cause Tooth Decay :** Tooth enamel is made up of an insoluble substance called hydroxyapatite $Ca_5(PO_4)_3OH$. Its dissolution is called dimineralization and its formation as remineralization. It exists in equilibrium as :

Ca5(PO4)3OH(S)

$$\underset{\text{Remineralization}}{\overset{\text{Demineralization}}{\rightleftharpoons}}$$

$5Ca^{+2}(aq) + 3PO_4^{3-}(aq) + OH^-(aq)$

Remineralization

When we eat sweets, sugar present in the sweets gets fermented to give $H^+$ ions which combine with the $OH^-$ ions shifting the equilibrium in the forward reaction. Therefore, $Ca_5(PO_4)_3OH$ dissolves causing tooth decay.

## Chemical Kinetics

**Rate of Reaction :** It is the speed with which the reactants are converted into products. In other words, rate of reaction is the rate of disappearance of a reactant or the rate of appearance of a product.

This can be expressed as :

$A \rightarrow B$

Rate = K[A]

$A + B \rightarrow$ Products

Rate = K[A][B]

K is called rate constant. As rate constant is specific for a reaction, it is also called 'specific rate constant.'

A reaction may occur in more than one step, the slowest step determining the rate of the reaction and hence is known as the rate determining step. The formation of $(CH_3)_2CHOH$ from $(CH_3)_2CHCl$ by the reaction with $OH^-$ can be expressed as :

(a) $(CH_3)_2\,CHCl + OH^- \xrightarrow[Slow]{K_1} (CH_3)_2\,CH^+ + Cl^- + OH^-$

$(CH_3)_2\,CH^+Cl^- + OH^- \xrightarrow[Slow]{K_1} (CH_3)_2\,CHOH^+ + Cl^-$

$(CH_3)_2CHOH + Cl^{-1}$

Rate of reaction in this case

$= K_1[(CH_3)_2CHCl][OH^-]$

**Order of Reaction:** The sum of the exponents in the rate expression of a reaction is called order of the reaction.

$A \rightarrow B$

Rate = K[A]

Order = 1

$A + B \rightarrow$ Products

Rate = K[A][B]

Order = 1 + 1 = 2

$2A \rightarrow$ Products

Rate = $K[A]^2$

Order = 2

Order of reaction is determined by experimental measurements and it can be a whole number or even a fraction.

| Order of Reaction | Molecularity of Reaction |
|---|---|
| (i) Sum of the exponents in rate expression is called order of reaction. If rate expression is K $[A]^2$, order or reaction is 2 and if rate expression is K [A], order of reaction is I. | (i) No. of moles of reactants involved in the transition state of rate determining step is called molecularity of the reaction. |
| (ii) It may be a whole no. or fraction | (ii) It is always a whole no. |
| (iii) It is determined by actual experimental data. | (iii) It is determined by reaction mechanism. |

**Molecularity of Reaction:** Before the discussion about molecularity we must study activated state or transition state. Before the reaction occurs, reactants collide and form the activated or the transition state

$A + B \rightarrow AB^*$

A and B are reactants, AB* is the transition state or the activated state. Product is formed from the activated state.

$AB^* \rightarrow$ Products

Thus the reaction can be given as $A + B \rightleftharpoons AB^* \rightarrow$ Products

The energy of activated or transition state is higher than both the of reactants and products. The number of moles of reactants involved in the transition state or activated state or the rate determining step of a reaction is called 'molecularity of reaction'. Let us consider the reaction of $CH_3Cl$ (methyl chloride) and NaOH (Sodium hydroxide):

i. $CH_3Cl \xrightarrow[Slow]{K_1} CH_3^+ + Cl^-$

ii. $CH_3^+ + Cl^- + OH^- \xrightarrow[Fast]{K_2} CH_3OH + Cl^-$

i. Is slow and is the rate determining step. In the transition state of this step, two moles (one each of $CH_3Cl$ and $OH^-$) are involved. Hence molecularity of the reaction is 2. The order of the reaction is also 2. Thus the reaction is a second order bimolecular reaction. Let us consider the reaction of $(CH_3)_2CHCl$ and NaOH

$(CH_3)_2CHCl \xrightarrow[Slow]{K_1} (CH_3)_2CH^{\oplus} + Cl$

$(CH_3)_2CH^{\oplus} + OH \xrightarrow[Fast]{K_2} (CH_3)_2CHOH$

govern the rate of a reaction.

**i. Concentration of reactants :**

$A \rightarrow B$

Rate = K[A]

If concentration of the reactant increases, rate of reaction increases. When concentration of reactant increases, number of molecules increases. If there is an increase in the number of molecules, no. of collisions and consequently effective number of collisions increases. With increase in the effective number of collisions, rate of reaction increases.

ii. **Temperature:** Rate of reaction increases with increase in temperature. With increase in temperature kinetic energy of the reactant molecules increases. With increase in kinetic energy velocity of the molecules increases. Due to increase in velocity of the molecule, number of collision and hence effective number of collision increase. Due to increase in effective number of collision, rate of reaction increases.

iii. **Chemical Nature of Reactants and Rate of Reaction :** Due to difference in chemical nature of reactant activation energy of the reaction is different and consequently rate is different. Activation energy is the minimum energy required for a chemical reaction to take place. The reaction of $FeSO_4$ with $KMNO_4$ in acidic medium is fast, but that of oxalic acid with $KMNO_4$ in acidic medium is slow. The difference in rate is due to difference in the chemical nature of $FeSO_4$ and $H_2C_2O_4$ (oxalic acid).

iv. **Physical State of Reactants :** This effect is pronounced for heterogeneous reactions. In homogeneous reaction, reactants are in a different phase.

A reaction between $FeSO_4$ solution + $KMNO_4$ solution is homogeneous, but a reaction between $CaCO_3$ (solid) and dilute HCL(l) is heterogeneous. The reaction of one gram solid piece of $CaCO_3$ with dilute HCL is slower than that of 1 gram powder of $CaCO_3$. This is due to increased surface area in the powdered form. Thus greater the surface area of the reactant, greater is the rate of reaction.

v. **Catalyst and its Effect on the Rate of Reaction:** Substances which change the rate of chemical reactions by their presence are called catalysts and the phenomenon is called catalysis. The catalyst takes part in the reaction and is regenerated at the end of the reaction. Thus the catalyst is not consumed in the chemical reaction and is recovered chemically unchanged at the end of the reaction.

There are four types of catalysts: (a) positive catalyst; (b) negative catalyst; (c) auto-catalyst; and (d) induced catalyst.

Positive catalyst increases the rate of reaction and negative catalyst decreases the rate of reaction. Thus in the decomposition of $KClO_3$ to $O_2$, $MNO_2$ acts as a positive catalyst. The airy oxidation of chloroform is prevented in the presence of a few drops of alcohol. This is an example of negative catalysis. Auto – catalyst is the product of the reaction. No catalyst is added from outside. The reaction of $KMNO_4$ and Oxalic acid in acidic medium is slow, but as soon as $MN^{+2}$ is produced in the reaction, rate of reaction increases. Thus $MN^{+2}$ acts as a catalyst for the reaction. $Na_2SO_3$ is oxidized by air, but $Na_2ASO_3$ (arsenite) is not. However, when $Na_2ASO_3$ is mixed, both are oxidized. The oxidation of $Na_2SO_3$ induces oxidation of $Na_3ASO_4$ and the catalyst is an induced catalyst.

Catalysts change the rate of reaction by changing the activation energy and the mechanism of the reaction. Positive catalysts decrease the activation energy and so the reaction is faster. Negative catalysts increase the activation energy and so the reaction is slower.

| | Manufacturing | Catalysts Used |
|---|---|---|
| 1. | To convert vegetable edible oil into vanaspati | Nickel |
| 2. | In manufacturing of ammonia gas by Haber process | Fe $\downarrow$ iron powder |
| 3. | In the formation of Nitric acid by Ostwald's process | Platinum wire-gauge |
| 4. | Production of Sulphuric acid by the Contact process | platinum powder |
| 5.. | Lead Chamber process of production of sulphuric acid | oride of nitrogen |
| 6. | Process of Ether formation from alcohol | Hot alumina |
| 7. | Deacon process for the production of chlorine gas | cupric chloride |

# ELECTRO CHEMISTRY

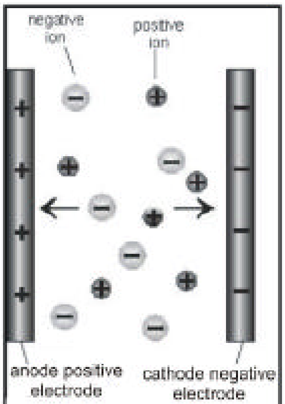
**It is the branch that deals with the study of the following two types of reactions :**

i. Reactions in which chemical energy is converted to electrical- energy (electrochemical cell or Galvanic cell or voltaic cell); and

ii. Reactions in which chemical energy is required to bring about a chemical reaction (electrolytic cell).

## Electrolysis

The production of a chemical reaction by passing an electric current through an electrolyte. In electrolysis, positive ions migrate to the cathode (negative electrode) and negative ions to the anode. (positive electrode) Hence the passage of electricity; through an electrolyte is called electrolysis.




if positive and negative ions are free to move as they are when in solution or in a liquid state then negative ions go to the anode and positive ions go to the cathode.

The reactions occurring depend on electron transfer at the electrodes and are therefore redox reactions. At the anode, negative ions in solution may lose electrons to form neutral species. Alternatively, atoms of the electrode can lose electrons and go into solution as positive ions. In either case, the reaction is an oxidation. At the cathode, positive ions in solution can gain electrons to form neutral species. Thus cathode reactions are reductions.

## Electrolyte and Non-electrolyte

In liquid state or in the form of solutions in some solvent (mostly water) substances allows electricity to pass through are called electrolytes and those substances which do not allow the passage of electricity are called as non-electrolytes. Water, Sodium Chloride and Molten Salts are electrolytes. Sugar, wax and naphthalene etc. are non-electrolytes.

**Cations and Anions:** During electrolysis, positively charged ions and negatively charged ions are formed. Positively charged ions are called cations and negatively charged ions are called anions.

## Electrolytic Cell

A cell in which electrolysis occurs i.e. one is which current is passed through the electrolyte from an external source.

In an electrolytic cell, usually two metallic or graphite rods or plates are used for allowing the electric current to pass through the electrolyte these are called electrodes. The one electrode which allow the electric current to enter into the electrolyte is called anode and the other electrode which allow the current to leave the electrolyte is called cathode. During electrolysis the electrodes may or may not take part in the chemical change.

## Electrolytic Cell Reactions

In electrolysis reactions the nature of reaction is oxidation-reduction. Oxidation takes place at anode and reduction takes place at cathode.

***Example :*** Electrolysis of NaCl in molten state

$NaCl \longrightarrow Na^+ + Cl^-$

at cathode $Na^+ + e^- \longrightarrow Na$

at anode $Cl^- \longrightarrow \frac{1}{2} Cl_2 + e^-$

Sodium is deposited at the cathode and $Cl_2$ is liberated at the anode.

## Characteristics of Electrolysis

i. The process of electrolysis starts when power is supplied and stops when power is cut.

ii. The primary products are discharged ions and these are liberated only at electrodes.

iii. Electropositive elements like hydrogen and metals are liberated at the cathode.

iv. Electronegative elements like non-metals are liberated at the anode.

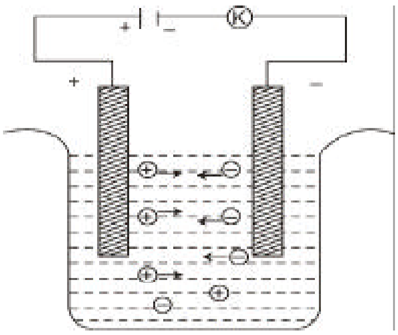
v. The weight of a substance produced on an electrode during electrolysis is proportional to the quantity of electricity passed through the electrolyte.

## Uses of Electrolysis

i. **Electroplating:** A method of plating one metal with another at the electrodes (the process of depositing ore metal on another by electrolysis).

The articles to be plated are made the cathode of an electrolytic cell and a rod or bar of the plating metal is made the anode. Electroplating is used for covering a metal with a decorative, more expensive or corrosion – resistant layer of another metal.

ii. **Electrorefining:** Metals can be refined (purified) by the electrolytic method. Anode is made up of an impure metal and Cathode is made up of a pure metal in the solution of a suitable salt of the metal to be purified. Passage of electricity results in the dissolving of the anode and deposition of metal at the cathode. The impurities fall down in the form of anode mud. Copper is industrially purified by this method.



iii. **Electrometallurgy:** Metal is extracted from its ore by electrolysis this process is called electrometallurgy. For example sodium and Aluminium are extracted from its ore by this process.

iv. **Electroprinting:** Type-page impression is made on wax plate or plaster of paris. By sprinkling graphite on wax, the plate is made conductor and thus made cathode in a copper plating bath. On the passage of electricity copper deposits on the wax plate. It is removed and strengthened by filling its back with type-metal. The mould is obtained which is an exact copy of the printer's page and is used in large scale printing.

v. **Industrial Applications:** There are a large no. of compounds formed electrolytically such as caustic soda, washing soda, chlorine and so on are obtained by electrolysis of Sodium Chloride.

## Strong and Weak Electrolytes

An electrolyte which dissociates to a greater extent is called a strong electrolyte. Whereas an electrolyte which is feebly ionized is a weak electrolyte. Strong acids like HCL (Hydrochloric acid), strong bases like Sodium Hydroxide (NaOH) and almost all salts like NaCl are strong electrolytes and weak acids such as acetic acid ($CH_3COOH$) and weak bases like ($NH_4OH$) ammonium Hydroxide are weak electrolytes. A strong electrolyte in dilute solution is supposed to be completely ionised.

## Electrochemical Cell

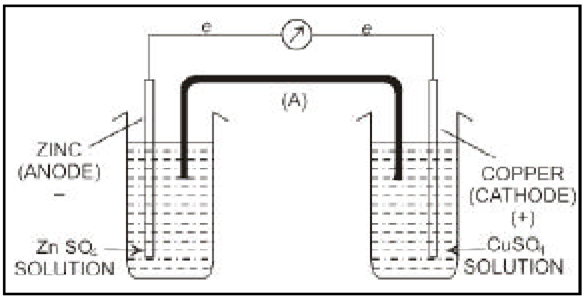
An electro chemical cell can be created by placing metallic electrodes into an electrolyte where a chemical reaction either uses or generates an electric current. This is also called Galvanic or Voltaic cell.

**Electrochemical cell**

| | **Cathode** | **Anode** |
|---|---|---|
| i. | Reduction ocurs at cathode. | Oxidation ocurs at anode. |
| | $Cu^{2+} + 2e \rightarrow Cu$ | $Zn \rightarrow Zn^{2+} + 2e$ |
| ii | is positive. | is negative. |

Electrons flow in the external circuit from anode to cathode while conventional current flows from cathode to anode.

In an electrochemical cell, there are two electrodes dipped into solutions of their salts, as for example, many metallic compounds generate electricity in many displacement reactions. Zn electrode is dipped into solution $ZnSo_4$ and Cu electrode into solution of $CuSo_4$.




Two solutions are separated by a partition A. When two electrodes are joined, electrical energy is produced. Zn forms $Zn^{+2}$ and 2e electrons moves from Zn to Cu electrode.

*The following reactions occur :*

$Zn \longrightarrow Zn^{+2} + 2e$ (Oxidation)

$Cu^{+2} + 2e \longrightarrow Cu$ (Reduction)

$Zn + Cu^{+2} \longrightarrow Zn^{+2} + Cu$

Electricity is produced at Zn electrode and moves to the Cu electrode.

At Zn electrode where oxidation occurs is the Anode. At Cu electrode where reduction occurs is the Cathode. At Zn electrode negatively charged electrons are produced and then move from it to the Cu electrode. Hence Zn electron i.e. anode is negatively charged and as electrode moves to Cu electrode i.e. Cathode, it is positively charged.

## Dry Cell

This is also called a flash light battery. Dry cell was invented by G. Le Clanche in 1868. A common dry cell has a solution of ammonium chloride and a carbon rod (surrounded by a paste of manganese oxide) at the center and the whole cell is covered by zinc. During the chemical reaction, zinc produces zinc ions and electrons.

These electrons are then used by reactions involving manganese dioxide. This reaction may be represented as below :

i. $2MnO_2 + 2NH_4Cl + 2e^-$

$\rightarrow Mn_2O_3 + 2NH_3 + H_2O + 2Cl^-$

This is Cathode reaction

ii. $2MnO_2 + 2NH_4Cl + Zn$

$\rightarrow [Zn(NH_3)_2Cl_2 .+ Mn_2O_3 + H_2O$

The voltage of the dry cell is 1.5V. Silver cells and the lithium cells are the examples of a dry cell.

## Storage Cells

Storage cells are recharged but other electrochemical cells are not recharged. Lead storage cells are used in cars and other vehicles. These are the most common examples.

Car battery has concentrated $H_2SO_4$ (density = 1.15 (in which Pb (lead) rod (negative electrode) and pb rod coated with $PbO_2$ (positive electrode) are dipped. When two electrodes are joined, chemical reaction occurs and electricity is produced.

There are other examples of storage cells like nickel-iron and nickel cadmium cells.

## Faraday's Law of Electrolysis

Faraday in 1833 established a certain relationship between the quantity of electricity passed and the amount of substance electrolysed, which is called Faraday's law of electrolysis.

**First Law:** The amount of a substance obtained in electrolysis is proportional to the quantity of electrolysis passed through its electrolyte.

$W \alpha Q$

$W \alpha it$ ($\because Q = it$)

W = amount of a substance deposited at cathode by using Q quantity of electricity

W = Z it

Z = Electrochemical equivalent of the substance

i = current in amperes

t = time in seconds

**Second law:** When the same quantity of electricity is passed through different electrolytes the amount of substances liberated is proportional to the chemical equivalents of different substances. Chemical equivalent means gm equivalent weight or 1gm eq. If $W_1$ gm … $W_2$ gm, $W_3$ gm of different substances are obtained when Q coulombs of charge is passed through their respective electrolytes and if $E_1$, $E_2$, $E_3$ are the chemical equivalents respectively from the second law of electrolysis: $W \alpha E$

or $\frac{W_1}{E_1} = \frac{W_2}{E_2} = \frac{W_3}{E_3}$ Since $\frac{\text{Weight}}{\text{Equivalent Weight}}$ is no. of gram-equivalent. Therefore, the same quantity of electricity will deposit the equal no. of gram equivalents of all substances in electrolysis.

It can also be inferred from this that quantity of electricity required for deposition of one gram equivalent of any substance must be the same and this quantity is called one faraday. It is denoted by F and is numerically equal to 96500 coulombs, approx.

# RADIOACTIVITY



The phenomenon of radioactivity was discovered accidentally by the French scientist, Henri Becquerel in 1896. The term radioactivity was first used by Marie Curie.

Radioactivity is essentially a nuclear phenomenon and a drastic process because the element changes in kind. It is spontaneous and an irreversible self-disintegrating activity because the element breaks itself up for good. Certain substances like Uranium, Thorium, Radium, etc. spontaneously emit radiation like a, b, g rays

**Characteristics of a, b, g Radiations**

| Radiation | a | b | g |
|---|---|---|---|
| Charge | +2 | –1 | 0 |
| Mass | 4 | 0 | 0 |
| Velocity | 1/10th of light velocity | less than light velocity | light velocity ($3\times10^8$m/s) |
| Penetrating power | Less than β and γ | less than γ but more than α | greater than α and β |
| Ionizing power | more than β and γ | more than γ and less than α | less than α and β |

and are converted into new elements. The property of emission of radiations from a substance is known as radioactivity. Spontaneous emission of radiations from a substance is called natural radioactivity. The substance which emits radiation is called radioactive substance. The process in which an element is converted into a new radioactive isotope (i.e. unstable isotope) by artificial means (i.e. by bombarding the element with fast moving particles like proton, deutron, helium, etc. ) is called artificial or induced radioactivity.

## Half-life Period

Half-life period of a radioactive substance is the time required to disintegrate one-half of the original amount of the substance. In other words, the half-life period of a radioactive substance is the time in which half of the radioactive substance will disintegrate. For example, any substance which has a half- life period of 5 days that means this substance disintegrates 50% in 5 days. In other words after reduction of 50% in five days, the radioactive substance is 25% after 10 days 12.5% after 15 days and so on.

Mathematically it can be shown as

$$t_{1/2} \text{ or } T = \frac{0.693}{\lambda}$$

$t_{1/2}$ or T = half-life period l = decay constant

## Mass Defect

Nucleus is formed by the combination of protons and neutrons. The mass of P = 1.00783 and the mass of n = 1.00866 amu. The mass of $_1H^2$ formed from one proton and one neutron is 2.01410 amu.

$$_1H^1 + {}_0n^1 \rightarrow {}_1H^2$$

1.00783 + 1.00866 2.01410

= 2.01649

Thus there is loss in mass when a nucleide is formed from the nucleus.

$\triangle$m = 2.01649 – 2.01410

= .00239 amu

This loss in mass is called 'mass defect.' The loss in mass is released as energy according to the relation

$E = mc^2$

1 atomic mass unit = 931.5 Mev

(Mev = million electron volt)

Thus in the formation of $_1H^2$ from a proton and neutron 0.03 x 931.5 Mev of energy is released.

## Packing Fraction

In the formation of heavy nucleide from the nucleus, there is decrease in mass due to loss of energy. The decrease in mass has been expressed by packing fraction defined as:3

$$f = 10^4 \times \frac{\text{Isotopic atomic weight – mass no.}}{\text{Mass Number}}$$

The isotopic weight of $_1H^2$ is 2.0141 and mass no. is 2 and so f for $_1H^2$ is

$$\frac{2.0141-2}{2}\times10^4 = \frac{0.0141}{2}\times10^4$$

$$= 0.00705 \times 10^4 = 70$$

## Nuclear Stability

Some nucleides or elements are stable and some are unstable. It is determined by $\frac{\text{Neutron}}{\text{Proton}}$ (n/p) ratio in the nucleus. If n/p = 1 the nucleide is stable, if n/p > 1 and n/p < 1, the nucleide is unstable and shows radioactivity.

## Nuclear Binding Energy

Energy released when neutrons and protons combine to form the nucleus is called Nuclear binding energy. The energy required to separate the neutrons and protons from the nucleus is also called nuclear binding energy.

## Radioactive Decay (Disintegration)

The main radiations in radioactivity are (i) a (ii) b. Emission of a -particles produces an element which has a mass of four units less and charge two units less than that of the parent element.

$_{Y}A^{X} \rightarrow {}_{Y-2}B^{X-4} + {}_{2}He^{4}$

A = Radioactive element

X = Atomic number

Y = Atomic mass

$_{92}U^{235} \rightarrow {}_{90}Th^{231} + {}_{2}He^{4}$

U = Uranium

Th = Thorium

He = Helium

Emission of $\beta$-particle produces an element having same mass but charge one unit greater than the parent element.

$_{Y}A^{X} \rightarrow {}_{Y+1}B^{X} + {}_{-1}\beta^{0}$

$_{81}Tl^{206} \rightarrow {}_{82}Pb^{206} + {}_{-1}\beta^{0}$

The process of radioactive disintegration continues till a non-radioactive element is produced. In case of $_{92}U^{238}$, $\alpha$ and $\beta$ particles are emitted and the final product is $_{82}Pb^{206}$

$_{92}U^{238} \xrightarrow{\alpha,\beta} {}_{82}Pb^{208}$

Thus the mass difference is 238 – 206 = 32 units and this corresponds to emission of 8$\alpha$ particles (mass of $\beta$ = 0). The charge difference is 92 – 82 = 10. Emission of 8$\alpha$ particles decreases the charge by 16 units and emission of each b increases the charge by one unit. Thus 16 **–10=6**$\beta$ particles are emitted.

## Group Displacement Law

When an a - particle is emitted, the new element is displaced 2 places left in the periodic table, and when a b -particle is emitted, the new element is displaced one place towards the right in the periodic table. This is group displacement law. It can be shown as below:

$_{92}U^{238} \xrightarrow{\alpha} {}_{90}Th^{234}$

VI B IV B

$_{90}Th^{234} \xrightarrow{\beta} {}_{91}Pa^{234}$

IV B V B

## Nuclear Fission

The nuclear reaction in which one heavier nucleus is split up into two lighter nuclei of releasing a, b and g radiation along with the release of a huge amount of energy is called nuclear fission or atomic fission.

In 1939, German Chemists Otto-Hahn and his associates Meitner and Strassman bombarded $_{92}U^{235}$ with slow moving neutrons and observed that $U^{235}$ nucleus, after capturing a neutron, gave $U^{236}$ nucleus which was radioactive called (compound nucleus) and hence had broken up to form ultimately a pair of stable products (called fission products) consisting of $_{56}Ba^{141}$ and $_{36}Kr^{92}$ and liberated three neutrons (called secondary neutrons) in addition to a huge amount of energy called fission energy.

$$_{92}U^{235} + {}_{0}n^{1} \rightarrow \underbrace{\left[{}_{92}U^{236}\right]}_{\text{Compound Nucleus}} \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\,{}_{0}n^{1} + \text{Energy}$$

## Chain Reaction

During a nuclear fission a large number of chain reactions take place. If we initiate fission of one $U^{235}$ nucleus by one neutron obtained either by cosmic rays or by some radioactive source. In this fission process each $U^{235}$ nucleus suffering fission will liberate three neutrons. These three neutrons will in turn cause the fission of three other $U^{235}$ nuclei and will liberate three more neutrons in the fission of each $U^{235}$ nucleus. Thus nine neutrons will be obtained and so on. Consequently, a self propagating or self sustaining chain reaction (also called auto catalytic reaction) starts in which the number of neutrons keeps on multiplying rapidly (in geometrical progression). This chain reaction is also accompanied by the liberation of a huge amount of energy which is called fission energy. This energy can either be very fast resulting in a violent explosion (as in an atom bomb) or it can be controlled and maintained at a steady rate (as in chain reacting nuclear piles or nuclear reactors).

## Nuclear Reactor

A nuclear reactor is a mechanism by which nuclear fission is produced in the form of a controlled self-sustaining chain reaction. In other words, it is a controlled chain-reacting system supplying nuclear energy.

## Moderators

The explosive effect of the nuclear fission chain reaction can be reduced by using some substances called moderators which slow down the fast moving neutrons. The secondary neutrons (which are formed after the first nuclear fission reaction) pass through the moderator and lose some of their kinetic energy and their speed is reduced. Thus the use of a moderator controls the explosive effect of the nuclear fission chain reaction.

When graphite is used as a moderator, the reactor is called Atomic Pile and when $D_2O$ (heavy water) is used it is called Swimming Pool reactor.

## Nuclear Fusion

Such a nuclear reaction in which two lighter nuclei are combined or fused together to form a heavier (and hence stabler) nucleus is called nuclear fusion. Nuclear fusion occurs at reasonable rates only at very high temperatures. It is because of this that the nuclear fusion reactions are also called thermonuclear reactions i.e. temperature – dependent reactions. Nuclear fusion adequately explains the:-

I. energy of the sun and other stars which is called Stellar energy.

II. the basic principle of the hydrogen bomb (Fusion bomb).

**i. Stellar energy :**

$4\,{}_1H^1 \rightarrow 2He^4 + 2\,{}_1e^0 +$ Energy

Proton Helium Positron

Above nuclear reaction indicates that four H-atoms (or protons) are fused together to produce one helium nucleus and two positrons. On the sun the fusion of four H-nuclei into helium nucleus does not take place through a single step but takes place through deuterium ${}_1H^2$.

ii. **Hydrogen Bomb:** Nuclear fusion reaction depends on high temperature. This is provided by the fission of $U^{235}$ nucleus which is an explosive chain reaction. This forms the principle of the hydrogen bomb. In the preparation of hydrogen bomb a suitable quantity of all the isotopes of hydrogen ( ${}_1H^1$; ${}_1H^2$ and ${}_1H^3$ ) is combined with an atomic bomb. The function of atomic bomb is to provide the high temperature which is necessary for bringing about the nuclear fusion reactions in hydrogen bomb. In the hydrogen bomb the following nuclear fusion reactions take place:

${}_1H^1 + {}_1H^2 \rightarrow {}_2He^3 +$ Energy « $H^2 + {}_1H^2 \rightarrow$

$2He^3 + {}_0n^1 +$ Energy

${}_1H^3 + {}_1H^2 \rightarrow {}_2He^4 + {}_0n^1 +$ Energy

## Uses of Radioisotopes

**1. Uses of radioisotopes as radioactive tracers:**

i. Uses of tracers in studying reaction mechanisms like photosynthesis as :

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Here a very important question arises – whether the oxygen evolved in this process comes from $CO_2$ or from $H_2O$ or from both. This question has been answered by the use of radioactive $O^{18}$ isotope $H_2O$ is made to react with Carbon dioxide containing $O^{18}$ (i.e. $CO_2^{18}$) and it is found that the oxygen evolved does not contain $O^{18}$ i.e. $O^{18}$ present in $CO_2^{18}$ goes to sugar and water while that of water is evolved as free oxygen. Thus oxygen evolved in the process of photosynthesis comes from $H_2O$ and not from carbon dioxide and consequently, the reaction shown above could be shown as :

$$6CO_2^{18} + 12H_2O \rightarrow C_6H_{12}O_6^{18} + 6H_2O^{18} + 6O_2$$

ii. Uses of tracers in the diagnosis of diseases : Radio – iodine (1-131) has been used to locate and detect the presence of tumour.

iii. Circulation of blood : Radioactive sodium ($Na^{24}$) has been used to study cases of restricted circulation of blood.

iv. Pumping action of heart has been studied by using radioactive sodium or radio iodine.

v. Radioactive iodine ($I^{131}$) is given to a patient with thyroid disorders.

vi. Tracer iron has been used in studying the disorders associated with pregnancy.

vii. $Co^{60}$ emits high energy g (gamma) rays which are used for testing deeply seated cancer growth.

viii. The wear of piston rings and of gears in engines and its prevention by means of suitable lubricants have been studied by radioactivity.

ix. Radioactive uptake of phosphorus by plants from soil and fertilizer is determined by adding radio phosphorus to the fertilizer.

x. Irradiation of maize with radioactive Cobalt produces 15% increase in the quantity of green parts over those plants growing in the same field, but not irradiated.

**2. Uses of radioisotopes in the treatment of diseases (Radiotherapy) :**

- Radioactive iodine $I^{131}$ has been used for the treatment of certain thyroid complaints. Actually $I^{131}$ is utilized in the treatment of hyperthyroidism and cancer of the thyroid.
- Radioactive phosphorus in the form of phosphate is widely used in the treatment of certain blood disorders.
- Radio Cobalt ($Co^{60}$) is used in the treatment of cancer. $Co^{60}$ has been called Poor Man's radium.
- Radioisotope of phosphorus is being used for the treatment of leukaemia.
- Radio phosphorus ($P^{30}$) is found good for skin diseases.
- $U^{238}$ isotope is used for the determination of the earth by rock dating method.
- The age of animal and plant fossil is is determined by using the radio carbon ($C^{14}$) dating method.

# CHEMICAL BONDING

CHRONICLE IAS ACADEMY
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Except noble gases atoms of all other elements have a tendency to combine either with each other or with the atoms of other elements to form clusters or aggregates of atoms with a definite composition. Thus, a chemical bond is defined as the attractive force that holds two or more atoms together in a molecule or an ion. Atoms combine chemically for the following reasons:

1. When two atoms come closer to combine together to form a bond between them, the attractive and repulsive forces begin to operate them. Attractive force is due to attraction between one atomic nucleus and electrons of another atom. Repulsive force is due to repulsion between electrons of different atoms. If attractive force is dominant over repulsive force then bond formation occurs and if the repulsive force is dominant over the attractive force there is no bond formation.

| Molecule | Shape |
|---|---|
| $BaCl_2$ | Linear shape |
| $Co_2$ | Linear shape |
| $Bcl_3$ | Trigonal planar shape |
| $CH_4$ | Tetrahedral shape |
| $NH_3$ | Trigonal pyramidal shape |
| $H_2o$ | V shaped (angular or bent |
| $PF_5$ | Trigonal bipyramidal |
| $Xef_2$ | Linear shape |
| $SF_6$ | Octahedral shape |
| $[Cu(NH_3)_2]^{2+}$ | Square planar |

2. Chemical bond is formed for getting stability. This stability occurs by acquiring a stable outer-shell of eight electrons.

   In the formation of a chemical bond atoms interact with each other by losing, gaining or sharing of electrons so as to acquire stable octet electrons.

3. The process of chemical bonding between the atoms decreases the energy of the combining atoms and gives rise to the formation of a system which has lower energy and hence greater stability.

## Types of Chemical Bonds

**There are mainly two types of chemical bonds as below :**

i. **Electrovalent Bond :** It is also known as ionic or polar bond. The chemical bond formed between two atoms by the transfer of one or more valence electrons from one atom to the other is called an ionic bond. This bond is also called Electrovalent bond.

Generally metals have the tendency to donate electrons and non metals have tendency to gain electrons. So in this stage an electrovalent bond forms. For example, in the formation of NaCl (Sodium Chloride), Na (Sodium) donates an electron to chlorine to get an octet.

$Na \rightarrow Na^+ + e$ (2,8,1 $\rightarrow$ 2,8)

$Cl + e^- \rightarrow Cl^-$ (2,8,7 $\rightarrow$ 2,8,8)

Donors are Cations and Gainers are Anions.

ii. **Covalent Bond :** The chemical bond between two atoms in which the electrons (in pairs) are shared by both the participating atoms is called Covalent bond. The covalent bond formed by the sharing of one, two or three electron pairs between the participating atoms is called single, double and triple covalent bond respectively. Single bond is represented by a single dash (-) in which one pair of electrons is involved as in H – H ($H_2$) and H – Cl (HCl). Double Covalent bond is represented by double dash (=) in which 2 pairs of electrons are involved as in O = O ($O_2$). Triple Covalent bond is represented by Triple dash ($\equiv$) in which 3 pairs of electrons are involved as in $N \equiv N$ ($N_2$). $H_2$, HCl, $NH_3$, $CH_4$, $CCl_4$, $BF_3$, $CO_2$ are examples of covalent compounds.

iii. **Co-ordinate Bond:** A covalent bond which is formed by the mutual sharing of two electrons both of which are provided entirely by one of the linked atoms (or ions) is called a co-ordinate bond. For example in $O_3$ molecule, one lone pair of one oxygen atom of $O_2$ is donated to the other oxygen atom to form $O_3$ molecule as in

$O = O \rightarrow O_2$

$\rightarrow$ denotes co-ordinate bond.

## Shapes of Molecules

In ionic compounds, the bond exists due to electrostatic attraction between oppositely charged species which are non-directional. So the structure is determined almost entirely by the relative sizes of the ions. Covalent bonds are however directional and the shape of a covalently bonded molecule is decided by the direction of the covalent bonds.

Many physical and chemical properties are decided by the shape of molecules. Specific properties of $H_2O$ are decided by its angular shape. Similarly, the biologically important DNA molecule which has special physiochemical behaviour, is due to its double spiral shape.

# PERIODIC TABLE



It would be difficult to study individually the chemistry of all the elements and their numerous compounds. Classification of elements into various sets or groups make it easy to study the characters of all these elements. In this regard, numerous scientists worked and gave ideas and subsequenty Mendeleev's periodic table came forth.

In 1869, J. Lothar Meyer, a German, and Dmitri I. Mendeleev, a Russian, independently constructed tables of elements. In these tables, the elements were arranged in the order of their increasing atomic weights. Thus Mendeleev's law may be stated as, "The properties of elements are a periodic function of their atomic weights, i.e. if the elements are arranged in the increasing order of their atomic weights the properties of the elements ( i.e. similar elements are repeated after definite regular intervals) or periods." Hence Mendeleev's table gave a strong base to further work on this field. His prediction about coming up of new elements like gallium, scandium and germanium has been proved.

Due to some anomalous findings in Mendeleev's periodic table such as position of hydrogen, position of lanthanides and actinides, etc the modern periodic table was put forward by Mosley to overcome the defects of Mendeleev's periodic table. Mosley in 1911, proposed that the physical and chemical properties of an element depend on the no. of electrons and their arrangement in different orbitals of the atom, and so the classification of the elements should be based on the number of these electrons (i.e. atomic number) and their arrangement in different orbitals. This idea led by Mosley made most of the defects of Mendeleev's periodic table disappear. According to the Modern periodic table "the properties of elements are a periodic function of their atomic numbers, i.e. if the elements are arranged in the increasing order of their atomic numbers, the properties of the elements (i.e. similar elements) are repeated after definite regular intervals or periods."

Modern periodic table includes groups or periods. The vertical columns are called groups. The total number of groups are 18 which are I A, II A, III A, IV A, V A, VII A, Zero, I B, II B, III B, IV B, V B, VI B, VII B and three columns of group VIII.

The horizontal rows shown in the periodic table are called periods or simply rows. There are seven periods in the table.

## General Characteristics of Groups

1. **Valency Electrons :** On moving down a given group the number of valency electrons does not change, i.e. remains the same.
2. **Valency :** The valencies of all the elements of the same group are the same.
3. **Physical and Chemical Properties:** All the elements of a given group possess very similar physical and chemical properties.
4. **Size of Atoms :** Size of atoms increases on descending a group.
5. **Metallic Character :** The metallic character of the elements increases in moving from top to bottom in a group.

## General Characteristics of Periods

1. **Valency Electrons :** Number of valency electrons increases from 1 to 8 when we proceed from left to right in a period.
2. **Valency :** The valency of the elements with respect to hydrogen in each short period increases from 1 to 4 and then falls to one while the same with respect to oxygen increases from 1 to 7.
3. **Size of Atoms :** Size of atoms decreases from left to right in a period.
4. **Metallic Character :** On moving from left to right in a period the metallic character of the elements decreases.
5. **No. of Shells :** In going from left to right in a period the number of electron shells remains the same and the number of a period corresponds to the number of the shells found in the elements of that period.

Atomic Masses of Elements referred to $^{12}C = 12.0000$

# Periodic Table

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H | | | | | | | | | | | | | | | | | 2 He |
| 3 Li | 4 Be | | | | | | | | | | | 5 B | 6 C | 7 N | 8 O | 9 F | 10 Ne |
| 11 Na | 12 Mg | | | | | | | | | | | 13 Al | 14 Si | 15 P | 16 S | 17 Cl | 18 Ar |
| 19 K | 20 Ca | 21 Sc | 22 Ti | 23 V | 24 Cr | 25 Mn | 26 Fe | 27 Co | 28 Ni | 29 Cu | 30 Zn | 31 Ga | 32 Ge | 33 As | 34 Se | 35 Br | 36 Kr |
| 37 Rb | 38 Sr | 39 Y | 40 Zr | 41 Nb | 42 Mo | 43 Tc | 44 Ru | 45 Rh | 46 Pd | 47 Ag | 48 Cd | 49 In | 50 Sn | 51 Sb | 52 Te | 53 I | 54 Xe |
| 55 Cs | 56 Ba | | 72 Hf | 73 Ta | 74 W | 75 Re | 76 Os | 77 Ir | 78 Pt | 79 Au | 80 Hg | 81 Tl | 82 Pb | 83 Bi | 84 Po | 85 At | 86 Rn |
| 87 Fr | 88 Ra | | 104 Rf | 105 Db | 106 Sg | 107 Bh | 108 Hs | 109 Mt | 110 Ds | 111 Rg | 112 Cn | 113 Uut | 114 Uuq | 115 Uup | 116 Uuh | 117 Uus | 118 Uuo |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57 La | 58 Ce | 59 Pr | 60 Nd | 61 Pm | 62 Sm | 63 Eu | 64 Gd | 65 Tb | 66 Dy | 67 Ho | 68 Er | 69 Tm | 70 Yb | 71 Lu |
| 89 Ac | 90 Th | 91 Pa | 92 U | 93 Np | 94 Pu | 95 Am | 96 Cm | 97 Bk | 98 Cf | 99 Es | 100 Fm | 101 Md | 102 No | 103 Lr |

Generally, non-metals have a tendency to gain electrons to complete their octets and thus they form negative ions. Hence they are called electronegative elements. For example, Nitrogen, Oxygen, Phosphorus, Bromine, etc. are non-metals. Non-metallic elements are placed on the right-hand side of the periodic table. Out of approximately 22 non-metallic elements, 11 are gases (oxygen, nitrogen and chlorine), one is liquid like bromine and rest are solids (e.g. Carbon, Sulphur, Phosphorus and Iodine).

## Hydrogen

There is great importance of hydrogen in our life. It is found in water, acids, carbohydrates (sugars, starch, cellulose), plants, animals, proteins, vitamins, wood, coal tar, oil, natural gas, etc. The atomic number and atomic weight is one and 1.00797 respectively. It is the first chemical element in the periodic system. Hydrogen is manufactured by Lane's process (By the action of steam on hot iron) and Bosch Process (from water gas). Under normal conditions hydrogen is a colourless, odourless, tasteless gas composed of diatomic molecules, $H_2$. It is the lightest substance known. At normal temperatures, hydrogen is comparatively unreactive but at higher temperature, it becomes highly reactive.

## Uses of Hydrogen

1. **In Chemical Industries:** Hydrogen has a great importance in the formation of ammonia by Haber's process, formation of hydrochloric acid and methanol, vanaspati ghee from vegetable oils such as coconut oil, cotton seed oil, etc. by the action of hydrogen in the presence of finely divided Nickel under 5 atmospheric pressure and at 150° - 200°C. Petrol substituents by the action of hydrogen, under pressure on finely – powdered coat suspended in oil (Bergins process) or by the hydrogenation of CO (Fischer – Tropsch process).
2. **In Engineering :** Hydrogen is used as a valuable fuel, because its heat of combustion is very high. Heat of combustion is the amount of heat produced when one gram of a substance is completely burnt. It is a constituent of many fuel gases like coal gas, water gas which contain 50% and 45% by volume of hydrogen respectively. When hydrogen is burnt with pure oxygen in oxyhydrogen blow torch, it gives a very hot flame (2800°C) which is employed for welding purposes and for melting platinum and quartz. Hydrogen is also used as a fuel in rockets and guided missiles.
3. **For Filling Air-Ships and Balloons:** Due to its lowest density, hydrogen is used as a gas for inflating meteorological balloons and in air-ships. As it is combustible and has a tendency to leak, a non-inflammable mixture of 85% He and 15% $H_2$ is used for the purpose.
4. **In Metallurgy :** Hydrogen is used in producing pure metals from their oxides.It is also used in producing a reducing atmosphere within the furnaces in the heat treatment of metals.

## Various Forms of Hydrogen

1. **Nascent Hydrogen :** It is a reactive form of hydrogen generated in situ in the reaction mixture (e.g. by the action of acid on zinc). Nascent hydrogen can reduce elements and compounds that do not readily react with normal hydrogen. It was once thought that the hydrogen was present as atoms in the atmosphere but this is not the case.
2. **Adsorbed or Occluded Hydrogen:** Some metals like Pd, Pt, Au, Fe, Ni etc. can absorb under, certain conditions relatively large volumes of hydrogen. The gas thus adsorbed by metals is given off when the metal is heated especially under reduced pressure. The phenomenon was termed occlusion or adsorption. The gas so adsorbed by the metal is termed occluded or adsorbed hydrogen. Occluded hydrogen is more active and a stronger reducing agent than ordinary hydrogen.
3. **Active Hydrogen :** When ordinary hydrogen at room temperature is subjected to the action of silent electric discharge at an electrical pressure of more than 30,000 volts, it changes into an active variety of hydrogen. This is called active hydrogen.
4. **Atomic Hydrogen :** When molecular hydrogen in contact with a tungsten or platinum wire was heated by an electric current at low pressure, it dissociates into atomic hydrogen. This is an endothermic reaction.

| | Properties | Metals | Non-Metals |
|---|---|---|---|
| | **PHYSICAL** | | |
| 1. | Metallic Lustre | Yes | No lusture with the exception of iodine which possesses metallic lustre. |
| 2. | Malleability | Malleable | Not Malleable |
| 3. | Ductility | Ductile | Not Ductile |
| 4. | Thermal conductivity | Good Conductivity | No Conductivity |
| 5. | Electrical properties | Good Conductors | Non-Conductors (Exception graphite) |
| 6. | Tenacity and Toughness | High | Low |
| 7. | Melting and Boiling points | High | Low |
| 8. | Density | Generally high | Generally low |
| 9. | Welding | Can be welded | Cannot be welded |
| 10. | State of existence at room temperature | Generally solid only Mercury (Hg) and Francium (Fr) are liquids. | They are solids, and gases, Bromine ($Br_2$) is a liquid. |
| 11. | Metallic sound | They produce a metallic sound when struck. | Do not produce any metallic sound when struck. |
| | **CHEMICAL** | | |
| 1. | Oxides | Basic | Acidic |
| 2. | Hydroxides | Basic | Acidic |
| 3. | Action of HCl or $H_2So_4$ | $H_2$ gas is liberated | Do not liberate $H_2$ |
| 4. | Electrolysis | They are liberated at cathode. | They are liberated at anode. |
| 5. | Electropositive nature | They form positive ions | They form negative ions. |
| 6. | Mechanism of reaction | They react by losing electrons. | They react by sharing, gaining or losing electrons. |
| 7. | Oxidising or Reducing | Metals are reducing agents. | Non- metals are generally good oxidising agents. |

The atomic hydrogen so produced was found to be more reactive than ordinary, nascent and adsorbed hydrogen. Atomic hydrogen is used for the production of atomic hydrogen welding torch which is employed for welding and cutting metals.

5. **Ortho and Para Hydrogen Molecules :** We already know that a hydrogen molecule is composed of two hydrogen atoms. Each of these two H-atoms of $H_2$ molecule has one proton in its nucleus and one electron revolving round the nucleus. Thus $H_2$ molecule which is formed from two H-atoms has two protons and two electrons in it. The two electrons in these two H-atoms always spin in opposite directions.

$$H(\uparrow)+H(\downarrow)\rightarrow H \uparrow\!\downarrow H$$

or H - H or $H_2$

However, the two protons present in the nucleus of both the H – atoms may spin either in the same direction (i.e. parallel direction) or in opposite direction(i.e. anti-parallel direction).

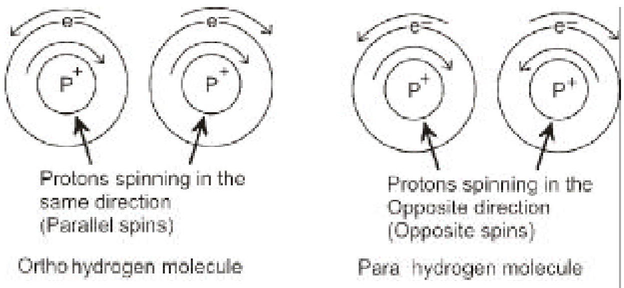
i. **Ortho Hydrogen Molecule :** Hydrogen molecule in which both the protons in the nuclei of both H – atoms spin in the same direction (i.e. parallel direction) is an ortho hydrogen molecule.

ii. **Para Hydrogen Molecule :** Hydrogen molecule in which both the protons in the nuclei of both H – atoms spin in opposite direction (i.e. anti-parallel direction) is called a para hydrogen molecule.

The two electrons in ortho as well as in para hydrogen molecule always spin in the opposite direction, otherwise it will not be possible to get stable hydrogen molecule.

## Water

It is an essential part of our life. It is the most abundant compound in the atmosphere. In the second half of the eighteenth century, Cavendish proposed the composition of water i.e. two volumes of hydrogen and one volume of oxygen ($H_2O$).




Ortho and para hydrogen molecules.
Here P+ Indicates proton.

Water is nearly about 70-80% of the total constituent of a living body. Of the total estimated global water supply of ~1.4 x $10^9$ $Km^3$, the oceans and inland saline water bodies hold 97.3% and fresh water amounts to only 2.7%. Unfortunately most of the fresh water is not readily accessible being locked up in frozen lakes, glaciers or under the ground. The fraction of water available for human use is only 0.003% of the total global water supply.

Naturally, water exists in three phases – solid, liquid and gas. Water is known as a universal solvent because it dissolves almost every substance to some extent except non-polar substances. Due to these properties it is widely used in agriculture, industry and chemical laboratories. Rain water is the purest form of natural water.

A molecule of water consists of two hydrogen atoms joined to an oxygen atom by covalent bonds. There are two lone pairs of electrons on the oxygen atom. Because of the high electronegativity of oxygen, water molecule is highly polar, the oxygen atom having partial negative charge and the hydrogen atoms having partial positive charge.

In liquid water, water molecules are held together by hydrogen bonding. The density of ice is less than that of liquid water. When ice melts some of the hydrogen bonds are broken and the water molecules become more closely packed. As a result, there is an increase in density above the melting point 0°C. As the temperature increases, the density increases gradually reaching a maximum at 4°C. Thereafter, increasing thermal motion of the molecules becomes more prominent and density decreases with temperature as found for most liquids. Because of its lower density compared with liquid water, ice floats on water. This floating block of ice prevents or delays the freezing of the underlying water enabling aquatic life to survive during the winter months.

**Physical Properties :** Hydrogen bonding plays a vital role in deciding the physical properties of water, such as its abnormally high freezing point, boiling point, heat of vaporization and heat of fusion (compared to the hydrides of other elements of the same group of the periodic table e.g. $H_2S$, $H_2Se$) which arise from the presence of hydrogen bonds. Water has a higher specific heat, thermal conductivity and surface tension than most other liquids. These properties are responsible for water to play a vital role in the biosphere. The high heat of vaporization and the high heat capacity of water are responsible for the moderating influence of water on the climate and body temperature of living organisms. Water is also an excellent solvent for transporting ions and

## Some Properties of Three Isotopes of Hydrogen

| Property | Ordinary hydrogen or protium | Heavy hydrogen or deuterium | Tritium |
|---|---|---|---|
| Symbol | $_1^1H$ or H | $_1^2H$ or $_1^2D$ | $_1^3H$ or $_1^3D$ |
| Atomic number | 1 | 1 | 1 |
| Mass number (i.e. atomic mass or atomic weight) | 1.0081 | 2.0147 | 3.0170 |
| Atomicity | 2 | 2 | 2 |
| Molecular formula | $H_2$ | $D_2$ | $T_2$ |
| No. of protons in the nucleus | 1 | 1 | 1 |
| No. of neutrons in the nucleus | Nil | 1 | 2 |
| No. of electrons | 1 | 1 | 1 |
| Relative abundance of their diatomic molecules in ordinary hydrogen | 99.984% | .0156% | 10.15% |
| Stability | Stable | Stable | Radioactive and hence unstable |
| Electronic configuration | $_1S^1$ | $_1S^1$ | $_1S^1$ |

molecules needed by plants and animals for their metabolism. Even covalent organic compounds such as alcohols and carbohydrates have a high solubility in water because of their ability to form hydrogen bonds with water molecules.

**Chemical Properties :** Water displays a versatile range of chemical behaviour. It acts as an acid, a base, an oxidant, a reductant and as a ligand to metal ions. Water molecules exhibit a high thermal stability as would be anticipated from its high negative heat of formation. Appreciable decomposition of water to the respective elements requires high temperatures. The extent of dissociation at 1500K is < 0.02%.

Pure water has a small but measurable electrical conductivity because of the following equilibrium:

$H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$

(Hydronium (Hydroxylion)

Thus water can act both as an acid and a base and is said to be Amphoteric. Water acts as a base towards acids stronger than itself and as an acid in the presence of a base stronger than itself, as shown below :

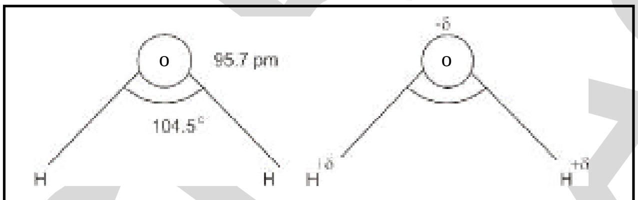
$H_2O(l) + HCl \rightleftharpoons H_3O^+(aq) + Cl^-(aq)$

base acid acid base

$H_2O(l) + NH_3(aq) \rightleftharpoons$ acid base

$NH_4^+(aq) + OH^-(aq)$ acid base

The autoprotolysis of water is thus of great importance in acid-base chemistry. Certain compounds without the presence of water, do not react. For example,




**Structure of water molecule**

chemical reactions in plant or animal tissues take place only in the presence of water. Iron combines with the oxygen of the air to form iron oxide, or rust, only because water is present in the air in the form of water vapour.

## Isotopes of Hydrogen

Naturally, hydrogen has three isotopes as below :

i. Hydrogen or Protium ($_1H^1$)

ii. Heavy Hydrogen or Deuterium ($_1H^2$)

iii. Tritium ($_1H^3$)

A bond to a protium atom can be added as much as 18 times faster than that to a deuterium atom. Thus protium reacts with $Cl_2$, 13.4 times faster than deuterium does. The addition of $H_2$ to ethylenic compounds takes place two times faster than with deuterium at the same temperature. Protium is more rapidly adsorbed on the surface than deuterium.

## Uses of Deuterium and Tritium

Deuterium is used in the preparation of hydrogen bomb. Heavy water ($D_2O$) is used as a moderator in nuclear reactors to slow down the speed of fast moving neutrons. Dueterium and its compounds are used as a tracer in the study of the mechanisms of various chemical and metabolic reactions taking place in the body, e.g. with the help of deuterium it has been shown that butyric acid (a component of butter) is never stored in the body and is an immediate source of energy which at once gets consumed while Stearic acid (a component of lard) is not used up at once and hence is useful in building up reverse stock in the body.

Tritium has the possibility of use as an artificial radioactive tracer in chemistry, medicine and biology.

## Hard Water and Soft Water

In water, some elements like calcium, magnesium and iron are present at an appreciable level, that why water does not form lather with soaps easily. The effectiveness of water for washing purposes is then reduced. This type of water is called hard water. Soaps are sodium salts of fatty acids (RCOOH) where R is usually a higher alkyl chain. Calcium or magnesium ions present in hard water form insoluble salts with soap and prevent the formation of lather.

$M^{2+} + 2RCOO^- \rightarrow (RCOO)_2M$

M = Mg or Ca

A large amount of soap will be used up, for the complete removal of calcium or magnesium salts and thus lather will be formed. Hard water poses problems when used in industrial boilers for producing steam, because it causes the formation of scales or deposits on the wall of boilers. The process of removal of calcium or magnesium salts is known as water softening.

**There are two types of hardness – Temporary and Permanent.**

**Temporary Hardness :** Temporary hardness is caused by the presence of Bicarbonate of Calcium and Magnesium. This type of hardness is removed by boiling, addition of lime (Clark method) and addition of NaOH (Sodium hydroxide) or $NH_4OH$ (ammonium hydroxide).

**Permanent Hardness:** Permanent hardness is caused by chlorides and sulphates of Calcium and Magnesium. This type of hardness is removed by the following methods:

i. By the addition of calculated amounts of washing soda ($Na_2CO_3.10H_2O$)

ii. Ion-Exchange method : Permanent hardness may be replaced by sodium ions and is known as the ion-exchange process. Naturally occurring zeolites or similar synthetic complex sodium aluminium silicates are used for this purpose. When hard water is passed through such a zeolite, the $Ca^{2+}$ or $Mg^{2+}$ ions are exchanged by equivalent amounts of sodium ions in the zeolite.

Besides these methods, Calgon Process (calgon is sodium hexameta-phosphate) and Filtration is also used to remove the permanent hardness.

## Oxygen

Oxygen is a colourless, tasteless and odourless gas. Its solubility in one litre of water at 293 K is ~30 $cm^3$ gas at STP. This small amount of dissolved oxygen is sufficient to sustain marine and aquatic life and for the destruction of organic wastes in water bodies.

Oxygen is the most abundant element on the earth. Oxygen constitutes nearly 50% by weight of the crust of the earth, bodies of water and the atmosphere. In the earth's crust, oxygen is found in combined form as silicates, carbonates and oxides of metals. Water consists of 88.8% oxygen by weight. Oxygen gas makes up about 23.2% by weight of the atmosphere. Almost all of the oxygen gas in the atmosphere is believed to be the result of photosynthesis by green plants.

Oxygen has an atomic number of 8, atomic weight 15.9994 and electron configuration as 2, 6. Oxygen gas ($O_2$) molecule has two of 16 electrons which are unpaired. So, $O_2$ is paramagnetic.

**Uses of Oxygen :** Oxygen molecule is used in making steel and in metal fabrication as an aid to combustion. It is essential for life support systems (e.g. in hospitals, in underwater diving) Liquid oxygen is used as an oxidizer in rockets for space exploration and in the launching of satellites.

## Air

The earth is surrounded by an ocean of the atmosphere. Atmosphere is divided into three layers such as lithosphere, stratosphere and ionosphere. Air is a mixture of different gases as is explained below:

| | | |
|---|---|---|
| Nitrogen ($N_2$) | $\rightarrow$ | 78.1% |
| Oxygen ($O_2$) | $\rightarrow$ | 20.29% |
| Carbon dioxide ($CO_2$) | $\rightarrow$ | 0.03% |
| Water vapour | $\rightarrow$ | 0.4% |
| Inert gases | $\rightarrow$ | 0.95% |

Dust particles, sulphur oxides, nitrogen oxides, etc. $\rightarrow$ variable

Air is a very important factor in our life. Due to its pressure, the various objects (living as well as non-living retain their existence on the earth's surface. We take oxygen from air which is responsible for respiration and combustion. Nitrogen is used in diluting the oxygen to moderate the process of burning and respiration. Nitrogen also takes part in the plant growth and protein formation in animals. Photosynthesis requires carbon dioxide which is available from the air. The importance of water vapour is revealed from its controlling the evaporation of water from the bodies of plants and animals and thus is essential for our health and body comfort. Dust particles provide a medium for the condensation of water vapour to cause rain.

Atomic number of oxygen is 8, atomic weight is 15.994 and electronic configuration is 2, 6.

## Sulphur and its Compounds

Sulphur has atomic number 16, atomic weight 32.1 and a molecular formula of $S_8$. Sulphur is found in both combined and free state form. It is a constituent of many important metallic minerals like cinnabar (HgS), Zinc blende (ZnS), Copper pyrites ($CuFeS_2$), etc.

There are several allotropic forms of Sulphur. Sulphur is used for vulcanizing rubber, in the manufacture of dyes, explosives e.g. gun powder and various chemicals for killing moulds and pests and in medicine as blood purifiers. Flower of sulphur is a yellow powder obtained by subliming the vapour. It is used as a plant fungicide.

Sulphuric acid ($H_2SO_4$). Molecular weight = 98

H = Hydrogen

S = Sulphur

O = Oxygen

Sulphuric acid is known as "oil of vitriol." It is a very important chemical. The industrial progress of a country is measured in terms of the consumption of sulphuric acid. It is manufactured by the lead Chamber process and the Contact process. In Contact process, platinum asbestos or vanadium pentoxide is used as a catalyst and in contact process, $NO_2$ acts like a catalyst.

Sulphuric acid is a colourless, viscous and oily liquid, highly soluble in water. Concentrated $H_2SO_4$ acts as a dibasic acid. It is a powerful oxidizing agent as well as dehydrating agent.

# ORGANIC CHEMISTRY



Study of Carbon compounds is known as organic chemistry. But some exceptions like Carbon monoxide, Carbonates ($Na_2CO_3$), Thiocynates, e.g. NaSCN, Carbon dioxide ($CO_2$), Bircarbonates, e.g. $NaHCO_3$, Cyanates e.g. KOCN, Carbon dislphides $CS_2$, Cyanides, e.g. KCN, Carbides, e.g. $CaC_2$ are inorganic compounds.

Originally, it was thought that such compounds could only be obtained from living matter (natural sources) – hence the name organic. However, this theory was disproved in 1828 when Friedrich Wholer obtained urea by heating the inorganic salt ammonium cyanate.

$$\underset{\text{(inorganic salt)}}{\underset{\text{Ammonium cyanate}}{NH_4^+oCN^-}} \xrightarrow{\text{heat}} \underset{\text{urea (organic)}}{H2N - \overset{\overset{O}{||}}{C} - NH_2}$$

## Catenation

Generally organic compounds are very large because carbon has the ability to form strong covalent bonds with other carbon atoms to form chains and rings of varying sizes. This property of carbon is called Catenation.

Other characters of organic compounds : Carbon has the ability to form single, double and triple bonds. Carbon has the ability to form strong covalent bonds with many other atoms such as H, O, S, N, Cl, Br and I.

***Difference between organic and inorganic compounds:***

| Organic Compounds | Inorganic Compounds |
|---|---|
| 1. Low melting points. | High melting points. |
| 2. Low boiling points. | High boiling points. |
| 3. Low solubility in water, high solubility in polar solvents. | High solubility in water, low solubility in non Polar solvents. |
| 4. Flammable. | Non-flammable. |
| 5. Solutions are non-conductors of electricity. | Solutions are conductors of electricity. |
| 6. Chemical reactions are usually slow. | Chemical reactions are rapid. |
| 7. Exhibit isomerism. | Isomers are limited to a few exceptions (e.g. the transition elements). |
| 8. Exhibit covalent bonding. | Exhibit ionic bonding. |

**Sources of organic compounds :**

There are four sources of organic compounds:

1. Coal – It is about 80% free carbon.
2. Crude oil – It is a complex mixture of organic compounds. Probably the most important source at present.
3. Natural gas – It is a mixture of low molecular weight organic compounds.
4. Water and other plant materials.

## Importance of Organic Chemistry

Importance of organic chemistry is great because approximately every activity around us is related with it. Thus it is the chemistry associated with all living matter in both plants and animals. Carbohydrates, fats, proteins, vitamins, hormones, enzymes and many drugs are organic compounds. Wool, silk, cotton, linen and such synthetic fibres as nylon, rayon and Dacron contain organic compounds. So do perfumes, dyes, flavors, soaps, detergents, plastics, gasoline and oils.

## Classification of Organic Compounds

**Organic compounds are divided into four categories:**

1. **Aliphatic Compounds :** These are open chain compounds. Examples are Methane, Ethane, n-Hexane, Ethyl alcohol and Ethylamine. It means that or

ganic compounds of alkanes, alkenes or alkynes or their derivatives are aliphatic compounds.

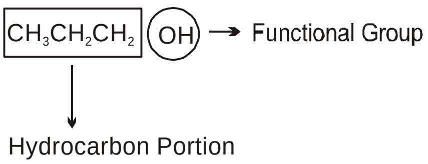
2. **Alicyclic Compounds :** These compounds are cyclic compounds which resemble aliphatic compounds in properties. Examples are cyclopropane and cyclohexane.

3. **Aromatic Compounds :** These unsaturated cyclic compounds are ringed structures which have special stability and properties. Examples are Benzene, Toluene and Naphthalene.

4. **Heterocyclic Compounds:** These are cyclic compounds in which the ring contains elements other than carbon. Examples are Pyridine, Pyrole and Furan.

## Functional Group

A functional group is the reactive part of an organic molecule. A functional group may be a single atom or group of atoms. Double and triple bonds are functional groups. Other examples include –Cl, -Br, -OH, $-NH_2$ groups. The functional group is the action group and the hydrocarbon portion of the molecule remains inert. As for example, Propyl alcohol is as given below:




-CHO (Aldehydic), -COOH (Carboxylic acid group), -COO (Esters), - (Ketones), $-NH_2$ (amines) are functional group.

Functional group serves as a basis of nomenclature (naming) of organic compounds. It serves to classify organic compounds into classes/families. Functional groups give organic compounds their chemical personalities. A functional group is a site of chemical reactivity in a molecule.

## Homologous Series

A homologous series is a series of compounds in which adjacent members differ by a $CH_2$ unit. The individual members of such a series are called homologs.

## Hybridization

The process of mixing of pure orbitals to give a set of new equivalent orbitals (same energy and same shape) is called hybridization. Obtained orbitals are called hybrid orbitals.

Three types of hybridization generally are found in organic compounds as below:

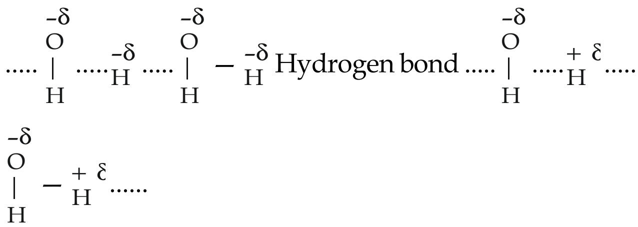
i. $sp^3$ – In this, three p orbitals and one s-orbital takes part to form four hybrid orbitals. It contains tetrahedral structure. As for example in ethane, methane and propane molecule $sp^3$ hybridization is found.

ii. $sp^2$ – In this hybridisation two p-orbitals and one s orbital take part to form three hybrid orbitals. As for example, Ethylene and Benzene have $sp^2$ hybridisation orbital which is similar to that of an $sp^3$ orbital.

iii. sp – In this hybridisation, one s-orbital and one p-orbital take part to form two hybrid orbitals. Acetylene is an important example. Its structure is linear.

## Hydrogen Bonding

Hydrogen bonding is an attractive force which occurs in any compound whose molecules contain O-H or N-H bonds (as in water, alcohols, acids, amines and amides). The O-H bond, for example, is a highly polar bond. Oxygen is more electronegative than hydrogen and pulls the bonding electrons closer to it. As a result of this displacement, the oxygen atom acquires a small negative charge (-d) and the hydrogen atom a small positive charge (+d).




Hydrogen bonded compounds have higher boiling points and higher melting points. A hydrogen-bonded substance is usually soluble in another hydrogen-bonded substance.

## Isomerism

Isomers are compounds with same molecular formulaes but different physical and chemical properties. The phenomenon is called isomerism. Since isomers have the same molecular formulae, the difference in their properties must be due to different arrangement of atoms within the molecule.

There are two main classes of isomerism known as structural isomerism and stereo-isomerism.

**Structural isomerism:** These isomers have the same molecular formula but differ in structural formula, that is, in the order in which the different atoms are linked in the molecule. Structural isomerism is of five types: chain isomerism, position isomerism, functional isomerism, metamerism and tautomerism.

**Stereo isomerism:** These isomers have the same molecular formula, same structural formula, but differ in the special arrangement of the groups. Stereo isomerism is of two types: geometrical isomerism and optical isomerism.

## Hydrocarbons

The compounds must have carbon and hydrogen. These are classified into Alkanes, Alkenes and Alkynes.

**Alkanes :** Alkanes are saturated hydrocarbons that contain only single bonds. They can be represented by the general formula $C_nH_{2n+2}$, where n is the number of carbon atoms in the molecule, C is the symbol of Carbon and H is the symbol of Hydrogen. Examples are methane ($CH_4$), ethane ($C_2H_6$), propane ($C_3H_8$) etc. Alkanes are also called paraffins. Methane, ethane, propane and butane are all part of the refinery gas. Hexane comes out in the diesel oil fraction. Alkanes with around 25 carbon atoms per molecule come out in the lubricating oil fraction. The bitumen fraction contains alkanes with over 50 carbon atoms per molecule.

**Alkenes :** Hydrocarbons that contain a carbon-carbon double bond are called alkenes. Their general formula is $C_nH_{2n}$ where 'n' is the number of carbon atoms, C is the symbol of carbon and H is the symbol of hydrogen. Alkenes are also called olefins. These are unsaturated hydrocarbons. Ethylene, Propylene, etc. are examples. Ethylene is used in the making of Polythene.

**Alkynes :** Alkynes are unsaturated hydrocarbons that contain a carbon-carbon triple bond. The general formula of alkynes is $C_nH_{2n-2}$, where n is the number of carbon atoms. Acetylene, Propyne, Pentyne are examples of Alkynes. Acetylene is used in oxyacetylene torch used for welding and cutting metals. Acetylene is also used for the manufacture of PVC, Polyvinyl acetate, Orlon, Neoprene Rubber and for the preparation of Acetaldehyde, Acetic acid and Ethyl alcohol.

## Important Organic Compounds

**Chloroform:** Molecular formula of chloroform is $CHCl_3$, Where C is carbon, H is hydrogen and Cl is chlorine. Chloroform is used as a solvent for fats, waxes and rubber, and in the preparation of chloropicrin ($Cl_3C\text{-}NO_2$) which is used as an insecticide.

**Carbon Tetrachloride:** Its molecular formula is $CCl_4$. It is used as a solvent for oils, waxes, fats and greases, as a fire-extinguisher under the name Pyrene and in the manufacture of Freon-12 which is a widely used refrigerant and propellant in aerosol sprays.

**Organometallic Compounds**: Compounds which contain a carbon-metal bond are called organometallic compounds. Examples are Methyl magnesium iodide ($CH_3MgI$), ethyl lithium ($C_2H_5Li$).

**Grignard Reagents:** Compounds which contain a carbon-magnesium bond are called Grignard reagents. Examples are ethyl magnesium bromide ($C_2H_5MgBr$).

**Alcohols:** Alcohols are compounds in which a hydroxyl group (-OH) is attached to a saturated carbon. Methyl alcohol ($CH_3OH$) and Ethyl alcohol are suitable examples.

**Pyroligneous Acid:** Water + Methyl alcohol + Acetone + Acetic acid

**Molasses:** Molasses is the mother liquor left after the crystallization of cane sugar from concentrated juice. It is a dark coloured thick syrupy mass. Molasses contain about 60% fermentable sugars, mostly sucrose, glucose and fructose. Molasses is converted into ethyl alcohol by several steps with fermentation.

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{Invertase}} \overset{C_6H_{12}O_6}{\text{Glucose}} + \overset{C_6H_{12}O_6}{\text{Fructose}}$$

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{Maltase}} \overset{2C_6H_{12}O_6}{\text{Glucose}}$$

$$C_6H_{12}O_6 \xrightarrow{\text{Zymase}} 2C_2H_5OH + 2Co_2$$

**Absolute Alcohol:** Absolute alcohol is 100% pure ethyl alcohol. Commercial alcohol is a mixture of 95% ethyl alcohol + 5% water. This mixture can not be separated by further distillation. Such a solution is called an azeotrope.

**Denatured Alcohol:** Denatured alcohol is commercial ethyl alcohol to which small amounts of poisonous substances (such as methyl alcohol or pyridine) have been added. This is done to make it unfit for human consumption.

**Proof Spirit:** The alcoholic content of a beverage is indicated by a measure known as proof spirit. The proof value is twice the alcoholic content by volume. Thus whiskey which is 50% alcohol is said to be 100 proof.

**Methyl Alcohol:** It is poisonous and used as a solvent and as a raw material for making urea – formaldehyde. It is known as wood alcohol, wood naphtha or wood spirit.

**Power Alcohol:** Benzene + Petrol + ethyl alcohol

**Wine:** It contains 12% ethyl alcohol

**Beer:** It contains 4% ethyl alcohol

**Whiskey and Brandy:** It contains 40-50% ethyl alcohol.

**Ethyl Alcohol:** Its molecular formula is $C_2H_5OH$. It is used as an antifreeze for car radiators, as a de-icing fluid for aeroplane wings and in the manufacturing of Dacron, dioxane and ethylene oxide.

**Glycerols:** Its molecular formula is $C_3H_8O_3$. It is used as a moisture-retaining agent in both tobacco, cosmetic industries, in plastic industry and in the manufacturing of nitroglycerine and dynamite.

**Diethyl Ether:** Its molecular formula is $C_4H_{10}O$. It is used as a solvent in the preparation of Grignard's reagents. It is also an excellent solvent for fats, waxes, oils, plastics and liquars. Diethyl ether has been used as a general anaesthetic.

**Ethyl Cellosolve (2- ethoxyethanol):** It is used as a solvent for quick-drying enamels and varnishes.

**Formaldehyde:** Its chemical formula is $CH_2O$. It is sold as 40% aqueous solution under the name formalin and is used in this form for most purposes. Formalin is used in the preservation of biological specimens, as an antiseptic and in the manufacture of synthetic plastics such as bakelite and Melmac.

**Acrolein:** Its molecular formula is $C_3H_4O$ and structure $CH_2=CH-\overset{O}{\overset{\|}{C}}-H$. It is used as a tear gas, in the preparation of resins and in the manufacture of insecticides.

**Vinegar:** Vinegar is 4-6% acetic acid and is obtained from fermented liquors containing 12-15% ethanol.

**Fermentation:** A form of anaerobic respiration occurring in certain microorganisms, e.g. yeasts. It comprises a series of biochemical reactions by which sugar is converted to ethanol and carbon dioxide. Fermentation is the basis of the baking, wine and beer industries.

**Soaps:** Soaps are sodium or potassium salts of long-chain fatty acids, chiefly oleic, stearic, palmitic and myristic acids. Soaps are products of hydrolysis of fats with NaOH (Saponification). Fats are mixed triglycerides and thus soaps are mixtures of long-chain fatty acids containing 12 to 18 carbon atoms.

**Synthetic Detergents:** Synthetic detergents called Syndets are composed of several different types of compounds. Link soaps, one end of the detergent is polar and the other end of the molecule is non-polar. Detergents differ from ordinary soaps in that they do not form insoluble salts (precipitates) with $Ca^{2+}$, $Mg^{2+}$, $Fe^{3+}$ ions. Thus detergents are superior to ordinary soaps. They can be used in either soft water or hard water, while soaps are precipitated in hard water and go waste. Sodium alkyl sulphonate and Benzene Sulphonate are detergents.

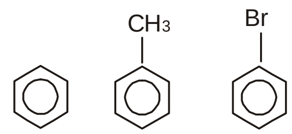
**Lipids:** Lipids are a group of compounds with widely different compositions and structures. They are defined as naturally occurring organic compounds that are insoluble in water, but soluble in non polar organic solvents such as ether, chloroform or carbon tetrachloride. Examples are : Oils, Fats, Terpenes and Steroids. Lipids are important to humans for three reasons:

i. **Lipids serve as Source of Energy:** Excess carbohydrates and other energy giving foods are converted and stored in the body as lipids and fats. These fat reservoirs constitute one of the main storage forms of chemical energy and carbon in the body.

ii. **Lipids surround and insulate Some Vital Body Organs:** In this capacity, they provide protection from mechanical shock and help to maintain the correct body temperature.

iii. **Lipids also serve as the basic structural components of all Cell Membranes.**

**Aromatic Compounds:** Benzene and all compounds that have structures and chemical properties resembling benzene are classified as aromatic compounds. Examples are:




Benzene Toluene Bromobenzene

**Gammexane:** It is also known as Benzene hexachloride (BHC). It is a powerful insecticide. Its molecular formula is $C_6H_6Cl_6$.

**(TNT) Trinitrotoluene:** Its molecular formula is $C_7H_3NO_2$ $C_7H_3(NO_2)_3$ and is used as an explosive. It is mixed with ammonium nitrate to form the blasting material which is used for blasting buildings and rocks.

**DDT:** It is known as dichlorodi phenyltri-chlorethane. Its molecular formula is $C_{14}H_9Cl_5$. DDT is an effective insecticide for mosquitoes, flees and crop pests.

**Saccharin:** Its molecular formula is $C_7H_5O_4SN$. It is widely used as a calorie-free sugar substitute for diabetics. It is 500 times sweeter than table sugar. It is sold in markets as soluble sodium salt (sodium saccharin). Saccharin is also used as a sweetening agent in tooth pastes, mouth washes and aerated drinks like Cola and Thums up.

**Chloramine-T:** $C_7H_7O_2NClNa$ is the molecular formula of chloramines-T. It is an effective antiseptic for treatment of wounds.

**Picric Acid:** Its molecular formula is $C_6H_3(NO_2)_3$. It is used for making explosives liks Lyddite and Melinite. It is a valuable dye for wool.

**Aspirin:** It is also known as acetylsalicyclic acid. Its molecular formula is $C_9H_8O_4$. It is used as an analgesic.

**LSD:** It is also known as Lysergic acid diethylamide. It is an example of a hallucinogenic drug.

a **-naphthol:** It is used as an insecticide.

b**-naphthol:** It is used as a tanning agent.

**Carbohydrates:** The term, carbohydrate literally means hydrate of carbon. This name arose from the fact that many carbohydrates have the molecular formula $C_x(H_2O)_y$. For example, glucose has the formula of $C_6H_{12}O_6$ or $C_6(H_2O)_6$

**Carbohydrates are classified into three groups :**

**Monosaccharides:** The Monosaccharides are carbohydrates which cannot be decomposed by hydrolysis to give simpler carbohydrates.

Examples are glucose and fructose.

$C_6H_{12}O_6 + H_2O \xrightarrow{H^{\oplus}}$ No reaction

1. **Oligosaccharides:** The Oligosaccharides are carbohydrates which yield a definite number (usually 2 to 10) of monosaccharide molecules on hydrolysis. They include :
2. **Diasaccharides:** They yield two monosaccharide molecules on hydrolysis. Examples are sucrose and maltose

$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^{\oplus}} \underset{\text{Glucose}}{2C_6H_{12}O_6} + \underset{\text{Fructose}}{2C_6H_{12}O_6}$$

$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}} + H_2O \;\; \underset{\text{Glucose}}{2C_6H_{12}O_6} + \underset{\text{Glucose}}{2_{16}H_{12}O_6}$$

**Trisaccharides:** Which yield three monosaccharide molecules on hydrolysis.

Example is raffinose.

$$\underset{\text{Raffinose}}{C_{18}H_{32}o_{16}} + 2H_2o \xrightarrow{H^{\oplus}} \underset{\text{Glucose}}{C_6H_{12}o_6} + \underset{\text{Fruclose}}{C_6H_{12}o_6} + \underset{\text{Glactose}}{C_6H_{12}o_6}$$

3. **Polysaccharides:** The polysaccharides are high molecular weight carbohydrates which yield many monosaccharide molecules on hydrolysis. Examples are starch and cellulose.

$$(C_6H_{10}O_5)_n + nH_2O \xrightarrow{H^{\oplus}} \underset{\text{glu cos e}}{\overset{nC_6H_{12}O_6}{\uparrow}}$$

**Cellulose:** It is a polysaccharide. It is mainly obtained from trees and other plants. Cotton wool is 90-95% cellulose. Wood is 50% wool. Cellulose nitrates are called gun cotton or cordite which are highly explosive. It is used in the manufacture of smokeless gun powder. Collodion is used as a covering over cuts and skin abrasion.

**Proteins:** Proteins are polymers of $\alpha$-amino acids bonded by peptide linkages. They occur in all living cells. Proteins are present in muscle, skin, hair and other tissues that make up the body's non bony structure. As enzymes they catalyse biochemical reactions; as hormones they regulate metabolic processes. Proteins are classified in two ways;

**Compositional Classification:** It classifies proteins as below:

a) **Simple Proteins:** It contains only amino acids.

**Albumins**: egg albumin, serum albumin, lactalbumin.

**Globulins**: tissue globulin, serum globulin

**Glutenins**: glutenin in wheat, coryzenin in rice.

b) **Conjugated Proteins :** It contains a non peptide group in addition to the amino acids in the structure. The non-peptide portion is called the prosthetic group. Examples are:

**Glycoproteins**: Mucin in saliva, prosthetic group, carbohydrates.

**Phosphoproteins**: Casein in milk, prosthetic group, phosphoric acid.

**Chromoproteins**: Haemoglobin in red blood cells, prosthetic group, coloured iron pigment.

**Structural Classification**: It classifies proteins as either fibrous or globular.

1. **Fibrous Proteins**: Examples are below:

**Keratin**: Present in skin, hair and nails.

**Myosin**: Present in muscles.

**Collagen**: Present in tendons, cartilages and bones.

**Globular Proteins**: Examples are below:

**Enzymes**: Pepsin from stomach helps in digestion.

**Insulin**: Secreted by pancreas, regulates glucose metabolism.

**Haemoglobin**: Present in blood, transports $O_2$ from lungs to all cellular tissues.

**Antibodies**: Protect the body from outside infection e.g. gamma globulins in blood.

**Cytochromes**: Present in blood, act as electron carri ers.

2. **Alkaloids**: Alkaloids are plant produced basic compounds which contain one or more nitrogen heterocyclic rings. Examples are Conine and Nicotine. The alkaloids are valuable because they find important applications in medicine. They may cause such physical effects as below :

**Nicotine**: Raising the blood pressure.

**Caffeine**: Stimulating nerves, stimulating production of urine.

**Atropine**: Dilating the pupils of the eyes.

**Ergonovine**: Causing the blood to clot.

**Morphine**: Relieving pain.

**Quinine:** Cure/prevention of malaria

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# NITROGEN, PHOSPHORUS, HALOGENS & CARBON



## Nitrogen

Atomic number = 7

Atomic weight = 14.008

Nitrogen occurs free gaseous state in atmosphere. It is present in air to the extent of 78.03% by volume and 75.51% by weight of dry air. It is also found in nature in the combined state as nitrates (Nitre $KNO_3$, Chile Salt Petre $NaNO_3$) or ammonium salt. It is also present in living animals or plants in the form of proteins. Nitrogen is obtained for industrial purposes by fractional distillation of liquid air.

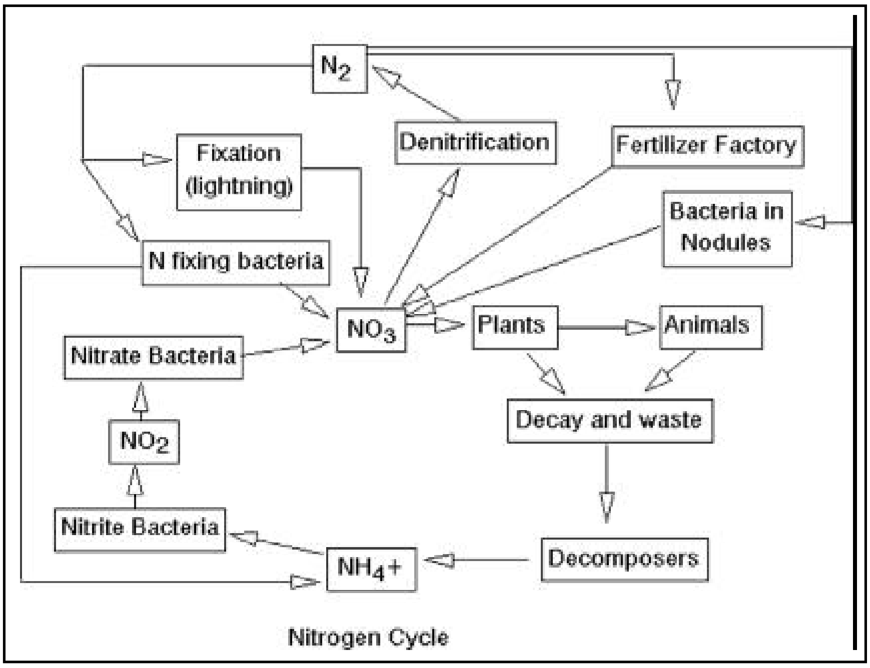
**Fixation of Nitrogen:** The conversion of atmospheric nitrogen into useful nitrogenous compounds by natural or artificial methods is called fixation of nitrogen. Nitrogen present in these nitrogenous compounds is called fixed or combined nitrogen.

**Nitrogen is fixed in nature by the following methods:**

**By lightning Discharge:** Under the influence of lightning discharges the nitrogen and oxygen in air form nitric acid. This acid is washed down by rain into the soil, where it reacts with limestone and alkalies of the soil to form nitrogen and is stored there as plant food.

**By Symbiotic Bacteria:** The atmospheric nitrogen is being constantly transferred to the soil through the agency of certain bacteria called symbiotic bacteria. These grow in small nodules in the roots of plants belonging to the family of leguminacea (pea, gram, etc.) and directly assimilate atmospheric nitrogen and convert it into products useful for plant growth.

**Nitrogen Cycle:** Nitrates in the soil are taken up by plant roots and may then pass along food chains into animals. Decomposing bacteria convert nitrogen-containing compounds (especially ammonia) in plant and animal wastes and dead remains back into nitrates, which are released into the soil and can again be taken up by plants. Though nitrogen is essential for all forms of life, the huge amount present in the atmosphere is not directly available to most organisms. It can however be assimilated by some specialized bacteria and algae and is thus made available to other organisms indirectly. Lightning flashes also make some nitrogen available to plants by causing the combination of atmospheric nitrogen and oxygen to form oxides of nitrogen, which enter the soil and form nitrates. Some nitrogen is returned from the soil to the atmosphere by denitrifying bacteria.



Nitrogen Cycle

**Ammonia Gas:** It is present in atmospheric air in traces being produced by the purification of animal or vegetable matter or from the decomposition of urine.

Ammonia is manufactured on a large scale by the following process :-

1. Haber's process for the manufacture of ammonia on a large scale includes the following catalysts :

i. Finely divided iron with traces of molybdenum and calcium metals; or

ii. Ferric oxide with traces of $SiO_2$

& $K_2O$; or

iii. Finely divided nickel and sodamide deposited over pumice stone support; or

iv. Finely divided osmium or uranium metal.

2. From destructive distillation of coal

3. Cyanamide process

Daily uses of $NH_3$:

i. It is used in refrigeration because it gets easily condensed and is called volatile alkali.

ii. For the production of ammonia fertilizers such as $(NH_4)_2SO_4$, $(NH_4)_3PO_4$, $NH_4NO_2$, and urea.

iii. In medicines

**Nitrous Gas ($N_2O$):** It is laughing gas.

**Nitric Acid ($HNO_3$):** Nitric acid is manufactured by Birkland and Eyde process from air and by Ostwald process from ammonia. Nitric acid is used as a solvent in gold ornament industry and it is used for the manufacture of explosives such as dynamites, picric acid, trinitrotoluene and for etching names on copper, brass or bronze articles.

## Phosphorus

Atomic Number is 15.

Atomic Weight is 31.

Phosphorus is a very reactive non-metal. It catches fire in air. Hence it is not found as phosphorus in nature. It occurs in nature in the form of stable phosphate. Animal bones contain about 58% calcium phosphate. It is also present in blood and urine of animals.

**White or Yellow Phosphorus:** White phosphorus produces light yellowish green light when kept in dark. This phenomenon is called phosphorescence, white phosphorus is poisonous. It turns yellow after sometime hence it is also called yellow phosphorus. It catches fire at room temperature because its ignition temperature is 30°C.

**Red Phosphorus**: It is less reactive than white phosphorus. It does not catch fire in air at room temperature. It is used in safety matches.

**Scarlet Phosphorus**: It is non-poisonous, insoluble in $CS_2$ (carbon disulphide) and more reactive than red phosphorus.

**Black Phosphorus**: It is a black solid, insoluble in carbon disulphide ($CS_2$), inactive like red phosphorus. It is a conductor of electricity.

**Phosphine**: Its molecular formula is $PH_3$ and shape is triangular pyramidal. It is a colourless gas with a smell of rotten fish and neutral to litmus paper. It is a poisonous gas. It is used in making home signals and producing smoke screen in battle-fields.

**Silicon**: Its symbol is Si. Its atomic number is 14 and relative atomic mass is 28.086. Silicon is the second most abundant element in the earth's crust (25.7% by weight) occurring in various forms of silicon (IV. o x - ide (e.g. quartz) and in silicate materials. It is used as a semiconductor. It has a diamond like crystal structure, an amorphous form also exists. Chemically silicon is less reactive than carbon.

**Silicon Carbide (Carborundum):** It is also known as carborundum which is hard like diamond. Its molecular formula is SiC. It is used as an abrasive for cutting and grinding glasses. It has a very high melting point and therefore used in furnace lining. It is also used as carbon rods in resistant heaters.

## Halogens

It is a group of elements in the periodic table (group VII B). These elements are Fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I), and Astatine (At). The halogens are typical non-metals, they have high electronegativities, high electron affinities and high ionization energies. They form compounds by gaining an electron to complete the stable configuration, i.e. they are good oxidizing agents. At $20^0$C, fluorine and chlorine are gases, bromine is liquid, and iodine is a sublimable solid. All exist as diatomic molecules. Fluorine reacts with all non metals except nitrogen and the noble gases helium, neon and argon, iodine does not react with any noble gas, nor with carbon, nitrogen, oxygen or sulphur. The elements fluorine to iodine, all react with hydrogen to give the acid, with the activity being the greatest for fluorine, which reacts explosively.

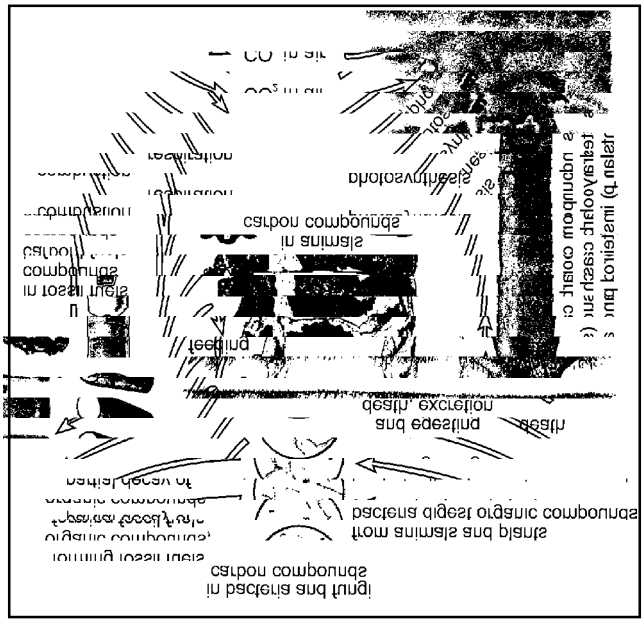
Chlorine and hydrogen react slowly at room temperature in the dark (sunlight causes a free radical chain reaction) Bromine and hydrogen react if heated in the soft catalyst. Iodine and hydrogen react only slowly and the reaction is not complete.

**Noble Gases (Inert Gases):** These are also known as rare gases or group elements. They include Helium, Neon, Argon, Krypton, Xenon and Radon. There is small amount of noble gases on the earth and they are chemically inert. The valence shells of noble gases are fully satisfied. Thus these elements represent the termination of a period and have closed-shell configuration and are associated with high ionization energies. Except radon all noble gases are present in atmosphere. These are colourless and odourless gases. In liquid form these gases provide very low temperatures.

Argon is used for the making of inert atmospheres in welding and special-metal manufacture (Ti and Zr) and (when mixed with 20% nitrogen) in gas filled electric light bulbs. Due to inertness, Argon is filled in light bulbs to prevent the filaments from burning out.

Neon is used in discharge tubes and neon lamps, in which it has a characteristic red glow. Helium has a variety of uses, including the provision of inert atmospheres for welding and semiconductor manufacture as a refrigerant for superconductors and as a dilutant in breathing apparatus. It is also used for inflating balloons. Helium is also used to dilute the oxygen which deep sea divers use because both pure oxygen and nitrogen are dangerous to breathe at the high pressures which exist under water. Xenon is used in fluorescent lamps and bubble chambers.

## Carbon



Symbol C
Atomic number =6
Relative atomic mass = 12.011
Group = IVA

**Period = 2nd**

Carbon occurs in nature as element carbon (coal) as well as in the form of its compounds such as $CO_2$ in air. Carbon is approximately 0.032% of the earth's crust. Carbon has a peculiar characteristic to form C-C covalent bonds. This property of carbon to link with another carbon atom is called the catenation property of carbon. Carbon also form stable C-H bond. Carbon is also capable of forming bonds with N, O, S and other C- atoms. Because of these properties of carbon, it forms millions of important compounds which are the subject matter of organic chemistry.

**Allotropic Forms of Carbon:** It exists in several allotropic forms such as diamond, graphite, coal, lamp black etc. Diamond and graphite forms are more interesting forms of carbon because of their unique structures and properties.

**Diamond**: Diamond is a precious gem. It is the hardest substance known. In diamond, carbon atoms are tetrahedrally $Sp^3$ hybridised and each carbon is linked very closely to four other carbon atoms. Thus, C-C linking is in three dimensions and all the four valence electrons are involved in bond formation. The close linking of C-atom results in its great hardness and involvement of its valence electrons in bond formation results in its non-conductivity to electricity. Diamond is deadly poisonous. Diamond is chemically inactive. Diamond is used as a gem. Because of its hardness, it is used in rock-drills, glass-cutting, instruments and gem-cutters.

**Graphite**: It is a soft crystalline substance with a greasy feel and metallic lustre. It is a conductor of electricity. Graphite has a a layered structure in which each C-atom is $Sp^2$ hybridised and is linked with three other carbon atoms in the same plane. In this way hexagons of six-carbon atoms are formed in one layer.

**Uses:**

i. Graphite marks paper and hence it is used in making lead pencils.

ii. It is a good conductor of electricity hence, it is used in making graphite electrodes, arcs and battery plates.

iii. It is used as a lubricant in machines to prevent rusting and friction.

**Charcoal:** Wood charcoal and animal charcoal are prepared by burning wood and distilling bones, when residue of bone charcoal is obtained in the retort.

Animal charcoal has a great capacity to absorb colouring matter. Hence it is used in the sugar industry for decolouring molasses. Activated wood charcoal is used for making gas-mask.

## Compounds of Carbon

**Carbon Monoxide (CO):** It is a colourless, natural gas, insoluble in water but soluble in ammonical cuprous chloride solution. It is a deadly poisonous gas because it has no smell. Carbon monoxide is poisonous because it reacts with the haemoglobin in blood and prevents the blood form acting as an oxygen carrier. It is largely liberated from car engines. It is used as a reducing agent. It reduces the oxides of copper, lead and iron to the metals. CO is the main reducing agent in a blast furnace.

**Carbon Dioxide:** It is a colourless, odourless gas. It occurs in the atmosphere (0.03% by volume) but has a short residence time in this phase as it is both consumed by plants during photosynthesis and produced by respiration and by combustion. Carbon dioxide has a small liquid range and liquid carbon dioxide is produced only at high pressures. Chemically, it is unreactive and does not support combustion. It dissolves in water to give carbonic acid.

Large quantities of solid carbon dioxide (dry ice) are used in processes requiring large-scale refrigeration. It is also used in fire extinguishers as a desirable alternative to water for most fires, and as a constituent of medical gases as it promotes exhalation. It is also used in carbonated drinks. The level of carbon dioxide in the atmosphere has been the subject of much environmental controversy as it is argued that extensive burning of fossil fuels will increase the overall $CO_2$ concentration and then by the greenhouse effect, increase atmospheric temperatures and cause climatic modification.

**Carbon Cycle:** One of the major cycles of chemical elements in the environment. Carbon (as carbon dioxide) is taken up from the atmosphere and incorporated into the tissues of plants in photosynthesis. It may then pass into the bodies of animals as the plants are eaten. During the respiration of plants, animals and organisms that bring about decomposition, carbon dioxide is returned to the atmosphere. The combustion of fossil fuels (e.g. coal and peat) also releases carbon dioxide into the atmosphere

**Carbon Dating (Radiocarbon Dating):** It is a method of estimating the ages of archaeological specimens of biological origin. The isotope ${}_6C^{14}$ of carbon is used in carbon dating.

**Photosynthesis:** It is the chemical process by which green plants synthesize organic compounds from carbon dioxide and water in the presence of sunlight. It occurs in the chloroplasts (most of which are in the leaves) and there are two principal series of reactions. In the light reactions, which require the presence of light, energy from sunlight is absorbed by photosynthetic pigments (chiefly the green pigment chlorophyll) and converted into chemical energy. In the ensuing dark reactions, which can take place either in light or darkness, this chemical energy is used in the production of simple organic compounds from carbon dioxide and water. Further chemical reactions convert these compounds into chemicals useful to the plant. Photosynthesis can be summarized by the equation:

$$6CO_2 + 12H_2O \xrightarrow[\text{absorbed by chlorophyll}]{\text{light energy}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

Photosynthesis is the basis for all life on earth. Furthermore virtually all the atmospheric oxygen has originated from oxygen released during photosynthesis.

# METALLURGY

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Metallurgy is the branch of applied science concerned with the production of metals from their ores, the purification of metals, the manufacture of alloys and the use and performance of metals in engineering practice. Process metallurgy is concerned with the extraction and production of metals, while physical metallurgy concerns the mechanical behaviour of metals.

Hence, except a few metals such as Cu, Ag, Au, Pt etc., most of the metals are found in nature in the form of minerals. Metals are extracted from the minerals by several methods.

## Important Terms

**Ore**: An ore is a mineral from which a metal can be extracted economically. As for example, iron pyrites are the ores of iron.

**Gangue**: The impurities present in an ore is called gangue.

**Flux**: A material which is added from outside in the ore during the process of smelting to remove gangue is called flux.

**Slag**: Slag is a light fusible waste material obtained during the extraction of metals. Slag, being lighter and fusible, floats on the surface of the molten metal.

Hence, gangue + flux = slag

An example is the use of $SiO_2$ flux to remove basic FeO gangue during the extraction of copper (Cu) from Copper Pyrite ($CuFeS_2$).

$$\underset{\text{Gangue}}{FeO} + \underset{\text{Flux}}{SiO} ® \underset{\text{Slag}}{FeSiO_3}$$

**Calcination**: It is the process of heating an ore below its melting point to remove volatile impurities from the ore.

$$Fe_2O_3 \times H_2O \xrightarrow{\text{Calcination}} Fe_2O_3 + \times H_2O -$$

$$Fe\,CO_3 \xrightarrow{\text{Calcination}} FeO + CO_2 -$$

**Roasting**: It is the process of heating an ore below its melting point in presence of air in order to oxidize it.

**Examples :** $2ZnS + 3O_2 \xrightarrow{\text{Roasting}} 2ZnO + 2SO2 -$

**Smelting**: Smelting is the process of heating an ore above its melting point with coke and flux in order to reduce the ore to metal.

**Amalgam**: An amalgam is a mixture of two metals, one of which is mercury.

**Extraction Principles of Metals:** Metals are generally extracted from their ores by means of the following methods:

### Alloy: An Alloy is Mixture of Two or More Metals

| No. | Some Important Alloys | Compositions | Uses |
|---|---|---|---|
| 1. | Brass | Cu(60-80%), Zn(40-20%) | For making household untensils. |
| 2. | Bronze | Cu(75-90%), Sn(25-10%) | For making coins, idols, bells, utensils, etc. |
| 3. | German Silver | Cu(60%), Zn(25%), Ni(15%) | For making utensils. |
| 4. | Magnelium | Mg (98%), Al(2%) | For making Aeroplane frames, can be worked on lathes. |
| 5. | Rolled gold | Cu(90%), Al(10%) | For making cheap ornament. |
| 6. | Monel metal | Cu(70%),Ni(30%) | Alkali resistant containers. |
| 7 | Bell metal | Cu(72-80%), Sn(28-20%) | For making, bells, utensils, idols, coins etc. |
| 8. | Gun metal | Cu(85%), Zn(10%), Sn(5%) | Used for engineering purposes. |
| 9. | Constantan | Cu(60%), Ni(40%) | For making electrical apparatus. |
| 10. | Munz metal | Cu(60%) and Zn(40%) | For making coins, tubes and castings. |
| 11. | Solder | Sn(50-14%), Pb(50-30%) | Soldering of metals. |

A. **Carbon-Reduction Process:** This process is for those metals which can be obtained by the reduction of their oxides. Examples of such metals are Zn(zinc), Cd(cadmium), Mercury(Hg), Tin(Sn), Copper(Cu), Lead(Pb) and Iron(Fe).

B. **Electrolytic Process:** This process is used for the extraction of reactive metals such as Na, K, Mg, Ca and Al.

C. **Goldschmidt Alumino Thermic Process:** This process is used for the extraction of metals such as chromium which can neither be obtained by Carbon-Reduction Process, nor by electrolytic process.

## Important Ores

- **Aluminium:** Corrundum, Ruby – $Al_2O_3$
  Bauxite – $Al_2O_3.2H_2O$
  Diaspore – $Al_2O_3.H_2O$
  Cryollite – $Na_3AlF_6$
- **Barium:** Heavy Spar or Barites – $BaSO_4$
  Witherite – $BaCO_3$
  Barytocalcite – $BaCa(CO_3)_2$
- **Calcium:** Calcite – $CaCO_3$
  Dolomite – $CaCO_3.MgCO_3$
  Limestone and Marble – $CaCO_3$
  Gypsum – $CaSO_4.2H_2O$
  Anhydrite – $CaSO_4$
  Fluorspar – $CaF_2$
  Phosphorite – $Ca_3(PO_4)_2$
- **Copper(Cu):** Chalchopyrite or Copper pyrites – $CuFeS_2$
  Chalcocite or Copper glance – $Cu_2S$
  Ruby Copper or Cuprite – $Cu_2O$
  Malachite – $CuCO_3.Cu(OH)_2$
  Azurite – $(CuCO_3)_3.Cu(OH)_2$
- **Iron:** Haematite – $Fe_2O_3$
  Magnetite – $Fe_3O_4$
  Cidderite – $FeCO_3$
  Iron Pyrite – $FeS_2$
  Spathose ore – $FeCO_3$
- **Lead:** Galena – PbS
  Anglesite – $PbSO_4$
  Cerussite – $PbCO_3$
- **Magnesium:** Magnesite – $MgCO_3$
  Carnallite – $KCl.MgCl_2.6H_2O$
  Dolomite – $MgCO_3.CaCO_3$
  Epsom Salt – $MgSO_4.7H_2O$
  Asbestos – $CaSiO_3.2MgSiO_3$
  Caesserite – $MgSO_4.H_2O$
- **Manganese:** Pyrolusite – $MnO_2$
  Magnite – $Mn_2O_3.H_2O$
- **Mercury:** Cinnabar – HgS
- **Potassium:** Felspar – $KAlSi_3O_8$
  Nitrite (Shora) – $KNO_3$
  Potash Alum – $K_2SO_4.Al_2(SO_4)_3.24H_2O$
  Rochelle Salt – CHOH COONa
  |
  CHOH COOK
- **Silver:** Silver glance or Argentite – $Ag_2S$
  Horn Silver – AgCl
  Pyragyrite – $Ag_3SbS_3$
- **Sodium:** Brine – NaCl
  Glauber Salt – $Na_2SO_4.10H_2O$
  Chile Salt Petre – $NaNO_3$
  Washing Soda – $Na_2CO_3.10H_20$
  Trona – $Na_2CO_3.2NaHCO_3.3H_2O$
  Borax – $Na_2B_4O_7.10H_2O$
- **Tin:** Cassiterite – $SnO_2$
  Tin Pyrites – $SnS_2.Cu_2S.FeS$
- **Zinc:** Zincite – ZnO
  Zinc blende – ZnS
  Franklinite – $ZnO.Fe_2O_3$
  Calamine – $ZnCO_3$

## Important Compounds

**Common Table Salt :** NaCl

**Caustic Soda :** NaOH

**Washing Soda :** $Na_2CO_3.10H_2O$ (Sodium Carbonate)

**Baking Soda :** $NaHCO_3$ (Sodium bicarbonate)

**Tincture Iodine :** It is a solution of $I_2$ and KI in ethyl alcohol

**Potash Alum :** $K_2SO_4Al_2(SO_4)_3$ $24H_2O$

**Cupric Sulphate or Blue vitriol ($CuSO_4.5H_2O$):** It is used as a germicide, in electroplating, in electric cells. A mixture of $CuSO_4.5H_2O$ and $Ca(OH)_2$ is called Bordeaux mixture and is used as a fungicide.

**Fehling Solution**: It is a deep blue solution obtained by dissolving $CuSO_4.5H_2O$ in water and adding NaOH solution and sodium potassium tartarate solution to it. It is used for the test of an aldehyde.

**Benedict's Solution**: When NaOH and sodium citrate is added to a solution of copper sulphate, a deep blue solution is formed which is called Benedict's Solution. It is used for testing the presence of sugar in urine. When Benedict solution is shaken with a few c.c. of urine in a test tube, a red ppt. of $Cu_2O$ is obtained indicating the presence of sugar in urine.

**Lunar Caustic**: It is also known as $AgNO_3$ (silver nitrate). It is used in photography to prepare AgBr (Silver Bromide). It is used for making hair dyes.

**Epsom Salt ($MgSO_4.7H_2O$):** It is used in cotton industry for soaking cotton threads before final spinning.

**Plaster of Paris :** It is used for making moulds, idols, surgical bandages and plastering of walls.

**Bleaching Powder Ca(OC)Cl:** It is used as a bleaching agent in paper and textile industry, as a germicide for spraying in drain, disinfecting drinking water.

**Soda Lime:** CaO + NaOH

**Nessler's Reagent:** It is a colourless solution of $K_2[HgI_4]$ made alkaline with NaOH solution.

**White Vitriol [$ZnSO_4.7H_2O$]:** It is used in the textile industry for soaking cotton threads before spinning and in dyeing industry.

**Calomel**: Its molecular formula is $HgCl_2$ (Mercurous Chloride). It is used in medicines in the form of blue pills.

**Lithopone**: It is a mixture of ZnS and $BaSO_4$ and used to prepare white paint.

**Boric Acid**: $H_3BO_3$ is the molecular formula. It is an anticeptic and is also used in glass, enamel and pottery industry.

**Borax [$Na_2B_4O_7.10H_2O$]**: It is used in cleaning household utensils and increasing its shine.

**Alumina or Aluminium Oxide ($Al_2O_3$) :** It is found in the form of gems. Some important aluminium oxide gems are:

(a) Topaz – yellow (b) Sapphire – blue

(c) Ruby – red (d) Amethyst – violet

(e) Emerald – green

**Lead Acetate [$Pb(CH_3COO)_2$]:** It is also called sugar of lead.

**Lead Tetra-ethyl:** Its molecular formula is $Pb(C_2H_5)_4$. It is soluble in petrol, and is a great anti-knock agent. When a very small quantity of it is added to petrol the knock given by petrol in internal combustion engines is suppressed. Petrol mixed with lead tetraethyl is coloured red with an organic dye to distinguish it.

**Ammonium Chloride**: Its molecular formula is $NH_4Cl$ and is known as Sal Ammoniac.

**Nitrous Oxide**: It is known as laughing gas. Its molecular formula is $N_2O$.

**Plastic Sulphur**: When sulphur is heated to a temperature above 160°C so that a viscous brown liquid sulphur is formed and when this molten sulphur is slowly poured in water contained in a beaker, an elastic form of sulphur is formed. This is called Plastic Sulphur.

**Polywater**: Its molecular structure is the same as that of general water but it has freezing point of –40°C and its boiling point is 500°C.

**Mustard gas:** a class of chemical warfare agent, can form blisters on skin and lungs.

$H_2C—S—CH_2—CH_2—Cl$

|

$H_2C—Cl$

**White Lead [$2PbCO_3.Pb(OH)_2$]:** It is used in the making of white paint.

**Red Lead [$Pb_3O_4$]:** It is a red coloured compound used as anti-corrosion pigment.

**Water Glass**: It is sodium silicate, soluble in water.

**Soda Water**: Water + solution of $CO_2$.

**Liquid Natural Gas**: It is liquid like LPG. Its main component is methane.

**Copper**: It is mixed with gold to make ornaments.

**Iron Sulphide or Iron Pyrites**: It is called as Fool's gold.

**Soda Ash or Sal Soda**: It is sodium carbonate.

**Fluorine**: It is the highest electronegative element.

**Frantium**: It is the highest electropositive element.

**Platinum**: It is the called white gold.

**Liquid Gold**: It is Petrol.

**Lithium**: It is the lightest metallic element and strongest reducing agent.

**Radon**: It is the heaviest among gaseous elements.

**Astatin**: It is the heaviest among solid non metals.

**Polonium**: It has the maximum number of isotopes.

**Oil of Vitriol**: It is sulphuric acid.

**Bath Salt**: $Na_2CO_3$. $NaHCO_3$. $2H_2O$

**Hair Salt**: $Al_2(SO_4).18H_2O$

**Oxy-acetylene Flame**: It is used in making and cutting of metals.

**Baryta Water**: $Ba(OH)_2$

**Blue Vitriol**: $CuSO_4.5H_2O$

**Green Vitriol**: $FeSO_4.7H_2O$

**White Vitriol**: $ZnSO_4.7H_2O$

**Gun-Powder**: 75% $KNO_3$, 12% S and 13% charcoal

**Lithopone**: $ZnS + BaSO_4$

**Philosopher Wool**: Zinc oxide (ZnO)

**Nitrolium Fertilizer**: $CaCN_2$

**Silver Chloride**: It is used to make Photochromic glass.

**Calcium Sulphide**: It causes Phosphorescence.

**Osmium**: It is the heaviest metal.

**Tear Gas**: Chloroacetophenol, acrolin and Chloroacetophenone are tear gas.

**Calgen: $Na(PO_3)_6$ :** Used to remove water-hardness.

**$SnS_2$:** Mosaic gold.

**Ammonium Carbonate**: It is called Smelting Salt.

**Calcium Phosphate :** It is used in the making of toothpaste.

**Nichrome**: It is made up of Cr, Ni and Fe. It is used in the making of heater-coil.

**Hydrogen Peroxide ($H_2O_2$):** It is used for adding brightness of old oil pictures.

**$AgNO_3$ Silver nitrate:** It is used to make identification on the finger of voters.

**Zinc Sulphide:** It is used to make Phosphorescence Screen.

**Aluminium hydroxide $Al(OH)_3$:** It is used as a fire retardant.

**Aldehydes:** Give Tollen's reagent $Ag(NH_3)_2OH$ test and Fehling's solution ($Cu(OH)_2$ + NaOH test but these tests are not shown by Ketones and aromatic aldehydes. Aldehydes also give Benedict's Solution (an alkaline solution of cupric ions complexed with sodium potassium citrate ions) test. Ketones do not give this test.

**Schiff's Test:** Dilute Solution of aldehydes when added to Schiff's reagent (rosaniline hydrochloride dissolved in water and its red colour decolourised by passing Sulphur dioxide) restores its red colour. This is known as Schiff's test for aldehydes.

**Formalin**: Formaldehyde is called as formalin.

**Hard Soap for Washing Clothes**: Sodium salt of fatty acid is used as hard soap.

**Soft Soap for Bathing**: Potassium salt of fatty acids is used as Soft Soap for bathing.

**Stainless Steel**: Constituents are Iron, Nickel and Chromium.

**Dichloro Difluoro Carbon**: It's molecular formula is $CF_2Cl_2$ and is known as Freon. It is used as refrigerant.

**The Cast Iron or Pig Iron**: The pig iron obtained from the blast furnace is the impurest form of iron. It contains the following impurities

C = 1%

Si = 1.4%

P = 2.5%

S = 0.1%

Mn = 1.8%

**Pig Iron is brittle:** It is used for the manufacture of steel, wrought iron and in foundry work. It is also used for making utensils, type-writer-cover, etc.

**Wrought Iron:** Wrought iron is the purest form of iron. It contains very little quantity of impurities. The total impurities of C, Si, P, Mn, etc. is not more than 0.25% in wrought iron.

**Wrought iron is:**

1. Soft
2. Malleable
3. Ductile
4. It has less physical strength as compared to pig iron. It is used for making steel by the Puddling Process.

**Steel:** Steel is an alloy of Fe, C, and Mn. It contains the following in small quantities.

Carbon = 0.2%

Silicon = 0.004%

Mn = 0.4%

P = 0.02%

S = 0.04%

Thus the impurities in steel are less than that present in Pig iron and more than that present in wrought iron.

• • •

The chemistry which deals with the chemical relations among various factors like atmosphere, earth, water, plants and animals is called environmental chemistry. Thus, an environmental chemical balance exists for the easy survival of living things, but some human activities such as rapid population growth, industrialization, modern technology are hampering our lives. Hence, Air, land and water are increasingly becoming more polluted and the survival of living beings is threatened.

There are two main classes of pollutants those that are biodegradable (e.g. sewage), i.e. can be rendered harmless by natural processes and, therefore, cause no permanent harm if adequately disposed off or treated and those that are non bio-degradable (e.g. heavy metals (such as lead and DDT), which eventually accumulate in the environment and may be concentrated in food chains.

## Air Pollution

Air is essential for living things. Waste substances like smoke and gases from chimneys escape into the air and pollute it. Air so changed is said to be polluted and the substances causing pollution are called pollutants. The main air pollutants are carbon dioxide, ammonia, sulphur dioxide, smoke, carbon monoxide and other waste gases let out through the chimneys of industry, automobiles (motor, buses) and others (like fuels). Since plants take in carbon dioxide and release oxygen during photosynthesis, therefore growing trees and plants in big cities and industrial towns is one way of controlling of air pollution.

## Water Pollution

Like air, water is also an essential factor for living beings. Various types of wastes such as sewage, industrial wastages are liberated into rivers, lakes, etc. Thus water becomes toxic for fish and other living beings.

The extent of pollution of river water (or any other type of water) is usually measured by oxygen standards. One is dissolved oxygen (DO) which should not be less than 4 mg per litre of water. The other is the biological oxygen demand (BOD) and is a measure of organic matter present in water. It should not exceed 3mg per litre of water.

The different values of DO and BOD for Ganga water at different cities are given below:

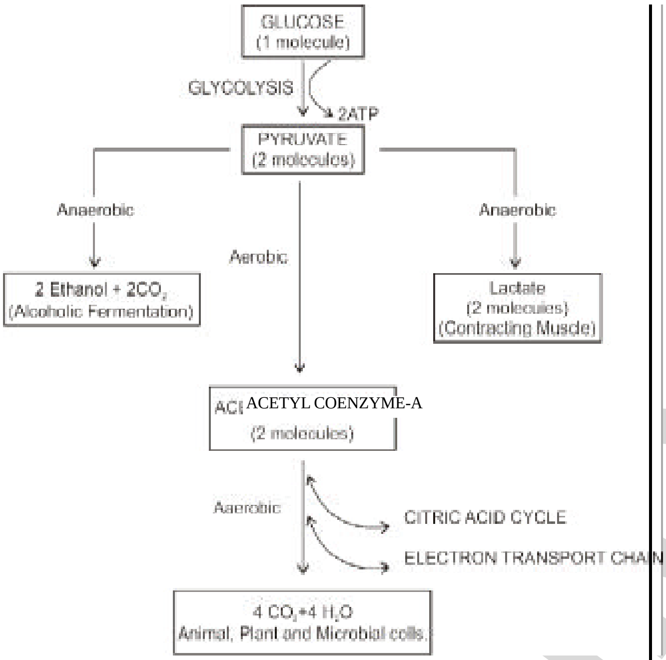
| City | DO (mg/l) | BOD(7 mg/l) |
|---|---|---|
| Rishikesh | 8.3 | 1.4 |
| Haridwar | 8.1 | 1.9 |
| Kanpur | 8.1 | 20.4 |
| Varanasi | 7 | 9.4 |
| Patna | 8.9 | 2.1 |
| Kolkata | 7.8 | 3.5 |

### Radioactive Pollution

Nowadays, nuclear tests are occurring in different parts of the world and atomic reactors are also being established for peaceful purposes. Due to careless activities exposure to radiations (from radioactive materials) causes death or genetic defects in man.

## Ozone Layer

It is a layer of the earth's atmosphere in which most of the atmosphere's ozone is concentrated. It occurs 15-50 km above the earth's surface. In this layer most of the sun's ultraviolet radiation is absorbed by the ozone molecules, a rise in the temperature of the stratosphere and preventing vertical mixing so that the stratosphere forms a stable layer. By absorbing most of the solar ultraviolet radiation the ozone layer protects living organisms on earth. The fact that the ozone layer is thinnest at the equator is believed to account for the high equatorial incidence of Skin Cancer as a result of exposure to unabsorbed Solar ultraviolet radiation. The existence of the ozone layer is maintained with creation and destruction of $O_3$. Oxygen molecules are destroyed by high energy ultraviolet radiation and form ozone ($O_3$). This ozone has an appreciable lifetime in the atmosphere until, it is effected from ultraviolet radiation and once again forms common oxygen gas. Ozone molecules are stable, however ozone can be broken down by stable organic chlorine compounds mainly Chlorofluoro carbons, where an active chlorine atom can catalytically destroy ozone. Due to this destruction ozone hole is developing.




## Agricultural Chemistry

Chemistry plays a vital role in agriculture particularly of fertilizers and pesticides. By the use of fertilizers we improve the quantity of nutrients in soil for plants. Pesticides are such chemicals which are used to destroy the harmful insects, fungi and others which are harmful to crops.

## Pesticides

Pesticides are chemicals which are subdivided into the following:

1. **Insecticides:** Insecticides kill those harmful insects, which attack growing and harvested crops, livestock, buildings and man himself. There are four ways in which insecticides may act:
   - i. directly
   - ii. by passage
   - iii. by ingestion
   - iv. by inhalation as a lethal vapour.
2. **Herbicides:** These are used to discourage weed growth without damaging the crop.
3. **Fungicides:** It controls parasitic and saprophytic fungi which are responsible for damaging the crops. It prevents further attack of fungi on plants.
4. **Nematicides:** It kills the parasitic worms residing in soil which feed on growing crops. Nematicides act by spreading their vapour through the soil to reach the invading eelworms.
5. **Molluscicides:** It kills slugs, snails, etc. which are harmful for crops. Hence the use of pesticides depends upon climate and the crop. In tropical and subtropical areas, insecticides predominate. In temperate regions herbicides are more important. Besides these pesticides some other chemicals are also used to destroy the harmful factors such as sodium monochloroacetate, sodium fluoroacetate, zinc phosphide, thalium sulphate and alpha naphthyl thio urea are used for killing rats or rodents which do not only destroy stocks of food, they also spread diseases. Insect control is also done by sex attractants (Pheromones or antifeedants). One example of such chemical is "disparlure" which has been used against gypsy moth.

## Fertilizers

Fertilizers are the substances which are added to the soil in order to make up the deficiency of essential elements like nitrogen, phosphorous and potassium required for the growth of the plants.

1. **Nitrogenous Fertilizers:** These fertilizers mainly supply nitrogen to the plants or soil. Ammonium sulphate $(NH_4)_2SO_4$, calcium ammonium nitrate, basic calcium nitrate, calcium cyanamide, urea, etc. are the examples of nitrogenous fertilizers.
2. **Phosphatic Fertilizers:** It provides phosphorus to the soil. Superphosphate of lime, triple superphosphate and phosphate slag are examples.
3. **Potash Fertilizers:** It supplys potassium to the plant. These are useful to the plants especially to meadows, tobacco, cotton, coffee, potatoes and corn. All these fertilizers occur in nature. Potassium chloride (KCl), Potassium nitrate ($KNO_3$) Potassium Sulphate ($K_2SO_4$. are examples.
4. **NP Fertilizers:** It provides two elements namely, nitrogen and phosphorus. These are obtained by mixing together nitrogenous and phosphatic fertilizers in suitable proportions. Examples are – dihydrogen ammoniated phosphate ($NH_4H_2PO_4$), Calcium superphosphate nitrate Ca $(H_2PO_4)_2$. $2Ca(NO_3)_2$ and ammoniated phosphate sulphate

   $NH_4H_2PO_4$. $(NH_4)2SO_4$.
5. **NKP or Complete Fertilizer:** These fertilizers supply all the three essential elements namely, nitrogen, phosphorus and potassium to the soil and are produced by mixing nitrogeneous phosphatic and potash fertilizers in suitable proportions. It is observed that these fertilizers produce much better results.

## Medicinal Chemistry

In this branch of Chemistry we study chemical structures, synthesis, toxicity, pharmaceutical effects and activites of medicines which are used for the treatment of diseases.

**Drugs:** Chemical substances used for treatment of diseases and for reducing the suffering from pain are called medicines or drugs.

**Chemotherapy:** It is the science in which chemicals are used for the treatment of diseases. It has developed into a vast subject today and efforts are being continuously made to search for new drugs for cancer, hypertension and mental illness among others.

**Replacement Drugs:** Substances used to replace or supplement a normal hormone or other compounds that are in short supply in a particular Patient's System. These are called replacement drugs. Example of a replacement drug is insulin which is used when persons are suffering from diabetes mellitus.

**Antipyretics:** Antipyretics are substances used to bring down body temperature in high fever. Their administration often leads to perspiration. Common examples are aspirin, phenacetin and paracetamol. Calcium and sodium salts of aspirin are more soluble and less harmful.

**Analgesics:** These are drugs used for relieving pain. Aspirin and some other antipyretics act as analgesics also. Certain narcotics (which produce sleep and unconsciousness) are also used as analgesics. Typical examples of narcotics are morphine, Marijuana, cocaine and heroin. They are known to be habit-forming.

| | Components | Function |
|---|---|---|
| 1. | Blood particles | |
| | (a) Red Blood cells (RBC) | Transport of molecular oxygen from lungs to tissues |
| | (b) White blood cells (WBC) | Defence against infection, |
| | (c) Blood Platelets | Blood Clotting |
| 2. | Plasma Solutes | |
| | (a) Electrolytes (ions) $Na^+$ and $ClHCO_3^-$ | Maintenance of osmotic pressure and fluid balance principal buffer in blood, transport of $CO_2$ from cells to the lungs |
| | (b) Protein Albumins | Maintain osmotic pressure of blood plasma, transport of water insoluble substance Globulins alpha, beta, gamma, transport of lipids as lipols, immunological (protective) |
| | (c) Carbohydrates | Source of energy |

**Antiseptics and Disinfectants**: Antiseptics are the chemicals which kill or prevent the growth of micro organisms. These are applied to living tissues. They can be applied to wounds, cuts, ulcers and diseased skin surfaces. Antiseptics reduce odours resulting from bacterial decomposition in the body or in the mouth. For such use, they are incorporated into deodorants, face powders and breath purifiers.

Disinfectants kill micro-organisms but are not safe for contact with living tissues. These are applied to inanimate objects such as floor, instruments, etc.

Antiseptics can act as disinfectants by varying the concentration of the solution used. Thus a 0.2 percent solution of phenol acts as an antiseptic and 1% solution of it as a disinfectant.

Chlorine is used for making water fit for drinking at a concentration of 0.2 to 0.4 parts per million. Low concentration of sulphur dioxide is used for sterilizing squashes for preservation. Commonly used as antiseptic, dettol is a mixture of chloro-xylenol and terpeneol in a suitable solvent. Bithional is added to soap to impart antiseptic properties. It reduces undesirable odours resulting from bacterial decomposition of organic matter on the skin. Iodine is a powerful antiseptic. It is employed as tincture of iodine, an alcohol-water solution containing 2-3% iodine. Iodoform ($CHI_3$) is widely used as an antiseptic wound powder. Gentian violet and methylene blue are simple examples of antiseptic dyes.

**Tranquilizers**: These are substances used for treatment of mental diseases. They act on higher centres of the central nervous system. They are the constituents of sleeping pills. These are also called psychotherapeutic drugs. They help the individuals to enhance capacities they already have, by alleviating symptoms to emotional distress when these are severe and interfere with their functions. Derivatives of barbituric acid (viz, luminal and seconal) have been known for their tranquilising activity for a long time. Equanil possesses a good tranquilizing effect and is used in depression and hypertension.

**Antibiotics**: Antibiotics are defined as chemical substances produced by micro-organisms (bacteria, fungi and molds) that can inhibit growth or even destroy other micro-organisms. Antibiotic therapy is a case of 'setting one thief against another' because antibiotics themselves are products of microbial growth. The first antibiotic penicillin was discovered by Alexander Flemming in 1929. It is an effective drug for pneumonia, bronchitis, sore throat and abcesses. Streptomycin is used for tuberculosis and chloramphenicol for typhoid. Tetracyclines like chloramphenicol are also antibiotics.

Ampicillin and amoxicillin are examples of antibiotics.

**Sulphur Drugs**: Sulphur drugs like Sulphanilamide, Sulphadiazine and Sulphaguanidine act against micro-organisms like antibiotics and have been used in place of them.

## Food Chemistry

All human activities either physical or mental, need energy. These energies are supplies by food. It helps in the replacement of dead cells and create new cells and its growth. Human body requires carbohydrates and fats for energy, proteins for body building and water, minerals, vitamins, hormones for regulating the different functions of life. Human body suffers from diseases due to lack of any of the nutrients.

Hence in this branch we concentrate on food-chemicals and its digestion. It means "All biological processes are chemical transformations.

## Chemistry of Biological Processes

A living system is a complex array of chemical reactions. Both small and macromolecules that compose a cell are synthesized by the cell itself from simple precursor molecules. The set of chemical reactions by which synthesis of various molecules of cells are achieved is called anabolism. Other reactions, including complex organic molecules which are degraded into smaller ones and into carbon dioxide and water with the liberation of energy are called Catabolism. The Catabolic reactions serve to provide both energy for various cellular functions as well as the starting materials for anabolism. The process of synthesis and degradation are not simply reverse of each other and may occur by different chemical paths. Together, the synthesis and degradation constitute metabolism.

## Photosynthesis

In this process conversion of solar energy into chemical energy takes place. Photosynthesis takes place in regions of the plant cells called chloroplasts. The reactions can be divided into two categories: the light reactions and dark reactions. In light reactions, the Solar radiation is absorbed by the pigment Chlorophyll and this energy is utilized to synthesize energy – rich molecules (ATP – Adenosine triphosphate) and liberate oxygen. The dark reactions then use these energy-rich molecules to convert atmospheric carbon dioxide into glucose and storage molecules such as starch. The overall process can be represented as follows:

$$6Co_2 + 6H_2o \xrightarrow{\lambda\nu} \underbrace{C_6H_{12}O_6}_{\text{Glucose}} + 6O_2$$

**Adenosine Triphosphate (ATP):** ATP is an energy-rich compound. It contains two oxygen-to-phosphorous bonds that are called High energy Phosphate bonds.

## Digestion

Digestion is the process by which complex foods are broken into simple molecules.

**Carbohydrate Digestion:** In the Carbohydrate-digestion process, firstly, starch is hydrolysed into maltose with the action of amylase enzyme in mouth. Carbohydrate digestion stops in the stomach where the Ph is acidic and the amylases are inactive. Food in intestine is mixed with amylases produced by the pancreas and small intestine walls. These hydrolyse the polysaccharides completely into monosaccharides such as glucose, fructose and galactose. These pass through intestinal walls into the bloodstream and to the liver. A number of Polysaccharides like celluloses in our diet are not nourishing because there are no enzymes to digest them.

The glucose absorbed into blood is the major source of energy of cells. Though most tissues can also use fatty acids for their energy needs, cells of brain and nervous system depend entirely on blood glucose for their function. The normal required level of glucose in blood is about 60 to 100 mg/100 $cm^3$ of blood. The excess glucose is stored as glycogen which is broken down by cells in time of need.

**Proteins and Lipids Digestion:** Protein digestion starts in the stomach where the environment is acidic (PH = 2). This helps in denaturation of proteins prior to digestion. Enzymes of protein digestion are called Proteases (breaking large protein molecules to smaller peptides) and Peptidases (Convert peptides into amino acids). The enzymes pepsin, trypsin, chymotrypsin and other peptidases are involved in protein digestion.

The main digestion of lipids takes place in the small intestine. Here the food gets mixed with bile fluid. This emulsifies fats and allows enzymes such as lipases to hydrolyse fat into glycerol and fatty acids which then pass into the bloodstream.

**Carbohydrate Metabolism:** Glucose is oxidized in cells into carbon dioxide and water. Thus glucose oxidation is one of the most important reactions in a living cell which leads to useful cellular energy. For each molecule of glucose broken down, 38 molecules of ATP are produced. Since two molecules of ATP are also consumed during the initial step of glycolysis, the net production of ATP per molecule of glucose is 36.

Glucose + 36 ADP (Adenosine diphosphate) + 36 Pi + $6O_2 \rightarrow 6CO_2$ + 36 ATP + $44H_2O$.

**Various Steps in Breakdown of Glucose:** Glucolysis occurs in cytosol. Citric acid cycle and oxidative phosphorylation takes place in mitochondria in the presence of oxygen. In the absence of oxygen, bacteria fermentation produces ethanol and in muscles, lactic acid is formed.

**Lipid Metabolism:** Most of the energy in fats is contained in the long chain hydrocarbons of fatty acids. They are the main energy reserves of the body producing 43.62 K J per gram on oxidation, much more than that generated by oxidation of carbohydrates or proteins (16.8 KJ/gm). On oxidation, Palmitic acid, a C-16 fatty acid produces 130 molecules of ATP.

$$\text{Lipids} \xrightarrow{\text{hydrolysis}} \begin{matrix}\text{Fatty acids}\\ +\\ \text{Glycerol}\end{matrix} \xrightarrow{\text{oxidation}} \text{Acetyl CoA} \xrightarrow[\text{cycle ATP}]{\text{citric acid}}$$

**Amino Acid Metabolism:** Amino acids provide dietary source of nitrogen and are used in the formation of new cells or repair of old cells, synthesis of other amino acids, enzymes, hormones, antibodies and non-protein molecules such as nucleic acids. Unlike carbohydrates and lipids which can be stored (as glycogen in muscles and as fats in adipose tissues, respectively) there are no storage molecules for amino acids. Some amino acids are metabolized to pyruvate, some to acetyl CoA and others to various intermediates in glucose metabolism and energy is obtained by their breakdown into carbon dioxide and water.

## Water

It is an ideal physiological fluid in living organisms because of the following characters:

i. Water has a high boiling point (100°C) which is well above the physiological temperature (37°C).
ii. Due to the smaller molecular size of water and extensive intermolecular hydrogen bonding it dissolves not only other ionic compounds, but also a large number of polar organic compounds.
iii. Water provides a medium for transport of chemicals to and from cells. Metabolic reactions take place in water.
iv. It is a common participant in many biochemical reactions.
v. 70% of total body weight is due to water: A normal healthy adult will ingest and excrete about 1.5 to 3.0 litres of water per day.
vi. The control of water balance is performed primarily by kidneys which regulate the amount of water and electrolytes excreted via urine in conjunction with thirst mechanism.

## Blood

The blood is a vehicle for metabolic communication among the organs of the body. It is the transporting medium for nutrients, waste products, oxygen and $CO_2$. Blood consists of an aqueous solution of ions and organic molecules in which are suspended particles called the red blood cells (erythrocytes), white blood cells (leucocytes) and blood platelets.

The Ph of blood must be maintained within the range of 7.36 to 7.42.

Haemoglobin is the key participant in the process by which gases $CO_2$ and $O_2$ interchange between the body and the environment. Haemoglobin is a globular protein consisting of four polypeptide chains arranged in a tetrahedral configuration. It contains a non-protein constituent called heme which is an iron prophyrin and is responsible for the red colour of blood. In lungs, haemoglobin combines with oxygen to form oxyhaemoglobin. Here the oxygen is bound to the iron atom of heme. In tissues where oxygen content is low, oxyhaemoglobin dissociates and releases oxygen for utilization. A related protein myoglobin, serves to store oxygen in the muscle tissues.

**Antibodies**: These are protectors from foreign invaders like bacteria, virus, etc. The presence of invaders in the body triggers the production of specialized protein molecules known as antibodies or immunoglobulins. Antibodies are Y-shaped protein molecules composed of four smaller polypeptides linked together. The invader which triggers the antibody formation is designated as antigen. Thus in response to the entry of antigen or infection the level of the corresponding antibody rises in blood. New born babies do not have a functioning system for antibody synthesis for several months. During this period, they are protected by antibodies from the mother's milk.

## Allergy

Some persons are sensitive to specific substances such as pollen, penicillin or cat fur because, he or she produces an antibody against this substance. The antigen may be airborne, producing a response in the eyes, respiratory tract or ingested with food-producing gastrointestinal or skin reactions. The binding of antigens and antibodies results in the cells releasing a variety of chemicals such as histamine, seratonin, etc. which in turn generate allergic response. The drugs used to combat the effects of allergy are antihistamines which block the production of histamines.

## Hormone

Hormones, are a class of chemical messengers produced in ductless glands, and transported by blood circulation to target tissues for producing an inhibitory or a stimulatory effect. Hormones are very potent and so are produced in small quantities only.

Hormones are classified into three classes on the basis of their Chemical Structure :

1. Steroid Hormones
2. Peptide Hormones
3. Amine Hormones

**1. Steroid Hormones**: Steroids are compounds whose structure is based on a four-ring network, consisting of 3 cyclohexane rings and 1 cyclopentane ring. Sex hormones like testosterone, dihydrotestosterone, androgens and estrogens are examples of steroid hormones. There are other steroids such as cortisone, corticosterone and aldosterone which affect metabolism, mineral and water balance. The deficiency of these leads to loss of fluids and excess results in an increase in blood pressure.

Androgens and estrogens also have significant effects on the anabolic system. So they are used by athletes, weight-lifters and other sports-persons to increase the muscle mass and strength. Such uses of anabolic steroids are banned in competitive sports.

Besides sterols and ergosterol, digitoxigenin is a Steroid extracted from plant digital and is used as a drug to regulate heart function. It is also the raw material for manufacture of several Steroid drugs.

**2. Peptide Hormones**: Oxytocin and vasopressin are two hormones of this class. Oxytocin causes contraction of the uterus during child birth. Vasopressin controls the reabsorption of water in the kidneys.

**3. Amine Hormones**: These are the water-soluble amine compounds. Examples are adrenaline (epinephrine) and thyroid hormones. Adrenaline is needed to prepare animals (humans) for emergency in several ways. It increases the heart beat rate, heart output and the blood pressure, preparing the cardio vascular system for emergency action, it stimulates the breakdown of liver glycogen into blood glucose, the fuel for anaerobic muscular work.

## Vitamins

Vitamins are a group of organic compounds which are required in very small amounts for the healthy growth and functioning of animal organisms. They cannot be made by organisms and so have to be supplied in the diet. They are chemically different from the main nutrients-fats, carbohydrates and proteins. Vitamins A, D, E and K are fat-soluble substances whereas Vitamin B-complex and Vitamin C are water soluble.

## Biochemistry and Life Processes

There are a large number of living organisms around us. Among these, man is the most adaptable species on the earth.

Cells are the smallest unit of living organisms with their independent existence. Cell needs food and energy to work. Besides other parts cells have chromosomes and genetic code are encoded on the chromosomes. These genetic codes are responsible for all characters of living organisms. One of the most important factors for deciding the natural selection to take place is mutation that is due to spontaneous changes in an organism's genes encoded in cells. These genetic codes are made up of deoxy-ribonucleic acid (DNA). It controls the manufacturing and functioning of proteins in animal systems. Ribonucleic acids (RNA) are the replicas of DNA and pass into the cytoplasm where proteins are formed. The genetic code transmits inherited characteristics from generation to generation.

**Mutation or Genetic Engineering:** These are the processes in which the sequence of bases in the chemical constitution of the DNA in the chromosomes is changed. This results in the synthesis of different proteins which are more useful and stable. This principle gives a basic foundation for biotechnology. Biotechnology helps us to use natural resources and our environment in a better, healthier, more efficient and economic way by the applications of organic chemistry, biology and industrial engineering. From biotechnology we get medicines, hormones and several other useful things. As for example Bacteria and other microorganisms can be genetically engineered to carry out intricate steps in important processes in chemicals and food industry. In the field of agriculture, genetic engineering holds a great promise for increasing the crop field and quality by making them resistant to certain diseases.

## Applications of Biotechnology

i. **Insulin Production:** Insulin is an important hormone which regulates the amount of glucose. So it is an animal protein. It is used as an antidiabetic drug. This hormone is secreted by Pancreas. By biotechnological method it is possible to prepare and link a synthetic gene, responsible for synthesis of insulin, to a plasmid of E. Coli. After genetic expression and translation of mRNA into proteins, insulin is obtained.

ii. **Interferon Production:** Interferon is an antiviral agent. It inhibits viruses. Interferons are glycoproteins. They may be classified into three types (on the basis of Physiochemical and antigenic properties) designed as a -interferon, b - interferon and g -interferon. Interferon causes the synthesis of several enzymes like protein Kinase and phosphodiesterase which inhibit viral replication by destroying mRNA and protein synthesis. There are no side effects of interferon. It is used for treatment of common cold, influenza, hepatitis, etc. It shows promise as a cure for bone cancer, skin cancer, breast cancer and leukaemia.

iii. **Hormonal Production:** Two hormones-somatostatin (hypothalamic hormone) and Somatotropin (human growth hormone) have been successfully synthesised using biotechnological techniques like recombinant DNA technology and gene cloning. By this production we can do the treatment of abnormal growth related diseases.

iv. **Tissue Plasminogen Factor:** Biotechnology provides tissue plasminogen factor which is used to dissolve unwanted blood clots.

v. **Blood Clotting Factor VIII:** It is an important biotechnology product which is used for the treatment of haemophilia.

vi. **Vaccines:** There are many productions of vaccines from biotechnology method which are used in curing various infective diseases.

## Polymers

**'Poly'** means many and **'mer'** means unit. Thus a polymer is a large but single chain-like molecule in which the repeating units derived from small molecules called monomers are covalently linked. The process by which monomers are transferred into a polymer is called Polymerization. For example, Polyethylene is obtained from its monomer ethylene as a result of Polymerization. Here the repeat unit is derived from the monomer ethylene.

$n\,CH_2 = CH_2$ ® $(-CH_2-CH_2-)n$

ethylene Polyethylene

In certain polymers repeat units can be different like nylon-66, carbohydrates and proteins.

| **Monomer** | **Polymer** |
|---|---|
| Ethylene | Polyethylene |
| Propylene | Polypropylene |
| Butadiene | Polybutadiene |
| Tetrafluoro | |
| Teflon | Polytetrafluoroethylene (Teffon) |
| Vinyl chloride | Polyvinyl chloride (PVC) |
| Adipic acid and | |
| Hexamethylene Diamine | Nylon-66 |
| Phenol and formaldehyde | Bakelite |
| Terephthalic acid | |
| and ethylene glycol | Polyester (Terylene) |

Polymers may be made from both inorganic and organic molecules. Examples of inorganic polymers are metaphosphoric acid $(HPO_3)_n$, silicates and silicones. Examples of organic polymers are mostly synthetic polymers which contain thousands of monomer units having very high molecular mass and thus are often called macromolecules.

## Classification of Polymers

Polymers can be broadly divided into two classes – Natural Polymers and Synthetic Polymers.

**Natural Polymers:** Polymers derived from nature mostly from plants and animals are natural polymers. Starch, cellulose and other polysaccharides, proteins, nucleic acids and natural rubber are examples of this type.

Starches are Polymers of glucose, i.e. Starch molecules consist of many hundreds of glucose molecules joined together. Cellulose is also a polymer of glucose. Protein is a polymer of amino-acids. Natural rubber is polymer which consists of repeat units of hydrocarbons 2-methyl 1-1, 3-butadiene (isoprene)

$$n\,CH_2 = \underset{\displaystyle CH_3}{\overset{\displaystyle C}{|}} - CH = CH2$$

Isoprene

$$(-CH_2 - \underset{\displaystyle CH_3}{\overset{\displaystyle C}{|}} = CH - CH_2 -)$$

Polyisoprene

(natural rubber)

Natural rubber is a thermoplastic but when mixed with sulphur and then heated gives a certain shape. This is known as Vulcanisation. Vulcanisation makes the rubber hard, strong, more elastic, causes it to lose its sticky qualities and greatly increases the abrasion resistance of natural rubber. Rubber is a soft material which can be hardened by adding carbon black to it. Hardened rubber is used for making tubes, tyres and conveyor belts.

## Synthetic Polymers

These polymers are synthesized by man in laboratory or factory. Most of the synthetic polymers are long-chain organic molecules containing thousands of monomer units. The names of many of these polymers are known to most of us. Some of them are polyethylene, polystyrene, polyvinyl chloride, bakelite, nylon, dacron, neoprene and thiokol.

**Classification based on Synthesis:**There are two modes of polymerization – addition polymerization and condensation polyerization. Polymers have been classified into two main groups based on these modes of synthesis as

i. Addition Polymers

ii. Condensation Polymers

**Addition Polymerization**: It involves the repeated addition of monomers to the polymer chain. Addition polymers have the same empirical formula as their monomers. Examples are polythene, natural rubber and synthetic rubber neoprene.

**Condensation Polymerization**: It involves condensation reaction between two monomers which have two functional groups following the removal of water. Examples are nylon, terylene, alkyne resins, bakelite.

**Plastics**: Most plastics are made from polymeric synthetic resins, although a few are based on natural substances (e.g. cellulose derivatives or shellac). Plastics can be shaped by applying heat or pressure. They fall into two main classes:

i. **Thermoplastic Materials:** These materials can be repeatedly softened by heating and hardened again on cooling. Polyethylene and Polystyrene, Polyvinyl Chloride, nylon and terylene are examples.

ii. **Thermosetting Materials:** These are initially soft, but change irreversibly to a hard rigid form on heating. Bakelite and melamine are examples.

Different Polymers and their monomers are described as here:

## Uses of Some Polymers

i. Polyethylene is used as packing films, containers and bottles, for moulding articles and as electrical insulators.

ii. Polypropylene is used in packing of textiles and foods, liners for bags and heat shrinkable wraps for records and other articles.

iii. Polystyrene is used for hot-drink cups, toys, household articles, etc.

iv. Polymethylmethacrylate is useful for lenses, transport domes and skylights, dentures, aircraft windows and protective coatings.

v. Teflon is used as a material resistant against heat and chemical attacks. It is also used for coating articles and cookware to make them non-sticky.

vi. Polyvinyl chloride is used in the manufacturing of raincoats, hand bags, plastic dolls, curtain clothes and vinyl flooring. It is also used as a good insulating material in wires and other electrical goods.

vii. Soft bakelites are used as bonding glue for laminated wooden plants and in varnishes and lacquers. Hard bakelite is used for making combs, fountain-pen barrels, phonograph records, electrical goods, formica table-tops and many other products. Sulphonated bakelites are used as ion-exchange resins.

**Natural Fibres**: These type of fibres are used in making fibres. Cotton, wool and silk are examples; in which cotton is a cellulose fibre, wool and silk are protein fibres.

**Synthetic Fibres**: These are man-made fibres. Synthetic fibres are found in two types

i. made from natural raw material, e.g. rayon.

ii. not requiring any natural raw materials which are pure synthetic. Examples- nylon and terylene.

**Rayon**: It is a textile made from cellulose. It is made from wood pulp. Two types of rayons are found

i. viscose rayon

ii. acetate rayon.

Rayon is used for making textiles, tyre-cord, carpets and surgical dressings.

**Nylon**: It is a synthetic polyamide fibre having a protein-like structure formed by the condensation between an amino group of one molecule and a carboxylic acid group of another. There are three main nylon fibres

i. nylon 6

ii. nylon 6, 6

iii. nylon 6, 10

Nylon is used in the making of high strength fibres like fishing nets, ropes, parachute fabrics and tyre-cord.

## Dyes

Dyes are coloured compounds used to impart colour to the textiles like silk, wool, food stuffs, etc.

India has a rich tradition in dyes and coloured fabrics. Probably the earliest known dyes were indigo (a blue dye) and alizarin (a red dye). These were obtained from plants. Indigo was primarily produced in India and exported all over the world.

Nowadays, a large number of synthetic dyes are being manufactured.

## Classification

Dyes may be classified on the basis of their applications:

a. **Acid Dyes**: Orange-I is example of acid dyes. Acid dyes can be applied to wool, silk and nylon but not to cotton.

b. **Basic Dyes**: These dyes are used to dye modified nylons and polyesters. Aniline yellow and malachite green belong to this class of dyes.

c. **Direct Dyes**: These dyes are thus useful for cotton, rayon, wool, silk and nylon. The examples are Martius yellow and Congo red.

d. **Disperse Dyes**: This class of dyes is used for polyesters, nylon and polyacrylonitrile. Martius yellow, Naphthol yellow, Congo red are examples.

e. **Fibre reactive Dyes**: These dyes are useful for cotton wool or silk.

f. **Azodyes**: These dyes are derived by coupling of a phenol or naphthol adsorbed on the surface of a fabric with a diazonium salt. Cotton, silk, polyster and nylon can be dyed by this method.

g. **Vat Dyes**: They can be applied to the fabrics. Indigo is a typical example of a vat dye.

h. **Mordant Dyes**: These dyes are used primarily for wool and are applied to the fabrics after treating it with a metal ion. Depending upon the metal ion used, the same dye can give different colours. Thus, alizarin gives a rose red colour with aluminium and a blue colour with barium.

## Petroleum and its Products

'Petroleum' word is formed from two words (Petra-rock, oleum-oil), which means Petroleum is rock oil. It is a mixture of hydrocarbons. Petroleum is formed from the fossils of marine animals and plants which were piled up on the sea bottom a long time ago. With the passage of time sand and mud covered them. Under high pressure these together were converted into rocks, whereas animal and plant fossils were converted into a dark liquid trapped in the pores of the rocks. Petroleum gas is found in the same rocks as coal and oil. It, too, was formed from the half-decayed remains of plants, animals and bacteria. Gas is often only found in small amounts, because it can easily leak away through tiny spaces in rocks.

Mineral crude oil is a mixture of liquids, solids and gases dissolved in the liquid. The mixture of chemicals is separated or refined using fractional distillation. The different components separate because they have different boiling points.

**Use of Petroleum Products:** In modern technology various substances like plastics (Polythene, Polyvinyl chloride, Polystyrene, all the synthetic fibres like nylon, terylene) acetate, glues, paints, dyes, drugs, cosmetics are manufactured from oil in the petrochemical industry.

a. **Gaseous Hydrocarbons**: Molecular composition of these hydrocarbons is $C_1$ to $C_4$. It is used as industrial or domestic fuel.

b. **Petroleum Ether**: It is used in perfumes and dry cleaning clothes

c. **Diesel oil or Gas Oil**: Molecular composition of Diesel oil is $C_{15}$ to $C_{18}$. It is used as furnace fuel and diesel engine fuel.

d. **Gasoline or Petrol**: Its molecular composition is $C_5$ to $C_{12}$. It is used as a motor fuel, as a solvent, for dry cleaning and for making Petrol gas.

e. **Kerosene**: Its molecular composition is $C_{12}$ to $C_{16}$. It is used in lamps, burners (Stoves) and also turbojet aircraft.

f. **Lubricating oils, Greases, Vaseline and Paraffin Wax**: The molecular composition of these products is $C_{16}$ to $C_{50}$. Lubricating oil is used for lubrication. Vaseline is used for making toilet goods, grease and different cosmetic goods. Paraffin wax is used for making candles and Paraffin wax is a major constituent of many ointments and cosmetics.

g. **Asphalt and Coke**: These are semisolid or solid residues. These are used for roofing, road building, making underground cables, battery boxes, electrodes and fuels.

**Octane Numbers**: Quality of petrol is determined by their anti-knock properties. The anti-knock properties are measured by the values of their octane numbers. Higher the octane number, higher the quality of petrol. Tetraethyl lead is mixed with Petrol to increase the octane number. The highest octane number is 100.

**Fuels**: Fuels are those substances which produce heat energy on combustion without producing undesirable wastes. Quality of fuels depends upon the carbon or hydrogen content (or both) of the fuel. Calorific values measure the amount of heat generated. Higher the calorific value the better is the quality of the fuel. Calorific value is the amount of heat produced by burning one gram of that fuel.

1 calorie = 4.1868 Joules

There are three types of fuels:

**Solid Fuels**: These fuels contain carbon having solid form. On combustion it forms carbon dioxide and carbon monoxide with a large amount of heat. Wood, coal and coke, charcoal, wax, etc. are examples.

**Liquid Fuels**: These fuels are obtained by fractional distillation of Petroleum. It produces a huge amount of heat evolving carbon dioxide and water. Kerosene oil, Petrol, Diesel, Alcohol and liquefied hydrogen are the examples of liquid fuels.

**Gaseous Fuels**: These fuels produce a huge amount of energy and do not leave ash on burning. The examples of gaseous fuels are given below:

i. **Liquefied petroleum gas (L.P.G):** It is mainly a mixture of propane and butane and is used in homes for cooking.

ii. **Water gas:** $CO + H_2$

iii. **Producer gas ($N_2$ + CO)**

iv. Semi-water gas

v. **Coal gas:** Mixture of hydrogen, methane, ethylene, carbon monoxide, nitrogen, oxygen and carbon dioxide.

vi. **Natural gas:** $CH_4$-methane (~75%) + ethane(~10%) Propane (~7%) and butane (~2%)

**Rocket Fuels**: Rocket propulsion requires fuels that are known as "Rocket fuels". Some important rocket fuels are liquid ammonia, alcohol, hydrazine, paraffin, liquid hydrogen and kerosene oil. It is a combination of oxidising agents like liquid oxygen, liquid fluorine, hydrogen peroxide or nitric acid. These fuels liberate a huge amount of hot gases which pass through the nozzle of the rocket motor and provide the necessary thrust for the rocket to move forward according to Newton's Third law of motion.

Rocket propellants are classified on the basis of their physical state into three types:

1. **Solid propellants:** These are a mixture of a solid hydrocarbon and an oxidising agent. A mixture of paraffin with potassium nitrate is a suitable example in which paraffin is the solid hydrocarbon and potassium nitrate is the oxidizing agent.

There are two types of solid propellants:

i. **Composite Propellants:** Polybutadiene and acrylic acid are solid fuels in which aluminium perchlorate, nitrate or chlorate are used as oxidising agents. In composite propellants magnesium or aluminium is used to burn solid propellants.

ii. **Double base Propellant:** These types of solid propellants consist of nitroglycerine and nitrocellulose.

2. **Liquid Propellants:** Alcohol, liquid hydrogen, liquid ammonia, kerosene oil, hydrozines, hydrides of boron, methyl nitrate, nitromethane, hydrogen peroxide, etc. are liquid propellants. Liquid oxygen, liquid fluorine hydrogen peroxide and nitric acid are used as oxidising agents.

3. **Hybrid Propellants:** These type of propellants consist of a solid fuel and a liquid oxidising agent. $N_2O_4$ and acrylic rubber are common examples in the use of rocket propellants.

i. Saturn booster rocket used in the American Space Programme derives its thrust from a combination of kerosene and liquid oxygen as the propellant for the initial stage and liquid oxygen and liquid hydrogen for the upper stages.

ii. The Titan Ballistic Missiles uses hydrazine (fuel) and nitrogen tetroxide (oxidising agent).

iii. The space shuttle uses liquid hydrogen, liquid oxygen along with solid boosters in the lower stages.

iv. The Russian rockets such as PROTON generally use a liquid propellant consisting of kerosene and liquid oxygen.

v. In the Indian scenario, the SLV-3 and ASLV rocket use composite solid propellants. The PSLV- rocket which is still in the experimental stage, will use a solid propellant in the first and third stages while the second and fourth stages will use liquid propellants consisting of $N_2O_4$ and unsymmetrical dimethyl-hydrazine (UDMH) and $N_2O_4$ and monomethyl-hydrazine (MMH), respectively.

## Fire Extinguishers

Any combustible substance catches fire if some required conditions are made available to it. Such conditions are ignition temperature (i.e. lowest temperature at which a substance catches fire), heat, supporter of combustion and combustible substance. If any of these conditions is removed burning stops. Hence to extinguish the fire a device is used that is known as the fire extinguisher. For an extinguisher it must be one that uses carbon dioxide.

**Electrical Fire Extinguisher**: In extinguishing the fire caused by electricity, carbon tetrachloride is used, because vapours of carbon tetrachloride are heavier than air, so they settle down on the burning material and cut off the air supply. Here carbon dioxide and dry sand may also be used.

**Soda-acid Extinguisher**: Here water is the main extinguishing agent but carbon dioxide is also used because it is denser than air and does not support combustion. Soda-acid extinguisher's principle is based on cooling down the temperature of the burning substance below the ignition temperature.

**Foam Extinguisher**: Water is not used in extinguishing the burning oil because water is heavier than oil or petrol so oil floats on water and burns fire but if carbon dioxide, sand or soil are used then foam-type fire is stopped by cutting off air supply.

**Water as Fire Extinguisher**: Water is used as a fire extinguisher except fire caused by burning oil or by electricity. It extinguishes the fire by cooling down the burning substance below the ignition temperature.

## Some Important Matters

**LPG**: It is liquefied petroleum gas. It is used as domestic fuel for cooking. It is supplied through cylinder by filling LPG at high pressure and low temperature in liquid form.

Thus fuel supplied in gas cylinders contains a mixture of liquified butane and iso-butane under pressure. The fuel in LPG is highly combustible and forms an explosive mixture with air so any type of carelessness can damage it. Ethyl mercaptan is added to LPG for detecting strong smell on leakage of gas.

**Glass**: Glasses are often regarded as supercooled liquids. It is a mixture of sodium silicate ($Na_2SiO_3$), calcium silicate ($CaSiO_3$. and silica ($SiO_2$).

**Soda Glass**: It is made by heating a mixture of lime (calcium oxide), Soda (Sodium carbonate) and sand (silicon oxide). It is a form of calcium silicate. This glass is used in windows, bottles, etc.

**Pyrex**: It is a borosilicate glass. It is made by incorporating some boron oxide, so that silicon atoms are replaced by boron atoms. They are tougher than soda glass and more resistant to temperature changes, hence their use in cooking utensils and laboratory apparatus. Glasses for special purposes (e.g. optical glass) have other elements added e.g. (barium, lead).

**Cement**: It is used for bonding or setting to a hard material. Portland cement is a mixture of calcium silicates and aluminates made by heating limestone ($CaCO_3$) with clay (containing aluminosilicates) in a kiln. The product is ground to a fine powder. When mixed with water it solidify in a few hours and then hardens over a longer period of time due to the formation of hydrated aluminates and silicates. Cement is used in various forms such as mortar, concrete or reinforced cement concrete.

**Soap**: It is made by boiling natural oils and fats with caustic soda (NaOH) or caustic potash (KOH) or $Na_2CO_3$ by saponification. Potassium hydroxide gives a more liquid product (soft soap).

Soaps produce sufficient lather with soft water. This lather emulsifies oily or greasy material and absorbs dirt particles which are removed along with water.

**Detergents**: Detergents are synthetic organic chemical substances. Their cleansing properties are better than those of soaps. Detergents are compounds that cause non-polar substances like grease and natural oils, to go into solution in water. Detergents are made from hydrocarbons obtained from coal or petroleum. There are 15-30% detergents in washing powders by weight. The rest is made of other chemicals.

- Solid $CO_2$ is called dry ice. It is soft, white snow like substance. It is used as a refrigerant under the name drikold.
- SiC is known as carborundum. It is manufactured as :

$$SiO_2 + 3C \xrightarrow{2000-2500°C} SiC + 2CO$$

  It is extermely hard, as hard as diamond.
- Butter of tin, $SnCl_4$, $5H_2O$ and pink salt, $(NH_4)_2 SnCl_6$ are used as mordant in dyeing.
- Portland cement got its name because of its resemblance with the famous Portland rock of England. Its main constituent is calcium oxide and other constitutents are $SiO_2$, $Al_2O_3$, MgO, $Fe_2O_3$, $SO_3$, $Na_2O$, etc.
- $CO_2$ is used with ether or acetone as refrigerant.
- A mixture of 95% of oxygen and 5% carbon dioxide (called Carbogen) helps in the artificial respiration.
- Kr also forms $KrF_2$.
- Noble gases form a number of compounds in which the gases are trapped within the crystal latties of certain organic or inorganic substances. These substance are called clathrates. For example clathrates of Ar, Xe, Kr in β-quinol.
- He and Ne do not form clathrate compounds.
- Neon lamps are used in botanical gardens and in green houses because it stimulates growth and is effective in the formation of chlorophyll.
- A mixture of 20% oxygen and 80%. It is used by divers for respiration.
- Neil Bartlett prepared the first noble gas compound, $XePtF_6$.
- HF dissolves $XeF_6$ forming highly conducting solution :

$$XeF_6 + HF \rightarrow XeF_5^+ + HF_2^-$$

- Kr and Xe are used in filling incandescent metal filament electric bulbs.
- Radon is used in treatment of cancer (radiotherapy).
- $N_2O$ is called laughing gas. When inhaled in small quantities, it causes hysterical laughter. In small amounts, it acts as an anaesthetic for minor operations. It can be prepared by heating ammonium nitrate.

$$NH_4NO_3 \xrightarrow{Heat} N_2O + 2H_2O$$

- $HN_3$ is called hydrazoic acid.
- $HNO_3$ attacks proteins giving a yellow nitro compound called xanthro protein. Therefore, $HNO_3$ stains the skin and renders wood yellow.
- Radioactive Phosphorus (P-32) is used for treatment of leukemia (blood cancer).
- Phosphine is used for preparing Holme's signals for ships to know about the position of the rocks in the sea.
- Phosphine is used to prepare smoke screens in warfare. Calcium phosphide reacts with water to form phosphine which burns to give smoke.
- Mixture of $CaCN_2$ and coke is called nitrolium and is used as a nitrogenous fertilizer.
- BiClO (Bismuth oxychloride) is called Pearl white.
- Suspension of calcium hydroxide in water is called milk of lime.
- Lime water is clear solution of calcium hydroxide.
- Sodium metal can be easily cut with a knife. Its surface when freshly cut is very shining.
- A mixture of $Na_2CO_3$ and $K_2CO_3$ is called fusion mixture.
- 28% NaCl solution is called brine solution.
- NaOH + CaO is called soda lime.
- K-40 is radioactive and emits β rays.
- Sodium hydroxide is used in textile industry for mercerising cotton fabrics.
- Sylvinite is a mixture of NaCl and KCl.
- We cannot store sodium in water.
- $Mg(OH)_2$ is called milk of magnesia.
- $MgCl_2$. 5MgO. $xH_2O$ is called magnesia cement or Sorel cement.
- Magnesium is present in chlorophyll, which is widely distributed in plants.

- A suspension of hydroxide of magnesium is called milk of magnesia and is used as stomach antacid.
- Dolomite is an ore which contains both Ca and Mg.
- Colloidal solution of gold is called purple of Cassuis.
- Copper, silver and gold are called coinage metals.
- Bordeaux mixture is $CuSO_4$ solution + lime. It is used as fungicide.
- $FeSO_4$ is used in the manufacture of blue black ink.
- $AgNO_3$ is called lunar caustic.
- Silver is best conductor of heat and electricity.
- CuSO4.5$H_2O$ is called blue vitriol or *'Nila thotha'*
- $FeS_2$ is called fool's gold.
- Pure gold is very soft and cannot be used as such for jewellery. Therefore, it is generally alloyed with other metals commonly copper or silver to make it harder and modify its colour. The purity of gold is expressed as carats. *Pure gold is of 24 carat.* A 18 carat gold means that it contains 18 parts of gold in 24 parts by weight of alloy.

  Therefore percentage of gold in 18 carat gold.

  $$=\frac{18}{24}\times 100 = 75\%$$

  Most of the jewellery is made of 22 carat gold.

## Reagents or Mixtures

- **Schweizer Reagent:** It is tetraamminediacquacopper dihydroxide which is used for production of cellulose products like rayon and cellophane.
- **Bordeaux Mixture:** $CuSO_4$ solution + lime - used to kill moulds and fungi on wines.
- **Soda Bleach:** A mixture of $Na_2O_2$ and dil. HCl- used for bleaching of delicate fibres like wool, silk, etc.
- **Soda Lime:** A mixture of $Ca(OH)_2$ + NaOH - used as an absorbent for a number of gases, and in decarboxylation of sodium salts of fatty acids.
- **Fusion Mixture:** A mixture of $Na_2CO_3$ + $K_2CO_3$- used as laboratory reagent.
- **Lithopone:** A mixture of ZnS + BaSO4 - used as white paint.
- **Carbogen:** A mixture of $O_2$ and 5 -10% $CO_2$ - used for artificial respiration.
- **Nessler's Reagent:** $K_2HgI_4$- used for detecting $NH_4^+$ ions.
- **Nitrolim:** Calcium cyanamide + graphite- used as fertilizer.
- **Superphosphate:** Calcium dihydrogen phosphate + $CaSO_4$- used as fertilizer.
- **Thomas Slag:** Tricalcium phosphate + cal. silicate - fertilizer.
- **Baeyer's Reagent:** Cold alkaline $KMnO_4$ solution - used for detecting olefinic and acetylenic linkages.
- **Molisch Reagent:** $\alpha$-Naphthol dissolved in alcohol- used for detecting carbohydrates.
- **Lindlar Catalyst:** Palladised charcoal deactivated with sulphur compounds- partial hydrogenation of tripe bond to double bond.
- **Milk of Magnesia:** Suspension of $Mg(OH)_2$ in water- used as antacid.
- **Gun Powder:** A mixture of S, charcoal and $KNO_3$- used as explosive.
- **Purple of Cassius:** Colloidal particles of gold absorbed by colloidal precipitate of stannic acid-used for colouring glass (rubby red) and pottery.
- **Lucas Reagent:** A mixture of conc. HCl and anhy. $ZnCl_2$- used for distinguishing three types of alcohols.
- **Rectified Spirit:** 93-95% ethanol.
- **Methylated Spirit:** (Denatured alcohol). Rectified spirit + $CH_3OH$, pyridine, acetone, etc.
- **Power Alcohol:** 4 parts petrol + 1 part alcohol.

## Physical Properties of Some Gases

- **Hydrogen, $H_2$:** Colourless, odourless, tasteless, lightest gas, sparingly soluble is water, combustible and burns in air or oxygen with nearly invisible pale blue flame, neutral, can be liquefied and solidified.
- **Carbon Monoxide, CO:** Colourless, faint odour, tasteless, as heavy as air, very sparingly soluble in water, burns in air with blue flame, neutral, poisonous.
- **Carbon Dioxide, $CO_2$:** Colourless, faint, pungent smell, heavier than air (1.5 times) and can be poured downward like water, fairly soluble in water. Acidic, non-poisonous, can be liquefied and solidified.
- **Nitrogen $N_2$:** Colourless, odourless, tasteless, slightly lighter than air, slightly soluble in water, non-posionous, can be liquefied.
- **Nitrogen Oxide, $N_2O$ (laughing gas):** Colourless, faint pungent smell, fairly soluble in cold water but not in hot water, heavier than air, poisonous.
- **Nitric Oxide, NO:** Colourless, slightly heavier than air, sparingly soluble in water, paramagnetic, neutral, can be liquefied with great difficulty.
- **Dinitrogen Trioxide:** Nitrous anhydride; $N_2O_3$. Reddish brown gas which on cooling gives a deep blue liquid.

- **Nitrogen Dioxide, $NO_2$:** Reddish brown gas, paramagnetic.
- **Nitrogen Tetroxide, $N_2O_4$:** Colourless solid (exists below 10°C), diamagnetic.
- **Ammonia, $NH_3$:** Colourless, characteristic pungent smell, lighter than air, extremely soluble in water, brings tears in eyes, basic in nature, can be liquefied and solidified.
- **Oxygen, $O_2$:** Colourless, odourless, tasteless, slightly heavier than air, slightly soluble in water, can be liquefied and solidified, non-inflammable, paramagnetic.
- **Ozone, $O_3$:** Pale-blue fishy smell, heavier than air, slightly soluble in water, poisonous due to its destructive action on tissues, can be liquefied, turns starch iodide paper blue, Hg loses its meniscus in contact with $O_3$.
- **Hydrogen Sulphide, $H_2S$:** Colourless, smell of rotten eggs, soluble in water, poisonous.
- **Sulphur Dioxide, $SO_2$:** Colourless pungent and suffocating odour, heavier than air, soluble in water, pisonous, can be liquefied and solidified.
- **Chlorine, $Cl_2$:** Greenish-yellow, suffocating smell, heavier (2.5 times) than air, fairly soluble in water, poisonous, can be liquefied.
- **Bromine, $Br_2$:** Reddish brown, heavier than air, highly soluble in water, poisonous, turns starch paper yellow.
- **Iodine, $I_2$:** Violet, sparingly soluble in water.
- **Hydrogen Halides, HX:** Colourless, pungent smelling, acidic taste, fairly soluble in water, heavier than air, can be liquefied.
- **Some Important Mixture of Gases:** Water gas ($CO + H_2$)- used for the production of $H_2$ and as a fuel. Producer gas ($CO + N_2$ + little $CO_2$) used as fuel gas.
- **Some Gases used in Warfare:** Phosgene ($COCl_2$), mustard gas ($ClC_2H_4$-S-$C_2H_4Cl$), tear gas ($CCl_3 NO_2$), lewisite ($CHCl = CHAsCl_2$).

## Important Compounds

- **Permutit, Ion Exchange Resins and Calgon:** For removing permanent hardness of $H_2O$.
- **Heavy Water ($D_2O$)**: A moderator in nuclear reactor.
- **Hydrogen Peroxide:** Bleaching agent, restoring colour of lead painting blackened by $H_2S$, antiseptic, germicide, propellant or fuel in rockets, etc.
- **Sodium Metal:** Preparation of TEL, sodium amalgam, in sodium vapour lamp, heat transfer medium in nuclear reactors, Na-K alloy (liquid at room temperature) is used in high temperature thermometers used for finding temperature above the b.p. of mercury.
- **Sodium Peroxide,** $Na_2O_2$: Oxidising agent, source of oxygen under the name of oxone, purification of air, bleaching agent (soda bleach- $Na_2O_2$ + dil. HCl)
- **Sodium Hydroxide, NaOH:** For mercerizing cotton to make cloth unshrinkable.
- **Sodium Carbonate, Washing Soda $Na_2CO_3$:** In laundries, manufacture of glass, fusion mixture ($Na_2CO_3 + K_2CO_3$)
- **Sodium Bicarbonate, Baking Soda, $NaHCO_3$:** Preparation of baking powder, sieditz powder, effervescent drinks and furit salts, in fire extinguishers, as antacid.
- **Sodium Sulphate, Glauber's Salt.** $Na_2SO_4$: $10H_2O$. Craft paper, window glass, mild laxative.
- **Potassium Metal.** Used in photoelectric cells.
- **Potassium Carbonate. $K_2CO_3$:** Soft soap, hard glass, fusion mixture, washing wool.
- **Potassium Bicarbonate, $KHCO_3$:** Used in medicine and baking powder.
- **Potassium Sulphate, K2SO4:** As fertilizer, in potash alum and glass, as a purgative in medicines.
- **Magnesium Metal:** Preparation of Grignard reagent (RMgX) used in organic chemistry, as a fuse in aluminothermic process, a source of light in photography.
- **Magnesia, MgO:** As antacid, as refractory lining, as basic lining, as insulator, rubber, filler, Sorel's cement ($MgCl_2$. 5MgOx$H_2O$) used in filling teeth and as a substitute for tiles.
- **Magnesia Alba ($MgCO_3$)x [mg(OH)z]y.Z$H_2O$:** In medicines as an antacid, laxative and in teeth powders and pastes and in silver polishes.
- **Magnesium Carbonate:** Refractory material, filler for rubber and paper.
- **Magnesium Sulphate:** Purgative, fire-proof fabrics, filler in paper.
- **Quick Lime, CaO:** Bleaching powder, slaked lime, lime colours, cement and calcium carbide, purification of sugar and coal gas, softening of water, as basic lining.
- **Slaked Lime, Ca $(OH)_2$:** Bleaching powder, caustic soda and soda lime, white washing, softening of water.
- **Calcium Carbonate, $CaCO_3$:** Used as limestone for the manufacture of lime and as a flux : as marble for building purposes and in the production of $CO_2$; as

chalk in paints and distempers and in the production of $CO_2$; as precipitated chalk in tooth pastes and powders, in medicines for indigestion.

- **Calcium Sulphate, $CaSO_4$:** Plaster of paris, cement, ammonia, black board chalks, $H_2SO_4$ and ammonium sulphate.
- **Copper Metal:** Electrical wires, cables, calorimeters. For electroplating and electrotyping, coinage metal, in ornaments and jewellery.
- **Copper Sulphate, $CuSO_4.5H_2O$:** in Bordeaux mixture, electroplating, electrotyping, dyeing, calicoprinting, detecting moisture, preparing Fehling solution, as insecticide.
- **Silver Metal:** In coins ornaments, filling teeth (silver-alloy), medicines, silver plating.
- **Lunar Caustic, $AgNO_3$:** In making inks and hair dyes, silvering of mirrors, as a caustic in surgery. AgX (except Agl) are used in photography.
- **Zinc Metal:** In galvinisation, desilverisation of lead, precipitation of Ag and Au (cyanide process) reducing agent (Zn dust).
- **Zinc White, ZnO:** As white pigment under the name of zinc white or chinese white, as zinc ointment as filler in rubber industry, white shoe polish.
- **Zinc Sulphide, ZnS:** In lithopone, X-ray screens and in luminous paint of the dials of watches.
- **Alumina, $Al_2O_3$:** As a refractory material, cement (bauxite + lime), abrasive, for preparing artificial gems, in chromatography.
- **Aluminium Chloride, $AlCl_3$:** In Friedel-Craft reaction to prepare synthetic polymers like polythene.
- **Alum, $K_2SO_4.Al_2(SO_4)_3.24H_2O$:** In purification of water, tanning of leather, as mordant in dyeing, as a styptic to arrest bleeding, for sizing of paper.
- **Carbon Monoxide, CO:** Production of water gas and producer gas, in extraction of iron and nickel, reducing agent.
- **Carbon Dioxide, $CO_2$:** As a fire extinguisher, refrigerant (as dry ice), for artificial respiration (as carbogen), manufacture of aerated water, white lead and $Na_2CO_3$ (Solvay process).
- **Tin Metal:** Tin foil is used for wrapping cigarettes, confectionery and for making tooth paste tubes.
- **Stannous Chloride:** Mordant in dyeing (under the name of tin salt), for preparing purple of cassius, as a reducing agent.
- **Butter of Tin (Oxymuriate of tin), $SnCl_4.5H_2O$:** Mordant
- **Pink Salt, $(NH_4)_2SnCl_6$:** Mordant
- **Litharge, PbO:** (buff coloured crystalline variety). For making lead glass, paints and varnishes; in glazing pottery.
- **Massicot, PbO** (yellow powder): When mixed with glycerine, it is used as a cement for glass and stone.
- **Lead Peroxide, $PbO_2$:** In storage batteries, in match industry, oxidising agent in laboratory.
- **Trilead, Minium, Red Lead, $Pb_3O_4$:** In paint, silver mirrors, lead glass (flint glass), matches and oxidising agent.
- **Basic Lead Carbonate, White Lead, 2PbCO3. Pb (OH)2:** White paint.
- **Nitrous Oxide, Laughing Gas, $N_2O$:** As propellent gas, anaesthetic.
- **Nitric Oxide, NO:** Intermediate in $HNO_3$ manufacture, catalyst in lead chamber, in detection of oxygen.
- **Nitrous Acid, $HNO_2$:** Used in preparation of azo dyes.
- **Nitric Acid, $HNO_3$:** In making explosives (T.N.T., picric acid, nitroglycerine, dynamite and gun cotton), fertilizers (ammonium nitrate, calcium nitrate), artificial silk, dyes, drugs, perfumes; in the purification of silver and gold; as a solvent for etching designs or names upon copper, brass and bronze articles.
- **Ammonia, $NH_3$:** In making $HNO_3$, $NaHCO_3$, $(NH_4)_2SO_4$ and amm. calcium sulphate (both fertilizers), $NH_4NO_3$ (explosive), artificial silk; as a cleaning agent for removing grease in dry cleaning.
- **Phosphrous:** Red P in match industry, white as rat poison.
- **Phosphorus Pentoxide, $P_2O_5$:** Dehydrating agent.
- **Calcium Ammonium Nitrate (CAN):** Nitrogenous fertilizer.
- **Oxygen, $O_2$:** Oxygen + $CO_2$ or $O_2$ + He for artificial respiration; liquid $O_2$ + finely divided C as a substitute of dynamite; liquid $O_2$ as rocket fuel; oxy-hydrogen and oxy-acetylene flames are used for cutting and welding purposes.
- **Ozone, $O_3$:** As sterilising agent for water, for improving the atmosphere of crowded places, mild bleaching agent, for detecting the position of double bond, for preparing $KMnO_4$ from $K_2MnO_4$, artificial silk and synthetic camphor.
- **Sulphur:** In match industry and fireworks, vulcanization of rubber, disinfectant for houses, skin medicines and in preparing sulphur dyes.
- **Hydrogen Sulphide, $H_2S$:** Reducing agent, laboratory reagent.

- **Sulphur Dioxide, $SO_2$:** Bleaching agent, antichlor, solvent (liquid $SO_2$).
- **Sulphur Trioxide, $SO_3$:** Manufacture of $H_2SO_4$, oleum; for drying gases.
- **Oil of Vitriol, $H_2SO_4$:** In preparing dyes, fertilizers, detergents, explosives, lead storage batteries, dehydrating agent, pickling agent.
- **Hypo, $Na_2S_2O_3.5H_2O$:** Fixing agent in photography, as an antichlor in volumetric analysis, in the extraction of Au and Ag from ores.
- **Chlorine, $Cl_2$:** Bleaching agent, purification of drinking water, as germicide, as disinfectant in swimming pools, preparation of domestic antiseptic solution (NaOCl), bleaching powder, chlorates, DDT, poisonous gases like $COCl_2$, tear gas and mustard gas.
- **Sodium and Potassium Bromides:** Sedatives, AgBr is used in photography.
- **Iodine, $I_2$ and Kl** are used in treating goitre; for increasing production of eggs.
- **Bleaching Powder, $CaOCl_2$:** Bleaching agent, sterilising drinking water, for making wool unshrinkable.
- **Green Vitriol (Hara Kasis), $FeSO_4$. $7H_2O$:** Preparation of blue-black (writing) ink, as mordant in dyeing and tanning industries, as insecticide in organic analysis.
- **Ferric Oxide, $Fe_2O_3$:** As a red pigment, as a polishing powder in jewellery, as a catalyst for the oxidation of CO to $CO_2$.
- **2, 2, 4-Trimethlpentane** (iso-octane), Increases the anti-knock quality of petrol (gasoline).
- **Tetratethyl Lead (TEL), $(C_2H_5)_4Pb$:** Anti-knocking agent.
- **Carbon Black:** In black paints, printer's ink, as filler in rubber.
- **Ethylene Bromide:** Increase the efficiency of TEL.
- **Ethylene:** General anaesthetic.
- **Acetylene:** Illumination of hawker's lamps, artificial ripening of fruits.
- **Westron and Westrosol:** Solvents.
- **Chloroprene:** In preparing polymer *neoprene* (a synthetic rubber).
- **Acrylonitrile, $CH_2 = CHCN$:** In preparing *buna N* (synthetic rubber) and *orlon* (synthetic fibre).
- **Vinly Acetate, $CH_2 = CHOCOCH_3$:** In plastic industry.
- **Vinly Chloride, $CH_2 = CHCl$:** In preparing polyvinyl chloride (PVC).
- **Gammexene, g-B.H.C:** (g-benzene hexachloride). Insecticide.
- **Chloroform:** Anaesthetic, preparing *chloropieren* (insecticide) and *chloretone* (hypnotic), preservative for anatomical specimens.
- **Iodoform:** Antiseptic.
- **Freon-12, $CCl_2F_2$:** As refrigerant and propellent.
- **Carbon tetrachloride, $CCl_4$:** Fire extinguisher *(pyrene),* solvent, anthelmentic (elimination of hookworms), fumigant.
- **Ethyl alcohol, $C_2H_5OH$:** Beverages, solvent, antifreeze for automobile radiators, in apparatuses like spirit levels, power alchol.
- **Phenol, $C_6H_5OH$:** Antiseptic, preparing, salol (intenstinal antiseptic,) aspirin (antipyretic and antiseptic). picric acid (explosive), phenolphthalein (indicator), bakelite (a synthetic plastic, used in buttons, electric switches, etc.)
- **Ether:** General anaesthetic, refrigerant, perfumes, solvent; for preparing Grignard reagent, in Wurtz reaction.
- **Phenacyl chloride, $C_6H_5.CO.CH_2Cl$:** Lachrymator to disperse mobs.
- **Urotropine (Hexamethylene Tetramine):** Urinary antiseptic.
- **Formaldehyde:** (40% solution is known as *formalin).* As a preservative for biological and anatomical specimens, in preparation of urotropine, bakelite, in silvering of mirror.
- **Acetaldehyde Ammonia:** A rubber accelerator.
- **Paraldehyde, $(CH_2O)_n$:** A hypnotic and sporofic.
- **Metaldehyde, $(CH_2O)_3$:** Solid fuel in spirit lamp.
- **Acetone:** For storing acetylene.
- **Chloretone:** Hypnotic and sedative.
- **Formic Acid:** In tanning for removing lime from hides, as a reducing agent.
- **Acetic Anhydride:** Acetylating agent; preparation of dyes, acetate rayon, aspiring.
- **Ethyl Acetate:** In perfumes, in skin diseases.
- **Aniline:** In preparation of dyes and dye intermediates, accelerators, antioxidants, sulpha drugs.
- **Acetanilide:** Antipyretic under the name of *antifebrin.*

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# CHEMISTRY (SAMPLE QUESTIONS)



1. Which of the following types of clothes is manufactured by using petroleum products?
   (a) Rayon Silk
   (b) Terelyne
   (c) Silk
   (d) Cotton

2. Which chemical weathering process affects limestone the most?
   (a) Oxidation
   (b) Sulphonation
   (c) Hydration
   (d) None of the above

3. Temporary hardness of water is due to the presence of
   (a) Chlorides of calcium and magnesium
   (b) Sulphates of calcium and sodium
   (c) Hydroxides of calcium and sodium
   (d) Bicarbonates of calcium and magnesium

4. The coil of an electric heater is made of
   (a) Zinc
   (b) Brass
   (c) Copper
   (d) Nichrome

5. If water contracts on freezing which of the following would happen?
   (a) Icebergs will completely float on the surface of water.
   (b) Ice would become more dense.
   (c) Lakes would freeze from top to bottom.
   (d) Rocks will crack due to freezing of internal water.

6. Mercury is commonly used as thermometric fluid rather than water. This is because
   (a) The specific heat of mercury is smaller than that of water.
   (b) The density of mercury is greater than that of water.
   (c) The specific heat of mercury is greater than that of water.
   (d) Mecrury has greater visibility than that of water.

7. Chemical composition of pearls is
   (a) Calcium carbonate
   (b) Calcium carbonate and magnesium carbonate
   (c) Calcium sulphate
   (d) Calcium chloride

8. Which one of the following is likely to be the end product of the chemical weathering of potash feldspar?
   (a) Bauxite
   (b) Calcite
   (c) Kaolin
   (d) Muscovite

9. Lead pencils
   (a) Contain lead
   (b) Contain copper
   (c) Do not contain lead but graphite mixed with a little of plastic clay
   (d) None of the above

10. A light sensitive compound used in photography is
    (a) Silver chloride
    (b) Silver sulphide
    (c) Silver bromide
    (d) Silver oxide

11. Alloys used in making airplane parts contain
    (a) Zinc and aluminium
    (b) Copper and zinc
    (c) Magnesium and zinc
    (d) Magnesium and aluminium

12. Match the following:

| | | | |
|---|---|---|---|
| (A) Lead | | 1. Pitchblende | |
| (B) Aluminium | | 2. Monazite | |
| (C) Thorium | | 3. Bauxite | |
| (D) Uranium | | 4. Galena | |

| | **A** | **B** | **C** | **D** |
|---|---|---|---|---|
| (a) | 4 | 1 | 2 | 3 |
| (b) | 2 | 3 | 1 | 4 |
| (c) | 1 | 4 | 3 | 2 |
| (d) | 4 | 3 | 2 | 1 |

13. Why does hard water not lather with the soap profusely?
(a) Hard water contains sulphates and chlorides of magnesium and calcium which form insoluble compounds with soap?
(b) Hard water does not contain calcium
(c) hard water does not contain chlorides
(d) Hard water does not contain sulphates

14. Which of the following is used in photography?
(a) Silver bromide
(b) Silver iodide
(c) Silver nitrate
(d) None of the above

15. Ripening of green fruits is hastened artificially by using
(a) Acetylene
(b) Methane
(c) Sulphur dioxide
(d) Carbon dioxide

16. The heads of safety matches do not contain
(a) Phosphrous
(b) Sulphur
(c) Antimony trisulphide
(d) Potassium Chlorate

17. HCI is a stronger acid than $CH_3$ COOH because
(a) It contains less number of H atoms
(b) It ionises completely to yield H+ions
(c) It contains chlorine
(d) It does not contain oxygen

18. 'Epsom Salt', a well known laxative, is chemically named as
(a) Sodium chloride
(b) Sodium sulphate
(c) Magnesium chloride
(d) Magnesium sulphate

19. An alcohol will always contain
(a) Oxygen, carbon and nitrogen
(b) Carbon, hydrogen and oxygen
(c) Nitrogen, hydrogen and oxygen
(d) Hydrogen, oxygen and chlorine

20. Reduction is a reaction in which
(a) There is loss of electrons
(b) An atoms gains electrons
(c) Transfer of negative valency takes place
(d) Gain of negative valency takes place

21. An oil can be made fat by the process of
(a) Hydrogenation
(b) Hydrolysis
(c) Oxidation
(d) Saponification

22. The nucleus of deuterium contains
(a) One proton and one neutron
(b) One proton and one electron
(c) One neutron and one electron
(d) Two protons

23. Which one of the following statements is incorrect?
(a) A catalyst is highly specific in action
(b) A catalyst alters the rates of the forward and backward reactions equally, in a reversible reaction
(c) A catalyst is used in the course of the reaction
(d) A catalyst remains unchanged at the end of the chemical reaction

24. The element which has the same atomic number and atomic weight is
(a) Hydrogen
(b) Helium

(c) Oxygen

(d) Nitrogen

25. Match the following :

| | | | |
|---|---|---|---|
| I. | Washing soda | A. | Sodium hydroxide |
| II. | Caustic soda | B. | Copper sulphate |
| III. | Blue vitriol | C. | Sodium thiosulphate |
| IV. | Hypo | D. | Sodium carbonate |

| | **I** | **II** | **III** | **IV** |
|---|---|---|---|---|
| (a) | D | A | B | C |
| (b) | B | C | A | D |
| (c) | A | D | B | C |
| (d) | D | A | C | B |

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# CHEMISTRY SAMPLE QUESTIONS (ANSWERS)



1 (b)

2 (c)

3 (d)

4 (d)

5 (b)

6 (d)

7 (a)

8 (c)

9 (c)

10 (c)

11 (d)

12 (d)

13 (a)

14 (a)

15 (a)

16 (a)

17 (b)

18 (d)

19 (b)

20 (b)

21 (a)

22 (a)

23 (d)

24 (a)

25 (a)