

Introduction

The origin of the word *chemistry* lies in the Latin word *chemo* (meaning "black colour"). Chemistry is the branch of science which deals with the properties, composition, interaction and synthesis of compounds involving action and reaction.

Main applications of chemistry: Thanks to painstaking researches of the chemists, chemistry has helped in agriculture, food, medicine, warfare, transportation, computers and in our everyday life. In fact, during every moment of our existence we depend upon chemistry directly or indirectly. With the advancement in science, chemistry has become an interdisciplinary science and today no scientific work can escape chemistry.

Chemistry for meeting our basic needs and necessities of life: Chemistry has helped significantly in meeting human needs for food, healthcare products and other necessities of life. It has provided chemical fertilizers and improved varieties of insecticides and pesticides to increase the yield of crops and fruits. The use of preservatives has helped keep food materials for longer periods. Chemistry has also helped for better health and sanitation. It has given us a large number of life-saving drugs. Epidemics such as cholera, small pox and plague have now become things of the past. The discovery of anaesthetics has made surgical operations more and more successful. Chemistry has also given us a variety of drugs such as antipyretics (to lower body temperature in high fever), analgesics (to relieve pain), tranquilizers (for treatment of stress and mental diseases), antimicrobials (to cure infections),

antimalarials (to treat malaria) etc. Antibiotics such as penicillin, amoxycillin and streptomycin and broad-spectrum antibiotics such as tetracycline and chloramphenicol have cured a variety of diseases caused by harmful microorganisms. Antifertility drugs have been used for birth control worldwide. Life-saving drugs like cisplatin and taxol for cancer therapy and AZT I (Azidothymidine) used for helping AIDS victims are the latest contributions of chemistry in medicines.

Future Goals and Challenges for Chemistry

In recent years, chemistry has solved with a fair degree of success some of the challenging aspects of environmental degradation. So far, alternatives to environmentally hazardous refrigerants like CFCs (chlorofluorocarbons) responsible for ozone depletion in the stratosphere have been successfully developed. Still many goals are there for the chemists to achieve successfully. Environmental problems, management of greenhouse gases (like methane and carbon dioxide), understanding bio-chemical processes, use of enzymes for large-scale production of chemicals, and synthesis of exotic materials are some of the main challenges for the future chemists. A developing country like India looks forward towards intelligent, talented and creative chemists for accepting these challenges.

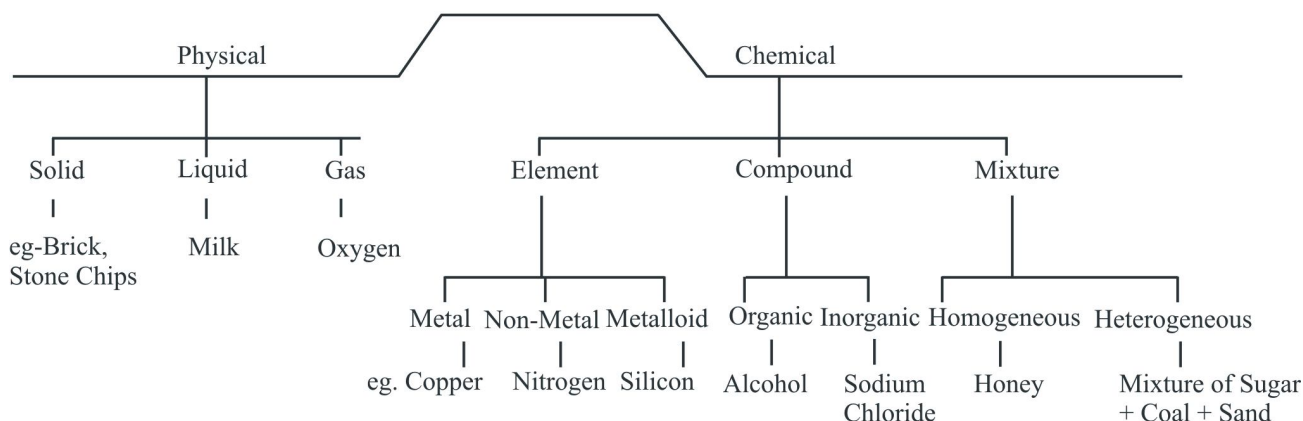
Branches of Chemistry : (a) Physical Chemistry, (b) Inorganic Chemistry, (c) Organic Chemistry and (d) Applied Chemistry.

Matter

Anything that has mass and occupies space is called matter. Matter can be classified on the basis of physical state and chemical constitution. In the physical state it is found in the form of **solids, liquids and gases**. These three forms of matter are found because of **intermolecular force** (force among atoms and molecules). Solids have a definite shape because

of strong intermolecular force. The molecular force is not so strong in liquids, and so liquids do not have a definite shape and have fluidity. Because of extremely weak intermolecular force gases move freely, and can occupy any space. According to chemical composition, matter can be classified into **elements, compounds and mixtures**.

State of Matter



Liquid State of Matter

Properties of Liquid

Boiling: Boiling point is the temperature at which the vapour pressure of a liquid becomes equal to the atmospheric pressure.

The boiling point, therefore, depends upon the atmospheric pressure. As the atmospheric pressure increases, it is necessary to heat the liquid to a higher temperature to make its vapour pressure equal to the atmospheric pressure. However, boiling point changes with the change in the pressure above the liquid. **At high altitudes atmospheric pressure is low and therefore liquids at high altitudes boil at lower temperature.**

Effect of change in External Pressure on the Boiling

Point: A liquid may be made to boil at any desired temperature by changing the external pressure. For example, a liquid may be made to boil at a lower temperature than the normal boiling point by reducing the external pressure or it may be made to boil at higher temperature by increasing the pressure. It may be noted that once the boiling starts, the temperature of the liquid remains constant, even though heating is continued until the whole of the liquid has vaporised.

Difference between evaporation and boiling:

Evaporation	Boiling
1. Evaporation takes place spontaneously at all temperatures.	Boiling takes place only at a definite temperature (boiling point) at which the vapour pressure of the liquid is equal to the atmospheric pressure.
2. Evaporation takes place only at the surface of the liquid.	Boiling takes place even below the surface of the liquid in the form of bubbles.

Surface Tension

Liquids exhibit an interesting property known as surface tension.

Surface tension is also defined as the force per unit length acting perpendicular to the tangential line drawn on the surface of the liquid.

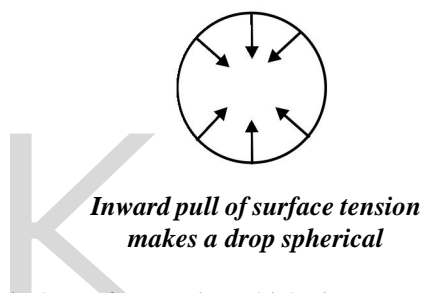
Due to surface tension, liquid drops have a nearly spherical shape because the sphere has the minimum surface area for a given volume of liquid. You must have noticed that when mercury spreads, it is in small spherical drops. It is also responsible for the rise or fall of a liquid in a capillary tube.

Effect of temperature: Surface tension decreases with rise in temperature. The decrease of surface tension with increase in temperature is because of the fact that the kinetic energy (or speeds) of the molecules increases. As a result, the intermolecular forces decrease and, therefore, surface tension also decreases. For example, clothes are washed more efficiently in hot water than in cold water due to decreased surface tension in hot water.

Effects of Surface Tension

The following important phenomena are due to surface tension:

Spherical shape of drops: Liquid drops have nearly spherical shapes. We have learnt that surface tension tries to decrease the surface area of a liquid to the minimum. Since the sphere has the minimum surface area for a given volume of liquid, therefore, the liquid tries to adopt a spherical shape. That is why mercury drops are spherical in shape. This is also the reason that sharp glass edges are heated to make them smooth. On heating, the glass melts and the surface of the liquid tends to take a rounded shape at the edges. This makes the edges smooth and is called **fire polishing** of glass.



It is the surface tension which gives stretching property to the surface of a liquid. On a flat surface, droplets are slightly flattened due to gravity. However, in a gravity-free environment, droplets are perfectly spherical. It may be noted that a water drop in vacuum is perfectly spherical. The shape of a water drop is distorted due to the action of gravity.

Capillary action: When one end of a capillary tube is put into a liquid that wets glass, the liquid rises into the capillary tube to a certain height and then stops. The rise of the liquid in the capillary tube is called capillary action. It is due to the inward pull of surface tension acting on the surface which pushes the liquid into the capillary tube. This phenomenon is very important. **Examples:** Water below the surface of the earth rises to the plants through the roots, oil rises into the wick of a lamp, ink rises in a blotting paper, etc.

Liquid wets things: Liquid wets things because it tries to spread across the surfaces. Moist soil grains are pulled together because surface area of thin water film is decreased.

Viscosity

It is a common observation that certain liquids flow faster than others. For example, water and kerosene oil flow rapidly while honey and castor oil flow slowly. Thus, **viscosity is the internal resistance to flow in liquids which arises due to the internal friction between layers of liquid as they slip past one another while liquid flows.**

Strong intermolecular forces between molecules hold them together strongly and, therefore, resist the movement of layers past one another.

Composition of Matter

Element: It is the purest form of a **substance** (a substance is a matter which cannot be separated into other kinds of matter by any *physical* force) which cannot be broken into simpler substances by any chemical or physical process. Only one kind of atom is present in an element. There are 118 known elements, out of which 22 are man-made.

We can divide elements into three groups — metals, metalloids and non-metals.

Metals : These are 90 in number.

Non-metals : There are 24 non-metals, out of which 12 are solids, 1 liquid (Br) and 11 gases.

Metalloids : Metalloids possess the characteristics of both metal and non-metal, eg Silicon (Si), Germanium (Ge) and Antimony (Sb).

Compound: Two or more elements chemically combined to form a substance is called a compound; for example, water that contains two elements, i.e. hydrogen and oxygen.

Mixture: More than one substance (elements or/and compounds) is combined together to form a mixture. It can be separated by physical processes into two or more substances. Classification of mixture is done under two categories:

- (i) Homogeneous
- (ii) Heterogeneous

Homogeneous mixture: A homogeneous mixture, which is also called a solution, has a uniform composition throughout. For example, air with nitrogen and oxygen as two main constituents, honey, a solution of salt or sugar, etc.

Heterogeneous mixture: A mixture which consists of basically distinct parts, each with different properties, is called a heterogeneous mixture. For example, when oil is mixed with water it forms a heterogeneous mixture.

Filtration, Sublimation, Decantation, Chromatography, Crystallization etc. are some of the methods by which substances can be separated from a mixture.

Separation of Matter

Filtration: It is a process of separating a suspended solid, such as a precipitate, from the liquid in which it is already suspended by straining it through a porous medium that can be penetrated easily by liquids.

Sublimation: Heating certain substances which directly change into vapour without changing into liquid. For example, **Camphor, Ammonium chloride (NH_4Cl)**.

Decantation: This process is applied to a mixture in which one compound is a liquid and the other an insoluble solid heavier than the liquid.

Crystallization: For the separation and purification of solid substances, this method is most widely used.

Some other terms

Diffusion of Gases: If not constrained in some way, gases expand to fill all available space. They also mix with other gases if no barriers keep them separate. Diffusion is the movement of a gas into a space or the mixing of one gas with another; e.g. when room deodorants or perfumes are released in one part of a room, they diffuse and one can soon detect the odour in all parts of the room. The detection of leakage of LPG, because of mixing of **ethyl mercaptan**, is also an example of diffusion of gases.

Effusion of Gases: It is the escape of a gas through a tiny hole. If gases are placed in a container with porous walls, such as in a balloon, the particles effuse through its walls, causing the volume to gradually decrease.

Freezing Point: The temperature at which a liquid freezes at a certain pressure is known as the freezing point. **Due to**

the presence of impurities in a substance, its melting point (MP) and freezing point (FP) decreases. This is the reason that in an ice-cream factory a little amount of salt (NaCl) is mixed with the substance to be frozen.

Melting Point: The melting point is the temperature at which a solid changes into a liquid. **The melting point of an alloy is less than that of its constituent elements** due to the presence of impurities.

Boiling Point: The temperature at which a liquid changes into gas or vapour is known as the boiling point. The boiling point of water is 100°C. The boiling point of alcohol is lower than that of water.

Vaporization: This is the process of change from liquid state to gaseous state.

Evaporation: Evaporation is the process of change of liquid into a gas. **Evaporation takes place at all temperatures.** Wet clothes dry even in shadow due to evaporation.

Atomic Structure

In 1803, John Dalton propounded the atomic theory, according to which an atom is indivisible, and this concept remained predominant up to the end of the 19th century. But later atomic models and atomic theories proved that atoms are divisible and they have a definite internal configuration and composition. Atomic models like Rutherford's model, Bohr's model and Vector's model have confirmed that the atoms are composed of a number of micro particles like electron, proton and neutron. Apart from electron, proton and neutron, some micro particles such as positron, meson and neutrino are also present.

Atom and Molecule: The atom of an element is that smallest particle which takes part in a chemical reaction but doesn't exist in a free state.

Similarly, the molecule of an element or compound is that smallest particle which doesn't take part in a chemical reaction but exists in a free state.

Fundamental particles of the atom

Electron: This fundamental particle was invented by J. J. Thomson in 1897. It is a negatively charged particle that rotates in various orbits around the nucleus. The mass of an electron = 9.1×10^{-31} kg and the charge of an electron = -1.6×10^{-19} coulomb.

Proton: This fundamental particle was invented by Goldstein in 1919 and it is a positively charged stable particle. The mass of a proton = 1.67×10^{-27} kg and the charge of a proton = $+1.6 \times 10^{-19}$ coulomb.

Neutron: This fundamental particle was invented by

Chadwick in 1932. It is a neutral unstable particle. The masses of a proton and neutron are nearly equal.

Rutherford atomic model

In 1911, Rutherford conducted an experiment to detect the inner composition or configuration of an atom. It was called **Rutherford's alpha particle scattering experiment**. He rejected the conclusions and facts detected by Dalton regarding atomic theory and propounded a comprehensive theory which is called the Rutherford atomic model.

This model has the following conclusions:

- In an atom there is a central massive part called **nucleus**, which is surrounded by the electrons. In this nucleus protons and neutrons are packed together.
- The atom is spherical and most of its part is empty.
- The size of the nucleus is very small in comparison to the entire atom.
- Rutherford predicted empirically that the electrons rotate in the various orbits around the nucleus, while the electrons and the proton of the nucleus have a coulomb force of attraction which is equal to the centripetal force to keep the electron orbiting in the circular orbits.

Bohr atomic model

In 1913, Neils Bohr introduced a revolutionary concept (quantum concept) to explain the stability of an atom. He asserted that the old classical laws which are applicable to macro bodies cannot be directly applied to the sub-atomic particles (micro particles) like electrons or protons.

Bohr provided the following new ideas on the basis of Planck's quantum theory called the postulates of Bohr's theory, which are as given below:

- (i) The centripetal force required for an orbiting electron is counterbalanced by the electrostatic Coulombian force of attraction between the nucleus and the electron.
- (ii) The electrons in an atom revolve only in a certain definite orbit in which energy is fixed and quantized. This orbit is stationary and in any such orbit electron doesn't radiate any energy although it is accelerated.
- (iii) Electrons of greater radii possess greater energy and vice versa. But if any electron jumps from any higher orbit to any lower one then a quantum of energy appears to be radiated, while when an electron moves from a lower orbit to a higher orbit a quantum of energy appears to be absorbed.

Atomic and Molecular Masses

In 1961, the International Union of Chemists selected a new unit of expressing the atomic masses. They accepted the stable isotope of carbon (C^{12}) with mass number 12 as the standard for comparing the atomic and molecular masses of elements and compounds. Now a days, this scale is known as mass spectrometer. The atomic mass can be determined by this instrument by comparing the mass of an atom with the mass of a particular atom chosen as standard.

This scale of relative masses of atoms is called **atomic mass unit scale** and is abbreviated as **a.m.u.** However, the new symbol used is 'u' (known as unified mass) in place of a.m.u. Hence, one atomic mass unit is defined as the quantity of mass equal to $1/12$ of the mass of an atom of carbon (C^{12}).

Thus, the **atomic mass** of an element is defined as **the average relative mass of an atom of an element as compared to the mass of an atom of carbon (C^{12}) taken as 12**. In other words, atomic mass is a number which expresses as to how many times an atom of the element is heavier than $1/12$ of the mass of carbon atom (C^{12}).

Therefore,

$$\text{Atomic mass} = \frac{\text{Mass of an atom}}{\frac{1}{12} \text{ mass of a carbon atom } (C^{12})}$$

and $1 \text{ amu} = 1.66056 \times 10^{-24} \text{ g}$

Mole Concept

Quite commonly, we use different units for counting – such as dozen for 12 articles, score for 20 articles and gross for 144 articles, irrespective of their nature. For example, one dozen books means 12 books, whereas one dozen apples means 12 apples. In a similar way, chemists use the unit **mole** for counting atoms, molecules, ions, etc. A mole is a collection of 6.022×10^{23} particles. Thus,

a mole represents 6.022×10^{23} particles.

The number **6.022×10^{23} is called Avogadro number** and is symbolised as N_A . In other words, a mole is an Avogadro number of particles. For example,

1 mole of hydrogen atoms = 6.022×10^{23} hydrogen atoms.

1 mole of hydrogen molecules = 6.022×10^{23} hydrogen molecules.

1 mole of sodium ions = 6.022×10^{23} sodium ions.

1 mole of electrons = 6.022×10^{23} electrons.

The number of entities in 1 mole is so important that it is given a separate name and a symbol. It is called the **Avogadro number** or **Avogadro constant** and is denoted by N_A in honour of the nineteenth century Italian scientist Amedeo Avogadro.

Thus, a mole is defined as **the amount of substance that contains the same number of entities (atoms, molecules ions or other particles) as the number of atoms present in 12 g (or 0.012 kg) of carbon-12 isotope.**

Mole in Terms of Volume

Mole is also related to the volume of the gaseous substance. The volume of one mole of any substance is called its molar volume. The molar volume of solids and liquids can be easily calculated if we know the molar mass and density at any given temperature and pressure because these do not change much with temperature and pressure. However, the molar volumes of gases change considerably with temperature and pressure. It has been observed that one mole of an ideal gas (i.e., 6.022×10^{23} molecules) occupies 22.4 litres at N.T.P. (0°C and 1 atm pressure).

For example,

1 mole of hydrogen gas at N.T.P. = 22.4 litres

1 mole of CO_2 gas at N.T.P. = 22.4 litres

The first definite theory about the structure of matter was put forward by John Dalton, a British school teacher in 1808. His theory, called **Dalton's atomic theory**, regarded atom as the ultimate particle of matter. According to his theory, all matters are composed of extremely small particles called atoms. The atoms were regarded to be structureless, hard spherical particles. Dalton's atomic theory remained undisputed up to the end of the 19th century. However, the discoveries towards the end of the 19th and early 20th centuries showed that the atom has a complex structure and is not indivisible. These studies further revealed that the atom consists of still smaller particles such as electron, proton and neutron, into which it may be divided. These particles are regarded as fundamental particles because these are the main constituents of all atoms.

An **electron** may be defined as a sub-atomic particle which carries one unit negative charge (1.6022×10^{-19} Coulomb) and has a mass (9.1×10^{-31} kg) equal to $1/1837$ of that of a hydrogen atom.

A **proton** is a sub-atomic particle which carries one unit

positive charge (1.6022×10^{-19} coulombs) and has a mass (1.67×10^{-27} kg) equal to that of an atom of hydrogen.

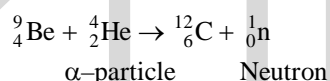
It has been observed that the mass of positively charged particles was one unit mass or 1.67×10^{-27} kg only when hydrogen gas was used. For other gases, it was found to be a whole-number multiple of this value, i.e. mass of the **proton**. This means that the atoms of other gases consist of two or more protons, i.e. a multiple of protons.

An atom consists of **electron**, **proton** and **neutron**. The electron was discovered by **JJ Thomson**. It is a negatively charged particle, i.e. the electron (${}_{-1}e^0$) has a charge of (-1) unit. The proton is a positively charged particle. It was discovered by **Goldstein**. The proton (${}_{+1}P^1$) has a charge of (+1) unit. The neutron is neutral, i.e. it has no charge. It was discovered by **James Chadwick**.

Constituents of an atom		
Particles	Discovered by	Charge
Electron	J. J. Thomson	-1
Proton	Goldstein	+1
Neutron	James Chadwick	0

Discovery of Neutrons

In 1932, **James Chadwick** bombarded a thin sheet of beryllium element with alpha particles and observed highly penetrating rays which consist of streams of neutral particles. The neutral particles were each found to have a mass of 1.675×10^{-27} kg which is nearly the same as that of hydrogen atom and have no charge. These were named **neutrons**.



Thus, a **neutron** is a sub-atomic particle having mass (1.675×10^{-27} kg) equal to that of hydrogen atom and carrying no electrical charge.

Thus, an atom consists of three fundamental particles: electron, proton and neutron. Their mass and charge are summarized in the following table.

Particle	Mass (kg)	Relative mass (u)	Approximate mass (u)	Charge	Relative charge
Electron (e)	9.10939×10^{-31}	5.4858×10^{-4}	0	$-1.6022 \times 10^{-19}\text{C}$	-1
Proton (P)	1.67262×10^{-27}	1.00737	1	$+1.6022 \times 10^{-19}\text{C}$	+1
Neutron (n)	1.67493×10^{-27}	1.00867	1	0	0

The nucleus consists of protons and neutrons and these are collectively known as **nucleons**. Since the electrons are

of negligible mass, the entire mass of the atom is due to the nucleus, i.e. nucleons. The sum of the neutrons and protons is known as the **mass number**.

Mass number = No. of protons + No. of neutrons

Mass number is generally represented by the letter A.

Isotopes, Isobars and Isotones

Isotopes

It has been observed that many elements have nuclei which contain the same number of protons but different number of neutrons. Since the nuclei of the atoms have the same number of protons, it means that they have the same atomic number, Z, but different values of the mass number, A. Such atoms of the same element are called isotopes. Thus, **isotopes are atoms of the same element which have the same atomic number but different mass number**.

Since the atomic number of different isotopes of the same element is the same, it means that they have the same number of electrons and protons. The difference in their mass numbers is due to the different number of neutrons present in their nuclei.

Hydrogen is a common example. It has three isotopes. The hydrogen which is most abundant (99.985%) contains

only one proton. It is also called **protium** (${}^1_1\text{H}$). Rest of the hydrogen contains two isotopes, one containing 1 proton

and 1 neutron called **deuterium** (${}^2_1\text{D}$ or ${}^2_1\text{H}$, 0.015%) and the other possessing 1 proton and 2 neutrons called **tritium**

(${}^3_1\text{H}$ or ${}^3_1\text{T}$). Tritium is found only in trace amounts on the earth. These have the same atomic number, one, but different mass numbers 1, 2 and 3.

These three isotopes are commonly known as hydrogen, deuterium and tritium as given below :

Hydrogen (H) : Z = 1, A = 1

(one proton only)

Deuterium (D) : Z = 1, A = 2

(one proton and one neutron)

Tritium (T) : Z = 1, A = 3

(one proton and two neutrons)

Isobars

Atoms of different elements having the same mass number but different atomic numbers are called isobars.

Since isobars have same mass number, the sum of protons and neutrons in the nucleus of each atom is the same. These atoms differ in their atomic number and, therefore have different number of protons (or electrons) and also different number of

neutrons. For example, $^{40}_{18}\text{Ar}$ (18 protons, 22 neutrons), $^{40}_{19}\text{K}$ (19 protons, 21 neutrons) and $^{40}_{20}\text{Ca}$ (20 protons, 20 neutrons) are isobars because they have the same mass number (40). Isobars are atoms of different elements and hence they have different properties.

Isotones

Atoms having the same number of neutrons but different mass numbers are called isotones.

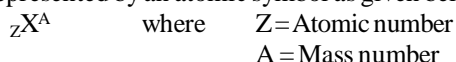
For example, $^{30}_{14}\text{Si}$ (14 protons, 16 neutrons), $^{31}_{15}\text{P}$ (15 protons, 16 neutrons) and $^{32}_{16}\text{S}$ (16 protons, 16 neutrons) are isotones because all have 16 neutrons.

Atomic Number: The number of protons or electrons of an atom of the element is called the atomic number of the element. It is represented by Z. The atomic number of any element is its basic characteristic.

The hydrogen atom has one proton and one electron; that's why it is said to have atomic number 1. Similarly, nitrogen has seven protons and seven electrons, and thus its atomic number is 7.

Mass Number: In every atom there is a small central massive part called nucleus, where almost all the mass of the atom is assumed to be concentrated. The nucleus of the atom consists of protons and neutrons, which are collectively called **nucleons**. The sum of the number of protons and neutrons in the nucleus of an atom of the element is called its mass number and it is represented by A.

Atomic Symbol of an element: Any atom X of an element can be represented by an atomic symbol as given below:



Bohr-Bury Scheme: Bohr and Bury propounded a comprehensive plan to explain the electronic arrangement of orbiting electrons in various orbits in 1921. This plan is called Bohr-Bury scheme.

According to this scheme,

- The maximum number of electrons in an orbit is $2n^2$, where n = orbit number.
- In the outermost orbit of an atom, there is a maximum of 8 electrons.
- Unless there are 2 electrons in the outermost orbit of an atom, there cannot be more than 8 electrons in an orbit.
- More than 18 electrons are accommodated in an orbit of an atom only when its inner orbits are completely filled up and its outermost orbit contains 2 electrons and penultimate orbit contains 8 electrons.

Shell or Orbit: The electrons revolve in the various orbits

with different and definite energies in the atom and these orbits which are the trajectories or paths of the electrons are called shells. The innermost orbit or shell has the lowest energy and the outermost orbit or shell has the maximum energy. The various shells from lower to upper are represented symbolically by K, L, M, N, O, P etc.

Subshell or Sub-orbit: According to the three-dimensional graphic plot of electronic wave function and the internal atomic composition, every shell or orbit has a number of subshells in which various orbitals are found and these are represented by the various small letters s, p, d and f. As in every orbit the number of electrons is fixed, similarly in every orbital of various subshell the number of electrons is fixed. The maximum number of electrons in the orbitals s, p, d and f are 2, 6, 10 and 14 respectively. It is also observed that in various shells K, L, M, N, etc., there are various corresponding subshells or suborbits s, s p, s p d, specific respectively.

Orbital: An orbital is the three-dimensional space around the nucleus of an atom where there is maximum probability of finding an electron.

Electronic Configuration: A comprehensive and proper distribution of various electrons in various shells and subshells of any atom is called electronic configuration. Examples:

Na (11) — Electronic configuration ($1s^2, 2s^2 2p^6, 3s^1$)

Mg (12) — Electronic configuration ($1s^2, 2s^2 2p^6, 3s^2$)

Ca (20) — Electronic configuration ($1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^2$)

Valance electron and Core electron: The electron present in the outermost orbit of the atom is called valence electron. But the electron present in inner orbit of the atom is called core electron.

Aufbau Principle: It gives the principle of building of the atomic structure of elements with electrons. According to this principle, the **electrons are filled in atomic orbitals in the order of their increasing energy.**

An electron occupies the orbital of lowest energy first. When this orbital is filled up with electrons completely, the remaining electrons are accommodated in the orbital of the next higher energy. The orbital having the highest energy is filled at the end.

According to Aufbau principle, the order of energy levels of the various subshells is $1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s < 5f$.

Quantum Numbers: Quantum numbers are those numbers through which the positions of electrons and their respective energies in various shells, subshells or orbitals are known.

There are four quantum numbers:

- Principal Quantum Number
- Azimuthal Quantum Number
- Magnetic Quantum Number
- Spin Quantum Number

(i) Principal Quantum Number: This quantum number simply indicates the orbit number of an electron and its energy

is represented by n ($=1, 2, 3, \dots$), where n is an integer. For $n = 1$, the electron is said to be in the normal state.

(ii) Azimuthal Quantum Number: This quantum number represents the angular momentum of the revolving electron and it is indicated by l . For principal quantum number n , l has all the values from 0 to $(n - 1)$.

Example:

If $n = 1$ then $l = 0$; If $n = 2$ then $l = 0, 1$;

If $n = 3$ then $l = 0, 1, 2$; If $n = 4$ then $l = 0, 1, 2, 3$; etc.

(iii) Magnetic Quantum Number: This quantum number indicates the direction of an orbit in space in a magnetic field and it is represented by m . The value of m depends on the value of l and its values are from $-l$ to $+l$ including zero.

Examples:

If $l = 0$ then $m = 0$; If $l = 1$ then $m = -1, 0, +1$;

If $l = 2$ then $m = -2, -1, 0, +1, +2$;

If $l = 3$ then $m = -3, -2, -1, 0, +1, +2, +3$.

Thus the total number of values of $m = 2l + 1$.

(iv) Spin Quantum Number: This quantum number represents the spin of the electron. It has been observed that electrons have two types of spin — clockwise ($+1/2$) and anticlockwise ($-1/2$). In fact, spinning electrons possess spin angular momentum that is quantized. Thus spin quantum number has two values $+1/2$ and $-1/2$ and is represented by s .

Quantum Number	Symbol	Description
Principal Quantum Number	n	Orbit number and the corresponding energy of the electron
Azimuthal Quantum Number	l	Angular momentum of the revolving electron of a subshell
Magnetic Quantum Number	m	Direction of an orbital in the space of magnetic field
Spin Quantum Number	s	Spin of the electron

Pauli's Exclusion Principle: Pauli understood the significance of quantum numbers and put forward a rule which fixes the maximum number of electrons in an orbit.

Pauli's Exclusion Principle states that

No two electrons in an atom can have the same set of four quantum numbers and at the maximum a set of three quantum numbers for two electrons can be identical but the fourth quantum number must be different for them.

Hund's rule: This is also called the law of maximum multiplicity. It states that electrons have the general tendency to remain unpaired in an incompletely filled orbital so as to have maximum spin multiplicity, maximum stability and minimum energy.

Radioactivity

Henry Becquerel discovered the phenomenon of radioactivity in 1896 and observed that certain invisible rays are emitted from Uranium and its salts. In early times these invisible radiations were called **Becquerel rays**. Later Madame Curie and Pierre Curie asserted that the emission of invisible radiations from Uranium and its compounds are totally a nuclear phenomenon and this specific characteristic of Uranium and its compounds doesn't depend upon physical and chemical parameters.

In 1898 Madame Curie and Gerhard Schimidt detected that thorium and its compounds also exhibit the phenomenon of radioactivity. Again, in 1902, Madam Curie and Pierre Curie observed a mineral of Uranium called Pitch Blende, whose radioactivity is about more than four times than Uranium. Later the Curies invented Radium from the Pitch Blende which was also radioactive.

All natural elements from atomic number 1 (Hydrogen) to 83 (Bismuth) are stable because their nuclei are stable.

Elements from atomic number 84 (Polonium) onwards have unstable nuclei and these are radioactive.

Radioactive rays and their properties: Radioactive elements and their compounds, by the process of nuclear spontaneous disintegration into smaller fragments, emit invisible radiations which are called Becquerel rays. These compose positively charged alpha-rays (α -rays), negatively charged beta-rays (β -rays) and electrically neutral gamma-rays (γ -rays).

Properties of α -rays:

- α -rays are the streams of He^{++} ions which have a mass of 4 a.m.u. and a charge of 2 units; that's why α -rays are called α -particles.
- They have the maximum power of ionisation through gases.
- Their velocity is less than that of light and it is equal to $1/10$ of the velocity of light in vacuum (3×10^8 m/s).
- They have the least penetrating power as compared to that of β - and γ -rays.

Properties of β -rays:

- (i) β -rays are streams of fast-moving electrons.
- (ii) Each β -particle is an electron having a mass of $\frac{1}{1836}$ a.m.u. and the charge of -1 unit.
- (iii) Its velocity is equal to (33 - 92)% of the velocity of light.
- (iv) It has more penetrating power than α -rays and less penetrating power than γ -rays.

Properties of γ -rays:

- (i) γ -rays are electro-magnetic radiations of high energy.
- (ii) They are composed of photons (rest mass zero) of high energy.
- (iii) They have the largest (maximum) penetrating power and can pass through 8 cm of thick lead block and 25 cm of thickened iron sheet.

Types of radioactive elements:

- (i) **Natural radioactive elements:** The elements Po (84), At (85), Rn (86), Fr (87), Ra (88), Ac (89), Th (90), Pa (91) and U(92) are naturally occurring radioactive elements.
- (ii) **Artificial radioactive elements:** The elements Np (93), Pu (94) ... Ha (105) are radioactive elements which have been synthesized inside the nuclear laboratory. These are called artificial radioactive elements.

Half-life period of a radioactive element: The half-life period of a radioactive element is the time during which half of its total number of atoms disintegrate. It is represented by $T_{1/2}$.

Half life period ($T_{1/2}$) of any element = $\frac{0.696}{\lambda}$
where λ is called disintegration constant or decay constant.

Characteristics of half-life period:

- (i) Every radioactive element has its own constant half-life and thus different radioactive elements have different half-lives.
- (ii) The half-life period of a radioactive element is independent of all external conditions such as temperature, pressure and mass.
- (iii) The smaller the half-life period of a radioactive element, the larger its radioactivity, and vice versa.

Radioactive element	Half life periods
${}_{92}\text{U}^{236}$	4.51×10^9 years
${}_{90}\text{Th}^{222}$	1.39×10^{19} years
${}_{89}\text{Ac}^{227}$	22 years
${}_{91}\text{Pa}^{231}$	2.48×10^4 years
${}_{88}\text{Ra}^{226}$	1622 years

Radioactive disintegration: Radioactive substances emit spontaneously either α -particles or β -particles and some γ -

rays but α - and β -particles both never are never seen to be emitted simultaneously.

Units and measurement of radioactivity

There are various units of radioactivity.

Curie: The radioactivity of 1 g of pure radium is called curie; 1 curie = 3.7×10^{10} disintegrations/second or decays/second.

Rutherford: The amount of a radioactive substance which gives 10^6 disintegration per second.

\Rightarrow 1 Rutherford = 10^6 disintegration/second

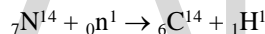
Becquerel (S.I. Unit): It is defined as that amount of radioactive substance which gives 1 disintegration per second.

\Rightarrow 1 Becquerel = 1 disintegration/second or decay/second
Incidentally one micro-Rutherford equals one Becquerel mass.

The radioactivity of a radioactive substance is measured by an instrument called **Geiger Muller Counter**.

Radioactive dating or Radio isotope dating: Naturally occurring radioactive isotopes have been very useful in dating (estimating age) of the geological events. Thus the technique of detecting the amount or quantity of any radio isotope in the sample of the rock, dead plants or organism in any bio residue to estimate and measure its actual or exact age is called **radioactive or radio isotope dating**.

Carbon dating is one of the best examples of radio isotope dating. The idea of carbon dating was suggested by Prof. Libby, a nuclear physicist of Chicago. Our atmosphere contains a large number of stable isotopes. When cosmic rays strike these isotopes, a number of radio isotopes are produced. One of these radio isotopes is carbon (${}^6\text{C}^{14}$), which is produced by the bombardment of atmospheric nitrogen with high-energy neutrons.



Radio carbon (${}^6\text{C}^{14}$) is unstable and decays to nitrogen with a half-life period of 5600 years. **By measuring the ratio of the concentration of ${}^6\text{C}^{14}$ to ${}^6\text{C}^{12}$ in any ancient organism like fossils, dead trees or plants, one can measure or estimate the exact age.**

The ages of non-living ancient geological substances like old rocks and earth are estimated by the use of uranium or its most suitable mineral Pitch Blende, in which Uranium and Thorium both are found. This technique is called Uranium dating. But **for the most ancient geological rocks, Potassium-Argon dating technique is used.**

Applications of radio-isotopes:

- (i) Radio-isotopes are used in the form of tracer in medicine. Tumours of unwanted growth of cells in human body are detected by the Tracer technique.
- (ii) Cancerous cells are destroyed completely by the use of radio-isotopes. For example, **cobalt-isotope (${}^{27}\text{Co}^{60}$) is today frequently used in the therapy of cancer and in**

destroying brain tumours. The element radium (Ra) has been used for burning and destroying cancerous cells.

- (iii) Radio-isotopes (radio-sodium) are used to detect any residue or unwanted circulatory system.
- (iv) Radio-iodine is used to detect any side effect appearing inside the thyroid gland.
- (v) Radio-phosphorus is used in curing bone diseases.
- (vi) Radio-sodium is used to measure the speed of blood flow in the human body.
- (vii) Radio-iron is used to detect diseases like anaemia, tuberculosis and other malnutrient diseases.

Nuclear energy: Due to nuclear transformation in any radioactive substance, there is always a loss in mass which appears in the form of nuclear energy. Thus nuclear energy is produced by the simple conversion of lost mass into energy by Einstein's mass-energy equivalent relation $E = mc^2$, where c = velocity of light in vacuum.

There are two sources of obtaining nuclear energy: fission and fusion.

Nuclear Fission: In 1939, two German scientists, Otto Hahn and Fritz Strassman, discovered a strange and new type of nuclear reaction. They found that when Uranium nucleus (${}_{92}\text{U}^{235}$) is bombarded with slow neutrons, the nucleus splits into almost equal fragments with the release of some free neutrons and tremendous energy. Such a nuclear reaction was termed as nuclear fission.

Thus the process (or nuclear reaction) in which a heavy nucleus splits up into two nuclei of nearly comparable masses with tremendous release of energy and some free neutrons is called nuclear fission. Elements having a higher value of neutron-to-proton ratio are more likely to undergo fission.

Neutron-induced fission of uranium is represented as below:



The neutrons produced in nuclear fission under favourable circumstances cause further atoms of uranium to undergo fission and in turn emit more neutrons, which will cause further fission explosion. Thus a chain reaction is established in a short time, releasing an enormous amount of energy. One gm of ${}_{92}\text{U}^{235}$ evolves about 2×10^7 kilo-calorie of energy upon fission.

Types of nuclear fission: Fission chain reaction is of two types:

- (i) Explosive or uncontrolled chain reaction
- (ii) Controlled chain reaction

Explosive or uncontrolled chain reaction: A nuclear chain reaction in which fission neutrons keep on increasing till the whole of fissionable material is consumed is called explosive or uncontrolled chain reaction.

Such a process (reaction) proceeds very quickly with the liberation of a tremendous amount of fission energy in a very short span of time. The atom bomb is a practical example

of explosive or uncontrolled fission. The nuclear fission device is used in the manufacturing of atom bomb using U^{235} isotope.

Controlled chain reaction: A fission chain reaction which proceeds slowly without any explosion and in which the energy released can be controlled is called controlled chain reaction.

The nuclear reactor is a practical example of controlled chain reaction. In a nuclear reactor the energy released through fission is used to generate electricity.

Basic components of a nuclear reactor

Nuclear fuels: The elements undergoing controlled fission in a reactor are called nuclear fuels. Some common nuclear fuels are uranium isotopes U^{233} and U^{235} , thorium isotope Th^{232} and Plutonium isotope Pu^{239} .

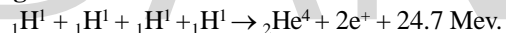
Moderators: Moderators are used to slow down emitted neutrons. Heavy water, graphite, beryllium, beryllium oxide, etc. are used as moderators. But **heavy water is the best moderator** because of its very small cross-section and large slowing-down power capacity.

Control rods: To start and stop a fission reaction, control rods are used. Due to large absorption cross-section area, **Cadmium and Boron rods are used as control rods.**

Nuclear reactors in India: The first nuclear reactor in the world was built by an Italian nuclear physicist **Enrico Fermi** in Chicago University in the USA in 1942. In India, the first nuclear reactor was built in 1956 at **Trombay**. It is a swimming-pool reactor with U^{235} rods hanging in a tank containing heavy water. Other nuclear reactors are Cirus, Zerlina, Purnima, and R-5 at Trombay.

Nuclear fusion: The process of **combining two light nuclei to form a heavy nucleus with tremendous release of energy is known as nuclear fusion.**

In fusion, lighter nuclei such as hydrogen, deuterium, tritium and helium are involved. A typical **nuclear-fusion reaction occurring in the sun is as below:**



For the occurrence of fusion, the kinetic energy of colliding nuclei must be high enough to overcome this repulsion. The order of this energy is about 0.1 MeV.

To impart energies as high as 0.1 MeV to the nuclei, the temperature would have to be raised to about 10^6K . Without achieving the temperature of this order, nuclear fusion is not possible, and that's why fusion is also called thermo-nuclear reaction. At a temperature of this order, fusion materials are found in an ionised state and behave like a swirling mass of high density and it is called plasma. At present **plasma is now assumed as the fourth state of matter. Fusion is the source of solar energy** (energy released by sun and other stars). The Sun is radiating energy at a rate of about 10^{26} Joule per second and thus losing about 4×10^6 tonnes of matter per second. Owing to its very large mass (nearly 10^{30} kg) the Sun will continue to exist for several billion years.

Chemical Bonding

Electronic theory of valency: This theory of valency is based on the electronic structures of elements and hence it is called electronic theory of valency. According to this theory, inert gases like Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe) and Radon (Rn), except Helium (He), do not exhibit valency because they contain a set of eight electrons called **octate** and their valency is said to be **zero**. This makes their electronic structures very stable and they do not participate in any chemical reaction. That's why inert gases are found in free state and are monoatomic. Helium (He) contains **two electrons** in the first orbit of its atom. Hence its first orbit becomes completely filled and its structure is therefore very stable. Consequently, atoms of inert gases have higher ionization potential than all other elements. They have zero electron affinity. Hence, they exhibit almost no tendency to lose or gain or share electrons and generally do not exhibit valency.

Chemical bonding: The binding force of the constituent atoms of the molecule to maintain a mutual atomic order and a definite but specific geometrical shape is called chemical bonding.

Types of chemical bonding: There are three types of chemical bonding: Electrovalent or Ionic bonding, Covalent bonding and Co-ordinate covalent bonding.

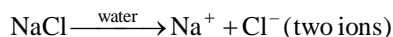
Electrovalent or Ionic bonding: The bond formed as a result of the electron transfer from one atom to another is called electrovalent or ionic bonding. The transfer of electrons takes place in such a way that ions obtained after electron transfer have a configuration of like that of inert gases.

Example: $\text{Na}^+ + \text{Cl}^- \rightarrow \text{NaCl}$
 2, 8, 1 2, 8, 7 (2, 8) (2, 8, 8)

Here, one electron is donated by sodium and accepted by chlorine.

Characteristics of electrovalent compounds

- These compounds are **generally soluble in water** because they generally ionise in water, ions become heavily hydrated and they disappear in the intermolecular spaces of water molecules and dissolve.
- In aqueous solution they get ionised as given below:



- The fused state of these electrovalent or ionic compounds is also a **good conductor of electricity**, because ions become mobile and can carry electricity across the fused mass. Electrovalent compounds are good electrolytes in aqueous solutions and in fused state.

Covalent bonding: The **bond formed as a result of sharing of electrons between two atoms** in which atoms form the chemical bonding in such a way that the molecules form attain the permanent electronic structure of the inert gas, is called covalent bonding.

Example:

- When a pair of electrons is produced by the electrons of two hydrogen atoms sharing in a hydrogen molecule, a single covalent bond is formed.
- When two pairs of electrons are produced by the sharing of electrons by two oxygen atoms in an oxygen molecule, a double covalent bond is formed.

Characteristics of covalent compounds

- Covalent compounds are insoluble in water but soluble in organic solvents.
- Covalent compounds in liquefied state or in the form of their solution are bad conductors of electricity because in these states they don't produce any ions. But covalent compounds like HCl and NH_3 in the form of their aqueous solution conduct electricity because of the presence of ions.

Co-ordinate covalent bonding: In a co-ordinate covalent bond the pair of electrons is obtained from only a single atom. In the bonding, the atom which supplies the electron pair is called the **donor** and the atom which receives the pair of electrons is called the **acceptor**. The electron pair donated by the donor atom is called **single atom pair**.

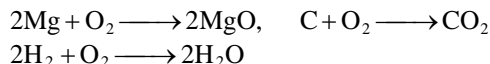
Usually co-ordinate covalent bond is represented by an arrow (\rightarrow). Here a convention is followed in which a +ve charge (S^+) is shown on the donor atom and a -ve charge (S^-) on the acceptor atom.

Example: Ions like carbonate (CO_3^{2-}) and ammonium (NH_4^+) are examples of co-ordinate covalent bond.

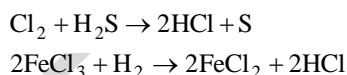
Oxidation-Reduction

Oxidation: Oxidation is the chemical process in which either the ratio of electronegative atoms or radicals of any element or compound increases or the ratio of electropositive atoms or radicals of the element or compound decreases.

Example:



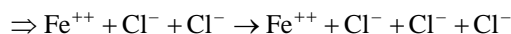
Reduction: Reduction is the chemical process in which either the ratio of electropositive atoms or radicals of any element or compound increases or the ratio of electronegative atoms or radicals of the element or compound decreases.



Definition of oxidation and reduction on the basis of ionic theory:

Oxidation: Oxidation is the chemical process in which either positive charges increase or negative charges decrease on the ions.

Example: $\text{FeCl}_2 \rightarrow \text{FeCl}_3$



Reduction: Reduction is the chemical process in which the positive charges decrease or negative charges increase on the ions.

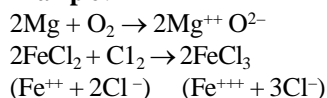
Example: $\text{SnCl}_4 \rightarrow \text{SnCl}_2$



Definition of oxidation and reduction on the basis of electronic theory

Oxidation: Oxidation is the chemical process in which atoms or ions transform themselves by losing some or more electrons and ultimately come to a high electropositive state or low electronegative state.

Example :



Reduction: Reduction is the chemical process in which atoms or ions transform themselves by gaining one or more electrons and ultimately come to a low electropositive state or high electronegative state.

Example : $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$

Oxidation And Reduction

Oxidation	Reduction
1. Loss of electron	1. Gain of electron
2. Addition of Oxygen	2. Removal of Oxygen
3. Addition of electronegative element	3. Removal of electronegative element
4. Removal of Hydrogen	4. Addition of Hydrogen
5. Increase in valency	5. Decrease in valency

Changes

Physical Change	Chemical Change
1. The change in which no new substance is formed. Just forms are changed and original substance can be found by reversing the process. For example, freezing of water, sublimation of camphor, magnetization of Iron, glowing of electric bulb, etc.	1. The change in which a new substance is formed and which cannot be reversed to its original form by reversing the conditions. For example, rusting of Iron, blood clotting, formation of curd from milk, charring of sugar, burning of coal and wood, photosynthesis in plants, etc.
2. It is a temporary change.	2. It is a permanent change.
3. It is a reversible change.	3. It is an irreversible change.
4. There is no change in mass.	4. Change in mass takes place.
5. A new substance is formed.	5. An entirely new compound is formed.

Rancidity

Oxidation has also damaging effects on food and eatables. When food containing fat and oil is left as such for a long time, it becomes stale. The stale food often develops bad taste and smell. This is very common in case of curd or cheese, particularly in summer. Actually, the oils and fats get slowly oxidised to certain bad-smelling compounds. These are of volatile nature and release foul smell. This is known as rancidity. **It may be defined as the slow oxidation of oils and fats present in food materials resulting in some bad-smelling compounds.**

Methods to check rancidity: Following measures can be adopted to prevent or slow down rancidity:

- Food materials are often packed in air-tight containers. Oxygen has no access to them and oxidation resulting in rancidity is prevented. These days, preference is given to packing under vacuum conditions.
- Refrigeration of food slows down rancidity because the temperature inside the refrigerator is very low and direct contact with air or oxygen is avoided.
- In bags containing potato chips and other similar stuff, air and oxygen are quite often replaced by nitrogen. This checks their oxidation as well as rancidity.
- It is always advisable to place food materials and cooked food in places away from direct sunlight. This will slow down the process of rancidity.

Acids, Bases and Salts

Acid

An acid may be defined as a substance which releases one or more H^+ ions in an aqueous solution.

Properties:

1. It turns blue litmus paper red.
2. It tastes sour.
3. It contains Hydrogen ions (H^+).
4. It donates protons.
5. It turns Methyl Orange pink.

Examples :

Hydrochloric acid – HCl

Nitric Acid – HNO_3

Sulphuric Acid – H_2SO_4

Acetic Acid – CH_3COOH or (HCH_2CO_2H)

Formic Acid – $HCOOH$ or (HCO_2H)

Sources of Acids

Name of Acid	Sources
Formic acid	Red ants
Citric acid	Lemons and Oranges
Lactic acid	Sour milk
Acetic acid	Vinegar
Maleic acid	Apples
Tartaric acid	Grapes
Butyric acid	Rancid butter
Uric acid	Urine of mammals
Oxalic acid	Tomato
Hydrochloric acid	Gastric juice (0.4%)
Stearic acid	Fat
Carbonic acid	Soda water & aerated drinks

Some common acids

Name	Type	Chemical Formula	Where found or used
Carbonic acid	Mineral acid	H_2CO_3	In soft drinks.
Hydrochloric acid	Mineral acid	HCl	In stomach as gastric juice, used in cleaning metal surfaces and in tanning industry.
Nitric acid	Mineral acid	HNO_3	Used in the manufacture of explosives like T.N.T. and fertilizers like ammonium nitrate.
Sulphuric acid	Mineral acid	H_2SO_4	Commonly used in car batteries, in the manufacture of fertilizers, detergents, dyes, explosives etc. It is often called king of chemicals.
Phosphoric acid	Mineral acid	H_3PO_4	Used in anti-rust paints and in fertilizers.
Formic acid	Organic acid	$HCOOH(CH_2O_2)$	Found in the sting of ants, nettle and bees, used in tanning leather and in medicines for treating gout.

Acetic acid	Organic acid	CH_3COOH	Used for preparing vinegar.
Benzoic acid	Organic acid	$\text{C}_6\text{H}_5\text{COOH}$	Used as food preservative.
Citric acid	Organic acid	$\text{C}_6\text{H}_8\text{O}_7$	Present in lemons, oranges and other citric fruits.
Tartaric acid	Organic acid	$\text{C}_4\text{H}_6\text{O}_6$	Present in tamarind.
Oxalic acid	Organic acid	$\text{C}_2\text{H}_2\text{O}_4$	Present in tomatoes.

Uses

Nitric Acid (HNO_3)

- In the manufacturing of explosives like TNT (Trinitro toluene) and Picric acid (trinitro phenol).
- In the manufacturing of Dynamite (Nitroglycerine).
- In the manufacturing of rayon, dyes and drugs.
- HNO_3 is found in rain water (first shower).**

Sulphuric Acid (H_2SO_4)

- In the manufacturing of alum.
For example, Potash alum or $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$
- In lead storage battery.
- In the manufacturing of explosives, drugs and detergents.

Boric acid (H_3BO_3): As an antiseptic

Phosphoric acid: In the manufacturing of phosphate fertilizers.

Citric acid: Food preservatives and flavouring agents.

Acetic acid: Food preservatives and flavouring agents.

Tartaric acid: Souring agent of pickles.

Ascorbic acid: Source of Vitamin C.

Aqua Regia (Royal Water)

Both gold and platinum placed at the bottom of the activity series are very little reactive chemically and are called noble metals. They do not react with any of the three mineral acids. We all know that gold ornaments are a weakness of all ladies. They wear them constantly. Because of the pollution in air, these slowly acquire a dull look. It is indeed a problem to clean and impart shine to them. Goldsmiths use Royal Water, also called Aqua Regia, for this purpose. They keep the ornaments in Royal Water for some time and then rub them

with a brush and finally with water. Do you know, what is Royal Water? It is a mixture of concentrated hydrochloric acid (HCl) and concentrated nitric acid (HNO_3) in the ratio of 3 : 1 by volume.

Hydrogen combines with nitrogen at about 500°C (or 773K) in the presence of iron as a catalyst to form ammonia gas. The reaction is of reversible nature.

- Gold and platinum placed at the bottom of the reactivity series are chemically the least reactive and are known as noble metals.
- The oxides of metals like aluminium and zinc are of amphoteric nature, which means they have both acidic and basic characters.
- Metals like **sodium and potassium are kept under kerosene** since they react with water violently.
- The high reactivity of aqua regia towards noble metals is because of nascent chlorine (Cl), which is also called just-born chlorine.

Bases

A base may be defined as a substance capable of releasing one or more OH^- ions in aqueous solution.

Properties:

1. Bases are bitter in taste.
 2. Turn red litmus paper blue.
 3. Contain replaceable hydroxide group (OH^-).
 4. Bases turn methyl orange yellow.
- All water-soluble bases are called alkalis.

A base may be defined as a substance capable of releasing one or more OH^- ions in aqueous solution.

Some common bases and their uses

Name	Commercial name	Chemical formula	Uses
Sodium hydroxide	Caustic soda	NaOH	In the manufacture of soap, refining of petroleum, paper, pulp etc.
Potassium hydroxide	Caustic potash	KOH	In alkaline storage battery, manufacture of soap, absorbing CO_2 gas etc.
Calcium hydroxide	Slaked lime	$\text{Ca}(\text{OH})_2$	In the manufacture of bleaching powder, softening of hard water, for whitewash etc.
Magnesium hydroxide	Milk of magnesia	$\text{Mg}(\text{OH})_2$	As an antacid to remove acidity from stomach.
Aluminium hydroxide	—	$\text{Al}(\text{OH})_3$	As foaming agent in fire extinguishers.
Ammonium hydroxide	—	NH_4OH	In removing grease stains from clothes, and in cleaning window panes.

The pH scale

An easier way to measure the strength of an acid or a base solution was worked out by the Danish biochemist S Sorensen. He was interested in checking the acidity of beer and introduced a scale known as pH scale (in German 'p' stands for 'potenz' meaning power). The scale runs from 0 to 14 and the characteristics of the scale are:

- Acids have pH less than 7.
- The more acidic a solution, the lesser its pH.
- Neutral solutions (e.g., water) have pH of 7.
- Alkalies have pH more than 7.
- The more alkaline a solution, the higher its pH.

Table:
Approximate pH values of some common solutions

Solution	Approximate pH	Solution	Approximate pH
1 M or Conc. HCl	0	Human saliva	6.5 to 7.5
Gastric juices	1.0 to 1.2	Pure water	7.0
Lemon juice	2.2 to 2.4	Human blood	7.36 to 7.42
Vinegar	3.0	Baking soda solution	8.4
Beer	4.0 to 5.0	Sea water	8.5
Tomato juice	4.1	Washing soda solution	9.0
Coffee	4.5 to 5.5	Milk of magnesia	10.5
Acid rain	5.6	House hold ammonia	12.0
Milk	6.5	1 M or Conc. NaOH	14.0

Relation between pH value and hydrogen ion concentration

For neutral solution: $\text{pH} = 7$, and $[\text{H}^+] = 10^{-7}$

For acidic solution: $\text{pH} < 7$ and $[\text{H}^+] > 10^{-7}$

For basic solution: $\text{pH} > 7$ and $[\text{H}^+] < 10^{-7}$

Importance of pH in daily life

We have studied in detail the pH of a solution. In general, pH ranges from 0 to 14. The pH of a neutral solution is 7. If it falls below 7, the solution becomes acidic. Similarly, if it increases above this value, the solution is regarded as basic. The pH scale is quite useful in comparing the relative acidic and basic strengths of solutions.

In general, the lesser the pH of a solution, the more will be its acidic strength. Similarly, the higher the pH of a solution, the more will be its basic strength.

pH in our digestive system: We all know that hydrochloric acid produced in our stomach helps in the digestion of food. However, excess of acid causes indigestion and leads to pain as well as irritation. The excessive acid can be neutralised with the help of antacids (or anti-acids) which are recommended by the doctors. Antacids are group of compounds (basic in nature) and have hardly any side effects. A very popular antacid is 'Milk of Magnesia', which is insoluble magnesium hydroxide.

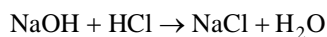
pH change leads to tooth decay: The white enamel coating on our teeth is of insoluble calcium phosphate, which is quite hard. It is not affected by water. However, when the pH in the mouth falls below 5.5, the enamel gets corroded. Water will have a direct access to the roots and decay of teeth will occur. Actually the bacteria present in the mouth break down the sugar that we eat in one form or the other to acids. Lactic acid is one of these. The formation of these acids causes decrease in pH. The acids react with calcium phosphate and the enamel coating slowly breaks. It is, therefore, advisable to avoid eating sugary foods and also to keep the mouth clean so that sugar and food particles may not be present. The toothpastes contain in them some basic ingredients and they help in neutralising the effect of the acids and also in increasing the pH in the mouth. These pastes help in checking corrosion of enamel and decay of teeth.

Self-defence by animals and plants through chemical warfare: The stings of bees and ants contain methanoic acid (or formic acid). They cause a lot of pain and irritation. The cure is in rubbing the affected area with a pinch of baking soda. Sodium hydrogen carbonate (NaHCO_3) present in it neutralises the acid and thus brings the pH back to its original level, bringing relief to the person who has been stung. Similarly, the effect of stings by wasps containing alkali is neutralised by the application of vinegar, which is ethanoic acid (or acetic acid).

- Oxides of metals are basic in nature while those of non-metals are of acidic nature.
- An acid solution in water always contains some OH^- ions. Similarly, a base solution in water always contains some H^+ ions.
- The reaction between an acid and a base to form salt and water is called **neutralisation reaction**.
- Neutralisation reactions are always **exothermic** and are accompanied by evolution of heat.
- The pH value and $[\text{H}^+]$ of a solution are inversely proportional to each other.
- The higher the pH value, the weaker the acid and the stronger the base.
- The pH of a neutral solution is 7 and that of human blood ranges between 7.36 to 7.42.

Salts

Salts are formed by the reaction between acids and bases.



(Common Salt)

Common Salt (NaCl) is formed as a product when Sodium Hydroxide (NaOH) reacts with Hydrochloric Acid, as shown in the above chemical reaction.

Uses

1. **Sodium Chloride (NaCl):**
 - (a) To make food salty/As a flavouring agent
 - (b) In case of dehydration, an injection of Saline Water is given (0.9% NaCl).
2. **Potassium Nitrate:** In gunpowder and matchsticks
3. **Sodium Benzoate:** As a food preservative for pickles
4. **Sodium Carbonate:** As washing soda; in the manufacturing of glass
5. **Sodium Iodate:** To prevent goitre
6. **Calcium Carbonate:** Cement Industry
7. **Calcium Sulphate:**
 - (i) Plaster of Paris ($2\text{CaSO}_4 \cdot \text{H}_2\text{O}$) or $\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$
 - (ii) Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)
8. **Bleaching Powder:**
 - (i) Removing colours
 - (ii) As a disinfectant
9. **Potash alum or $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$:**
 - (i) As an antiseptic after shave
 - (ii) Purification of water
 - (iii) In the dyeing industry

More about Salts

Sodium Chloride or Common Salt

Sodium chloride (NaCl), also called common salt or table salt, is the most essential part of our diet. Chemically it is formed by the reaction between solutions of sodium hydroxide and hydrochloric acid. Sea water is the major source of sodium chloride where it is present in the dissolved form along with other soluble salts such as chlorides and sulphates of calcium and magnesium.

Sodium Chloride – Essential for Life

Sodium chloride is quite essential for life. Biologically, it has a number of functions to perform such as in muscle contraction, and in sending of nerve impulses in the nervous system. It is converted into hydrochloric acid in the stomach, which helps in the digestion of food. When we sweat, there is loss of sodium chloride along with water. It leads to muscle cramps. Its loss has to be compensated suitably by giving certain salt preparations to the patient. Electral powder (oral rehydration solution or ORS) is an important substitute of common salt.

Washing Soda ($\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$)

Washing soda has been known since very early times. It is primarily used for washing of clothes. Chemically, washing soda is sodium carbonate decahydrate ($\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$). In the anhydrous form (Na_2CO_3), it is called **soda ash** and has

been found to be present in the ashes of certain marine plants. In this form, it is found in the dry lakes of **East Africa, Egypt, USA** etc. In India, deposits of the salts are located mainly in **Dehradun, Mathura, Jaunpur** and a few other places.

Properties of Washing Soda

1. Washing soda is a white crystalline solid.
2. It is soluble in water and its solution in water is of alkaline nature (pH is more than 7). It turns red litmus paper blue.
3. Upon strong heating, it loses the molecules of water of crystallisation and changes to anhydrous salt, which is a white amorphous powder. It is called **soda ash**.
4. Washing soda has the property to remove dirt and grease from dirty clothes. That is why it is called washing soda.

Uses of Washing Soda

Washing soda or sodium carbonate is one of the most useful chemicals in industry. It is used

1. in the manufacture of glass, soap, paper and also chemicals like caustic soda (NaOH), borax ($\text{Na}_2\text{B}_4\text{O}_7$) and baking soda.
2. in the laundry for washing clothes and is a constituent of a number of dry soaps.
3. as a cleansing agent for domestic purposes.
4. for removing permanent hardness of water.
5. as a useful reagent in the laboratory.

Caustic Soda or Sodium Hydroxide (NaOH)

Sodium hydroxide, commercially known as caustic soda, is a very strong base. It is a starting material for many other chemicals and is also useful in the industry in a number of ways.

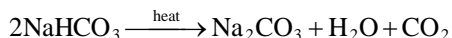
Uses of Caustic Soda:

1. In the manufacture of soaps, detergents, paper, rayon (artificial silk) and a large number of chemicals.
2. In cotton industry for mercerizing (or making unshrinkable) cotton fabrics.
3. In the refining of petroleum and also of vegetable oils.
4. In the preparation of soda lime (a mixture of NaOH and CaO).
5. as a cleansing agent for machines and metal sheets.
6. as a laboratory reagent.

Baking Soda (NaHCO_3)

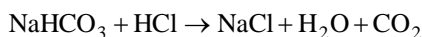
Baking soda, as the name suggests, is the major constituent of baking powder. Chemically, it is sodium hydrogen carbonate, also called sodium bicarbonate.

Baking Soda in Baking Powder: Baking soda, as the name suggests, is used in baking powder along with tartaric acid ($\text{C}_4\text{H}_6\text{O}_6$). Baking powder is normally added to the dough to be used for making cake or bread. When the dough is baked or heated, sodium hydrogen carbonate releases carbon dioxide gas.



The bubbles of the gas that escape leave behind pores which increase the size of the cake or bread and make it fluffy. Tartaric acid present in the baking powder neutralises sodium carbonate. In case it is not done, the cake will taste bitter. Moreover, sodium carbonate also has injurious side effects.

Baking Soda as antacid: The acidity in the stomach is caused due to the formation of excess of hydrochloric acid (HCl). Sodium hydrogen carbonate (baking soda) reacts with the acid because of its alkaline nature and neutralises this effect.



It, therefore, acts as an antacid and is the major constituent of antacid medicines along with **magnesium hydroxide**.

Baking Soda in fire extinguishers: Sodium hydrogen carbonate or baking soda is used in soda acid fire extinguishers.

It is in the form of a conical metallic vessel. A strong solution of NaHCO_3 is taken in a container. A glass ampoule containing H_2SO_4 and provided with a knob is placed inside the container. When required, the ampoule can be broken by hitting the knob. As a result, the acid will come into contact with sodium hydrogen carbonate. The two will react to evolve CO_2 gas. When enough pressure gets generated inside the container, the gas pushes the water solution, which escapes out of the nozzle with force and extinguishes fire.

Bleaching Powder (CaOCl_2)

Bleaching powder is one of the most useful bleaching agents, particularly for textile and paper. Chemically, bleaching powder is CaOCl_2 . It has been given different chemical names such as calcium oxychloride, calcium hypochlorite or chloride of lime.

Uses of Bleaching Powder:

1. for bleaching cotton, linen, wool, pulp etc.
2. for sterilisation of drinking water.
3. in rendering wool unshrinkable.
4. in the manufacture of chloroform.
5. as an oxidising agent in the laboratory.

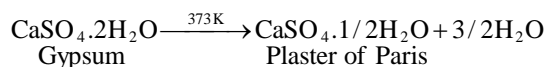
Plaster of Paris ($\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$)

Plaster of Paris, as the name suggests, has something to do with Paris. Actually it was initially prepared by heating gypsum, which was found in Montmatre in Paris. To start

with, it was mainly used in the construction industry, but nowadays a number of substitutes are available and Plaster of Paris is used for plastering fractured bones, making statues and moulds. It has application in covering the roofs and walls. It is known as POP.

Preparation of Plaster of Paris

Chemically, Plaster of Paris is **calcium sulphate hemihydrate ($\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$)**. It can be obtained by heating gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) carefully to a temperature of 373K in a kiln.



Uses of Plaster of Paris:

1. In making moulds or casts for toys, pottery, ceramics etc.
2. For covering the walls and roofs and for making designs on them.
3. In surgical bandages for setting fractured bones.
4. In the laboratory for making airtight apparatus by sealing the gaps.
5. For making fire-proof materials.

Hydrate salts (salts containing water of crystallisation)

Certain salts contain a definite amount of H_2O molecules loosely attached to their own molecules. These are known as hydrated salts and are of crystalline nature. The molecules of H_2O present are known as **water of crystallisation**. A few examples of hydrated salts are:

Salt	Commercial name	Chemical formula	Colour
Sodium carbonate	Washing soda	$\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$	White
Sodium borate	Borax	$\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$	White
Magnesium sulphate	Epsom salt	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	White
Calcium sulphate	Gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	White
Copper sulphate	Blue vitriol	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	Blue
Ferrous sulphate	Green vitriol	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	Green

Nature of everyday-use materials

Basic: Toothpaste, Whitewash, Washing Soda, Antacids (Milk of Magnesia)

Acidic: Vinegar; Soft drinks (Cola & Soda water); Tomato, Orange, Lemon Juice; Vitamin C; Bathroom Acid

Gas Laws

Charles's Law : The volume of a definite amount of any gas at constant pressure is directly proportional to the absolute temperature.

$$V \propto T \text{ or } \frac{V}{T} = K, \text{ where } K \text{ is a constant.}$$

$$\text{or } \boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$$

V = Volume

T = Temperature

Boyle's Law: The volume of a definite amount of any gas at constant temperature is inversely proportional to the pressure.

$$V \propto \frac{1}{P}$$

$$\text{or } PV = K \quad K = \text{Constant}$$

$$\text{or } \boxed{P_1 V_1 = P_2 V_2}$$

(P = Pressure, V = Volume)

Gaseous equation of state: It is obtained by combining both Boyle's and Charles's Law.

$$P \propto \frac{T}{V}, \text{ when } T \text{ and } V \text{ both vary.}$$

or $P = \frac{RT}{V}$ Where R is a constant called **universal gas constant**.

Or $\boxed{PV = RT}$ is called **gaseous equation of state**.

Graham's Law of Diffusion: A lighter gas diffuses quicker than a denser gas. The rate of diffusion of various gases is inversely proportional to the square roots of their densities at constant temperature and pressure.

$$\text{Rate of diffusion} \propto \sqrt{\frac{1}{\text{Density}}} \quad \text{or, } r \propto \sqrt{\frac{1}{d}}$$

$$\text{or, } \frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$$

Where r_1 = rate of diffusion of gas R_1

r_2 = rate of diffusion of gas R_2

d_1 = density of R_1 (R_1 = lighter gas)

d_2 = density of R_2 (R_2 = denser gas)

Absolute Temperature : The absolute temperature is equal to -273°C .

In terms of Kelvin, It is equal to **373K**.

Standard temperature and pressure (STP) or Normal temperature and pressure (NTP): 0°C or 273K is called standard temperature. 760 mm (76 cm) of Hg is called standard pressure.

Water gas: $\text{CO} + \text{H}_2$; It is used as a gaseous fuel.

Producer gas: $\text{CO} + \text{N}_2$; It is used as a substitute for petrol.

Biogas : The main component is **methane (CH_4)** and it is about 65%.

Solution

Classification of solutions

Types of solution	Examples
Solution of gas in gas	Air, the mixture of gases.
Solution of liquid in gas	Solution of gases like O_2 , CO_2 , NH_3 etc in water, cloud, mist, fog etc.
Solution of solid in gas	Solution of iodine in air, smoke etc.
Solution of gas in liquid	Solution of CO_2 in water (H_2O), solution of HCl gas in benzene (C_6H_6) etc.
Solution of liquid in liquid	Solution of alcohol in water, solution of bromine in carbon disulphide, solution of H_2SO_4 in water etc.
Solution of solid in liquid	Solution of sugar in water, solution of iodine in carbon tetrachloride, solution of lead in mercury, starch, gel, protein etc.
Solution of gas in solid	Solution of hydrogen in palladium metal.
Solution of liquid in solid	Solution of mercury in Thallium, solution of water in sugar, solution of water in salt etc.
Solution of solid in solid	Zinc in copper, tin in copper, aluminium in copper, solution (alloys) of zinc and nickel in copper.

Electrochemistry

Electrolysis: The process of decomposition or dissociation by passing electric current through liquified state of the substance (compound) or through its aqueous solution is called electrolysis.

Applications of electrolysis :

- (i) **In electroplating:** To give a low-quality metal long life and to make it attractive, a thin layer of good-quality metal is laminated on a low-quality metal by the process of electrolysis. This is called electroplating.
- (ii) **In electrotyping:** The blocks, graphics etc. in the printing industry are composed by the process of electrolysis. This is called electrotyping.
- (iii) **In electro-refining of metals:** Metals like copper, silver,

gold etc. are obtained in the pure form by the process of electrolysis. This is called electro-refining of metals.

- (iv) **In electro-metallurgy:** There are certain metals like sodium, potassium, aluminium, calcium, magnesium etc. that are extracted from their respective compounds by the process of electrolysis. This is called electro-metallurgy.
- (v) In the evaluation of equivalent weight of metals.
- (vi) **In the manufacturing of chemical compounds:** By the process of electrolysis, various types of drugs, organic and inorganic compounds are manufactured.

Examples: Caustic soda, hydrogen peroxide, chloroform, iodoform, ethane, acetylene etc. are produced by the above process.

Fuels

The substances which provide heat either alone or by combining and reacting with another are called fuels. Almost all fuels have a substantial amount of carbon within themselves and produce heat on burning in air. The gaseous fuels are most suitable and preferable to solid and liquid fuels.

Water gas: This is basically a molecular mixture of carbon monoxide (CO), hydrogen (H_2) and carbon dioxide (CO_2), while water (H_2O) and nitrogen (N_2) remain as impurities. This gas is produced by passing the current of water vapour on the superheated coke. The calorific value of water gas is more than producer gas. Water gas mixed with coal gas is used as a good fuel. It is also used in the preparation of hydrogen gas, which is useful in the industrial production of ammonia (NH_3). Methyl alcohol is also prepared from water gas.

Producer gas: This is basically the mixture of carbon monoxide (CO) and nitrogen (N_2), in which nitrogen and carbon monoxide are mixed by volume in the ratio of 2 : 1. Also, in it some CO_2 is found as impurity and the calorific value of the producer gas is the lowest among all fuels, but it is the cheapest fuel which provides extremely high temperature. In the manufacturing of glass and in metallurgy, this gas is used vigorously and frequently.

Natural gas: Natural gas is mainly composed of methane or CH_4 (83%) and ethane or C_2H_6 (16%), which are abundantly present at the exploration sites of the petroleum substance.

Due to the inflammable nature of methane, ethane and other simple hydrocarbons, the natural gas is used as the best fuel in the nature.

Fossils fuels

Coal: Coal is a very important type of fossil fuel which is found on comprehensive level inside the earth. It is mainly composed of 60-90% free carbon and its compounds. Besides, the compounds of nitrogen, sulphur, iron etc. are also present in small amounts.

There are four types of coal on the basis of amount of carbon present in them.

1. **Peat coal :** 50-60% carbon
2. **Lignite :** 60-70% carbon
3. **Bituminous :** 78-86% carbon
4. **Anthracite :** 94-98% carbon

Peat coal is a poor-quality coal. It is produced in the first phase of extraction. **Lignite** coal is also called brown coal. **Bituminous** coal is very soft and it is used for domestic purposes. It is about 80% of the total coal in the world. **Anthracite** is the best type of coal among all. On burning the anthracite coal, no smoke is produced and extremely large amount of heat is generated. Also, the anthracite coal is obtained in the last phase of coal extraction.

Petroleum: It is a brown-black liquid which has a special type of smell. Basically, it is composed of various hydrocarbons (solid, liquid and gas) and sulphur, whose

Liquid Petroleum Gas (LPG) and Compressed Natural Gas (CNG) are mixtures of ethane, propane and butane and their main components are **normal butane** and **iso-butane**. In domestic gas cylinders, normal butane and iso-butane burn very quickly and give out a good amount of heat. Actually, on increasing

Calorific value of the fuels: The calorific value of any fuel is the amount of heat obtained by the complete burning of 1 gram of the fuel in air or in oxygen. The heat produced or generated is expressed in calorie, kcal, or in Joule.

Periodic classification of elements

Mendeleev's classification of elements: In 19th century various attempts were made by chemists worldwide for the classification of the elements on the basis of their fundamental

The physical and chemical properties of the elements are the period functions of their atomic weights.

The modern periodic table was fabricated and composed by Moseley. He removed almost all discrepancies of Mendeleev's periodic table.

The diagram illustrates the periodic table with trends in metallic character. A vertical arrow on the left points downwards, labeled "METALLIC CHARACTER INCREASES". A horizontal arrow at the bottom points to the left, labeled "METALLIC CHARACTER INCREASES". The periodic table is color-coded: blue for groups 1-10, green for groups 11-18, and yellow for the transition elements (groups 3-10). The table includes element symbols and atomic numbers.

Group	1	2	Transition Elements										13	14	15	16	17	18
1st Period	1 H	2 He																
2nd Period	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3rd Period	11 Na	12 Mg	3	4	5	6	7	8	9	10	11	12	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4th Period	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
5th Period	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
6th Period	55 Cs	56 Ba	57 La*	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
7th Period	87 Fr	88 Ra	89 Ac**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	111 Ds	110 Rg	112 Cn	113	114 Uuq*	115 Uuq*	116 Uuq*	117	118

Chief characteristics of a period (Modern periodic table):

- (i) In the periodic table, in any period from left to right the metallic properties of the elements decrease, while non-metallic properties increase.
- (ii) In the periodic table, in any period from left to right chemical reactivities of the elements first decrease and then increase.
- (iii) In a period, the valency of the elements increases from 1 to 4 and then it diminishes and becomes 0.
- (iv) In a period, the atomic size of the elements decreases from left to right from 1 to 8.
- (v) Generally, in a period, the value of electron affinity increases from left to right.
- (vi) Also, in a period, the value of electronegativity of the elements increases from left to right.
- (vii) The value of ionization potential of the elements increases from left to right in a period.
- (viii) The size or atomic radius of the elements decreases from left to right in a period.

Chief characteristics of a group (Modern periodic table):

- (i) The metallic properties of the elements increase from top to bottom in a group.
- (ii) The chemical reactivities of the metallic elements increase from top to bottom in a group, while the chemical reactivities of the non-metallic elements decrease.
- (iii) The valency of the elements of any particular group is the same for all elements.
- (iv) The number of valence electrons are the same for all elements kept in a group.
- (v) The value of the electron affinity of the elements decreases from top to bottom in the group.
- (vi) Generally the value of electronegativity of the elements decreases from top to bottom in a group.
- (vii) The value of ionization potential of the elements decreases from top to bottom in a group.
- (viii) The size or atomic radius of the elements increases from top to bottom in a group.

Major facts about the elements

Total elements discovered	118
Elements existing in nature	88
Artificially produced (man-made) elements	27
Number of metallic elements	90
Number of non-metallic elements	22
The element found to be most abundant on the earth's surface	Oxygen
The lightest element	Hydrogen
The lightest metallic element	Lithium
The liquid metallic element	Mercury
The metal which is the best conductor of electricity	Silver
The metal which is the second best conductor of electricity	Copper
The most malleable element	Gold
The most reactive non-metallic element	Fluorine
The most reactive metallic element	Caesium
The most ionization-potential (IP) element	Helium
The most electro-negative element	Fluorine
The most powerful oxidising substance	Fluorine
The group of the most gaseous elements	Zero group
The most abundantly found element in the human body	Oxygen
The element kept inside kerosene oil	Sodium

Metals and Metallurgy

Metallurgy

Mineral: The natural solid materials containing compounds of metals in a combined state along with impurities and found abundantly beneath the earth's surface are called mineral.

Ore: Those minerals from which the metals are extracted commercially and economically are called ores of the metals. For example, bauxite ($\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$), Cuprite (Cu_2O) and Haemetite (Fe_2O_3) are the ores of Aluminium, Copper and Iron respectively.

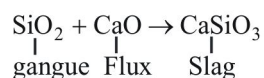
Gangue: The impurities associated with the minerals are known as gangue.

Flux: The material added to the ores to remove gangue is called flux.

Slag: The substance formed as a result of flux and gangue is known as slag.

$$\text{ie } \boxed{\text{Gangue} + \text{Flux} = \text{Slag}}$$

For example:



Alloy: It is the homogeneous mixture of two or more metals or metals and non-metals. Alloys have a lower melting point than the original metals.

Metals and their Ores

Metals	Ores	Formula
1. Iron (Fe)	Haemetite Magnetite	Fe_2O_3 Fe_3O_4
2. Uranium (U)	Pitchblende	U_3O_8
3. Lead (Pb)	Galena	PbS
4. Mercury (Hg)	Cinnabar	HgS
5. Zinc (Zn)	Calamine	ZnCO_3
6. Gold (Au)	Calaverite Silverites	AuTe_2 $[(\text{Ag}, \text{Au})\text{Te}_2]$
7. Sodium (Na)	Borax Chile Saltpeter	$\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ NaNO_3
8. Aluminium (Al)	Bauxite Corundum Cryolite	$\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ Al_2O_3 Na_3AlF_6
9. Calcium (Ca)	Dolomite Gypsum	$\text{CaCO}_3 \cdot \text{MgCO}_3$ $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
10. Magnesium (Mg)	Dolomite Epsom Salt	$\text{MgCO}_3 \cdot \text{CaCO}_3$ $\text{MgSO}_4 \cdot \text{H}_2\text{O}$
11. Potassium (K)	Nitre Carnalite	KNO_3 $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$

Metals

Metals have the capability to lose electrons and provide cations. They are located towards the left and in the middle in the periodic table.

- **Aluminium** is the most abundant metal in the earth's crust (8.3%).
- The combined states of the metals are called **minerals** while the free states are known as **native states**.
- The process of extraction of a particular metal from its ore is called **Metallurgy**.
- **Froth Floatation process** is used for the concentration of sulphide ores.
- The removal of impurities from a metal by chemical method is called **leaching**.
- **Calcination** is the heating of an ore below its melting point in the absence of air.
- **Roasting** is the heating of an ore below its melting point in excess of air.
- The reduction of a metal oxide with coke or carbon is called **smelting**.
- **Zone refining** and **van Arkel** method are used to get completely pure metals.

Magnesium (Mg)

Occurrence and extraction: Magnesium is the sixth most abundant element following calcium. It occurs as dolomite ($\text{MgCO}_3 \cdot \text{CaCO}_3$), magnesite (MgCO_3), epsomite ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$), etc. The metal magnesium doesn't exist in

nature in free state because it is highly reactive. It occurs in crystal rocks mainly as insoluble carbonates, sulphates and silicates. It also occurs about 0.13% in sea water as chloride and sulphate. The organic compound **chlorophyll**, which provides green colour to the leaves of the plants, has mainly magnesium in it.

Uses: The metal magnesium is used in making flashlight ribbon, in photography and in fire crackers, in the composition of alloys etc.

Alloys

Magnelium – Mg (2%), Al (95%), Cu-Fe (2-3%).

Duralumin – Al (94%), Cu (4%), Mg (0.5%), Zn (4.5%), Mn (0.5%).

Compounds

Magnesia (MgO): It is also called milk of magnesia. It is a white-coloured powder. It is slightly soluble in water and fluorescent to light. It is fused at a very high temperature; that's why it is used in layer linking of the blast furnace. It is also used in removing acidity from the human stomach.

Magnesium Hydroxide [$\text{Mg}(\text{OH})_2$]: It is a substance of white colour and slightly soluble in water. It is a base and is utilised in the production or extraction of sugar from molasses.

Magnesium Sulphate (MgSO_4): This compound naturally occurs in the form of Epsomite in Epsom, which is abundantly found in hot-water spring. It is a colourless crystalline solid substance. It is frequently utilised in cotton industry, in the manufacturing of soap, paint etc. It is also utilised as a catalyst with platinum in the production of sulphuric acid (H_2SO_4). It is used as a purgative and Epsom salt ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$) in a deliquescent compound.

Magnesium carbonate (MgCO_3): This compound occurs naturally in the form of magnesite or dolomite, which is a white solid substance soluble in water. It is utilised in the production of printing ink, toothpaste, face-cleaning powder etc. It is also used as magnesium alba in the form of drug in removing acidity from the human stomach.

Magnesium alba [$\text{Mg}(\text{OH})_2 \cdot \text{MgCO}_3 \cdot 3\text{H}_2\text{O}$]: This compound is used in removing acidity from the human stomach and it is in fact an antacid.

Beryllium (Be)

Uses: The important uses of beryllium are:

- Beryllium is used in the manufacture of many alloys. For example, copper-beryllium alloys are used in the preparation of high-strength springs.
- Metallic beryllium is used in making windows of X-ray tubes.

Calcium (Ca)

Uses: The important uses of calcium are:

- (i) It is used to remove traces of air from vacuum tubes since it has strong affinity for both nitrogen and oxygen.
- (ii) It is used to remove last traces of moisture from alcohol.
- (iii) Compounds of calcium such as limestone and gypsum are used as constituents of cement and mortar.
- (iv) When alloyed with lead, it is used for cable coverings. When alloyed with aluminium, it is used in casting and forging.

Some important compounds of Calcium

Calcium Oxide

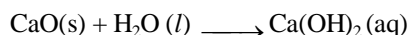
Preparation: It is prepared on a commercial scale by heating limestone (CaCO_3) in a special type of rotary kiln at 1070–1270K.

Properties

- (i) It is a white amorphous solid having melting point about 2870K.
- (ii) On exposure to atmosphere, it absorbs moisture and carbon dioxide.



The reaction with water is highly exothermic:



$$\Delta H = -64.5 \text{ kJ mol}^{-1}$$

Uses of calcium oxide

- (i) It is an important primary material and is the cheapest form of alkali.
- (ii) It is used in the manufacture of sodium carbonate from caustic soda.
- (iii) It is used as a flux in metallurgy.
- (iv) It is used in the **purification of sugar** and in the manufacture of dye stuffs.
- (v) It is used in drying gases and alcohol.
- (vi) It is used as a building material.

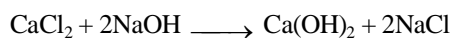
Calcium hydroxide or Slaked lime or Ca(OH)_2

Preparation

- (i) **From quicklime:** Calcium hydroxide is prepared by adding water to quicklime, CaO. This process is called slaking of lime.



- (ii) **From calcium chloride:** It can also be obtained by treating caustic soda with calcium chloride.



Uses of calcium hydroxide

- (i) Calcium hydroxide is used in the preparation of mortar.
- (ii) It is used as a **whitewash** due to its disinfectant nature.

- (iii) It is used for the **softening of hard water**.
- (iv) It is used for the detection of carbon dioxide as lime water.
- (v) It is used for absorbing acidic gases.
- (vi) It is used for preparing ammonia from ammonium chloride.
- (vii) It is used in **glass making**, tanning industry, for **preparation of bleaching powder** and for **purification of sugar**.

Calcium Carbonate or Limestone or Marble, CaCO_3

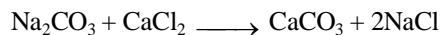
Calcium carbonate occurs in nature along with magnesium carbonate.

Preparation

- (i) **From slaked lime:** It can be prepared by passing carbon dioxide through slaked lime in a limited amount.



- (ii) **From calcium chloride:** It can be prepared by adding aqueous solution of sodium carbonate to calcium chloride.

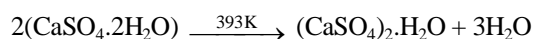


Uses of Calcium Carbonate (CaCO_3)

- (i) Calcium carbonate is used as a building material in the form of marble.
- (ii) It is used in the manufacture of quicklime.
- (iii) It is also used as a raw material for the manufacture of sodium carbonate in Solvay process.
- (iv) It is used as a flux in the extraction of metals such as iron.
- (v) Specially precipitated calcium carbonate is extensively used in the manufacture of high-quality paper.
- (vi) It is also used as **an antacid**, **a mild abrasive in toothpaste**, a constituent of chewing gum and a filler in cosmetics.

Plaster of Paris ($\text{CaSO}_4 \cdot \frac{1}{2} \text{H}_2\text{O}$ or $\text{CaSO}_4 \cdot \frac{1}{2} \text{H}_2\text{O}$)

Preparation: It is prepared by heating gypsum to 393K.

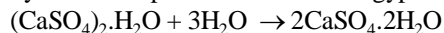


Thus, it contains one molecule of water for every two calcium and two sulphate ions. It may be noted that the temperature should not be allowed to rise because at 437K the whole of water is lost and the anhydrous salt left is called *dead burnt plaster*. It has no setting properties.

Properties

- (i) It is a white powder.
- (ii) On mixing it with water, it forms a plastic mass which sets into a hard solid in 5-15 minutes. This is called

setting of plaster of Paris. The setting is due to hydration of plaster of Paris into gypsum.



Gypsum

During setting, there is a slight increase in volume. This helps plaster of Paris to take the shape of any mould in which it is added.

Uses of plaster of Paris

- Plaster of Paris is used for producing moulds for pottery, ceramics, etc.
- It is used for making statues, models and other decorative materials.
- It is used in the building industry as well as plasters.
- It is used in surgical bandages known as plaster for setting broken and fractured bones in the body because it immobilises the affected part of the organ where there is a bone fracture or sprain.
- It is also used in dentistry.

Cement

Cement is one of the most important building materials. It was first introduced in England in 1824 by **Joseph Aspdin**. It is also called **Portland cement** because it resembles the famous building stone found near Portland in England. In India, the cement industry started in 1914. Now India is producing above 100 million tonnes of cement annually. Chemically, it is a finely ground mixture of calcium silicates and aluminates which set to a hard mass when treated with water.

Composition of Cement

The average composition of cement is:

CaO = 50-60%	MgO = 2-3%
SiO ₂ = 20-25%	Fe ₂ O ₃ = 1-2%
Al ₂ O ₃ = 5-10%	SO ₃ = 1-2%

For good-quality cement the ratio of silica (SiO₂) to alumina (Al₂O₃) should be between 2.5 and 4.0. Similarly, the ratio of lime (CaO) to the total oxide mixtures consisting of SiO₂, Al₂O₃ and Fe₂O₃ should be roughly 2 : 1. If lime is in excess, the cement cracks during setting. On the other hand, if lime is less than required, the cement is weak in strength. Therefore, a proper composition of cement must be maintained to get cement of good quality.

Manufacture of Cement

The main raw materials for the manufacture are *limestone* and *clay*. The former supplies lime while the latter is the source of silica, alumina and iron oxide.

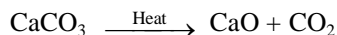
The process involves the following steps:

- The powdered limestone (3 parts) and clay (1 part) are mixed.
- The mixture is heated at about 1770-1870 K in a rotary kiln. In this kiln, the temperature varies between 1100-

1800 K.

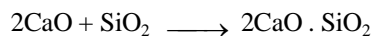
In this process, the following changes occur:

- Limestone decomposes to give lime and CO₂.



- Lime (obtained from limestone), alumina and silica (constituents of clay) react together to form a mixture of calcium silicate (2CaO.SiO₂, 3CaO.SiO₂) and calcium aluminate (3CaO.Al₂O₃, 4CaO.Al₂O₃).

The reactions taking place are:



Dicalcium silicate



Tricalcium silicate



Tetracalcium aluminoferrite

Due to very high temperature in this zone, about 20-30% mass melts and combines with solid mass to form pebbles known as **cement clinkers**.

The hot clinkers are cooled and are mixed with 2 to 3 per cent by weight of gypsum (CaSO₄.2H₂O). It is finely powdered and the powder is called Portland cement. The gypsum slows down the setting of cement so that it gets sufficiently hardened.

The important compounds present in Portland cement are:

Dicalcium silicate: (Ca₂SiO₄) : 26%

Tricalcium silicate (Ca₃SiO₅) : 51%

Tricalcium aluminate (Ca₃Al₂O₆) : 11%

Setting of cement: When cement is to be used, it is always mixed with water. It is an exothermic reaction and the cement recasts with water to form a gelatinous mass which slowly sets into a hard form.

Uses: Cement is used as an important constructional material. It is used in concrete and reinforced concrete, in plastering and in construction of buildings, bridges and dams.

After iron and steel, cement has become a commodity of national necessity for any country.

Aluminium (Al)

Occurrence and extraction: Aluminium doesn't occur in nature in free state but occurs in the forms of compounds like Bauxite (Al₂O₃.2H₂O), Corundum (Al₂O₃), Diaspore (Al₂O₃.H₂O), Felspar (K₂O.Al₂O₃.6SiO₂), Mica (K₂O.3Al₂O₃.6SiO₂.2H₂O), Kaolin (3Al₂O₃.6SiO₂.2H₂O), Cryollite (Na₃AlF₆) etc. **Aluminium is the most abundantly occurring metal on the earth crust.** After oxygen and silicon, this is the third element to occur in so large an amount. Its main ore is bauxite.

Alloys, compositions and uses

Alloys	Composition	Uses
Aluminium	Al (10%), Cu (90%)	In making kitchen utensils, coins etc
Magnalium	Al (95-96%), Mg (2%), CuFe (2-3%)	In the manufacturing of aircraft
Nickelloy	Al (90%), Ni (6%), Cu (4%)	In making aircraft
Duralium	Al (95%), Cu (4%), Mn (0.5%), Mg (0.4%)	In the manufacturing of aircraft and pressure cooker

Compounds

Alumina (Al_2O_3): It occurs in nature in the form of bauxite, corundum etc. It is also found in the form of **gems**. On a large scale it is manufactured by the bauxite ore. It is white, crystalline and soluble in water. Also, Al_2O_3 is an amphoteric oxide: it reacts with both acid and base.

Potash alum [$\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24 \text{H}_2\text{O}$]: It is a **double salt** which appears as a colourless crystalline solid. It is used in pulp-paper and leather industries, as an antiseptic and germicide after shaving, as a germicide for purification of water etc.

Aluminium hydroxide [$\text{Al}(\text{OH})_3$]: It is a white amorphous powder insoluble in water. It is a covalent compound. It is used in making **fire-proof and water-proof clothes**. In the name of aluminium gel, it is used as a drying agent.

Iron (Fe)

Occurrence and extraction: It is a transition metal. It doesn't occur in nature in a free state; it is found in the form of ore. It has fourth position among all the elements found on the

earth's crust. In nature it is also found abundantly in **green vegetables** and in the **haemoglobin** of blood. There are various ores which naturally occur in nature; they are mainly red haemetite (Fe_2O_3), brown haemetite ($2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$) and magnetite (Fe_3O_4).

Most of the iron is extracted from red haemetite (Fe_2O_3) in the blast furnace by carbon-reduction process.

Varieties of iron

Cast iron or Pig iron: In this variety of iron, the amount of carbon (2.5%) is comparatively high. That's why such iron is hard and brittle. Also, very small amount of impurities like phosphorous, silicon, manganese etc. are found in it. Such iron is of a lower quality. It is of two types: **white** cast or pig iron and **brown** cast or pig iron. In white cast iron, most amount of the carbon is in complex form, while in brown cast iron most amount of the carbon is confined in the form of micro crystals of graphite and distributed in the entire body. It is used in the manufacturing of steel, wrought iron and in foundry work. It is also used in making utensils, typewriter cover etc.

Wrought iron: It is obtained directly from cast iron or pig iron and it is comparatively a pure metallic iron. It is malleable and ductile; that's why foils, sheets and wires are made of it. The amount of carbon is very low (0.12 - 0.25%) in wrought iron.

Steel: It is basically **an alloy of iron and carbon**. In it the amount of carbon is less than that of cast or pig iron. Thus, in steel, the amount of carbon is 0.25 to 1.5%. There are usually four types of steel.

Tempering of Steel: When red hot steel is emerged in water or oil and quickly cooled then the steel becomes extremely strong and brittle. This process is called **hardening of steel** and this steel is called **quenched steel**. Again, if this steel be made to cool slowly and steadily, it becomes elastic and brittle.

Steel	Special composition	Special feature or properties	Uses
Stainless steel	Cr (12-15%)	Very hard and strong, doesn't form rust.	Used in making cooking utensils, surgical instruments, blades etc.
Manganese steel	Mn (6-15%)	Very hard, free from rusting.	Used in making railway tracks, switches, axles and cutting tools.
Chrome steel	Cr (5%)	Extremely hard and strong.	Used in making safe vaults, ball bearings, jaws of stone-crushing machine.
Nickel steel	Ni (3-4%)	Very hard and elastic, free from rusting.	Used in making axles, electric wire, aircraft, auto parts etc.
Tungsten steel	W (10-20%)	Very hard and strong.	Used in making springs, magnets saws, axles and cutting tools.
Chrome Vanadium steel	Cr (1-10%) V (0.15-0.5%)	Has high tensile Vanadium steel strength and load-bearing capacity.	Used in making ball bearings, gears and axles.

Silver (Ag)

Silver chloride (AgCl): It is called Horn silver and is frequently used in making **photochromatic glass**.

Silver nitrate (AgNO₃): It is the main compound of silver and is also called **Lunar Caustic**. It is prepared by the reaction of silver on hot and dilute HNO₃. It is a white crystalline substance whose melting point is 214°C. It is extremely soluble in water. It is used as laboratory reagent, in making hair dyes, in electroplating of silver compounds, in making special ink which is used by washermen in marking clothes and as voter marker on the finger.

Eating egg from a silver spoon is dangerous because silver directly reacts with the sulphur of the egg and forms black-coloured silver sulphide (Ag₂S), which damages the spoon.

Gold (Au)

Occurrence and extraction of gold: It occurs as metal in nature as well as in the forms of its ores. Some important ores of the gold are calaverite (AuTe₂), sylvanite (Ag, Au)Te₂ etc. Gold is also recovered from auriferous quartz and from alluvial auriferous sands. This is extracted from auriferous sand by the amalgamation process.

Physical and chemical properties of gold: It is a golden-yellowish solid substance insoluble in any individual acid like HCl, HNO₃, H₂SO₄ etc. but soluble in aqua regia and NaCN solutions. It is the most malleable of all metals.

Compounds

Auric chloride (AuCl₃): It is a brownish-yellow crystalline solid substance moderately soluble in water and forms a golden yellow solution. It is used in making **antidote for snake poisoning**, in preparation of gold fulminate, purple of cassius, colloidal gold etc.

Rolled gold [Cu (90%), Al (10%)]: It is an artificial form of gold which resembles gold and is utilised in making cheap ornaments. In the electroplating process of gold, potassium aurocyanide is utilised as an electrolyte.

Zinc (Zn)

Physical and chemical properties: It is a bluish white, hard and brittle metallic substance. The m.p., b.p. and specific density of zinc are 419°C, 920°C and 7.1 respectively. At normal temperature it is neither malleable nor ductile. It is a good conductor of heat and electricity.

Uses: It is used in the laboratory in the preparation of ZnS gas. It is also used in the **galvanization of iron sheets** to protect iron from rusting. Buckets, boxes and many household articles are made from these sheets. Zinc is used in making alloys like brass, bronze, german silver, and coins. It is also used in the extraction of gold, and in the production of **smokescreen** in battle fields.

Compounds

Zinc sulphate (ZnSO₄): Hydrated zinc sulphate (ZnSO₄·7H₂O) is called **white vitriol**. It is a colourless crystalline solid substance soluble in water.

It is used in textile industry for soaking cotton threads before spinning, in making the preserver of wood, in the manufacturing of **lithopone**, in calico printing and dye industries.

Zinc oxide (ZnO): It is an amphoteric oxide. It is also called **philosopher's wool**.

Lithopone (ZnS + BaSO₄): The mixture of zinc sulphide (ZnS) and barium sulphate (BaSO₄) is called Lithopone. It is obtained by the reaction of ZnSO₄ and barium sulphide (BaS). It is a white pigment which is used to prepare white paint and this paint doesn't turn black because atmospheric H₂S has no action on it.

Zinc sulphide (ZnS): It occurs in nature in the form of zinc blende. It is a white solid substance which is insoluble in water. It exhibits the virtue of **phosphorescence** and that's why it is utilised in making phosphorescent screens.

Zinc phosphide (ZnP): It is used as rat poison.

Mercury (Hg)

Occurrence and extraction: Mercury, also called **quick silver**, is not found abundantly in free state. It occurs in the form of ores. The main ore of mercury is **cinnabar (HgS)**. Mercury is extracted from cinnabar by carbon reduction process.

Physical and chemical properties: Mercury is a white shining metal like silver which occurs in liquid state at ordinary temperature. It is a good conductor of heat and electricity. On mixing it with fats or sugar and shaking it vigorously, a grey powder is formed. This is called **deadening of mercury**. Mercury is neither malleable nor ductile. At 4.12K its electrical resistance is gone completely and it becomes a superconductor.

Mercuric sulphide (HgS): It is also called **vermillion**, which is a red solid crystalline substance. It is insoluble in water and acid. But it dissolves easily in aqua regia and forms mercuric chloride (HgCl₂). It is used in making medicines, in preparing **water colours** etc.

Amalgam

An **amalgam** is a combination of metals in which one metal is mercury (Hg). The normal combination of metals is called **alloy**.

The metal mercury is kept inside an iron pot (container) because it doesn't form amalgam with iron.

Usually a tubelight is filled up with **mercury vapour** and **argon gas**.

The immediate rise and fall of mercury reading in barometer is an indicator of clear weather and predicts the occurrence of cyclone.

Lead (Pb)

Occurrence and extraction: Lead occurs in nature mainly in the form of its ores. There are various ores of it which exist in nature such as galena (PbS) and anglesite (PbSO₄). The main ore is galena (PbS), from which lead is extracted by self-reduction process. Lead is the **most stable element** among all the elements.

Compounds

Lead Oxide (PbO): It is a volatile yellowish compound which is called **litharge**. It is an amphoteric oxide and is used in **rubber industry**, in the manufacture of **flint glasses** and storage batteries.

Lead dioxide (PbO₂): It is a chocolate-coloured insoluble powder and it is used in match industry for making **ignition surface of match boxes**, used for preparation of KMnO₄.

Tri-plumbic tetraoxide (Pb₃O₄): It is also called **red lead** and is used in making **red paint**, **flint glass**, red-lead element etc.

Lead acetate [Pb (CH₃COO)₂]: It is also called **sugar of lead**. It is a white crystalline sugar-like substance soluble in water and its crystals are sweet in taste. It is also called **inorganic sugar**. It is used as a laboratory reagent to examine chloride, sulphide and sulphate radicals. Lead acetate paper is used to detect the presence of H₂S and as a mordant.

Lead carbonate Pb(CO₃): It is also called white lead due to its white colour. It is insoluble in water but soluble in HCl and HNO₃. It is basically used in making white pigment.

Lead tetraethyl [Pb (C₂H₅)₄]: It is a colourless liquid having a special smell. It is soluble in petrol and is used as an antiknock agent. When a very small quantity of it is added to petrol, the knocking given by petrol in internal combustion engines is suppressed. Petrol mixed with tetraethyl lead is coloured red with an organic dye to distinguish it as a motor fuel.

Alloy	Composition
Type metal	Pb (75%), Sb (20%) and Sn (6%)
Solder	Sn (50-70%) and Pb (50-30%)

Uranium (U)

Occurrence and extraction: It is a rarely found element in nature and it doesn't occur in free state. Almost all its minerals are radioactive. The main ore of uranium is **pitchblende**.

Uses of Uranium: Uranium carbide is used as a catalyst in the production of ammonia (NH₃) by **Haber's process**. Uranium is used in the production of **nuclear energy**. It is used in the production of alloys and as electrodes in gas discharge device. The nitrate, chloride etc. of uranium are utilised in drug-manufacturing industries. The nitrate and acetate of uranium are used in photography etc.

Isotopes of Uranium: There are three isotopes of

uranium: ⁹²U²³⁴, ⁹²U²³⁵ and ⁹²U²³⁸. The most abundantly occurring Uranium in nature is ⁹²U²³⁸ (99.28%) while ⁹²U²³⁵ (0.71%) and ⁹²U²³⁴ (0.006%) occur in very small amounts. The isotope ⁹²U²³⁵ is used in nuclear or atomic reactor as a nuclear fuel.

Plutonium (Pu)

Plutonium is a heavy radioactive element (metal) and is the most active member of Actinium radioactive series. It is in fact not a naturally existing element but formed artificially and specially utilised in the **nuclear fission bomb**. In most nuclear reactors or atomic reactors of the world, about 20 ton plutonium is used. Two cities of Japan, **Hiroshima and Nagasaki**, during were destroyed completely during World War II by **nuclear fission bombs (atom bombs)** and in these bombs plutonium was used.

Tungsten (W)

The symbol of Tungsten is W and its m.p. is 3500°C. Tungsten is produced from **Degana mines of Rajasthan**.

Manganese (Mn)

Compounds

1. **Manganese Dioxide (MnO₂):** It is used in dry cells.
2. **Potassium Permanganate (KMnO₄):** It is called red medicine. It is used as a bleaching agent for wool and silk. It is also used as colour remover of oils and as germicide or insecticide of water.

Copper (Cu)

Copper is extracted mainly from **copper pyrites (CuFeS₂)**. It is used in making household utensils, alloys and coins, so it is also called coinage metal.

Alloys of Copper		
Alloys	Composition	Uses
Brass	Cu (70%), Zn (30%)	Used in making idols, utensils
Bronze	Cu (88%), Sn (12%)	Used in making coins, bells
German Silver	Cu (60%), Zn (25%), Ni (15%)	Used in making idols, jewellery
Rolled Gold	Cu (90%), Al (10%)	Used in making jewellery
Gun Metal	Cu (88%), Sn (10%), Zn (2%)	Used in making gun, parts of machine
Bell Metal	Cu (80%), Sn (20%)	Used in making bells, idols, coins

1. **Cuprous Oxide (Cu_2O)**: Used in making **ruby glass** (due to its red colour).
2. **Cupric Sulphate (CuSO_4)**: It is called **Blue Vitriol** or ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$). It is used in preparing **green dyes** and also in electroplating and electric cells.

Platinum (Pt)

Platinum is called **white gold**. It is also called **Adam's catalyst**. It is used in making ornaments and the tip of the nozzle of the pen.

Thorium (Th)

Thorium is used in the production of nuclear energy. It is used as **X-ray targets** and glow tube targets.

Germanium (Ge)

Uses: Germanium has largest use in **transistor technology**, in making **transistors** and other **semiconductor** devices. It is transparent to infrared light and is therefore also used for making **prisms** and **lenses** and window in infrared spectrometers and other scientific apparatus.

Tin (Ti)

Uses: Because of low strength and high cost of tin, it is rarely used by itself, but it is used for electroplating and as alloys. Tin plates obtained by electroplating steel with tin are extensively used for making cans, for food and drinks. It is used in the preparation of a number of important alloys such as **solder** (Sn/Pb or Cu/Pb/Sn/Sb), **pewter** (Pb/Sn/Sb/Cu), **type metal** (Pb/Sn/Sb), etc.

Non-Metals

There are non-metals in which there are 11 gases, 1 liquid and 10 solids. (Bromine (Br) occurs in liquid state).

Hydrogen (H)

Hydrogen is the lightest element. Its atomic no. is 1. It is the first element of the periodic table.

Uses of Hydrogen

1. In the hydrogenation of edible oils such as groundnut oil, cotton seed oil etc. to form vegetable ghee, also called **margarine**.
2. In the manufacture of compounds like ammonia, water gas ($\text{CO} + \text{H}_2$) and methyl alcohol (CH_3OH).
3. As a rocket fuel in liquefied form.
4. In the manufacture of hydrochloric acid.

Water

Water is essential for all forms of life. It is the most common, abundant and easily obtainable of all chemical compounds. It is a solvent of great importance and is regarded as a *universal solvent*. It is the most studied of all chemical compounds. It can be easily transformed from liquid to solid and to gaseous state. It is the principal constituent of the earth's surface. It is an important compound of animal and vegetable matter and plays a vital role in their life processes. Water constitutes about 65% of our body and is an essential for its growth. We can live without food for some days but cannot live without water. Some plants have about 95% water.

Distribution of water over the earth's surface

Water is the principal constituent of earth's surface. The distribution of water over the earth's surface is not uniform. There is no permanent surface water in desert regions while the oceans cover vast areas of 78% of the earth surface, i.e., $1.61 \times 10^8 \text{ km}^2$. They contain 97% of the available water. Fresh water amounts to only 2.7%. Most of it is locked in Antarctic ice cap and in the Arctic. Antarctic ice cap covers $1.5 \times 10^7 \text{ km}^2$ and contains $2.5 - 2.9 \times 10^7 \text{ km}^3$ of fresh water.

Freshwater lakes contain $1.25 \times 10^5 \text{ km}^3$ of water and more than half of it is in the four largest lakes: Baikal ($26,000 \text{ km}^3$), Tanganyika ($20,000 \text{ km}^3$), Nayassa ($13,000 \text{ km}^3$) and Superior ($12,000 \text{ km}^3$). Fresh water is also present in many other smaller lakes, springs and rivers. The purification and recycling of water has now become a major industry. The production of fresh water from sea and other saline water has been commercialised.

The estimated source water

Source	Percentage of total
Oceans	97.33
Saline lakes and Inland seas	0.008
Polar ice and glaciers	2.04
Ground water	0.61
Lakes	0.009
Soil moisture	0.005
Atmospheric water vapour	0.001
Rivers	0.0001

Apart from water, hydrogen and oxygen form another oxide, namely **hydrogen peroxide**, which has the molecular formula H_2O_2 .

Physical properties of water

Many of the properties of water are due to hydrogen bonding in their molecules.

The important physical properties of water are:

- (i) Water is liquid with freezing point of 273.2 K and boiling point of 373.2 K.
- (ii) **Water has maximum density of 1.00 g cm^{-3} at 277 K (4°C).**
- (iii) Water has strong hydrogen bonding in its molecules and exists as associated molecules, $(\text{H}_2\text{O})_n$.
- (iv) Water is polar in nature having dipole moment of 1.84D. It has solubility for a variety of substances and is regarded as a **universal solvent**.

Heavy Water (D_2O)

Chemically heavy water is **deuterium oxide** (D_2O). It was discovered by Urey in 1932. He showed that ordinary water contains small proportion (about 1 part in 5000) of D_2O . It can be prepared by the prolonged electrolysis of water. When water is electrolysed, H_2 (hydrogen) is liberated much faster than D_2 (deuterium) and the remaining water becomes enriched in heavy water, D_2O . If the process is continued until only a small volume remains, then almost pure D_2O is obtained. It has been estimated that about 29,000 litres of water must be electrolysed to get one litre of D_2O that is 99% pure.

Like ordinary water, heavy water is colourless, odourless and tasteless liquid. The physical constants of heavy water are generally slightly higher than ordinary water (H_2O). This is quite expected because the molecular mass of heavy water is greater than that of ordinary water.

Uses of heavy water

1. **As a moderator:** Heavy water has been finding use in *nuclear reactors* as a **moderator** because it slows down the fast-moving neutrons and, therefore, **helps in controlling the nuclear fission process**.
2. **As a tracer compound:** Heavy water has also been used as a tracer compound to study mechanism of many chemical reactions.
3. **In nuclear magnetic resonance:** Heavy water is used as one of the references in nuclear magnetic resonance spectroscopy.
4. **For the preparation of deuterium:** Heavy hydrogen or deuterium can be obtained by the electrolysis of heavy water or by its decomposition by Na metal.

Hard and Soft Water

Natural water contains dissolved salts. Depending upon its

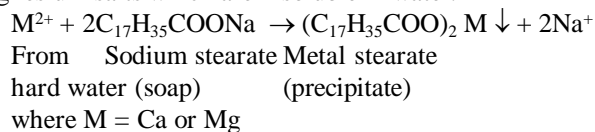
behaviour towards soap solution, water may be classified as *soft water* or *hard water*.

(a) **Soft water:** Water which produces lather with soap solution readily is called **soft water**. For example, distilled water and demineralised water.

(b) **Hard water:** Water which does not produce lather with soap solution readily is called **hard water**.

Cause of Hardness of Water

The hardness of water is due to the presence of the bicarbonates, chlorides and sulphates of calcium and magnesium. These salts dissolve in water when it passes through the grounds or rocks. Hard water does not produce **lather** because the cations (Ca^{2+} and Mg^{2+}) present in hard water react with soap to form insoluble precipitates. **Soaps are sodium salts of higher fatty acids like stearic acid ($\text{C}_{17}\text{H}_{35}\text{COOH}$).** When soap is added to hard water, these anions combine with Ca^{2+} and Mg^{2+} ions to form calcium and magnesium salts which are insoluble in water.



Therefore, no lather is produced until all the calcium and magnesium ions are precipitated. This also results into wastage of a lot of soap.

Therefore, hard water is unsuitable for laundry washing and dyeing. In addition, hard water is also harmful for steam boilers. The inner surface of the boiler gets crusted with scale known as *boiler scale*. It is mainly calcium sulphate, calcium carbonate and magnesium oxychloride. The deposition of scale decreases the efficiency of the boiler and also damages it. Therefore, hard water should not be used in boilers.

Type of Hardness of Water

The hardness of water is of two types: temporary hardness and permanent hardness.

(a) **Temporary hardness:** This type of hardness in water is due to the presence of *bicarbonates of calcium and magnesium dissolved in it*. The hardness is called temporary because it can be very easily removed by simply boiling the hard water for some time. Temporary hardness is also called **carbonate hardness**.

(b) **Permanent hardness:** This hardness is due to the presence of chlorides and sulphates of calcium and magnesium dissolved in water. Since the hardness cannot be easily removed, it is therefore, called permanent hardness. The permanent hardness is also called **non-carbonate hardness**.

Softening of Water

The process of the removal of hardness from water is called **softening of water**.

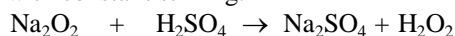
Hydrogen Peroxide (H₂O₂)

Hydrogen peroxide was discovered by a French chemist **JL Thenard** in 1818. Its molecular formula is H₂O₂.

Preparation of hydrogen peroxide

Hydrogen peroxide can be prepared in the laboratory by the action of cold, dilute sulphuric acid on sodium or barium peroxide.

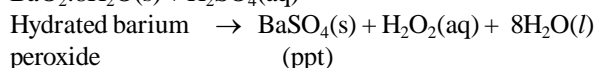
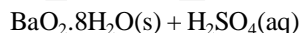
(a) **From sodium peroxide (Merck's process):** Hydrogen peroxide is prepared by adding calculated amounts of sodium peroxide to ice-cold dilute (20%) solution of sulphuric acid. The addition is carried out slowly in small amounts with constant stirring.



Sodium peroxide

Upon cooling, crystals of Na₂SO₄·10H₂O separate out. The crystals of Na₂SO₄·10H₂O are decanted, leaving behind solution of hydrogen peroxide. In this method, 30% hydrogen peroxide is obtained.

(b) **From barium peroxide:** Hydrogen peroxide was first prepared by JL Thenard in 1818 by acidifying barium peroxide and removal of excess water by evaporation under reduced pressure. In this method, a paste of hydrated barium peroxide is prepared in ice-cold water and is treated with about 20% ice cold solution of sulphuric acid.



Uses of Hydrogen Peroxide

1. It is used in industry as a **bleaching** agent for textiles, paper, pulp, straw, leather, oils, fats, etc.
2. Domestically, it is used as a **hair bleach** and as a mild disinfectant.
3. It is used in the manufacture of many inorganic compounds such as sodium perborates and percarbonates which are important constituents of high-quality detergents.
4. It is used as an **antiseptic** for washing wounds, teeth and ears under the name *perhydrol*.
5. It is used for the production of epoxides, propylene oxide and polyurethanes.
6. It is used for the synthesis of hydroquinone, pharmaceuticals (cephalosporin), and food products like tartaric acid.
7. It is used as an antichlor in bleaching.
8. It is used for restoring the colour of lead paintings.
9. It is used for **preserving milk, wine and other liquors**.
10. Recently, H₂O₂ is being used in environmental chemistry such as in **pollution control**, treatment of domestic and industrial effluents, oxidation of cyanides and restoration of aerobic conditions to sewage wastes.

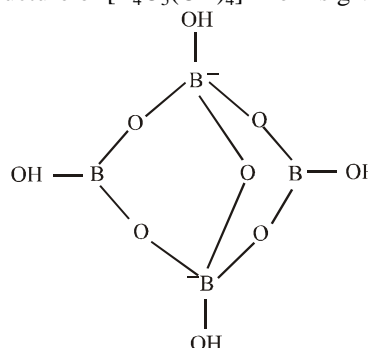
Boron (B)

Some important compounds of Boron

Borax or **sodium tetraborate** is an important compound of boron. It occurs naturally as tincal (*suhaga*) in certain dried-up lakes of India, Tibet, Ceylon and California.

Borax contains the tetranuclear units [B₄O₅(OH)₄]²⁻ and, therefore, its correct formula is Na₂[B₄O₅(OH)₄·8H₂O].

The structure of [B₄O₅(OH)₄]²⁻ ion is given below:



Uses of Borax

- (i) Borax is used in the laboratory for borax bead test.
- (ii) It is used in the manufacture of **enamels and glazes** for earthen pots.
- (iii) It is used in the candle industry.
- (iv) It is used in the preparation of **medicinal soaps** due to its antiseptic character.
- (v) It is used in making **optical glass**.
- (vi) It is used in **softening of water and cleansing agent**.

Orthoboric acid, H₃BO₃:

Boric acid is trivial name for orthoboric acid.

Uses of boric acid

- (i) Boric acid is used in the manufacture of enamels and pottery glazes.
- (ii) It is used as a **food preservative** in food industry.
- (iii) It is used in the manufacture of **pigments and borax**.
- (iv) It is used in medicines as an **eyewash**.

Phosphorus (P)

Occurrence: It is found in rocks, minerals and animal bones. It exists in several allotropic forms, two of which are well known: red phosphorus and white phosphorus. **Red phosphorus is used in safety matches.** Phosphorus is present in DNA and RNA besides being present in bones and teeth.

Elemental phosphorus exists in two major forms — White Phosphorus and Red Phosphorus — but due to its high reactivity, phosphorus is never found as a free element on Earth. White phosphorus emits a faint glow upon exposure to oxygen — hence its name was given light-bearer (**Lucifer**), referring to **morning star** (the planet Venus). The

term 'phosphorescence' means glow after illumination. A vast majority of phosphorus compounds are consumed as fertilizers. Other uses are in detergent, pesticides and manufacturing.

Red phosphorus may be formed by heating white phosphorus at 250°C or by exposing white phosphorus to sunlight.

Violet phosphorus is a form of phosphorus that can be produced by daylong annealing of red phosphorus above 550°C. Black phosphorus is the least reactive allotrope and the thermodynamically stable form below 550°C. Its structure resembles that of graphite.

Phosphorus is not found free in nature, but it is widely distributed in many minerals, mainly phosphate. Phosphate rock, which is partially made of **apatite**, is an important commercial source of this element. About 50% of the global phosphorus reserves are in the **Arab nations**.

Matches: Phosphorus-containing matches were first produced in the 1830s and contained a mixture of white phosphorus, an oxygen-releasing compound (potassium chloride, lead dioxide or sodium nitrate) and a binder in their heads. They were rather sensitive to storage conditions, toxic and unsafe, as they could be lit by striking on any rough surface. Therefore their production was gradually banned.

Later '**Strike anywhere**' matches were gradually replaced by '**Safety matches**', where white phosphorus was substituted by phosphorus sesquisulphide (P_4S_3), Sulphur or Antimony Sulphide. Such matches are hard to ignite on an arbitrary surface and require a special strip. The strip contains red phosphorus which heats up upon striking, reacts with the oxygen-releasing compound in the head and ignites the flammable material of the head.

Uses

1. Phosphates are utilized in the making of special glasses that are used for **Sodium lamps**.
2. Bone ash (Calcium Phosphate) is used in the production of **bone china**.
3. Phosphoric acid, made from elemental phosphorus, is used in food applications such as some **soda beverages**.
4. White Phosphorus, called 'WP' (Slang term "Willie Peter"), is used in military applications as incendiary bombs, for **smoke screening**, as smoke pots and **smoke bombs**.

Functions: The main function of phosphorus is in the formation of bones and teeth. It plays an important role in the body's utilization of carbohydrate and fats and in the synthesis of protein for the growth, maintenance and repair of cells and tissues. It is also crucial for the production of ATP (Adenosine Triphosphate), a molecule the body uses to store energy. Phosphorus works with vitamin B. It also assists in the **contraction of muscles**, in the functioning of kidneys, in maintaining the regularity of heartbeat and in **nerve conduction**.

Sulphur (S)

It is a non-metallic element which occurs in many allotropic forms. It is mined by a special technique called **Frasch Process**. It is used for **vulcanizing of rubber** and in the manufacture of dyes and explosives. Sulphur is a multivalent non-metal. It is a yellow crystalline solid. Sulphur is infamous for its smell, frequently compared to **rotten eggs**. Compounds of Sulphurs are very useful as medicines, drugs and insecticides. The most important compound of Sulphur is Sulphuric Acid (H_2SO_4). Sulphur is used in batteries, detergents, fungicides, **gunpowder**, matches and **fireworks**. Other applications are making corrosion-resistant concrete, which has great strength.

Sulphur is found in all living organisms where it forms part of the amino acids **cysteine** and **methionine** and also other proteins. Proteins like **Keratin** (found in hair, feathers, nails and claws) are rich in sulphur. Some bacteria can make use of sulphur. Some bacteria can make use of sulphur compounds, producing **hydrogen sulphide or rotten-eggs gas (H_2S)**. This gas may be produced by the breakdown of organic matter in swamps or sewers.

Uses

1. Sulphur reacts with methane (CH_4) to give Carbon Disulphide (CS_2), which is used in the manufacturing of **cellophane** and **rayon**.
2. One of the uses of Sulphur is in **Vulcanization of rubber**.
3. Sulphides are used to bleach paper and as **preservatives of dried fruit**.
4. **Gypsum** ($CaSO_4 \cdot 2H_2O$) is mined for the use in **portland cement** and **fertilizer**.
5. Sulphur is one of the components of **gunpowder**.
6. The most important form of sulphur for fertilizer is the mineral **Calcium Sulphate**.
7. **Epsom Salt** (Magnesium Sulphate), when in hydrated crystal form, can be used as a **laxative** and additive.
8. **Dusting sulphur**, elemental sulphur in powdered form, is a common fungicide for grapes, strawberry and several other crops.
9. In organic production, sulphur is the most important **fungicide**. It is the only fungicide used in organically formed apple production against the main disease apple scab.

Important: The burning of coal and petroleum by industry and power plants generates sulphur dioxide (SO_2), which reacts with atmospheric water and oxygen to produce Sulphuric Acid (H_2SO_4) and Sulphurous Acid (H_2SO_3). These acids are components of **acid rain**, which lowers the pH of soil and fresh water bodies, something resulting in **chemical weathering** of statues and structures.

Nitrogen (N)

It is about **78% in atmospheric air**. Plants and trees take nitrogen in the form of nitrate from the soil. **Nitrogen is used in artificial insemination of cows** for which the sperm of bull is kept in it. Nitrogen is also present in urea. **About 46% of urea is nitrogen**. Nitrogen does not have any allotropes.

Nitrogen Fixation in Plants : In leguminous plants, in the joints of the roots, **rhizobium** bacteria helps in nitrogen fixation.

Compounds

1. **Ammonia (NH₃) :** It is prepared in the laboratory by **Haber process**. At high pressure, when ammonia is heated with carbon dioxide, urea is formed. Liquefied ammonia is used in freezing water in the refrigerators.
2. **Ammonium Chloride (NH₄Cl):** It is used in dry cells.
3. **Nitrous Oxide (N₂O):** It is also called **laughing gas**. N₂O is used as **anaesthesia**.
4. **Aquaregia (Conc. HNO₃ + 3 Conc. HCl):** This is a mixture of one part conc. HNO₃ and three parts conc HCl by volume. In aqua regia, gold, platinum and silver easily dissolve, which ordinarily do not dissolve in strong acids.

Facts

1. **Hydrazine (NH₂)** is used as fuel for rockets and aircraft.
2. **HNO₃** (Nitric acid) is used in the manufacture of explosives like Dynamite, TNT (trinitrotoluene) and TNB (trinitrobenzene).

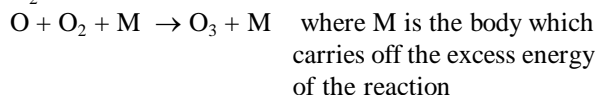
Oxygen (O)

It is prepared in the laboratory by heating potassium chlorate (KClO₃) in the presence of a catalyst MnO₂ at 375°C.

Ozone

It is an allotrope of oxygen. It is a very active gas. The ozone layer is a layer in the upper sphere, 10-50 km above the earth's surface. Ozone, the first allotrope of any chemical element, was named by **Christian Friedrich Schoanbein** in 1840. **Ozone is a pale blue gas**, slightly soluble in water. It is responsible for absorbing a large proportion of the sun's UV (ultra-violet) radiation which is otherwise harmful. It also causes cancer.

The unit to express ozone in Earth's atmosphere is called **Dobson unit**. The highest levels of ozone in the atmosphere are in the **stratosphere**. Ozone in the stratosphere is mostly produced from short-wave ultraviolet rays reacting with oxygen.



In recent decades the amount of ozone in the stratosphere has declined, mostly because of the emissions of CFCs (chlorofluorocarbons) and similar other chlorinated and brominated organic molecules, which have increased the concentration of ozone-depleting catalysts.

UV absorption in ozone layer is important. The small unabsorbed part that passes through ozone causes sunburn in humans and direct damage to DNA, both in human and in plants. However, **UV-B radiation** is responsible for the production of Vitamin D in humans. There is evidence of significant reduction in agriculture yields because of increased ground-level ozone and pollution, which interferes with photosynthesis and reduces overall growth of some plant species.

Ground-level ozone pollution (tropospheric ozone) is created near the Earth's surface by the action of daylight-UV rays on a group of pollutants (pollutants emitted during the combustion of fossil fuels). The ozone at ground level comes primarily from fossil fuel precursors, but methane (CH₄) is a natural precursor. There are a lot of evidences to show that ground-level ozone can harm lung function and irritate the respiratory system. Exposure to ozone and the pollutants that produce it is linked to premature death, asthma, bronchitis, heart attack etc.

The air quality guidelines, such as those from WHO (World Health Organisation), the EPA (The United States Environmental Protection Agency) and the European Union are based on detailed studies designed to identify the levels that can cause measurable ill health effects. The EPA has developed an Air Quality Index to help explain pollution levels for the general public. Under the current standards, 8-hour average ozone mole fractions of 85 to 104 n mol/mol are described as '**unhealthy for sensitive group**', 105 n mol/mol to 124 n mol/mol as **unhealthy** and 125 n mol/mol to 404 n mol/mol as **very unhealthy**.

Corona discharge method is the most common type of ozone generator for most industrial and personal uses. Another method to produce ozone is known as **Cold Plasma**. In the cold plasma method, pure oxygen gas is exposed to plasma created by dielectric barrier discharge. **Ozone cannot be stored** and transported like other industrial gases (because it quickly decays into diatomic oxygen) and therefore it must be produced on the site of requirement itself.

Use: Ozone is used in the preparation of pharmaceuticals and synthetic lubricants. It can also be used for bleaching substances and for killing micro organisms in air and water sources. **Many municipal drinking water systems kill bacteria with ozone instead of the more common chlorine (Cl₂)**. Industrially ozone is used to disinfect laundry in hospitals, food factories, care homes. It is used to sanitize swimming pools and spas, and kill insects, bacteria and yeast.

Halogens

Halogen means salt producer. Halogens are Fluorine (F) Chlorine (Cl), Bromine (Br), Iodine (I) and Astatine (At). Iodine **exhibits the characteristics of metalloid**, because it has a metallic lustre.

Chlorine (Cl)

Bleaching powder and chloroform are compound of chlorine. Chlorine is used in the production of **Mustard Gas** and **phosgene**.

Uses of Chlorine:

1. In sterilising drinking water and also water in swimming pools. This is because of the germicidal nature of chlorine which kills harmful bacteria present in water.
2. In the manufacture of Poly Vinyl Chloride (PVC), chlorofluorocarbons (CFCs), chloroform (CHCl_3), etc.
3. In the commercial preparation of bleaching powder and hydrochloric acid.
4. In the manufacture of pesticides and disinfectants.

Bromine (Br)

In India it is found in the form of brine in the Rann of Kutch. It is used in the manufacturing of **sleeping drugs** and **weeping gases**.

Iodine

In human body, iodine exists in the form of organic compound **thyroxin** in **thyroid gland**. Due to the deficiency of iodine, thyroid glands increase abruptly. This swelling in the gland is called **goitre**. The compound of iodine is used as pain relievers. The main source of iodine is nature is **chile saltpetre**, in which sodium iodate (NaIO_3) is its main component. Iodine occurs in abundance in laminarian seaweeds.

Astatine (At)

It is the heaviest non-metallic, radioactive element.

Inert Gases

Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe) and Radon (Rn) are **inert gases**. These are also known

as **noble gases**.

Helium (He): It is the second largest element found in the universe. This gas is filled in balloons and left in open sky for making predictions and relevant calculations.

Neon (Ne): It is used in fluorescent bulbs and Neon lamps.

Argon (Ar): It is used in filling ordinary bulbs.

Radon (Rn): This element is used in **radiotherapy** in the treatment of cancer. Radon is non-existent in nature. Rn comes out as a by-product of disintegration of radium.

Points to remember

- CF_2Cl_2 or Dichloro difluoro methane is called **Freon**. It is **used as a refrigerant**.
- Francium is a radioactive **liquid metal**.
- Gold, Platinum, Silver and Mercury are called **noble metals**.
- Special **smell in onion and garlic** is due to the presence of **potassium**.
- The isotope of **cobalt** is used in the treatment of **cancer**.
- The symbol of **tungsten** is W and its m.p. is very high, ie 3500°C .
- **Baddeleyite** is an ore of zirconium.
- The heaviest metal is **osmium**.
- Lithium is the **lightest** metallic element.
- The symbol of Thallium is **Tm**.
- Gallium (Ga) exists in **liquid state**.
- **Nichrome** is used in heating the element in an electric heater. It is an alloy of **Ni, Cr** and **Fe**.
- Cadmium (Cd) is used as a **moderator** in atomic reactor.
- Boric acid is produced with the help of **Boron**.
- **Boric acid (H_3BO_3)** is used in manufacturing **antiseptic** medicines.
- **Germanium (Ge)** is a **semi-conductor**. It is used in electronic devices like transistor, photoelectric cells, photo diode etc.
- **Polonium (Po)** is the **first man-made element**. It has the maximum number of isotopes — **27**.
- **Silicon (Si)** is a semiconductor. It is used in electronic devices.

Alloys and their uses

Alloy	Percentage Composition	Uses
Magnalium	Al = 95%, Mg = 5%	Pressure cookers, balance beams, some light instruments.
Duralumin	Al = 95%, Cu = 4%	Making parts of aeroplanes and automobiles, pressure cookers etc.
Bronze	Cu = 90%, Sn = 10%	For making statues, coins, utensils etc.
Brass	Cu = 80%, Zn = 20%	For making utensils, parts of machinery, condenser tubes, wires etc.
Gun metal	Cu = 90%, Sn = 10%	For making gun barrels.
Bell metal	Cu = 80%, Sn = 20%	For making bells and gongs.
German silver	Cu = 60%, Zn = 20%, Ni = 20%	For making silverware, resistance wires.
Phosphor bronze	Cu = 95%, Sn = 4.8%, P = 0.2%	For making springs, electric switches.
Monel metal	Cu = 30%, Ni = 67%	For making corrosion-resistance pumps and containers for storing acids.
Coinage silver	Ag = 90%, Cu = 10%	For making silver coins.
Silver solder	Ag = 63%, Cu = 30%, Zn = 7%	For soldering.
Dental alloy	Ag = 33%, Hg = 52%, Sn = 12.5%, Cu = 2%, Zn = 0.5%	For filling teeth.
Solder	Pb = 50%, Sn = 50%	For soldering broken pieces.
Type metal	Pb = 70%, Sb = 20%, Sn = 10%	For making printing type.
Stainless steel	Fe = 73%, Cr = 18%, Ni = 8%, C = 1%	Utensils, cycle and automobile parts, shaving blades, watch cases.
Nickel steel	Fe = 98–96%, Ni = 2–4%	Cables, automobile and aeroplane parts, armour plates, gears and drilling machines.
Alnico	Fe = 60%, Ni = 20%, Al = 12%, C = 8%	Permanent magnets.
Chrome steel	Fe = 98%, Cr = 2%	Axles, ball bearings, files and cutting tools.

Silicon (Si)

Uses: Silicon is used as n-type and p-type semiconductors. Silicon and germanium are extensively used in very pure forms in **semiconductor** devices, which are the basis of the whole electronic industry, including computer hardware. Silicon is a very important component of ceramics, glass and cement. It is added to steel or iron as such or more usually in the form of ferrosilicon to increase its resistance from attack by acids. Very pure silicon is used to make computer chips. Its alloys such as silicon bronze and manganese-silicon bronze possess strength and hardness even greater than steel.

Silicon dioxide

Silicon dioxide is also called **silica**. Most of the earth's crust (95%) is made of silica and silicates. Silica occurs in several crystallographic forms such as tridymite. Each of these has

different structures at high and low temperatures and they are inter-convertible at suitable temperature. Among these, α -quartz is the most common form and the major constituent of many rocks such as granite and sandstone. Pure SiO_2 is colourless but traces of other metals may colour it, giving semiprecious gem stones such as **amethyst** (violet), **citrine** (yellow), **rose quartz** (pink), **smoky quartz** (brown) and non-precious materials such as **flint** (often black due to C), **agate** and **onyx**.

Uses of Silica

Different forms of silica have many uses. The most important application of **quartz** is as a **piezoelectric** material and is used in **crystal oscillators** for radios and computers, filters for frequency control and in electro-metallurgical devices such as **transducers** and pick-ups. Silica has made it possible to develop extremely accurate clocks, modern radio

and television broadcasting and mobile radio communications. The coloured varieties of quartz are used as gemstones, e.g., **amethyst, jaspur, opal**, etc.

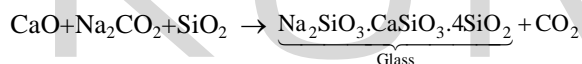
Uses of silicone polymers: The important uses of silicone polymers:

- Silicone polymers are used in high-temperature oil baths, high vacuum pumps etc.
- Silicone polymers are used as **sealant, greases, varnishes** and these can be used even at very low temperatures (of the order of -40°C).
- Because silicones are water repellants and good insulators, they are used for **water-proofing of fabrics** and in **electrical condensers**.
- These are used as **lubricants** at both high and low temperatures.
- Silicon rubbers are very useful because they retain their elasticity at lower temperatures as compared to other rubbers. They are also **mixed in paints to make them damp-resistant**.
- They are used as **excellent insulators** for electric motors and other electrical appliances.
- Being biocompatible, they are also used in surgical and cosmetic plants.

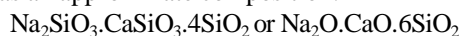
Glass

Glass is an amorphous and transparent or translucent solid obtained by the solidification of a mixture of silicates of different metals, one of which is always an alkyl metal.

Ordinary glass is a mixture of sodium and calcium silicates and is obtained by heating a mixture of sand (SiO_2) with sodium carbonate and calcium oxide in a furnace at around 1700 K and then rapid cooling.



This type of glass is called **soda lime glass** or **soft glass**. It has an approximate composition:



- Addition of small amounts of transition metal salts to the glass mixture imparts colour to glasses. For example, addition of **Cr(III) compounds** imparts **green colour**, addition of **Mn(IV) compounds** imparts **violet colour**, addition of **CO(II) salts** imparts **blue colour**, addition of **Fe(III) salts** imparts **brown colour** and so on.

Some other varieties of glass are:

- Lead potash glass** or **flint glass** is obtained by addition of lead oxide and potassium carbonate, which has a high **refractive index**. It is used for making cut-glass objects and lenses for optical purposes.
- Borosilicate glass** is obtained by the addition of boric oxide or borax to replace part of SiO_2 . It is **heat-resistant** glass with a low coefficient of thermal expansion. This type of glass is called **Pyrex glass, Corning** or **Borosil** (trade names), and can withstand sudden changes in temperature and is used for making laboratory glassware.
- Crook's glass** contains caesium oxide (Cs_2O) and has the properties to cut off ultraviolet rays, which are harmful to eyes. It is used in making **lenses**.

Coloured Glasses

Colour	Colour-Producing Substance
1. Deep Blue	Cobalt Oxide
2. Red	Cuprous Salt
3. Green	Sodium Chromate/Ferrous Oxide
4. Yellow (Light)	Cadmium Sulphide
5. Ruby Red	Gold Chloride/Purple of Cassius
6. Orange Red	Selenium Oxide
7. Peacock Blue	Cupric Salt
8. Green and Green Yellow	Potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$)
9. Glitter Red	Cuprous Oxide/Cadmium Sulphide
10. Blue to light orange	MnO_2 (Manganese dioxide)

Carbon (C)

Dry ice

Solid carbon dioxide is known as **dry ice**. It is soft, white, snow-like substance and looks like ice. However, it does not wet a piece of cloth or paper because it sublimates without melting. On the other hand, ordinary ice wets a piece of cloth on melting since it does not sublime. Solid carbon dioxide is used as a **refrigerant** under the commercial name **Drikold**.

Allotropes of Carbon

Elemental carbon exists in many allotropic forms. **Allotropic forms** or **allotropes** are the different forms of the same element having different physical properties but almost similar chemical properties.

The phenomenon of existence of allotropic forms of an element is called **allotropy**.

Carbon exists in two types of allotropic forms:

1. **Crystalline:** Diamond and graphite are two crystalline forms of carbon having a well-defined structure.
2. **Amorphous:** There are many amorphous forms of carbon such as coal, wood charcoal, animal charcoal, lamp black, coke, gas carbon, etc.

Of these allotropic forms, diamond and graphite are the most important and are discussed below.

Diamond and Graphite

Diamond: There are various types of diamond which are found all over the world. The important ones are

- (a) Culinan (3032 carats)
- (b) Hopp (445 carats)
- (c) Kohinoor (186 carats)

Diamond is deadly poisonous substance. It is transparent to x-ray. It is a bad conductor of heat and electricity.

Bort: Some diamonds are black which are called **Bort**. Extremely shining characteristics of diamond is due to **internal reflection** of light.

Use: Black diamonds (Bort) are used in making glass-cutting devices and rock-drilling machines. Bort is known as **carbonado** in market.

Diamond and graphite are two crystalline allotropic forms of carbon. Some of the important properties of these are:

- (i) Diamond is denser than graphite. The density of diamond is 3.514 g cm^{-3} while that of graphite is 2.226 g cm^{-3} .
- (ii) Diamond is hard while graphite is soft. Graphite has lubricating properties. On the other hand, diamond is the **hardest** substance known.
- (iii) Diamond is a bad conductor of electricity while graphite is a good conductor of electricity.
- (iv) Diamond is extremely chemically unreactive whereas graphite is quite reactive.

Uses of Diamond

- (i) Due to its hardness, it is used for cutting glass, for making bores for rock drilling and for making abrasives for sharpening hard tools.
- (ii) Due to its brilliance, diamond is used in jewellery as a precious stone. When it is cut at certain angles and polished, brilliant light is refracted from its surfaces, it becomes a precious gem.
- (iii) It is used for grinding and polishing hard materials.
- (iv) It is also used for making dice for drawing thin wires of metals.
- (v) It is used in the manufacture of tungsten filaments for electric light bulbs.

Uses of Graphite

- (i) Graphite is used in making electrodes.

- (ii) It is used as a **lubricant for heavy machines** running at high temperature, where oil cannot be used as a lubricant.
- (iii) It is used in the manufacture of crucibles which can withstand high temperatures.
- (iv) Mixed with wax or clay, graphite is used for making **lead pencils**.
- (v) Graphite is also used as a **moderator** for fast-moving neutrons in atomic reactors.

Amorphous forms of Carbon

Some important amorphous forms of carbon are:

- (i) **Coke:** It is a greyish-black hard solid which is obtained by destructive distillation (strong heating in the absence of air) of coal. It is commonly used as a fuel in boilers and engines. It is also used in furnaces as a reducing agent in metallurgy.
- (ii) **Charcoal:** It is a black, soft and highly porous substance. It can be obtained in three varieties:
 - (a) **Wood charcoal:** It is obtained by heating wood in a limited supply of air. It is highly porous and is therefore used as an adsorbent for gases.
 - (b) **Animal charcoal:** It is obtained by destructive distillation of bones and is also known as bone black. It contains about 10% carbon. It is mainly used for decolourising sugar syrup in the manufacture of sugar and other organic substances.
 - (c) **Sugar charcoal:** It is the *purest form of amorphous carbon* and is obtained by the action of concentrated sulphuric acid on cane sugar.
$$\text{C}_{12}\text{H}_{22}\text{O}_{11} \xrightarrow{\text{Conc. H}_2\text{SO}_4} 12\text{C} + 11\text{H}_2\text{O}$$

Cane sugarSugar charcoal

It is used as black pigment.

- (iii) **Lamp black:** It is a fine black powder and is obtained by burning oils (such as kerosene oil, turpentine oil, petroleum, natural gas, etc.) in a limited supply of air. It is mainly used for making **printer's ink, black paints** and shoe polish. It is also used as a filler in making rubber tyres.

Fullerenes

Up to 1985, carbon was considered to have only two allotropes: graphite and diamond. In 1985, scientists discovered a new family of carbon allotropes consisting of a cluster of carbon atoms such as C_{32} , C_{50} , C_{60} , C_{70} , C_{84} , etc. These were called **fullerenes**. These were discovered by **H.W. Kroto, RF Curl and RE Smalley**. This exciting discovery has opened a new era in chemistry. The 1996 Nobel Prize in chemistry was awarded to the above scientists for their discovery of fullerenes. Among these, the allotrope having the molecular formula C_{60} is important. It is

named **Buckminster fullerene**. It was named after the name of American architect Robert Buckminster Fuller, who designed 'geodesic domes' that exactly resembled it.

Fullerenes were originally made by the evaporation of graphite, using a laser. Now, these are synthesized from soot obtained by striking an electric arc between graphite electrodes at about 3773 K in the presence of an inert atmosphere of helium or argon. The sooty material formed by the condensation of vapourised C_n small molecules consists of mainly C_{60} with a small amount of C_{70} and traces of other fullerenes consisting of an even number of C atoms up to 350 or more.

Uses of Carbon

Carbon is used extensively in its different forms.

Coal is used as a fuel in boilers, engines, furnaces, etc. It is also used for the manufacture of coal gas, water gas, producer gas and synthetic petrol. It is largely used as a reducing agent in metallurgy.

Carbon black is used as black pigment in black ink and as filler in automobile tyres.

Charcoal (activated) being porous is used as an excellent adsorbent to purify and deodorize sugar and other chemicals. It is also used to adsorb poisonous gases in gas masks and for removing offensive odour from the air used in air conditioning processes. It is also used in water filters to remove organic contaminants.

Graphite, being a good conductor of electricity, is used for making electrodes in batteries and industrial electrolysis. Graphite fibres embedded in plastic material form high-strength, lightweight composites. The composites are used in products such as tennis rackets, fishing rods, aircraft and canoes. Graphite is also used in steel making, metal foundries for crucibles, as a lubricant and in pencils etc. Crucibles made from graphite are inert to dilute acids and alkalies. Graphite is also used as the moderator in the cores of gas-cooled nuclear reactors to slow down neutrons.

Diamonds (allotropes of carbon) are cut as gemstones and used in jewellery and other articles. It is measured in carats (**1 carat = 200 mg**). It is also used for industrial purposes, mainly for making drills or as an abrasive powder for cutting and polishing.

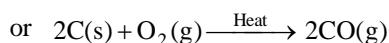
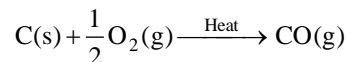
Important compounds of Carbon

Carbon combines with a variety of other elements to form binary compounds such as oxides, halides and carbides.

Oxides of Carbon: Carbon burns in air or oxygen to form two oxides, namely (a) carbon monoxide (CO) and (b) carbon dioxide (CO_2).

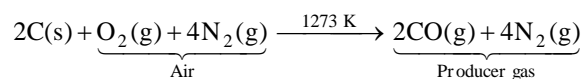
Carbon monoxide (CO)

Preparation: Carbon monoxide is prepared by the incomplete combustion of carbon or carbon-containing compounds in a limited supply of oxygen.

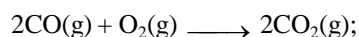


Carbon monoxide is present in exhaust gases from automobiles due to incomplete combustion of carbon or carbon compounds during burning of petrol or diesel.

The mixture of **CO and H_2** is called **water gas** or **synthesis gas**. When air is passed instead of steam, a **mixture of CO and N_2** are formed. This mixture is called **producer gas**.



Water gas and producer gas are very important industrial fuels. Carbon monoxide present in water gas or producer gas can undergo further combustion, forming carbon dioxide with the evolution of heat.

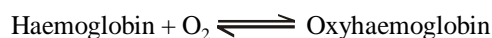


$$\Delta_r H^\circ = -566 \text{ kJ mol}^{-1}$$

Carbon monoxide is also present in volcanic gases, gases from the furnaces where coal is burnt, exhaust gases from automobile engines, fumes of tobacco, etc.

Properties

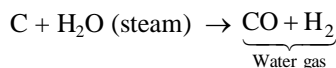
1. Carbon monoxide is colourless, odourless and is almost insoluble in water.
2. **Toxic nature:** It is highly toxic in nature. The toxic nature of CO is due to its ability to form a complex with haemoglobin in the red blood cells. Haemoglobin in the blood combines with oxygen and forms **oxyhaemoglobin** by a reversible reaction:



Oxyhaemoglobin is formed in the lungs and is carried to the different cells where it gives its oxygen. However, CO forms a complex with haemoglobin stronger than oxygen. The CO complex with haemoglobin is about 300 times more stable than the oxygen-haemoglobin complex. Therefore, if CO is present, it will form stable compound with haemoglobin and this will destroy the oxygen-carrying ability of blood. As a result, blood will not take up oxygen easily, causing suffocation and finally death.

Uses: Carbon monoxide is used as an industrial fuel in the form of water gas and producer gas:

- (a) **Water gas** is a mixture of carbon monoxide and hydrogen. **It is obtained by passing steam over red hot coke.**



- (b) Both water gas and producer gas contain CO as their important component which can undergo further oxidation to form carbon dioxide and liberate enormous amount of heat. Therefore, these are used as important industrial fuels.
- (c) It is used in some metallurgical processes. For example, in the metallurgy of iron, it is used as a reducing agent.

$$\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$$
- (d) It is used in *Mond's process* for the purification of nickel by forming nickel carbonyl.
- (e) It is used in the manufacture of methyl alcohol, formic acid, etc.
- (f) Its compound with iron (iron carbonyl) is used in the manufacture of magnetic tapes for tape recorders.

Carbon dioxide (CO₂)

Carbon dioxide has different physical characteristics from carbon monoxide. Some important physical properties of CO₂:

Solubility: Carbon dioxide is slightly soluble in water. Its solubility in water, however, increases with increase in pressure. **Soda water and other aerated soft drinks are solutions of carbon dioxide in water** (containing sugar, some flavouring and colouring substances) under pressure.

Carbon dioxide can be readily liquefied under a pressure of 50-60 atm. at room temperature. When liquid carbon dioxide is allowed to evaporate rapidly, it changes in to a solid called solid carbon dioxide. The solid carbon dioxide is also called **dry ice** because it looks like ice. However, unlike ordinary ice, it does not wet a piece of cloth because it sublimates (changes to vapours without melting). It is a soft, snow-like substance. It is used as refrigerant for ice-cream and frozen food. On mixing with ether or acetone, it forms a freezing mixture with a very low temperature and is used as a **coolant** for preserving perishable foodstuffs.

A mixture of solid CO_2 and ether can generate a low temperature of about -108°C , which is used in the liquefaction of other gases.

Non-combustible nature: Ordinary carbon dioxide is neither combustible nor a supporter of combustion. Therefore, it is used in fire extinguishing.

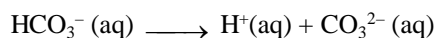
Acidic nature: Carbon dioxide turns blue litmus red and is therefore acidic in nature. It dissolves in water, forming carbonic acid (H_2CO_3).



Therefore, carbon dioxide is regarded as an *anhydride of carbonic acid*.

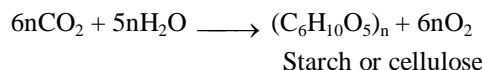
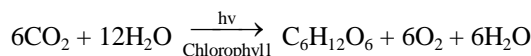
Carbonic acid is a weak dibasic acid and forms two series of salts, namely *bicarbonates* (hydrogen carbonates)

containing the HCO_3^- anion, and *carbonates* containing CO_3^{2-} anion.



Thus, a solution of carbon dioxide in water is an equilibrium mixture of CO_2 , H_2CO_3 , HCO_3^- and CO_3^{2-} . It may be noted that these equilibria play an important role in carbonic acid-hydrogen carbonate ion buffer system in maintaining the pH of human blood between 7.26 and 7.42.

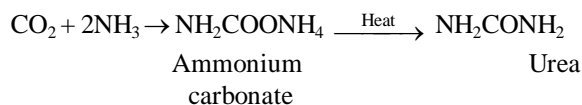
Photosynthesis: Carbon dioxide, which is normally present to the extent of about 0.03% by volume in the atmosphere, is removed from it by the process known as photosynthesis. **It is the process by which green plants convert atmospheric CO₂ into carbohydrates such as glucose.** Carbon dioxide is absorbed by plants in the presence of chlorophyll (green colouring matter in the leaves) and sunlight to form glucose, starch and cellulose (which are known as carbohydrates).



By the process of photosynthesis, the plants prepare food for themselves as well as for animals and human beings. But the increased use of fossil fuels for combustion and decomposition of limestone for cement manufacture in recent years has considerably increased the CO_2 content in the atmosphere. This may lead to an increase in greenhouse effect and thus raise the temperature of atmosphere, which might result in serious consequences.

Uses of carbon dioxide: Carbon dioxide is used

- (i) in the preparation of aerated waters like soda water.
- (ii) as a fire extinguisher because it is a non-supporter of combustion.
- (iii) in the manufacture of washing soda by Solvay's process.
- (iv) as a refrigerant in the form of **solid carbon dioxide (dry ice)**. Solid carbon dioxide can sublime to the gaseous state without passing through the liquid state and, therefore, it is called dry ice. **It is also used as a coolant for preserving perishable food items such as meat.** Dry ice is also used for curing local burns and in hospitals for surgical operations of sores.
- (v) in the manufacture of urea by its reaction with ammonia.



(vi) for artificial respiration (for the victims of carbon monoxide poisoning) as a mixture of 85% oxygen and 5% carbon dioxide (called **carbogen**).

(vii) for the purification of cane sugar juice in the manufacture of sugar.

(viii) in plants during photosynthesis of glucose, starch and cellulose.

Important inorganic compounds and their formula

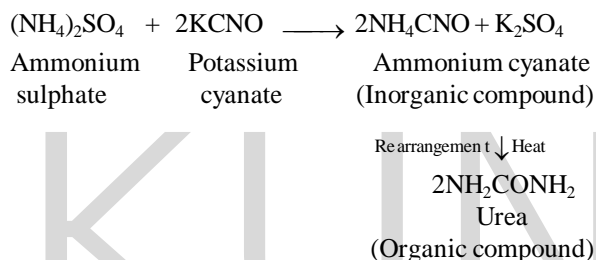
Name of Compound	Chemical Formula	Chemical Name
Baking Soda	NaHCO_3	Sodium Bicarbonate
Washing Soda	$\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$	Sodium Carbonate
Caustic Soda	NaOH	Sodium Hydroxide
Borax	$\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$	Sodium Borate
Potash Alum	$\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$	Potassium Aluminium Sulphate
Bleaching Power	CaOCl_2	Calcium Oxychloride
Gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	Calcium Sulphate
Plaster of Paris	$\text{CaSO}_4 \cdot \frac{1}{2} \text{H}_2\text{O}$	Calcium Sulphate
Laughing Gas	N_2O	Nitrous Oxide
Red Vermilion	Pb_3O_4	Lead Peroxide
Oil of Vitriol	$\text{Conc. H}_2\text{SO}_4$	Conc. Sulphuric Acid
Aqua Regia	$\text{HNO}_3 + 3\text{HCl}$	Royal Water
Water Gas	$\text{CO} + \text{H}_2$	Mixture of Carbon Monoxide and Hydrogen
Bauxite	$\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$	
Solid Ice/Dry Ice	CO_2	Solid Carbon Dioxide
Green Vitriol	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	Ferrous Sulphate
White Vitriol	$\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$	Zinc Sulphate
Vermillion	HgS	Mercuric Sulphate
Heavy Water	D_2O	Deuterium Oxide
Blue Vitriol	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	Copper Sulphate
Producer Gas	$\text{CO} + \text{N}_2$	Mixture of Carbon Monoxide and Nitrogen
Gammexene	$\text{C}_6\text{H}_6\text{Cl}_6$	Benzene Hexachloride
Vinegar	CH_3COOH	Dilute Solution of Acetic Acid
Juice of Grapes	$\text{C}_6\text{H}_{12}\text{O}_6$	Glucose
Freon	CF_2Cl_2	Dichloro Difluoro Carbon
Urea	NH_2CONH_2	Carbamide
Chloroform	CHCl_3	Trichloromethane
Iodoform	CHI_3	Tri-iodomethane
MIC (Methyl Isocyanate)	CH_3NC	Methyl Isocyanate
Starch	$\text{C}_6\text{H}_{10}\text{O}_5$	
Sugar	$\text{C}_{12}\text{H}_{22}\text{O}_{11}$	

Organic Chemistry

Some Basic Principles and Techniques

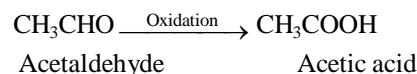
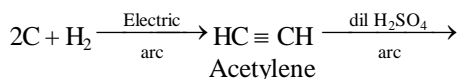
In the earlier period of development of chemistry, chemists tried their best to prepare organic compound in the laboratory. But all their efforts proved to be futile. Their failures led them to believe that organic compound could be prepared only by and within living beings and that they could never be synthesised in the laboratory like inorganic compounds. **Berzelius**, a Swedish chemist, proposed that the synthesis of these compounds within the plants and animals required some mysterious force. This force was called the vital force and the theory was referred to as **Vital Force Theory**.

However, the vital force theory received a crippling blow in 1828 when *Friedrich Wohler*, a German chemist, accidentally obtained **urea**, $(\text{NH}_2)_2\text{CO}$, an *organic compound* found in the urine of mammals. In fact, Wohler tried to prepare **ammonium cyanate**, a substance with mineral origin, by heating ammonium sulphate and potassium cyanate. But under the reaction conditions, ammonium cyanate got rearranged to urea, a compound which was of organic nature.



This chance discovery of Wohler brought about a revolution in the field of organic chemistry. The synthesis of organic compound no longer remained a mystery and many organic compounds were prepared in the laboratory. For example, Kolbe (1845) prepared acetic acid, Hennel (1828)

prepared ethyl alcohol, and Berthelot (1856) prepared methane in the laboratory from mineral resources. Acetic acid was prepared from carbon and hydrogen:



The synthesis of organic compounds changed the very concept of organic chemistry. By the middle of the 19th century, the vital force theory was discarded completely. Chemists never looked back after that and at present about 95 per cent of the organic compounds are man-made.

Organic chemistry is now defined as **the chemistry of carbon compounds** as all organic compounds contain carbon as their essential constituent.

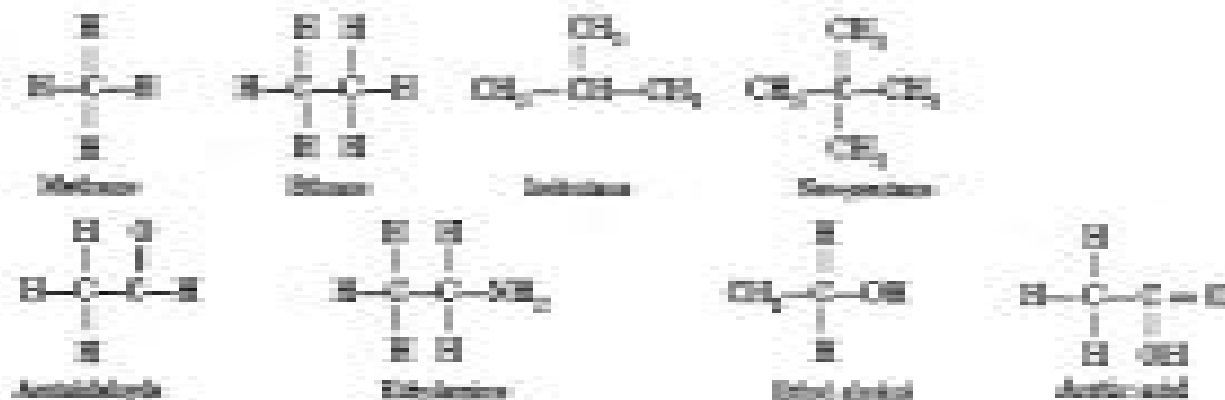
Classification of Organic Compounds

The simplest organic compounds containing only carbon and hydrogen are called *hydrocarbons*. These are regarded as the parent organic compound and all other compounds are considered to be derived from them by the replacement of one or more hydrogen atoms by other atoms or groups of atoms. They have been broadly classified as:

1. Open-chain or acyclic compounds.
2. Closed-chain or cyclic or ring compounds

1. Open chain or acyclic compounds

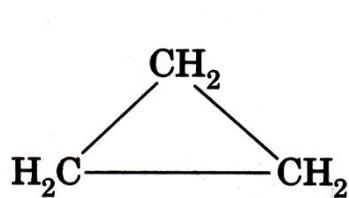
These compounds contain open chains of carbon atom in their molecules. The carbon chains may be either straight chains or branched chains. They are called **aliphatic compounds**.



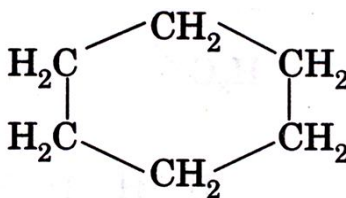
2. Closed chain or cyclic or ring compounds

These compounds contain closed chains or rings of atoms in their molecules. These are of three types:

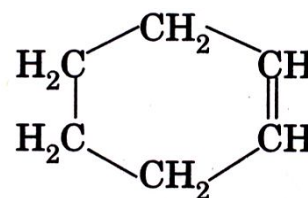
(i) **Alicyclic compounds:** These compounds contain a



Cyclopropane



Cyclohexane

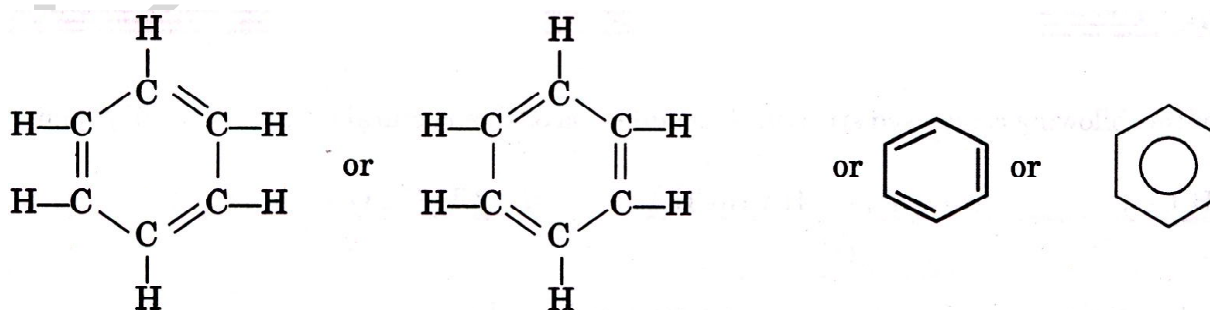


Cyclohexene

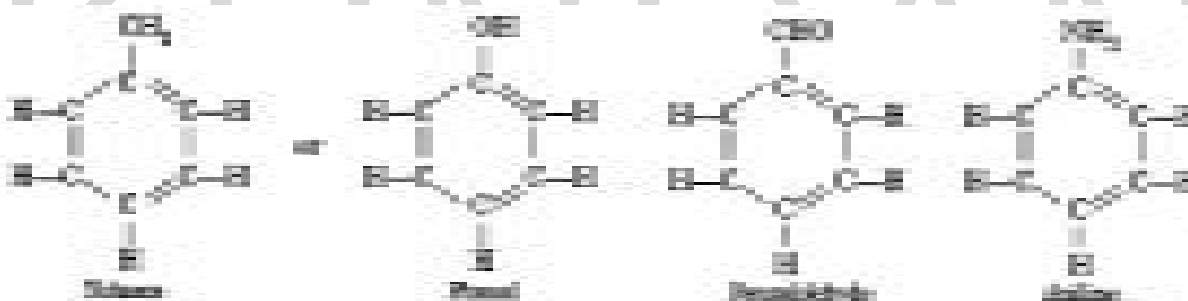
ring of three or more carbon atoms in them. They resemble aliphatic compounds in many of their properties. For example,

(ii) **Aromatic compounds:** These have a cyclic system containing at least one benzene ring. The parent member of the family is called **benzene**. Benzene has a

homocyclic hexagonal ring of carbon atoms with three double bonds in the alternate positions. Benzene can be represented by any of the following structures:



Some other examples are:



These compounds are also called **benzenoid compounds** and they exhibit special property known as **aromaticity**. Bicyclic and tricyclic compounds also belong to this category.

(iii) **Heterocyclic compounds:** A heterocyclic compound is a cyclic compound that has atoms of at least two different elements as members of its ring(s). The counterparts of heterocyclic compounds are homocyclic compounds, the rings of which are made of a single element.

Homologous Series

The organic compounds have been classified into various

families. Each family contains a closely related organic compound as far as their structures and chemical properties are concerned. The different families or classes are known as homologous series. A homologous series may thus be defined as **a series of similarly constituted compounds in which the members possess the same functional group and have similar chemical characteristics**.

The two consecutive members differ in their molecular formula by —CH_2 group.

The different members of a series are known as **homologues**. A few members of the alcohol family are given below:

Formula	Name
CH ₃ OH	Methyl alcohol
C ₂ H ₅ OH	Ethyl alcohol
C ₃ H ₇ OH	Propyl alcohol
C ₄ H ₉ OH	Butyl alcohol

Characteristics of homologous series: The common characteristics of the members present in a homologous series are :

- All the members of a series can be represented by the general formula. For example, the members of the alcohol family are represented by the formula C_nH_{2n+1}OH where *n* may have values 1, 2, 3, ... etc.
- Two successive members differ in their formula by —CH₂ group or by 14 atomic mass units (12 + 2 × 1).
- Different members in a family have common functional group, e.g., the members of the alcohol family have —OH group as the functional group.
- The members in any particular family have almost identical chemical properties and their physical properties such as melting point, boiling point, density, solubility etc., show a proper gradation with the increase in the molecular mass.

Different Classes of Aliphatic Compounds and their nomenclature

Nomenclature implies assigning proper name to a particular organic compound on the basis of certain standard rules so that the study of these compounds may become systematic. In case of aliphatic compounds, two systems of naming are generally used:

- Trivial system
- IUPAC system

Trivial system: In earlier days, the organic compounds were named after the source from which they were obtained. For example, urea got its name because the compound was obtained from the urine of the mammals. Similarly, **methyl alcohol** was called *wood spirit* since it could be obtained as one of the products during the destructive distillation of wood; *formic acid* derived its name from the Greek word *formicus* (**red ants**) since the acid could be obtained from red ants. These names are without any systematic basis and are known as **common names** or **trivial names**. Such a system of nomenclature is known as **trivial system**.

The common names of some popular organic compounds are given below:

Compound	Common Name
CH ₄	Methane
C ₂ H ₄	Ethylene
C ₂ H ₂	Acetylene
H ₃ CCH ₂ CH ₂ CH ₃	n-Butane
(H ₃ C) ₂ CHCH ₃	Isobutane
(H ₃ C) ₄ C	Neopentane

HCHO	Formaldehyde
CH ₃ CHO	Acetaldehyde
(H ₃ C) ₂ CO	Acetone
CH ₃ CH ₂ OH	Ethyl alcohol
CH ₃ CH ₂ CH ₂ OH	n-Propyl alcohol
CH ₃ CONH ₂	Acetamide
CH ₃ OCH ₃	Dimethyl ether
(CH ₃ CH ₂) ₂ O	Diethyl ether
CHCl ₃	Chloroform
CHI ₃	Iodoform
CH ₃ CN	Acetonitrile
CH ₃ COOH	Acetic acid
CH ₃ OCH ₂ CH ₃	Ethyl methyl ether
C ₆ H ₆	Benzene
C ₆ H ₅ CH ₃	Toluene
C ₆ H ₅ NH ₂	Aniline
C ₆ H ₅ OH	Phenol
C ₆ H ₅ OCH ₃	Anisole
C ₆ H ₅ COCH ₃	Acetophenone
C ₆ H ₅ CONH ₂	Benzamide

IUPAC system: In order to rationalise the system of naming, an *International Congress of Chemists* was held in Geneva in 1892. They adopted certain uniform rules for naming the compounds.

The system of nomenclature was named as the **Geneva system**. Since then, the system of naming has been improved from time to time by the *International Union of Pure and Applied Chemistry* and the new system is called **IUPAC system** of naming.

Different Classes of Organic Compounds

Hydrocarbons

These are organic compounds containing carbon and hydrogen atoms only. They may be further classified into two classes: saturated and unsaturated hydrocarbons.

Saturated Hydrocarbons — Alkanes:

General formula = C_nH_{2n+2} Suffix: **ane**

These are the organic compounds which contain only carbon-carbon single bond. These were earlier named as *paraffins* (Latin: meaning little affinity) due to their least chemical reactivity. According to IUPAC system, these are named as *alkanes* (**ane** is the suffix with word root). Various members of the series are given below:

Formula	IUPAC name	Common name
CH ₄	Methane	Methane
CH ₃ CH ₃	Ethane	Ethane
CH ₃ CH ₂ CH ₃	Propane	Propane
CH ₃ CH ₂ CH ₂ CH ₃	Butane	n-Butane
CH ₃ (CH ₂) ₃ CH ₃	Pentane	n-Pentane
CH ₃ (CH ₂) ₄ CH ₃	Hexane	n-Hexane

Unsaturated hydrocarbons: These are hydrocarbons

which contain a carbon-to-carbon double bond ($\text{C}=\text{C}$) or a carbon-to-carbon triple bond ($\text{C}\equiv\text{C}$) in their molecules. These are further classified into two types: *alkenes* and *alkynes*.

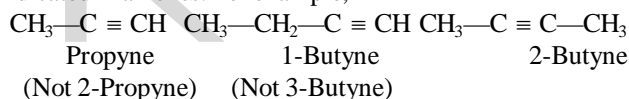
Alkenes: General formula: C_nH_{2n} Suffix: **ene**

The molecules containing a carbon-carbon double bond are called alkenes. They have the general formula C_nH_{2n} . These were previously called **olefins** (in Greek *olefiant* means oil-forming) because the lower gaseous members of the family form oily products when treated with chlorine.

Alkynes: General formula: $\text{C}_n\text{H}_{2n-2}$ Suffix: **yne**

Alkynes are the unsaturated hydrocarbons with a triple bond ($\text{C}\equiv\text{C}$). They are represented by the general formula $\text{C}_n\text{H}_{2n-2}$.

Alkynes are named in the same way as alkenes, i.e., by replacing suffix **ane** of alkane by **yne**. In higher members, the position of triple bond is indicated by giving numbers 1, 2, 3, 4, ... etc. to the carbon atom in the molecule. The numbering of the chain is always done from one end in such a manner that the triple-bonded carbon atom gets the least number, as indicated in alkenes. For example,



Alcohols or alkanols

General formula: $\text{C}_n\text{H}_{2n+1}\text{OH}$ or ROH

Functional group: OH **Suffix:** -ol

These are derived by replacing one hydrogen atom from an alkane by one hydroxyl group. In the IUPAC system, these are called **alkanols** and their names have been derived by changing the -e of corresponding alkane by -ol (alkane -e + -ol = alkanol). Molecules having more than one —OH group are called diols (2 —OH groups), triols (3 —OH groups) etc.

Formula	IUPAC name	Common name
CH_3OH	Methanol	Methyl alcohol
$\text{CH}_3\text{CH}_2\text{OH}$	Ethanol	Ethyl alcohol
$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$	Propan-1-ol	n-Propyl alcohol
$\text{CH}_3(\text{CH}_2)_2\text{CH}_2\text{OH}$	Butan-1-ol	n-Butyl alcohol
$\text{CH}_3\text{CHCH}_2\text{CH}_3$	Butan-2-ol	sec-Butyl alcohol

$\begin{array}{c} \\ \text{OH} \\ \text{CH}_2-\text{CH}_2 \end{array}$	Ethane-1, 2-diol	Ethylene glycol
$\begin{array}{cc} & \\ \text{OH} & \text{OH} \\ \text{CH}_2-\text{CH}-\text{CH}_3 \end{array}$	Propane-1, 2-diol	Propylene glycol
$\begin{array}{cc} & \\ \text{OH} & \text{OH} \end{array}$		

Ethers or Alkoxyalkanes

General formula: $\text{C}_n\text{H}_{2n+1}\text{OC}_n\text{H}_{2n+1}$ ROR'

Functional group: —O— Prefix: **alkoxy**

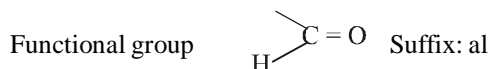
These are derived from alkanes by replacing one hydrogen atom by alkoxy group (—OR). For example, methoxy (OCH_3), ethoxy (OC_2H_5) or propoxy (OC_3H_7). In an ether molecule, two alkyl radicals are linked on either side to a divalent oxygen atom (—O—). They are called simple ether if $\text{R} = \text{R}'$ (e.g., CH_3OCH_3) and mixed ethers if R and R' are different (e.g. $\text{CH}_3\text{OC}_2\text{H}_5$). In the IUPAC system, ethers are called **alkoxyalkanes**. The alkoxy group is taken with a smaller alkyl group.

Ether	IUPAC name	Common name
CH_3OCH_3	Methoxymethane	Dimethyl ether
$\text{C}_2\text{H}_5\text{OC}_2\text{H}_5$	Ethoxyethane	Diethyl ether
$\text{CH}_3\text{OC}_2\text{H}_5$	Methoxyethane	Ethyl methyl ether

It may be noted that the last compound is not ethoxy methane because the alkoxy group is taken with a lesser number of C atoms.

Aldehydes or Alkanals

General formula: $\text{C}_n\text{H}_{2n+1}\text{CHO}$ (where n can be 0 also, e.g. HCHO)



These compounds are obtained by replacing a hydrogen atom attached to the terminal carbon atom in the alkane molecule by an aldehyde (CHO) group. The first member is, however, obtained by replacing a hydrogen atom in the hydrogen molecule.

These are called **alkanals** in the IUPAC system of nomenclature and the names of individual members are derived by changing -e of the corresponding alkane by -al (alkane -e + -al = alkanal).

Note: Aldehyde, the —CHO group, is always present at the end of the chain and there is no need to designate its position as 1.

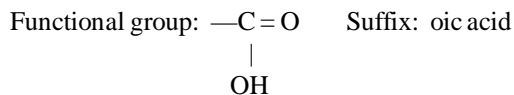
While counting the carbon atoms in the parent chain, the carbon of the —CHO group is also counted. For example, the parent chain in $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$ corresponds to 4C atoms and not 3. Further, it should be simply named as butanol.

Aldehyde	IUPAC name	Common name
HCHO	Methanal	Formaldehyde
CH_3CHO	Ethanal	Acetaldehyde
$\text{CH}_3\text{CH}_2\text{CHO}$	Propanal	Propionaldehyde
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$	Butanal	n-Butyraldehyde

Monocarboxylic acids or Alkanoic acids

General formula: $\text{C}_n\text{H}_{2n+1}\text{COOH}$

(where n can be zero also)



In these compounds, one hydrogen atom in the alkane molecule is replaced by a carboxyl (COOH) group. The first member is, however, obtained by replacing a hydrogen atom in the hydrogen molecule.

In the IUPAC system, they are called **alkanoic acids** and are named by replacing the *-e* of the corresponding alkane by *-oic* acid (alkane $-e + -oic$ acid = alkanoic acid)

Monocarboxylic acid	IUPAC name	Common name
HCOOH	Methanoic acid	Formic acid
CH ₃ COOH	Ethanoic acid	Acetic acid
CH ₃ CH ₂ COOH	Propanoic acid	Propionic acid
CH ₃ CH ₂ CH ₂ COOH	Butanoic acid	n-Butyric acid

Isomerism

Two or more compounds having the same molecular formula but different physical and chemical properties are called **isomers**. The phenomenon of existence of two or more compounds possessing the same molecular formula but different properties is called **isomerism**.

Types of Isomerism

Isomerism is of two main types:

- Structural isomerism
- Stereo isomerism

Structural isomerism: The compounds having the same molecular formula but different structures, i.e. different arrangements of atoms or groups of atoms within the molecules, are called **structural isomers** and the phenomenon is called **structural isomerism**.

Stereo isomerism: The isomers which have the same structural formula but have different relative arrangement of atoms or groups of atoms in space are called **stereo isomers** and the phenomenon is called **stereo isomerism**.

The stereo isomerism is of three types:

- Geometrical isomerism,
- Optical isomerism, and
- Conformational isomerism.

Purification of Organic Compounds

The most common methods used for the purification of organic compounds are:

- Filtration:** Filtration is used to separate an insoluble solid component of the mixture from the soluble component in a given solvent.
- Recrystallisation:** The method is based on the differences in the solubility of the organic compound and its impurities in a suitable solvent.
- Sublimation:** Certain organic solids on heating change from solid to vapour state directly without passing through

a liquid state. Such substances are called *sublimable*. This process is called *sublimation*. The vapours on cooling change back to the solid form, eg camphor, Ammonium Chloride (NH₄Cl).



The **sublimation process** is used for the separation of sublimable volatile compounds from non-sublimable impurities.

- Distillation:** This method is used for the purification of liquids which boil without decomposition and contain non-volatile impurities. Simple distillation involves heating of liquid to its boiling point so that it is converted into vapour. On cooling the vapour, pure liquid is obtained and collected separately.
- Fractional Distillation:** This process is used to separate a mixture of two or more miscible liquids which have boiling points close to each other.
- Distillation under Reduced Pressure: Vacuum Distillation:** Vacuum distillation is used for liquids which decompose at a temperature below their normal boiling points.
For example: Glycerol boils with decomposition at 563 K, but if the pressure is reduced to 12 mm, it boils at 453 K without decomposition.
- Steam Distillation:** The process of steam distillation is used for the separation and purification of liquid which is appreciably volatile in steam from non-volatile components of a mixture.
- Differential Extraction:** This method is used to separate a given organic compound present in aqueous solution by shaking with a suitable organic solvent in which the compound is more soluble than water.
- Chromatography:** This is a modern method used for the separation of mixtures into its components, purification of compounds and also testing the purity of compounds. The name *chromatography* is based on the Greek word *chroma* meaning "colour" and *graph* meaning "writing" because the method was first used for the separation of coloured substances found in plants. This method was described by Tswett in 1903.

Some Important Organic Compounds

- Methane (CH₄):** It is also called **marsh gas**. In nature, methane is obtained through decomposition of green leaves and vegetables. It is found in **swampy areas**. It is the main component of natural gas. Methane is used in making carbon black.
- Acetylene (C₂H₂):** It is used in making **camphor**; in the form of **anaesthetic**; in **welding and cutting** the metallic objects; and in **ripening of fruits**.
- Chlorofluorocarbon (CFC) or Freon:** It is used as a

coolant in refrigerators.

- **Ethy Alcohol (C_2H_5OH)**: It is used in making transparent soap, perfume, wine etc.
- **Ethylene glycol**: It is used for reducing the melting point in the radiator of cars in cold regions.
- **Diethyl ether**: It is used as an **anaesthetic**. It is considered a better anaesthetic than chloroform.
- **Chloroform**: It is also used as an **anaesthetic**.
- **Pyrin**: It is used in extinguishing electric fire.
- **Urea (NH_2CONH_2)**: It has **46% Nitrogen**. It is a good fertilizer.
- **Formic acid**: This acid is found in **red ants** and **bees**. It is used as injection; in the form of medicine for **arthritis**.
- **Oxalic acid**: It is found in very small quantities in human beings and sometimes accumulates in the kidneys in the form of **calcium oxalate**; that's why prostate (**stone**) appears in the kidney.
- **Saccharin**: It is **550 times sweeter** than ordinary sugar. The calorific value of saccharin is **zero**, so it is utilized in beverages and as **sugar for diabetic persons**.
- **Napthalene**: It is used as **germicides** and kept in boxes where garments are kept.
- **Neoprene**: It is **synthetic rubber**. It is used in making electrical insulating material, electric cable.
- **Bakelite**: It is used in making the **body of cabinet** of radio and television, **bucket** etc.
- **Teflon**: Teflon is a non-volatile substance and on it there is no effect of concentrated acid and alkali. It is used as **coating on blades** or such other things.
- **PVC**: It is used in making **raincoats/air-filling toys, pipes** etc.
- **Tear gas**: It is used to control mob, crowd etc. Compounds used as tear gas are **acrolein, omega chloroacetophenone**, etc.
- **MIC (Methyl isocyanate)**: It was responsible for Bhopal gas tragedy.
- **Methane (CH_4)**: It is the main component of **Gobar Gas**.
- **LNG (Liquefied Natural Gas)**: Its main component is (CH_4).
- **Gammexane**: It is a compound of **Benzene Hexachloride (BHC)**. It is a strong **insecticide**.
- **Aspirin**: It is **painkiller** drug.

Petroleum

Petroleum is a natural fuel found between the sedimentary rock layers inside the earth's crust. Chemically it is complex

saturated hydrocarbon, which is also called crude oil or mineral oil.

Knocking: Fuels are mixed in air to burn in the engine. These fuels burn before the appropriate time of combustion. The heat of the fuels does not transform into exact work and produces harsh metallic sound called **knocking**. The fuels whose knocking is very low are assumed to be the best fuels. The compounds that lower the knocking are called **anti-knocking compounds**. The compound **Tetra Ethyl Lead (TEL)** is the best anti-knocking compound. **BTX** (Benzene Toluene Xylene) is one of the best anti-knocking compounds.

LPG (Liquefied Petroleum Gas): It is a mixture of hydrocarbons in which **80-90% methane (CH_4)** gas is present. This gas emits less CO (about 70%) than petrol and diesel.

Soaps and Detergents

Soaps: Soaps are sodium salts of higher fatty acids like palmitic acid, stearic acid and oleic acid.

Detergents: Detergents are prepared from fatty acids and vegetative oils.

Explosives

RDX (Research Department Explosive): It is pure white crystalline powder. The chemical name of **RDX** is **cyclotrimethylene trinitramine**. Another form of explosive is C-4, which is a deadly destructor. Plastic Bonded Explosive (**PBE**) is being frequently used by terrorists and fundamental groups these days.

TNG (Tri Nitro Glycerin): It is used in making **dynamite**. It is also called **Nobel's oil**.

Drugs and chemicals

1. **Antibiotics**: These are prepared by micro organisms, moulds, fungi etc. These are used to check the growth of virus and bacteria. For example, tetracycline, streptomycin etc.
2. **Antiseptics**: Antiseptics are helpful in killing micro organisms (viruses and bacteria) and preventing their spread. For example, H_2O_2 , Iodine.
3. **Antipyretics**: Antipyretics are used as body pain reliever. For example, Crocin, Aspirin etc.

Environmental Pollution

Environmental pollution is the effect of undesirable changes in our surroundings (air, water or land) that have harmful effects on human, animal and plant life as well as on materials.

Pollution may be natural or man-made. It can be classified according to the components of environment being damaged. These are:

- (i) Air pollution
- (ii) Water pollution
- (iii) Soil (land) pollution

A substance which causes pollution is called a **pollutant**.

In general, pollutants are the substances made by us, used by us and even thrown by us as waste products which pollute the environment directly or indirectly in one way or other.

Some commonly used terms

Some commonly used terms in environmental chemistry are:

Pollutant: When the concentration of a substance already present in nature or of a new substance increases to undesirable proportions, causing danger to human beings, other animals or vegetation and other materials, the substance is treated as a pollutant. The pollutants spoil the environment and are harmful to living organisms and other materials.

The common pollutants are:

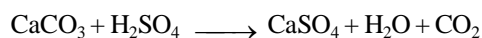
- (i) gases like carbon monoxide, sulphur dioxide, oxides of nitrogen, etc.
- (ii) compounds of metals like lead, mercury, zinc, cadmium, arsenic, etc.
- (iii) pollen grains, dust
- (iv) pesticides and detergents
- (v) sewage
- (vi) radioactive substances

Contaminant: A substance which does not occur in nature but is introduced by human activity into the atmosphere, affecting its composition, is called a contaminant.

The contaminant is classified as pollutant when it has some harmful effect. For example, pyrosulphuric acid ($\text{H}_2\text{S}_2\text{O}_7$) leaked from a defective tank killed many persons and caused skin and breathing problems to many persons in Delhi. Since pyrosulphuric acid does not occur in the atmosphere, it is a contaminant. But because of its dangerous effect, it is also regarded as a pollutant.

Source: The site from which the pollutants or contaminants come is called a source. Every pollutant originates from a source. The source is particularly important because its knowledge helps to develop the methods to eliminate pollutants.

Sink: The material or medium which consumes or interacts with a long-lived pollutant is called a sink. For example, a marble wall acts as a sink for atmospheric sulphuric acid because of the following reaction:



The oceans are sinks for atmospheric carbon dioxide and other water soluble gases.

Ground water and sub-soil water also act as sinks for pesticides used in agriculture.

Receptor: Anything that is affected by the pollutants is called a receptor. For example, human beings are the receptor of photochemical smog causing irritation in eyes and breathing problems.

Speciation: Speciation means the identification of different chemical forms or species of an element or a compound present in the environment. For example, mercury may be present in the environment in various forms such as elemental mercury, mercury salts, organometallic mercury species, CH_3Hg^+ , $(\text{CH}_3)_2\text{Hg}$. It is very essential to identify the chemical species of the pollutants because some species may be more toxic than others and need special care. For example, alkyl mercury derivatives [CH_3Hg^+ , $(\text{CH}_3)_2\text{Hg}$] are highly poisonous as compared to other species of mercury.

Threshold Limit Value (TLV): This indicates the permissible limit of a toxic pollutant in the atmosphere to which a healthy worker can be exposed during 8 hours a day or 40 hours a week for lifetime without any adverse effect. TLVs are determined by experimentation on animal, medical knowledge and experience, epidemiology surveys and environmental studies.

For example, the TLV of CO is 50 ppm and that of CO_2 is 5000 ppm. But the TLV for the poisonous gas phosgene is only 0.1 ppm.

Chemical Reactions in the Atmosphere

The gaseous envelope surrounding the earth is known as the **atmosphere**. The two major components of dry and clean air in the atmosphere (by volume) are **nitrogen** (78.09%) and **oxygen** (20.95%). Argon (0.934%) and carbon dioxide (0.034%) are minor components of the atmosphere. Air can hold water vapour from 0.1 to 5% by volume and also contains trace of elements such as noble gases (neon, helium, krypton, xenon).

The atmosphere surrounding us may be divided into four regions:

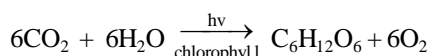
- (i) Troposphere

- (ii) Stratosphere
- (iii) Mesosphere
- (iv) Thermosphere

About 80% of the total mass of air and almost all of the water vapour of the atmosphere is found in the inner layer known as **troposphere**, which extends to 8 to 12 km above the earth's surface. The stratosphere (11-50 km) contains nitrogen, oxygen and ozone.

Many chemical reactions occur in the atmosphere in which oxygen plays an important role.

The carbon dioxide and water present in the atmosphere are used by green plants in the presence of sunlight in the process of photosynthesis as:



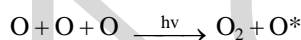
During photosynthesis, oxygen is again returned to the atmosphere.

In the upper atmosphere, oxygen exists in some forms which are different from those stable at lower levels. Thus, in addition to O_2 (molecular oxygen), the upper atmosphere also has O (atomic oxygen), O_2^* (excited molecular oxygen), O^* (excited atomic oxygen), O^+ (ionic oxygen) and O_3 (ozone).

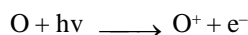
The atomic oxygen is produced by photochemical dissociation of oxygen by ultraviolet radiation ($E = h\nu$).



Due to the above photochemical dissociation of O_2 , molecular O_2 is virtually non-existent at very high altitudes. At altitudes exceeding 40 km, only less than 10% of oxygen is present as molecular oxygen. The atomic oxygen combines in the presence of radiation to form excited oxygen atom according to the reaction



The excited oxygen atom gives out visible light at 636 nm, 630 nm and 558 nm wavelength and is responsible for **air glow**. Oxygen ions (O^+) are formed when ultraviolet radiations react with oxygen atom



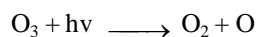
The oxygen ion is present in some regions of the ionosphere. It may be noted that the region beyond the stratosphere is dominated by +ve ions such as O^+ , O_2^+ , NO^+ and free electrons. It is called the **ionosphere**.

Ozone is present in the stratosphere which acts as a protective radiation shield for living organisms on earth. It is formed by photochemical reactions of oxygen as:



where M is another species like a molecule of N_2 or O_2 . It absorbs the excess energy liberated by the above reactions and hence stabilizes the O_3 molecule. Ozone strongly absorbs ultraviolet light in the region of 220-330 nm according to the

following reactions:



Types of Environmental Pollution

Environmental pollution may be of the following types:

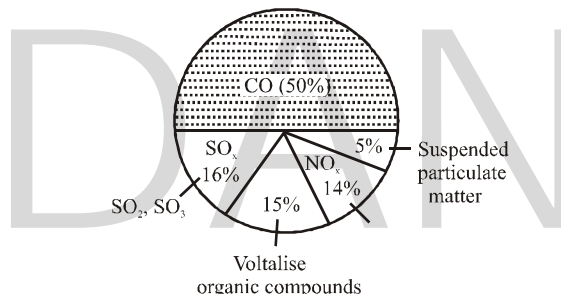
1. Atmospheric pollution
2. Water pollution
3. Soil or land pollution

Atmospheric pollution is generally studied under two heads:

- (a) Tropospheric pollution
- (b) Stratospheric pollution

Air Pollution

Air pollution occurs when the concentration of a normal component of the air or a new chemical substance added or formed in air builds up to undesirable proportions, causing harms to humans, other animals, vegetation and materials. The chemical substance causing pollution is called **air pollutant**. About 90% of air pollution problems are caused by the pollutants such as carbon monoxide, sulphur oxides, volatile organic compounds, nitrogen oxides and suspended particulate matter (such as carbon, dust, pollen, metal, etc.) as shown below.



Major air pollutants (approximate abundance)

Sources of Air Pollutants

The air pollution is caused by natural activity and human activity. The natural sources of air pollution are volcanic eruptions, forest fires (caused by lightning), pollen dispersal, evaporation of volatile organic compounds from leaves, bacterial decomposition of organic matter, wind erosion of soil and natural radioactivity.

Air Pollutants

There are two types of air pollutants:

1. Primary air pollutants
2. Secondary air pollutants

Primary air pollutants: A primary air pollutant is a

harmful chemical substance that directly enters the air as a result of natural events or human activities. The primary pollutants are:

- (i) Carbon oxides (CO and CO₂)
- (ii) Nitrogen oxides
- (iii) Sulphur dioxides (SO₂)
- (iv) Hydrocarbons
- (v) Suspended particulate matter (spm)

Secondary air pollutants: A secondary air pollutant is a harmful chemical that forms in the air due to a chemical reaction between two or more air components or a primary pollutant and one or more air components. For example, sulphur dioxide is a primary pollutant in air. It reacts with oxygen gas in the atmosphere to form the secondary pollutant sulphur trioxide (SO₃).



Primary pollutant Secondary pollutant

Even, the sulphur trioxide formed may react with the water vapour in air to form sulphuric acid.



Sulphuric acid is, therefore, also a secondary pollutant.

The common secondary pollutants are: SO₃, H₂SO₄, NO₂, N₂O, HNO₃, H₂O₂, O₃, nitrate and sulphate salts, etc.

Tropospheric Pollution

Tropospheric pollution occurs because of the presence of undesirable solid or gaseous particles in the air. The pollutants may be broadly classified into two major types:

1. **Gaseous air pollutants:** These include oxides of sulphur, nitrogen and carbon, hydrogen sulphide, hydrocarbons, ozone and other oxidants.
2. **Particulate pollutants:** These are dust, fumes, mist, spray, smoke, etc.

Some Common Air Pollutants

Carbon monoxide (CO)

It is a colourless, odourless and tasteless gas. It is heavier than air and is not soluble in water. It is one of the most serious air pollutants. It is **highly poisonous** to living beings because of its ability to block the delivery of oxygen to the organs and the tissues.

Sources of CO in air

The main sources of air pollution of CO are the **automobile engines** and **defective furnaces**. One of the sources of CO in air is the incomplete combustion of carbon, fossil fuel or carbon-containing compounds.



Some natural processes such as volcanic activity, natural gas emission, electrical discharge during storms, marsh gas

production, seed germination, etc. release some CO in the atmosphere.

The main contribution of CO in air pollution is from **human activity**. Of the total carbon monoxide content in the atmosphere, about 74% is contributed by automobile exhaust (motor vehicles, aircraft, rail, road). About 16% is contributed by forest fires and agriculture burning (burning of forest debris, crop residues, weeds and other vegetation). Industrial processes, mainly iron and steel, paper, and petroleum industries contribute about 9.6% of CO in the atmosphere.

Sinks of CO

Human activities release CO in the atmosphere and it is expected to double its concentration in the surrounding atmosphere every 5 years. However, the actual increase in CO in the atmosphere is less because of some natural sinks.

Soil is the major sink for CO. Some microorganisms in the soil remove CO from the atmosphere.

Effects of CO on human health

At higher concentrations of CO, suffocation, loss of consciousness or even death after several hours may occur. This is the reason why **pregnant women who have the habit of smoking are advised not to smoke** as the increased CO level in the blood may induce premature birth of the baby, spontaneous abortions or deformed babies. It is so poisonous that within half an hour, 1300 ppm is fatal.

Because of harmful effects of carbon monoxide, **it is dangerous to sleep in a closed room with a coke fire burning inside on a cold winter night**. When coke burns in an insufficient supply of oxygen (due to the closed room), a lot of carbon monoxide is produced. This can cause poisoning and may lead to death.

Effects of CO on Plants

Carbon monoxide has detrimental effects on plants when exposed for longer times. It inhibits the nitrogen-fixing ability of bacteria. It also affects leaf drop, leaf curling, decrease in leaf size and premature ageing of the plants.

Carbon dioxide (CO₂)

Carbon dioxide is a normal and essential component of the atmosphere. Animals exhale it. Therefore, it is vital to all forms of plant and animal life. It is normally not a pollutant. It is not an important contributor to acid rain. It can cause acidity when it dissolves in water, but it is relatively less soluble in water than the oxides of nitrogen and sulphur. Normally, it forms about 0.03% by volume of the atmosphere.

Sources

The main sources of CO₂ in the atmosphere are:

- Carbon dioxide released into the air by respiration
- Complete combustion of fossil fuels and carbon-containing compounds



- Carbon dioxide gas emitted during volcanic eruptions

Sinks of CO₂

The main sinks for CO₂ are natural processes. **Ocean is an important sink of carbon dioxide.**

Oxides of Nitrogen (NO_x)

Three oxides of nitrogen, namely nitrous oxide (N₂O), nitric oxide (NO) and nitrogen dioxide (NO₂), occur in the atmosphere. Nitrous oxide is produced by microbiological process in soils and is a component of unpolluted air.

Nitric oxide (NO) is a colourless, odourless gas and nitrogen dioxide (NO₂) is a reddish-brown gas having pungent suffocating odour. These two are important pollutants in air.

The irritant red haze in traffic and congested places is due to **oxides of nitrogen**.

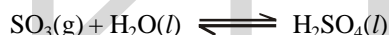
Sinks of NO_x

Many natural processes act as sink for oxides of nitrogen. These oxides are inherently unstable and decompose to N₂ and O₂ after some time.

Sulphur oxides (SO₂)

The oxides of sulphur are probably the most harmful of the common gaseous pollutants. Sulphur dioxide (SO₂) is the main pollutant among the sulphur oxides. It is a colourless gas with a pungent odour.

Under humid conditions, SO₃ reacts with water vapour to form H₂SO₄ droplets.

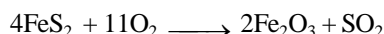


Sources of SO₂

Most of the sulphur dioxide in the atmosphere originates from the combustion of fossil fuels which contain some sulphur. Most coal and petroleum contain high levels (0.3 to 3% of the coal by mass) of sulphur. When coal is burnt, sulphur is oxidised to SO₂ and is released into the atmosphere.

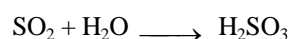


Coal also contains sulphur in some form of pyrites, which are also converted into sulphur dioxide during burning.



Sinks of SO₂

Sulphur dioxide in the air can undergo several reactions and therefore can be removed. A part of SO₂ combines with water droplets to form sulphurous acid.



It can also be oxidised to sulphur trioxide in air but uncatalysed oxidation of sulphur dioxide is slow.

Effects of SO₂

Sulphur dioxide and its compounds (formed from SO₂ such as SO₃, H₂SO₄ or sulphates) are dangerous air pollutants. These have dangerous effects on human life. Some of the harmful effects are:

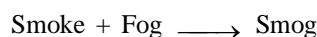
1. SO₂ affects the respiratory tract, producing nose, eye and lung irritation. It has been reported that lower concentration of SO₂ causes temporary spasm of the smooth muscles of the bronchioles, resulting in respiratory weakness. Mucus secretion is also stimulated by exposure to SO₂. It is also considered to cause cough, shortness of breath and spasm of larynx (uppermost part of windpipe) and respiratory diseases, e.g., asthma, bronchitis, emphysema in human beings. It also causes irritation to the eyes, resulting in tears and redness. A high concentration of SO₂ may cause lung diseases and lung cancer. SO₂ has been considered the most serious single air pollutant, causing many health hazards.
2. Atmospheric SO₂ is also harmful for plants. It damages vegetable crops and affects plant growth and nutrient quality of plant products. **The exposure of plants to SO₂ causes damage to leaf tissues and causes chlorosis** (a bleaching or yellowing of normally green portions of the leaves). **A high concentration of SO₂ leads to stiffness of flower buds, which eventually fall off from plants.**

Effects of Particulates

The effects of particulate pollutants depend upon the size of the particles. The coarser particles of size more than 5 microns are likely to lodge in the nasal passages whereas the smaller ones are more likely to penetrate into the lungs. The rate of penetration is inversely proportional to the size of the particles. Some of these particles are carcinogens. Continuous inhaling of these small particles for long periods of time irritates the lungs and causes 'scarring' or 'fibrosis' of the lung lining. This type of disease is very common in industrial settings and is known as **pneumoconiosis**.

Smog

Smog is a mixture of **smoke, dust particles** and small drops of **fog**. It is a major air pollutant in big cities. This is the best known example of air pollution that occurs in many cities throughout the world. The small drops of smog contain poisonous gases produced by burning of fuels in homes, factories and automobiles.



Containing harmful gases

Smog is of two types:

- (i) Classical smog, and
- (ii) Photochemical smog.

Classical smog: This type of smog is formed by the combination of smoke, dust and fog containing sulphur

dioxide from polluted air. It is formed in those areas which have cool and humid climate and where sulphur dioxide in air is very high. This is also called **chemical smog**.

This type of smog was observed in 1962 in London. The city remained covered with smog for 5 days and it caused deaths of many persons. Chemically, it is a reducing mixture, so it is also called **reducing smog**.

Photochemical smog: This type of smog is formed by the combination of smoke, dust and fog with an air pollutant in the atmosphere as a result of photochemical reaction. **It occurs in those areas which have warm, dry and sunny climate. It has a high concentration of photochemical oxidants.** These are produced when some of the primary pollutants interact under the influence of sunlight. Photochemical smog develops in cities in which the atmosphere is loaded with large quantities of automobile exhausts, stagnant air masses and intense sunlight. It has been observed in cities which have sunny, warm and dry climates such as Los Angeles and Denver in USA. Therefore, it was earlier called Los Angeles smog. The photochemical smog is chemically oxidising because it has a high concentration of oxidants. It is characterized by brown hazy irritating fumes. As a result of photochemical smog having characteristic brown haze, cities such as **Los Angeles** are sometimes called **brown air cities**.

Formation of photochemical smog

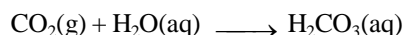
The brownish haze of photochemical smog is largely due to the brown colour of NO_2 .

Harmful effects of Photochemical Smog

1. Pungent-smelling smog containing ozone is very toxic. It can cause coughing, sneezing, bronchial constriction and irritation to the respiratory mucous system.
2. Aldehydes and **peroxyacetyl nitrate (PAN)** components of photochemical smog cause irritation to eyes and affect the respiratory tracts of human beings.
3. Photochemical smog reduces visibility and causes nose, throat and eye irritation. It may lead to several chronic diseases of eyes, heart and lungs.
4. It affects plant growth and damages plants. **PAN has also highest toxicity to plants. It attacks younger leaves and causes bronzing and glazing of their surfaces.**
5. Materials are also adversely affected by photochemical smog. For example, rubber has strong affinity for ozone and is cracked and aged by smog.

Acid Rain

Fossil fuels contain compounds of sulphur and nitrogen in addition to carbon. The combustion of fuels contributes significantly to atmospheric pollution. The burning of fossil fuels gives CO_2 . The gaseous CO_2 dissolves in water droplets to form a weak acid — carbonic acid.



Rain water normally has a pH of 5.6 due to the formation of H^+ ions from the reaction of rain water with carbon dioxide present in the atmosphere. When the pH of rain water falls below 5.6, it becomes acidic and is called **acid rain**. Thus, acid rain means the way in which acid from the atmosphere is deposited on the earth's surface.

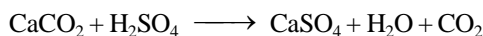
However, CO_2 is not the major component of acid rain because it is not soluble in water like the oxides of sulphur and nitrogen. The oxides of nitrogen and sulphur undergo many photochemical reactions in atmosphere and form HNO_3 and H_2SO_4 acids. During rains, these acids fall to the earth with rain.

Harmful effects of Acid Rain

- **It causes extensive damage to buildings and sculptural materials of marble, limestone, slate, etc.** These materials react with rain water and get damaged.
$$\text{CaCO}_3 + \text{H}_2\text{SO}_4 \rightleftharpoons \text{CaSO}_4 + \text{CO}_2 + \text{H}_2\text{O}$$
As a result of acid rain, the invaluable statues and buildings deteriorate. In Greece and Italy, many invaluable statues have been partially damaged. **Taj Mahal is facing the same problem.**
- Acid rain has also caused elimination of life from some freshwater lakes by destroying the living bodies.
- It also corrodes metals.
- It damages leaves of trees and plants and retards the growth of forests.
- It dissolves heavy metals from soils, rocks and sediments. Heavy metal ions such as copper, lead, mercury and aluminium leached from the soil enter well water and produce many toxic effects.
- Acid rain corrodes water conduit pipes resulting in the leaching of some heavy metals such as lead and copper into our drinking water.

Acid rain and Taj Mahal

Acid rain causes extensive damage to buildings and sculptural materials of marble, limestone, slate etc. The air in the city of Agra where Taj Mahal is located contains very high levels of oxides of sulphur and nitrogen. This causes acid rain and it reacts with the marble (CaCO_3) of Taj Mahal.

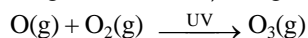


As a result, the marble becomes pitted and weakened mechanically because the soluble salts are easily leached out by rain water. Therefore, the wonderful monument is being slowly eaten away and the marble is getting discoloured and lustreless.

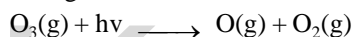
Ozone Layer

Stratospheric Pollution: Formation and Depletion of Ozone Layer

Ozone is an important constituent of the stratosphere at altitudes between 15 and 25 km. It is formed in the atmosphere by the decomposition of oxygen by ultra-violet radiation from the sun having wavelength shorter than 260 nm.



Most atmospheric **ozone is found in the stratosphere**, where its concentration is about 10 ppm (parts per million) by volume. Ozone is thermodynamically unstable and decomposes into molecular oxygen. It has the important photochemical property of absorbing solar radiation between the wavelengths of 200 nm and 300 nm.



The reactive atomic oxygen formed in the above reaction recombines with molecular oxygen to form ozone. This completes the ozone cycle.

The thick layer of ozone is called **ozone blanket** because it is very effective in absorbing harmful ultraviolet rays given out by the sun. Therefore, the ozone layer is also known as the **protective shield**. Since living cells can be destroyed by ultraviolet radiation, the ozone layer protects us from its damaging effects. If there were no ozone in the atmosphere even a small decrease in the concentration of ozone could lead to an increased incidence of skin cancer. The main effects of depletion of ozone layer in the stratosphere are increased cataracts, skin cancer, and reduction of planktons in ocean waters.

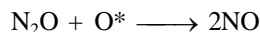
Depletion of the Ozone Layer

Recently in 1980, scientists have observed a hole in the ozone blanket covering the upper atmosphere around Antarctica. Recent observations have also shown that the ozone layer diminishes over the south pole in spring during August-September to a greater extent year after year. This depletion of the protective blanket of ozone will cause a damaging effect because harmful ultra-violet rays can come to earth through this hole. The increased level of ultra-violet rays will result in damage to plants, animals, human beings and even inanimate matter posing a great threat to the ecosystem over the globe.

Thus, the depletion of ozone layer is a serious threat to mankind. Scientists believe that every 1% decrease in ozone leads to 2% increase in skin cancer due to exposure to the sun's ultra-violet rays.

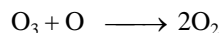
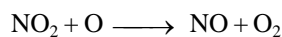
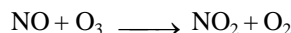
The depletion of ozone may be due to some natural processes or industrial activities.

Nitrous oxide (N_2O) occurs naturally at very trace levels in stratosphere. It can react with electronically excited oxygen atoms obtained by the ozone cycle to give NO.



Excited Nitric
atomic oxide
oxygen

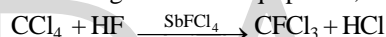
This removes an oxygen atom needed by the ozone cycle and the product, NO can destroy a second ozone molecule which breaks up another cycle.



Therefore NO is very damaging because just one NO molecule sets up a chain reaction which removes ozone again and again. There are similar ozone-depleting chain reactions involving other stratospheric gases.

Chlorofluorocarbons and Ozone Layer

Chlorofluorocarbons are compounds such as CFCl_3 , CF_2Cl_2 , CF_2Cl , commonly known as **freons**. These have properties such as low boiling points, low viscosities, being odourless, non-toxic, non-flammable, having least chemical reactivity and being thermally stable. These came into use as refrigerants around 1930. Later on, these proved to be highly useful as aerosol propellants, cleaning solvents, fire-fighting materials, fast food packing materials, plastic foams, for sterilizing surgical instruments in medicinal products, cleaning and decreasing electronic equipment, etc.

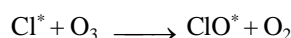


A large amount of these products is being extensively used in air conditioners, refrigerators, spray cans, and industrial solvents. It is released into the atmosphere and is causing air pollution.

The loss in ozone layer is because of its reaction with chlorofluorocarbons. Unlike other chemicals, chlorofluorocarbons are not removed from the atmosphere by usual scavenging processes like photo dissociation, oxidation, rainfall, etc. As a result, they move to the stratosphere by random diffusion. Then these are destroyed by photolysis and release atomic chlorine. These released Cl atoms cause a catalytic chemical reaction and significant depletion of the stratospheric ozone layer.



The free radical, Cl^* , reacts with O_3 through a chain reaction:



These chlorine atoms are free to react with more *ozone*. As a result, many O_3 molecules can be destroyed for each

chlorine atom produced. It has been shown that over one thousand ozone molecules can be destroyed by one Cl.

The net result of these reactions is destruction of several molecules of O_3 for each Cl atom produced.

Effects of Depletion of the Ozone Layer

The depletion of ozone layer has the following harmful effects:

- It poses serious threat to mankind. It results in **skin cancer** due to exposure to the sun's ultra-violet rays.
- Ultra-violet rays may **damage immune system**, which may lead to increased **viral infections**.
- Increased exposure to ultra-violet radiation will damage marine plants, marine animals and fish, which form an important part of human food.
- These may **damage the land's plants and crops**.
- Freons trap the warmth of the sun and disturb the greenhouse effect, leading to a higher temperature which could damage crops and pose dangers to low-lying ocean port cities from increased melting of ice.

Ozone Depletion over Antarctica

The chain reactions described above can occur all over the stratosphere. However, the depletion of ozone layer leading to the ozone hole has mainly been observed in the stratosphere over Antarctica.

To control the harmful effects of CFCs, serious efforts are being made to control the use of CFCs and find alternative methods. The **Montreal Protocol**, signed by 24 countries in October 1987, was the first step to bring down the production of freons. At some places these are being replaced by safe substitutes like hydrochlorofluorocarbons (HCFCs), which have only one-tenth as destructive effect as CFCs.

Greenhouse Effect

The sun emits light of different wavelengths consisting of ultra-violet ($\lambda < 400$ nm), visible region ($\lambda < 400 - 700$ nm) and infra-red ($\lambda < 700$ nm). Of these, the harmful ultra-violet radiations are absorbed by the ozone layer in the stratosphere and warm the air rather than coming to the surface of the earth. The visible and infra-red radiations pass through the atmosphere and reach the surface of the earth. However, some of the light incident on the earth is reflected back. For example, of the total incoming light that falls upon the Earth, about 50% reaches the surface and is absorbed by it. About 20% of the incoming light is absorbed by gases in the atmosphere, such as ultra-violet (uv) light by ozone in stratosphere and infra-red (IR) by CO_2 and water vapour present in the air. The remaining 30% is reflected back into space by sand, snow, cloud, ice snow and other reflecting bodies without being absorbed.

Some gases in the air, such as CO_2 , has the property of allowing visible light to pass through it but absorbing the

infra-red radiations reflected from the surface of the earth. Therefore, all the IR emitted from the earth's surface and atmosphere escape directly into the space. After the absorption of IR radiation by CO_2 molecules, these thermal IR radiations are re-emitted in all directions and some are redirected back towards the earth's surface and heat up the atmosphere (earth and air). This heating of the earth due to trapped radiation is called **greenhouse effect**.

The common atmospheric gases that have predominantly produced greenhouse warming are CO_2 , water vapours (H_2O) and ozone (O_3). Out of these, water vapours and ozone do not contribute much to the greenhouse effect of the earth's atmosphere because water vapours are found only near the surface of the earth whereas ozone is present only in the upper atmosphere. On the other hand, carbon dioxide is uniformly distributed in the atmosphere and hence makes major contribution towards the greenhouse effect. Thus, **carbon dioxide is regarded as the most important greenhouse gas**. The other greenhouse gases whose concentration- has been small in atmosphere but have ability to warm the air substantially are CH_4 , N_2O , CFC_{13} , CF_2C_{12} , O_3 , etc. Their concentration in atmosphere is increasing with industrialisation and air pollution. Methane is produced naturally when vegetation is burnt, digested or rotted in the absence of oxygen. Large quantities of **methane are released in paddy fields**, in coal mines, from rotting of garbage dumps and by fossil fuels. Chlorofluorocarbons (CFCs) are man-made industrial chemicals used in airconditioning, etc. CFCs also damage the ozone layer (discussed earlier). Nitrous oxide occurs naturally in the atmosphere.

Greenhouse Effect in an Automobile

The heating due to greenhouse effect can also be observed inside an automobile such as a car parked in the sun with all its windows closed. The glass windows of the car allow the sun's rays to enter the car. Some of these rays are reflected from the inside surface of the car in the form of infra-red light. These rays are trapped by glass windows (just like the CO_2 layer) and cause the interior of the car to heat up. Hence, the inside of the car becomes considerably hot.

Because of increasing air pollution, the concentration of trace gases such as CO_2 , CH_4 , N_2O , CFCs, etc. is increasing in the air. These gases absorb thermal IR radiation and would, therefore, redirect back more and more outgoing thermal IR energy, causing increase in the average surface temperature.

Implications of Greenhouse Effect

Modern human activities are releasing large quantities of CO_2 in the atmosphere. The major activities which contribute towards this are:

- burning of fossil fuels, and
- cultivation of soil.

CO_2 is a normal and essential component of atmosphere.

It is not considered a pollutant. However, increase in its proportion in the atmosphere can lead to global warming through increased greenhouse effect.

Chlorofluorocarbons (CFCs) have also the greatest potential to cause global warming due to their greater efficiency of absorbing thermal IR radiations. **Each molecule of a CFC has the potential to cause the same extent of global warming as do tens of thousands molecules of CO₂.** CFCs are being excessively used in insulating freezers, refrigerators and air conditioners and are posing the threat of global warming. However, Government is now trying to control the production of CFCs.

It has been observed that the average temperature of the earth has increased by about 1°F due to greenhouse effect. If CO₂ is continued to be released into the atmosphere at the present rate then by the end of this century the earth's average temperature is expected to increase by **3.6°F**. This excessive heating of the earth would melt all the snow on poles and different mountains. This would increase the water level of the sea and, as a result, the cities located on the coastal areas are likely to be flooded.

The increase in average global temperature can have the following effects on the climate of the earth:

- In temperate regions, the summer will be longer and hotter and the winter will be shorter and warmer. A warmer climate will make certain cities extremely hot to live.
- There will be increase in the total amount of global rainfall but some regions will receive less rainfall.
- The number of days having intense showers and high temperatures both will increase.
- The problems of desertification, drought and soil erosion will become worse.
- As a result of rise in temperature of the earth, the ocean will get warmed up and the sea level would rise, flooding low-lying regions. The increase in sea level would have profound effects on habitation patterns and will threaten to submerge many coastal countries like Bangladesh, Indonesia, Maldives, parts of coastal India and many other island nations.
- Increase in greenhouse effect is expected to cause the cooling of the stratosphere. This is because most thermal IR radiation will be absorbed at low altitudes and little will be left to warm the stratosphere.
- Tropical storms, hurricanes, etc. will be stronger and more frequent, and will cause devastation.
- Some areas may become wetter or more humid; some other areas will become dry. The tropics may become wetter and the subtropics, which are already dry, are expected to be drier.
- Due to global warming, human health will be affected. Increased number of hot days and extreme weather may cause chronic respiratory diseases. This also causes increase in the incidences of infectious diseases like

dengue, malaria, yellow fever, sleeping sickness, etc.

- Insects carrying diseases such as malaria may also increase.
- Animal health will also be affected due to the spread of diseases by parasites.
- Ocean temperature change may also affect marine life adversely.

Water Pollution

Domestic sewage

Domestic sewage contains oils, human excreta, dirt, paper, rags, sand grains, dissolved materials such as detergents and inorganic compounds such as sodium chloride, ammonium sulphate and ammonium phosphate, and decomposed kitchen waste. The sewage also contains many diseases causing bacterias called **pathogens**, which are most serious water pollutants. Pathogens include bacteria and other organisms which enter water from domestic sewage and animal excreta. Human excreta contains bacteria such as **Escherichia coli** and **Streptococcus faecalis**, which cause gastrointestinal diseases.

Industrial wastes

Some common types of industrial wastes polluting water are:

- Heavy metals:** These are metals such as cadmium, lead and mercury which are present in industrial or mining wastes. These metals are poisonous and can be dangerous to humans. For example, cadmium and mercury can cause kidney damage, whereas lead poisoning can cause damage to liver, intestines, brain, kidney and central nervous system. All of these metals are **cumulative poisons** because the body does not excrete them and their concentration builds up.
- Detergents and fertilizers:** These may contain phosphates as additives. It may be noted that these do not pose any threat to the aquatic life but serve as nutrients for plants leading to their excessive growth in ponds, lakes and rivers. These encourage the formation of algae, which reduce the dissolved oxygen concentration of water. This process is known as **eutrophication**. This impedes the development of higher life forms such as fish.
- Petroleum products:** Petroleum products also pollute many sources of water, e.g., major oil spills in ocean. This is because of wreckage of oil tankers in open sea or accidents of ships carrying oil in the sea. The spreading of oil in the sea is called **oil spill** and the thick layer of oil on the surface of sea water is called **oil slick**. In India, an oil spill occurred in Bombay on March 17, 1993, due to the rupture of a pipeline which damaged the ecosystem and marine life.
- Acid polluted water:** The acid polluted water having pH less than 3 is deadly to most forms of aquatic life. The water

downstream from a mine may get contaminated by acid mine drainage formed by microbial oxidation of discarded waste materials at the mine site. The acid mine water mainly contains sulphuric acid produced by the oxidation of iron pyrites (FeS_2). Industrial wastes and acid rain also contribute to the acidic nature of natural water.

- (v) **Polychlorinated biphenyls (PCBs):** Polychlorinated biphenyls have very high stabilities and are, therefore, finding many applications these days. For example, these are used as fluids in transformers and capacitors, as cleansing solvents, detergents and fertilizers. PCBs are resistant to oxidation and their release into the environment has become a serious pollutant. These are carcinogenic and cause skin disorders in humans.

Water Quality Parameters and International Standards

The quality of water is of vital concern for mankind because it is directly linked with human welfare. Drinking water should be fit for human consumption having the following essential parameters for water quality:

- (i) It should be colourless and odourless.
- (ii) It should be pleasant in taste.
- (iii) It should be clear and turbidity should be less than 10 ppm.
- (iv) **Its pH should be between 5.5 and 9.5.**
- (v) The total dissolved solids should not be more than 500 ppm.
- (vi) It should be free from disease causing micro-organisms.
- (vii) It should be reasonably soft.
- (viii) It should be free from objectionable chemicals.

There are some international standards for drinking water which must always be adhered to if water is to be used for drinking purposes. The parameters and standards for water quality and harmful effects of pollutants behind permissible limits are briefly discussed below:

1. **Fluoride:** Soluble fluoride is normally added to drinking water and its concentration should be up to 1-1.5 ppm or $1-1.5 \text{ mg dm}^{-3}$. This limit is within agreed safety limits and protects teeth against decay. The deficiency of this compound in drinking water is harmful to man and causes diseases such as **tooth decay**. The F^- ions make the enamel on teeth much harder, by converting hydroxyapatite $[\text{3Ca}_3(\text{PO}_4)_2 \cdot \text{Ca}(\text{OH})_2]$, the enamel on the surface of the teeth, into harder fluorapatite $[(\text{3Ca}_3(\text{PO}_4)_2 \cdot \text{CaF}_2)]$. However, F^- ion concentration above 2 ppm causes brown mottling of teeth. Higher concentrations of fluoride are poisonous and are harmful to teeth and bones at levels above 10 ppm (mg dm^{-3}). This problem has been reported from some parts of Rajasthan.
2. **pH:** The pH of drinking water should be between 5.5 and 9.5. A decrease in the pH of water increases the solubility of heavy metal ions.
3. **Sulphate:** Sulphate is harmless at moderate concentrations but **excessive concentration of sulphate above 500 ppm produces laxative effects and hypertension**.
4. **Nitrate:** Excessive nitrate in drinking water is also harmful and can cause *methemoglobinemia* (blue baby syndrome). It is linked to stomach cancer. The maximum limit of nitrate ions in drinking water is 50 ppm.
5. **Lead:** Lead pipes are very commonly used for water transport and are liable to get contaminated with lead, particularly when water is acidic.

Permissible Limits of Elements in Drinking Water

Parameter	Permissible limits (ppm)	Ill-effects of pollutants
Dissolved Oxygen	250	—
Arsenic	0.05	Cramps, paralysis
Barium	1.0	Toxic to heart
Cadmium	0.005	Anaemic, kidney dysfunction
Chromium	0.05	Carcinogenic
Fluoride	1-1.5	Skeleton disorder, nervous breakdown and mottling of teeth enamel
Lead	0.05	Anaemic, kidney dysfunction, nervous disorder
Aluminium	0.2	Brain damage
Selenium	0.01	Toxic at high levels
Copper	3.0	Toxic to plants and algae
Mercury	0.001	Highly toxic, mental disorders and death
Zinc	5.0	Toxic
Alkyl benzene-sulphonate	0.5	Irritation of the gastrointestinal tract
Chloride	600	Harms agricultural crops
Sulphate	500	Laxative and hypertension
Pesticides	0.005	Toxic, carcinogenic, kidney dysfunction

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

Certain chemicals other than organic wastes also react with dissolved oxygen in water. This is referred to as **chemical oxygen demand (COD)**. Thus, BOD measures the oxygen consumed by living organisms assimilating organic matter present in waste while **COD is a measure of biological oxidisable as well as biological inert organic matter such as cellulose**. Thus, if BOD or COD values of water are large, it indicates that water is heavily polluted.

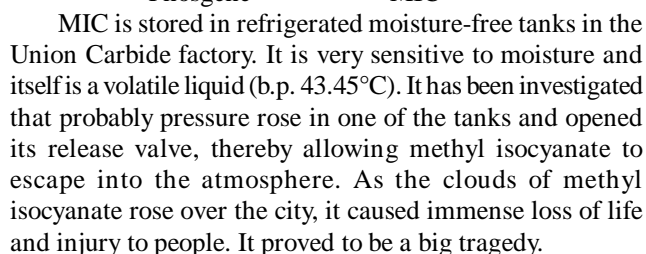
Soil receives large quantities of hazardous wastes from different sources and gets polluted. Any factor which deteriorates the quality, texture and mineral content of the soil and disturbs the biological balance of the organisms in it and has lethal effect on plant growth is called **soil pollutant**.

Pesticides may be classified into the following categories:

- environment, toxic to insects in small amounts but much less so to humans, because they are not very soluble in water. These are persistent and show their biological activity for long periods of time.

- ## A Major Air Pollution Accident — Bhopal Gas Tragedy

Methyl isocyanate (MIC) was used to manufacture the insecticide **carbaryl** marked under the commercial name **Sevin** in this plant. It was prepared by the reaction of methylamine and phosgene.



Recycling: This is the simplest method in which the waste is recycled. When the materials are recycled, it saves

on the cost of raw materials as well as reduces the costs of waste disposals.

Sewage treatment: The sewage treatment involves the following three types of stages:

1. The **first stage** known as **primary treatment** involves the removal of large solid particles. This is done by mechanical process consisting of **screening** and **sedimentation**. For this, the waste is filtered through different types of screens. The solids that are removed are disposed off at landfill sites. They are then allowed to flow into sedimentation tanks. This process allows the removal of solids that settle out (called **sludge**). This process also allows the removal of grease, which floats to the surface and can be skimmed off.
2. The **second stage** known as **secondary treatment** involves the biological oxidation of organic content of waste materials by micro-organisms followed by filtration.
3. The **third stage**, also known as final treatment, is a series of specialized physical and chemical processes that reduce the quantities of specific pollutants left after primary and secondary treatments. These improve the quality of waste water. The processes commonly used in this treatment are chemical removal of phosphate, coagulation, filtration, treatment with activated charcoal, disinfection by chlorine, reverse osmosis, etc.

Green Chemistry

Green Chemistry as an Alternative Tool for Reducing Air Pollution

With growing awareness of environmental pollution, the international community is under increasing pressure to find methods to save our lives from the increasing pollution. This does not mean that we should stop the process of advancement that has been set in but to search methods which would help in reduction of pollution of our environment. The scientists are searching new alternatives which do not cause environmental pollution. This new approach is called **Green Chemistry**, which was introduced in the early 1990s. **It means zero discharge of toxic, persistent substances into the environment**, guaranteed by the fact that they are never produced. Green chemistry may be defined as **a strategy to design chemical processes and products that reduce or eliminate the use and generation of hazardous substances**. This would bring about minimum pollution or deterioration to the environment.

The basic aims of green chemistry are:

- (i) Reformulation of synthetic routes so that hazardous substances do not enter into the atmosphere.
- (ii) During synthesis, care must be taken to select starting materials that can be converted into end products with almost 100% yield. This can be achieved by arriving at optimum conditions.
- (iii) The methods used to obtain starting materials, e.g. mining, refining, etc. should have minimum impact on the natural environment.
- (iv) The synthetic reactions may preferably be carried out in aqueous medium because water has high specific heat and low volatility. Water is cost-effective, non-inflammable and does not have any carcinogenic effects.
- (v) The awareness among common man to use green products.

Achievements of Green Chemistry

A lot of success has been achieved in developing new techniques. Some of these are:

- (i) Consider the production of adipic acid, which is used for the manufacture of nylon 66. The most common process is petroleum-derived benzene as the starting material. The last step for the synthesis of adipic acid requires oxidation by nitric acid, resulting into nitrous oxide as a by product. Nitrous oxide released in the atmosphere causes air pollution. Recent green chemistry research has developed a new method known as **Draths-Frost synthesis of adipic acid**. In this method, adipic acid is obtained by genetically engineered microbes from glucose. This method prevents air pollution by nitrous oxide.
- (ii) A new method has been developed for synthesizing ibuprofen in about 99% yield. This method avoids the use of large quantities of solvents and wastes associated with traditional stoichiometric use of auxiliary chemicals during chemical conversions.
- (iii) For the manufacture of polystyrene foam sheet packaging materials, the process of carbon dioxide as the blowing agent was developed. This method does not use conventional chlorofluorocarbon blowing agents which contribute to ozone depletion, global warming and ground-level smog.

Green Chemistry in Day-to-Day Life

Some common examples of green chemistry in our day-to-day life are:

Dry cleaning of clothes

Tetrachloroethene ($\text{C}_1_2\text{C} = \text{CCl}_2$) was earlier used as solvent for dry cleaning. This compound is suspected to be carcinogenic and contaminates ground water. The process of using this compound has now been replaced by a new process in which liquefied carbon dioxide is used along with a suitable detergent. This causes less harm to ground water. Replacement of halogenated solvent by liquid CO_2 will result in less harm to ground water.

Similarly, **hydrogen peroxide (H_2O_2)** is used for the **purpose of bleaching clothes in the process of laundry**. This gives better results and makes use of less water, thereby saving a lot of water. It is also not harmful.

Bleaching of paper

Chlorine gas was used earlier for bleaching paper. It is a highly toxic chemical. Its use has been replaced by hydrogen peroxide with a suitable catalyst which promotes the bleaching action of hydrogen peroxide.

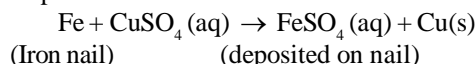
A Quick Recap

Silver halides are sensitive to sunlight and are decomposed by it. This forms the basis of black and white photography. Silver halides are generally kept in coloured bottles.

Rusting of iron and rancidity are caused due to **oxidation**. Chemically, rust is **hydrated ferric oxide** ($\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$). Respiration in cells of all living beings is an **oxidation** reaction.

Rancidity is the slow oxidation of certain oils or fats present in food materials resulting in foul smell.

When iron nail is dipped in copper sulphate solution, it acquires a **brown coating** of copper as a result of the displacement reaction.



Among Al, K, Ca and Au, **K** is the most reactive while **Au** is the least reactive metal.

Au (Gold) does not get corroded.

When quick lime (CaO) is added to water, slaked lime or $\text{Ca}(\text{OH})_2$ is formed. The reaction is highly **exothermic** in nature.

Souring of milk is due to the presence of **lactic acid**.

Alexander Flemming invented **penicillin**.

The acid present in the stomach is **hydrochloric acid** and causes acidity.

Litmus is the extract of the plant **lichen**.

In general, mineral acids like HCl , HNO_3 and H_2SO_4 are strong acids. HCOOH and CH_3COOH are weak acids.

The pH of human blood varies between 7.36 and 7.42.

Saliva produced in the mouth by salivary glands is of **alkaline** nature.

Wrought iron is the purest form of iron.

Oxides of metals are basic in nature while those of non-metals are acidic.

Neutralisation reactions are always **exothermic**.

The higher the pH value, the weaker the acid and the stronger the base.

The isotope used for the production of atomic energy is **U-235**.

Gypsum, upon strong heating, changes to **plaster of paris**, which gives back gypsum upon hydration.

A strong solution of sodium chloride in water (about 30%) is called **brine**.

Baking powder is a mixture of baking soda and tartaric acid.

Antacid is a substance which can neutralise acidity in the stomach.

Bleaching powder (CaOCl_2) is prepared commercially by reacting chlorine with slacked lime.

Curie point is the temperature at which a metal loses its magnetic properties.

Gypsum is chemically $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$.

Plaster of Paris is chemically $\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$.

Hydrated copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) is also called **Blue Vitriol**.

Joseph Aspdin patented the first true artificial cement.

Common salt becomes sticky during the rainy season due to the presence of **Magnesium Chloride (MgCl_2)**.

$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ is called **Green Vitriol** or hydrated ferrous sulphate.

Glass is a supercooled liquid.

Bees sting contains methanoic or **formic acid (HCOOH)**.

Enamel coating of our teeth has calcium phosphate or $\text{Ca}_3(\text{PO}_4)_2$.

$\text{Mg}(\text{OH})_2$ and NaHCO_3 are **antacids**.

Positron is not a nucleon.

Baking Soda is NaHCO_3 or sodium bicarbonate.

Graphite is a very **good conductor** of electricity.

Metals like Gold and Platinum placed at the bottom of the activity series are known as **noble metals**, which means that they are very little reactive chemically.

Although hydrogen is a non-metal, it has been included in the reactivity series. Actually it behaves like metals and forms positive ion (H^+) by losing its only electron present.

Lignite contains recognisable traces of the original plant material.

The water-soluble metal hydroxides are known as **alkalis**, eg NaOH , KOH etc. Water-insoluble hydroxides are known as bases, eg $\text{Ca}(\text{OH})_2$, $\text{Al}(\text{OH})_3$ etc.

The oxides which exhibit the characteristics of both acids and bases are known as **amphoteric oxides**. For example, Aluminium Oxide and Zinc Oxide.

Ruby and Sapphire are oxides of **Aluminium**.

A piece of Sodium metal when thrown into water catches fire. However, it is not the metal but the hydrogen evolved in the reaction which is involved in the reaction and catches fire.

Hydrogen sulphide (H₂S) gas has a characteristic smell which resembles that of **rotten eggs**.

Metals like **Sodium** and **Potassium** are kept under kerosene since they react violently with water.

Gunpowder consists of a mixture of nitre, sulphur and charcoal.

Gold and platinum are dissolved in aqua regia, also called **royal water**.

Among the metals, **aluminium** is the most abundant in the earth's crust.

Magnesium (Mg) is present in chlorophyll and iron is a constituent of haemoglobin.

Gallium (Ga) and **Caesium (Cs)** have very low melting point. They melt with heat provided by hand.

When conc. H₂SO₄ is added to dry KNO₃, **brown fumes** are evolved. These fumes are due to NO₂.

Galvanisation is the process of coating a layer of zinc on the surface of the metal iron in order to protect it from getting rusted.

Common Salt (NaCl) is a neutral salt and its pH is the same as that of water.

Urea was the first organic compound to be prepared in the laboratory.

Supersonic jet causes pollution by the thinning of O₃ layer.

Methane is also called **marsh gas**.

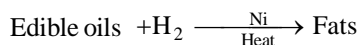
The combustion of Ethyne with Oxygen is generally used in **gas welding**. Ethyne needed for the process is formed by dropping water on Calcium Carbide.



Hydrogen bomb is based on the principle of **uncontrolled fusion reaction**.

LPG (liquefied petroleum gas) contains mainly **propane** and **butane** in liquefied form.

Vegetable ghee such as **Dalda** are of saturated nature and are formed by **catalytic hydrogenation reaction**.



Unsaturated Saturated

Freon gas, which is used is used as a **refrigerant** to cause cooling, is chemically dichlorodifluoromethane (CCl₂F₂).

In a photocell, light energy is converted into **electrical energy**.

Ethyl alcohol is prepared from sugar (C₁₂H₂₂O₁₁) by the process known as **fermentation**.

Ethanoic acid or Acetic acid (CH₃COOH), whose dilute aqueous solution containing only 5-8% acid, is called

vinegar. It is for the preservation of sausages, pickles etc.

One of the constituents of tear gas is **chloropicrin**.

The manufacture of soap is called **saponification**.

Fullerenes represent the recently prepared allotropic forms of carbon.

Tetraethyl lead is an antiknock compound.

A small amount of methyl alcohol, pyridine or copper sulphate is added to ethyl alcohol for making **denatured alcohol**.

Fluorine (F), the first member of the halogen family, is the **most electronegative** element.

The combining capacity of an element is called **valency**. The atomic size of the elements increases down the group and decreases along the period.

Silicon, germanium, boron and arsenic are **metalloids**.

Metals are **electropositive** in nature.

Fructose is the sweetest sugar among glucose, fructose and sucrose.

Vulcanization of rubber is carried out by adding sulphur.

¹⁴C is used in dating **archaeological findings**.

Melamine is used in making plastic crockery.

The fourth state of matter is known as **plasma**.

Heavy water is D₂O.

Water gas is a mixture of CO and H₂.

Pure water does not conduct electricity because it does not ionize.

In a nuclear reactor, **graphite** is used as a moderator.

Milk of magnesia is chemically Magnesium Hydroxide.

Commercial **Nitric acid** is coloured because it contains dissolved Nitrogen dioxide (NO₂).

Urea has **46%** Nitrogen in it.

The three elements most needed in common fertilizers are **NPK** (Nitrogen, Phosphorus and Potassium).

D₂O (Heavy water) is used to absorb neutrons to **control the chain reaction** during nuclear fission.

Francium is a radioactive liquid metal.

The heaviest metal is **Osmium**.

Lithium is the lightest metallic element and it is the strongest reducing agent.

Silver and **Copper** are the two best metallic conductors of heat and electricity.

The special smell in onion and garlic is due to the presence of **potassium**.

Nickel is used as catalyst in the hydrogenation process of vegetable oils.

Greenokite is an ore of **cadmium**.

Radium is extracted from **pitchblende** and it was extracted firstly by Madame Curie.

Zeolite is used in softening drinking water.

Nichrome is the alloy of Nickel, Chromium and Iron. The coil of the electric heater is made of nichrome.

- Respiration is basically a **combustion** reaction.