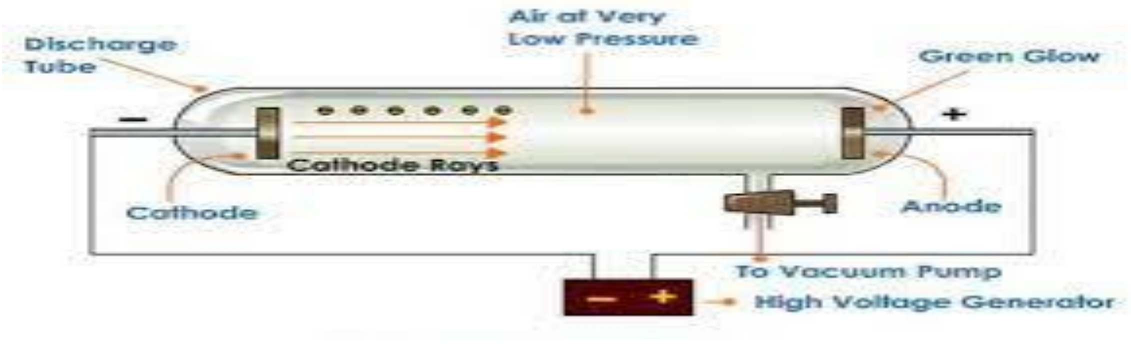
Unit-I

Concept of Atom

An atom is **a particle of matter that uniquely defines a chemical element**. An atom consists of a central nucleus that is surrounded by one or more negatively charged electrons. The nucleus is positively charged and contains one or more relatively heavy particles known as protons and neutrons

J.J. Thomson and the discovery of the electron

In the late 19th Century , start superscript, start text, t, h, end text, end superscript century, physicist J.J. Thomson began experimenting with cathode ray tubes. Cathode ray tubes are sealed glass tubes from which most of the air has been evacuated. A high voltage is applied across two electrodes at one end of the tube, which causes a beam of particles to flow from the cathode (the negatively-charged electrode) to the anode (the positively-charged electrode). The tubes are called cathode ray tubes because the particle beam or "cathode ray" originates at the cathode. The ray can be detected by painting a material known as phosphors onto the far end of the tube beyond the anode. The phosphors spark, or emit light, when impacted by the cathode ray.



Discharge Tube

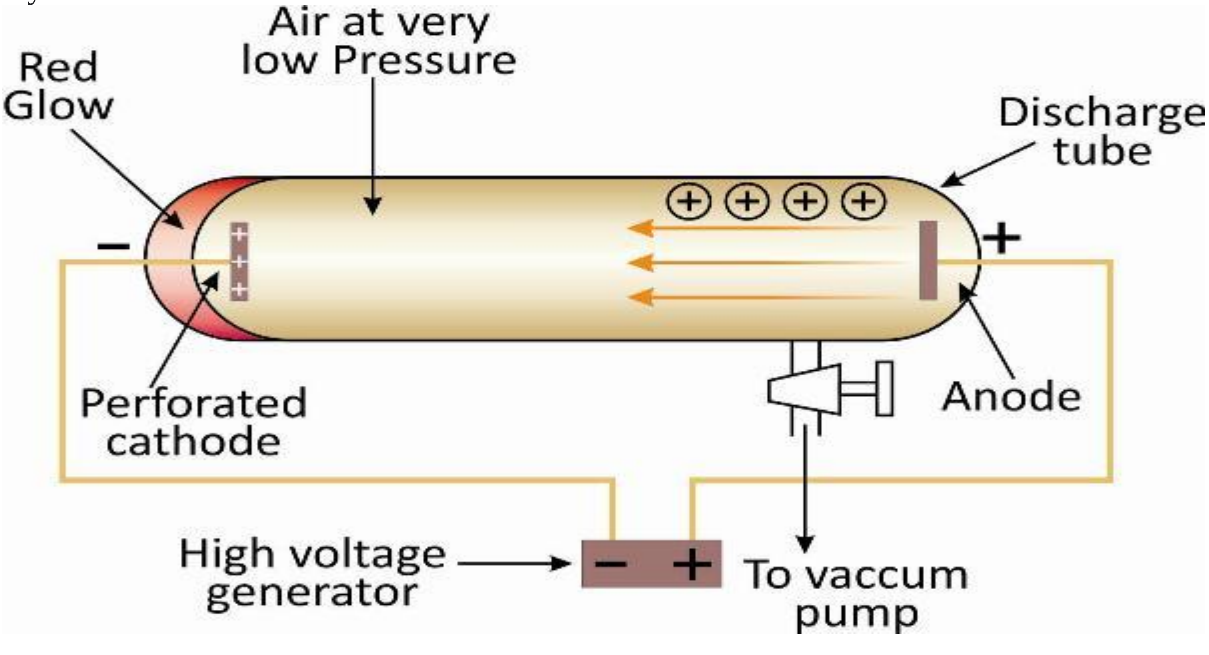
To test the properties of the particles, Thomson placed two oppositely-charged electric plates around the cathode ray. The cathode ray was deflected away from the negatively-charged electric plate and towards the positively-charged plate. This indicated that the cathode ray was composed of negatively-charged particles.

Thomson also placed two magnets on either side of the tube, and observed that this magnetic field also deflected the cathode ray. The results of these experiments helped Thomson determine the mass-to-charge ratio of the cathode ray particles, which led to a fascinating discovery—minus the mass of each particle was much, much smaller than that of any known atom. Thomson repeated his experiments using different metals as electrode materials, and found that the properties of the cathode ray remained constant no matter what cathode material they originated from. From this evidence, Thomson made the following conclusions:

- The cathode ray is composed of negatively-charged particles.
- The particles must exist as part of the atom, since the mass of each particle is only 1/2000 start fraction, 1, divided by, 2000, end fraction the mass of a hydrogen atom.
- These subatomic particles can be found within atoms of all elements.

Discovery of Protons

The presence of positively charged particles in an atom had been first observed in 1886 by E. Goldstein based on the concept that atoms are electrically neutral i.e., it has the same number of positive and negative charges. He performed a series of experiments and observed that when high voltage electricity passed through a cathode tube fitted with a perforated cathode (pierced disk) containing gas at low pressure a new type of ray was produced from the positive electrode (anode) which moves towards the cathode. These new rays he termed as canal rays, positive rays, or anode rays.



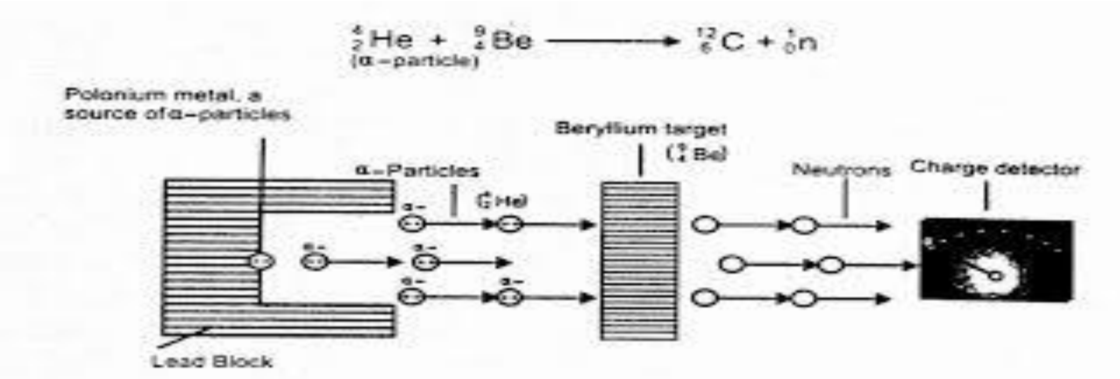
The characteristics of positively charged particles of canal rays are listed below –

- Unlike cathode rays, mass of positively charged particles depends upon the nature of gas present in the anode ray tube. These are simply positively charged gaseous ions.
- The charge to mass ratio of the particles depends on the gas from which these originate.
- Some of the positively charged particles carry a multiple of the fundamental unit of electric charge.
- The behavior of these particles in the magnetic or electrical field is opposite to that observed for electron or cathode rays in cathode ray’s experiment.

Discovery of Neutron

In 1932, the physicist James Chadwick conducted an experiment in which he bombarded Beryllium with alpha particles from the natural radioactive decay of Polonium. The resulting radiation showed high penetration through a lead shield, which could not be explained via the particles known at that time.

With the postulate of an uncharged (neutral) particle, of about the same weight as a proton, however, Chadwick's interpretation problems disappeared quite naturally. Thus, his results could be explained within the known laws of nature, in particular with regard to energy and momentum conservation.

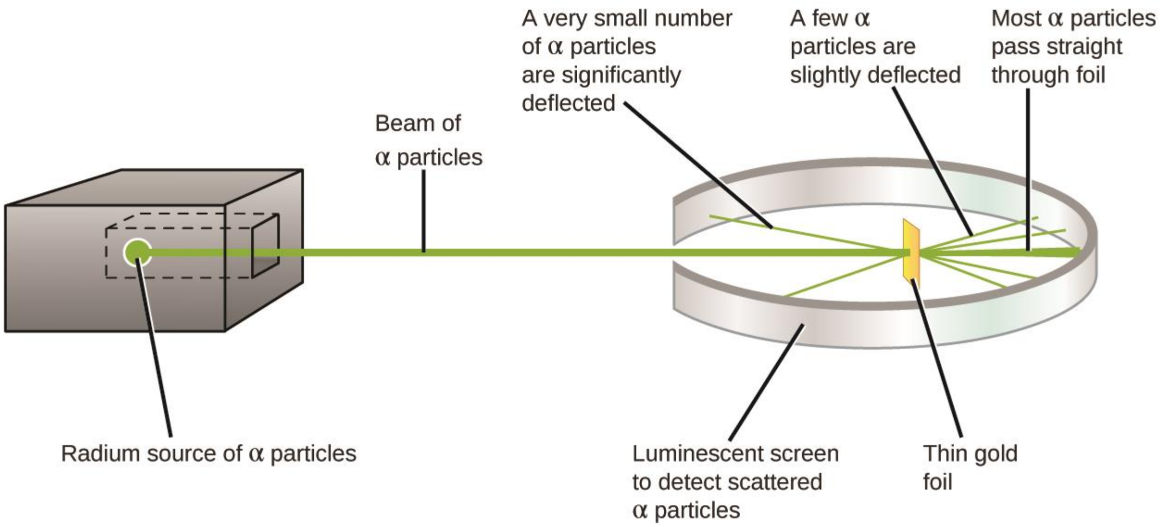


Rutherford Nuclear Model

Ernest Rutherford and the gold foil experiment

The next ground breaking experiment in the history of the atom was performed by Ernest Rutherford, a physicist from New Zealand who spent most of his career in England and Canada. In his famous gold foil experiment, Rutherford fired a thin beam of \alphaαalpha particles (pronounced *alpha* particles) at a very thin sheet of pure gold. Alpha particles are helium nuclei $_2{}^4$ He^{2+})left parenthesis, start subscript, 2, end subscript, start superscript, 4, end superscript, start text, H, e, end text, start superscript, 2, plus, end superscript, right parenthesis, and they are given off in various radioactive decay processes. In this case, Rutherford placed a sample of radium (a radioactive metal) inside a lead box with a small pinhole in it. Most of the radiation was absorbed by the lead, but a thin beam of \alphaαalpha particles escaped out of the pinhole in the direction of the gold foil. The gold foil was surrounded by a detector screen that would flash when hit with an \alphaαalpha particle.

[Why was the foil made out of gold? Couldn't he have saved a buck and used nickel?]

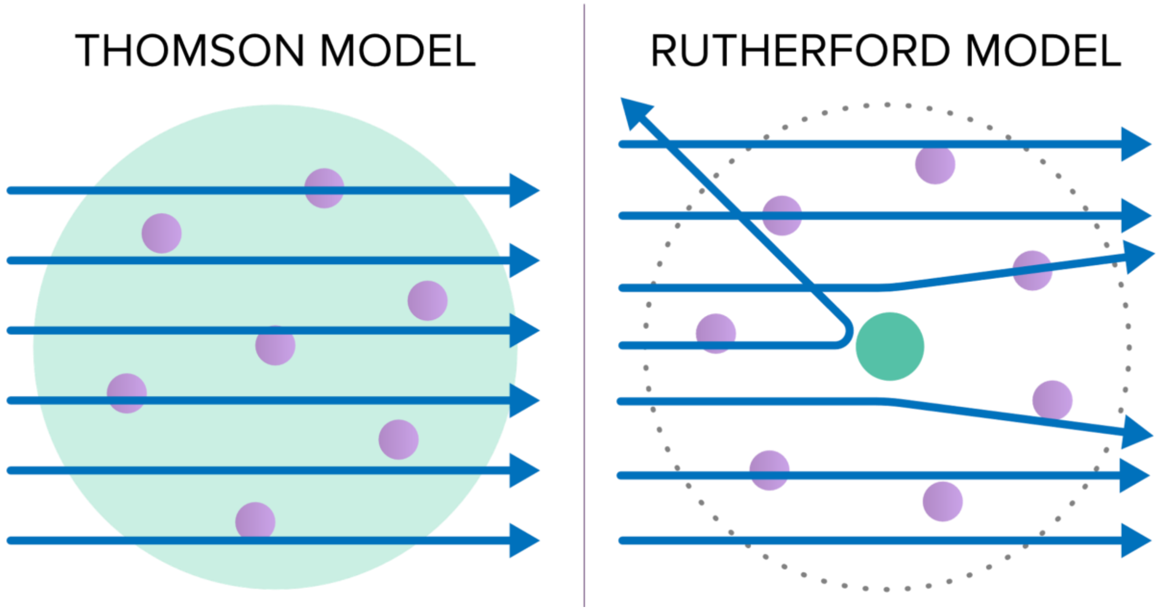


The apparatus used in Rutherford's gold foil experiment.

In Rutherford's gold foil experiment,.

Based on Thomson's plum pudding model, Rutherford predicted that most of the \alphaαalpha particles would pass straight through the gold foil. This is because the positive charge in the plum pudding model was assumed to be spread out throughout the entire volume of the atom. Therefore, the electric field from the positively charged "soup" would be too weak to significantly affect the path of the relatively massive and fast-moving alpha particles.

The results of the experiment, however, were striking. While almost all of the \alphaαalpha particles passed straight through the gold foil, a few \alphaαalpha particles (about 1 in 20,000) were deflected more than 90º, degrees from their path! Rutherford himself described the results with the following analogy: "It was quite the most incredible event that has ever happened to me in my life. It was almost as incredible as if you fired a 15 inch end text shell at a piece of tissue paper and it came back and hit you."



The nuclear model of the atom

Based on his experimental results, Rutherford made the following conclusions about the structure of the atom:

- The positive charge must be localized over a very tiny volume of the atom, which also contains most of the atom's mass. This explained how a very small fraction of the \alpha particles were deflected drastically, presumably due to the rare collision with a gold nucleus.
- Since most of the alpha particles passed straight through the gold foil, the atom must be made up of mostly empty space!

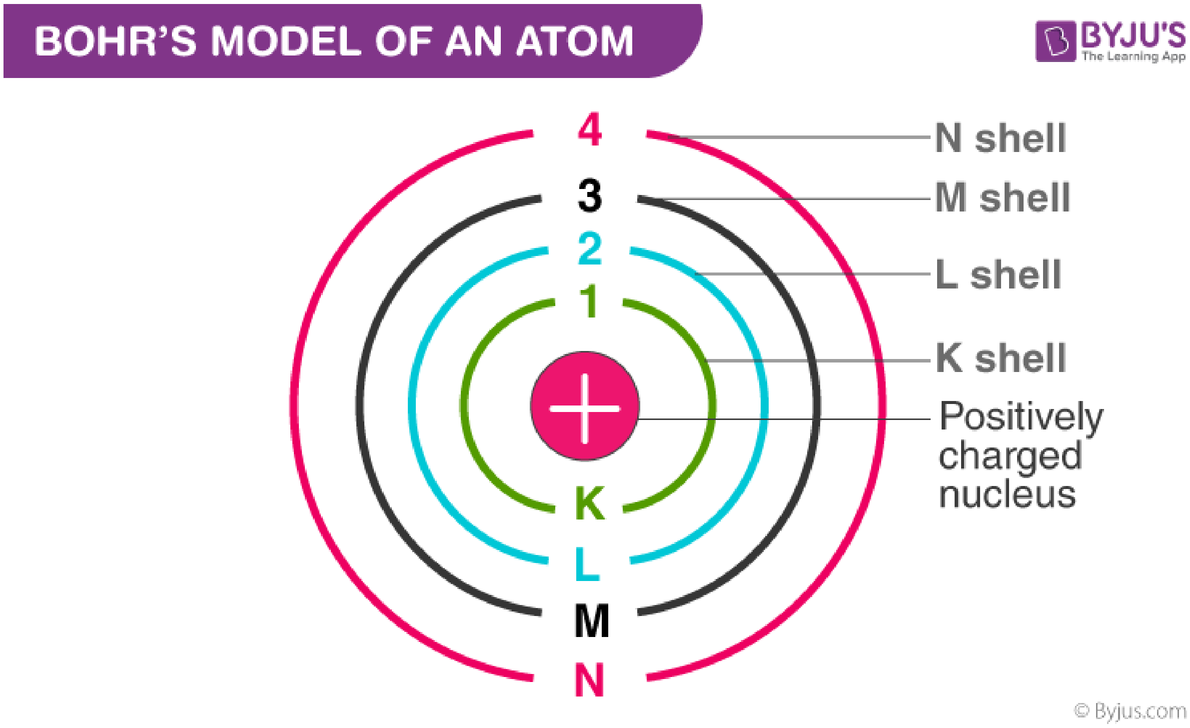
BHORS ATOMIC MODEL

The Bohr model of the atom was proposed by Neil Bohr in 1915. It came into existence with the modification of Rutherford’s model of an atom. Rutherford’s model introduced the nuclear model of an atom, in which he explained that a nucleus (positively charged) is surrounded by negatively charged electrons.

Introduction to the Bohr Model

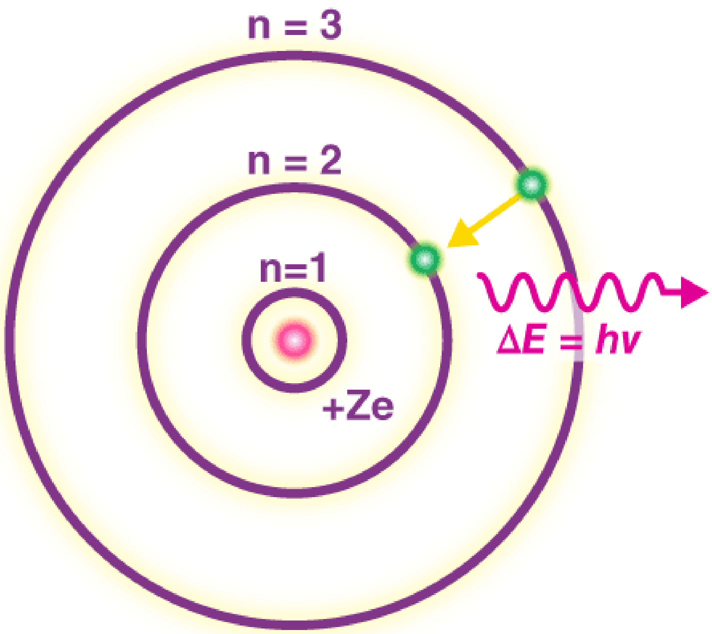
Bohr theory modified the atomic structure model by explaining that electrons move in fixed orbitals (shells) and not anywhere in between and he also explained that each orbit (shell) has a fixed energy. Rutherford explained the nucleus of an atom and Bohr modified that model into electrons and their energy levels.

Bohr's model consists of a small nucleus (positively charged) surrounded by negative electrons moving around the nucleus in orbits. Bohr found that an electron located away from the nucleus has more energy, and the electron which is closer to nucleus has less energy



Postulates of Bohr's Model of an Atom

- In an atom, electrons (negatively charged) revolve around the positively charged nucleus in a definite circular path called orbits or shells.
- Each orbit or shell has a fixed energy and these circular orbits are known as orbital shells.
- The energy levels are represented by an integer (n=1, 2, 3…) known as the quantum number. This range of quantum number starts from nucleus side with n=1 having the lowest energy level. The orbits n=1, 2, 3, 4… are assigned as K, L, M, N…. shells and when an electron attains the lowest energy level, it is said to be in the ground state.
- The electrons in an atom move from a lower energy level to a higher energy level by gaining the required energy and an electron moves from a higher energy level to lower energy level by losing energy.



Limitations of Bohr’s Model of an Atom

- Bohr’s model of an atom failed to explain the Zeeman Effect (effect of magnetic field on the spectra of atoms).
- It also failed to explain the Stark effect (effect of electric field on the spectra of atoms).
- It violates the Heisenberg Uncertainty Principle.
- It could not explain the spectra obtained from larger atoms.

BHOR- BURRY SCHEME

Bohr-Bury scheme:

1. The distribution of electrons in different shells is known as electronic configuration.
2. Each shell has a limited capacity to hold electrons and each electron tries to occupy a shell with a lower energy value first and then occupies the shell with higher energy.
3. According to the Bohr Bury scheme, a system is stable when it has less energy.
4. Thus, the electrons first occupy the first shell i.e. K which has the lowest energy then go to the second shell i.e. L, then M, N, and so on.
5. The first shell K shell accommodates 2 electrons, the second shell L shell accommodates 8 electrons, the third shell M shell accommodates 18 electrons and the fourth shell N shell accommodates 32 electrons.
6. The scheme also states that the outermost shell cannot hold more than 8 electrons.

the concept of the Bohr-Bury scheme where it states as the maximum number of electrons that could be present in a shell is given by a formula 2n22n2.
Where “n” is the orbit or shell number of that atom.
2) Now if we apply this formula for shells we will get the maximum occupancy as below,
For first orbit i.e. K shell =2n2=2×12=2=2n2=2×12=2 electrons.

For second orbit i.e. L shell $=2n2=2\times22=8=2n2=2\times22=8$ electrons.
For the third orbit i.e. M shell $=2n2=2\times32=18=2n2=2\times32=18$ electrons.
For fourth orbit i.e. N shell $=2n2=2\times42=32=2n2=2\times42=32$ electrons.
3) The Bohr-Bury scheme further elaborates as the electrons in an orbit must be filled in a stepwise manner, that is one cannot fill the electrons in a higher shell if the lower shell is not fully filled.
4) Electrons revolve around the nucleus in a specific fixed path and that path is called an orbit. There is a certain limit of each orbit that can have a certain number of electrons.
5) The Bohr-bury scheme also elaborates its theory as an electron when revolving in an orbit does not lose energy which means it sustains its energy.

Note: In an atom, there are orbits or shells as K, L, M, N from lower to higher respectively. Each shell or orbit has a subshell named as s, p, d, f which has 2, 6, 10, 142, 6, 10, 14 electrons occupancy respectively.

HEISENBER'S UNCERTAINITY PRINCIPLE

uncertainty principle, also called **Heisenberg uncertainty principle** or **indeterminacy principle**, statement, articulated (1927) by the German physicist Werner Heisenberg, that the position and the velocity of an object cannot both be measured exactly, at the same time, even in theory. The very concepts of exact position and exact velocity together, in fact, have no meaning in nature.

The complete rule stipulates that the product of the uncertainties in position and velocity is equal to or greater than a tiny physical quantity, or constant ($h/(4\pi)$, where h is Planck's constant, or about 6.6×10^{-34} joule-second). Only for the exceedingly small masses of atoms and subatomic particles does the product of the uncertainties become significant.

Heisenberg Uncertainty Principle Formula and Application

If Δx is the error in position measurement and Δp is the error in the measurement of momentum, then

$\Delta X\times\Delta p\geq h4\pi$
Since momentum, p = mv, Heisenberg's uncertainty principle formula can be alternatively written as-

$\Delta X\times\Delta mv\geq h4\pi$
or
$\Delta X\times\Delta m\times\Delta v\geq h4\pi$
Where, ΔV is the error in the measurement of velocity and assuming mass remaining constant during the experiment,

$\Delta X\times\Delta V\geq h4\pi m$
.
Accurate measurement of position or momentum automatically indicates larger uncertainty (error) in the measurement of the other quantity.

Applying the Heisenberg principle to an electron in an orbit of an atom, with $h = 6.626\times10^{-34}$Js and $m= 9.11\times10^{-31}$Kg,

$\Delta X\times\Delta V\geq6.626\times10-344\times3.14\times9.11\times10-31=10-4\ m2\ s-1$
If the position of the electron is measured accurately to its size (10^{-10}m), then the error in the measurement of its velocity will be equal or larger than 10^{6}m or 1000Km.

Heisenberg's principle applies to only dual-natured microscopic particles and not to a macroscopic particle whose wave nature is minimal.

QUANTUM NUMBER, SUB ENERGY LEVEL

The set of numbers used to describe the position and energy of the electron in an atom are called quantum numbers. There are four quantum numbers, namely, principal, azimuthal, magnetic and spin quantum numbers.

Four quantum numbers can be used to completely describe all the attributes of a given electron belonging to an atom, these are:

- Principal quantum number, denoted by n.
- Orbital angular momentum quantum number (or azimuthal quantum number), denoted by l.
- Magnetic quantum number, denoted by m_l.
- The electron spin quantum number, denoted by m_s.

Principal Quantum Number

- ***Principal quantum numbers are denoted by the symbol 'n'. They designate the principal electron shell of the atom.*** Since the most probable distance between the nucleus and the electrons is described by it, a larger value of the principal quantum number implies a greater distance between the electron and the nucleus (which, in turn, implies a greater atomic size).
- The value of the principal quantum number can be any integer with a positive value that is equal to or greater than one. The value n=1 denotes the innermost electron shell of an atom, which corresponds to the lowest energy state (or the ground state) of an electron.
- Thus, it can be understood that the principal quantum number, n, cannot have a negative value or be equal to zero because it is not possible for an atom to have a negative value or no value for a principal shell.
- When a given electron is infused with energy (excited state), it can be observed that the electron jumps from one principal shell to a higher shell, causing an increase in the value of n. Similarly, when electrons lose energy, they jump back into lower shells and the value of n also decreases.
- The increase in the value of n for an electron is called absorption, emphasizing the photons or energy being absorbed by the electron. Similarly, the decrease in the value of n for an electron is called emission, where the electrons emit their energy.

Azimuthal Quantum Number (Orbital Angular Momentum Quantum Number)

- The azimuthal (or orbital angular momentum) quantum number describes the shape of a given orbital. It is denoted by the symbol 'l' and its value is equal to the total number of angular nodes in the orbital.
- A value of the azimuthal quantum number can indicate either an s, p, d, or f subshell which vary in shape. This value depends on (and is capped by) the value of the principal quantum number, i.e. the value of the azimuthal quantum number ranges between 0 and (n-1).

- For example, if n =3, the azimuthal quantum number can take on the following values – 0,1, and 2. When l=0, the resulting subshell is an ‘s’ subshell. Similarly, when l=1 and l=2, the resulting subshells are ‘p’ and ‘d’ subshells (respectively). Therefore, when n=3, the three possible subshells are 3s, 3p, and 3d.
- In another example where the value of n is 5, the possible values of l are 0, 1, 2, 3, and 4. If l = 3, then there are a total of three angular nodes in the atom.

Magnetic Quantum Number

The total number of orbitals in a subshell and the orientation of these orbitals are determined by the magnetic quantum number. It is denoted by the symbol ‘m_l’. This number yields the projection of the angular momentum corresponding to the orbital along a given axis.

For example, if n = 4 and l = 3 in an atom, the possible values of the magnetic quantum number are -3, -2, -1, 0, +1, +2, and +3.

Azimuthal Quantum Number Value	Corresponding Number of Orbitals (2l + 1)	Possible Values of m_l
0 (‘s’ subshell)	2*0 + 1 = 1	0
1 (‘p’ subshell)	2*1 + 1 = 3	-1, 0, and 1
2 (‘d’ subshell)	2*2 + 1 = 5	-2, -1, 0, 1, and 2
3 (‘f’ subshell)	2*3 + 1 = 7	-3, -2, -1, 0, 1, 2, and 3

The total number of orbitals in a given subshell is a function of the ‘l’ value of that orbital. It is given by the formula (2l + 1). For example, the ‘3d’ subshell (n=3, l=2) contains 5 orbitals (2*2 + 1). Each orbital can accommodate 2 electrons. Therefore, the 3d subshell can hold a total of 10 electrons.

Electron Spin Quantum Number

- The electron spin quantum number is independent of the values of n, l, and m_l. The value of this number gives insight into the direction in which the electron is spinning, and is denoted by the symbol m_s.
- The value of m_s offers insight into the direction in which the electron is spinning. The possible values of the electron spin quantum number are +½ and -½.
- The positive value of m_s implies an upward spin on the electron which is also called ‘spin up’ and is denoted by the symbol ↑. If m_s has a negative value, the electron in question is said to have a downward spin, or a ‘spin down’, which is given by the symbol ↓.
- The value of the electron spin quantum number determines whether the atom in question has the ability to produce a magnetic field. The value of m_s can be generalized to ±½.

The electron configuration of an atom of any element is the of electrons per sublevel of the energy levels of an atom in its ground state. This handy chart compiles the electron configurations of the elements up through number 104.

Electron Configurations

- An atom's electron configuration describes the way its electrons fill sublevels when the atom is in its ground state.
- Atoms seek the most stable electron configuration, so sublevels are half-filled or fully-filled whenever possible.
- Rather than writing out the whole electron configuration, scientists use a shorthand notation that starts with the symbol for the noble gas before the element on the periodic table.

Determine Electron Configuration

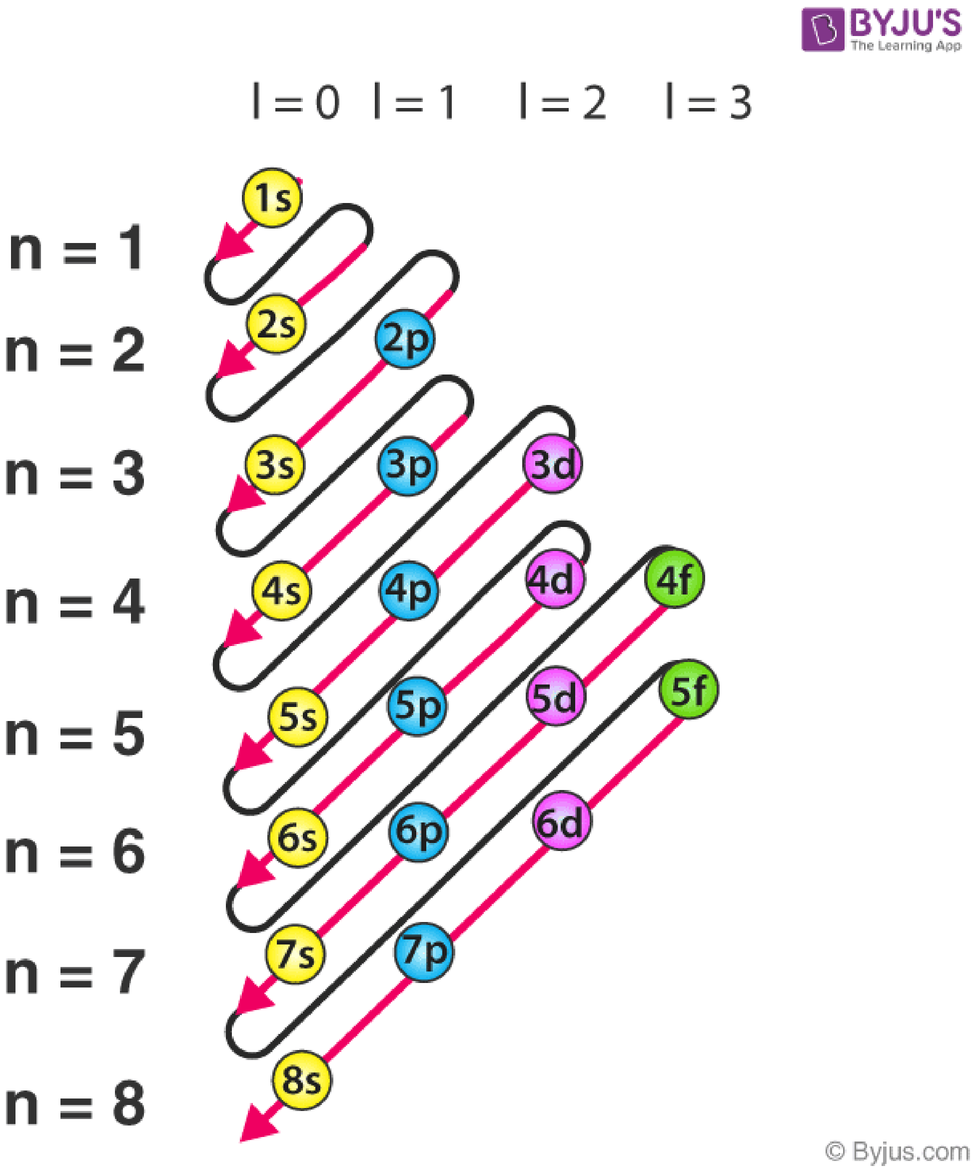
To arrive at the electron configurations of atoms, you must know the order in which the different sublevels are filled. Electrons enter available sublevels in order of their increasing energy. A sublevel is filled or half-filled before the next sublevel is entered.

For example, the *s* sublevel can only hold two electrons, so the 1*s* is filled at helium ($1s^2$). The *p* sublevel can hold six electrons, the *d* sublevel can hold 10 electrons, and the *f* sublevel can hold 14 electrons. The common shorthand notation is to refer to the noble gas core, rather than write out the entire configuration. For example, the configuration of magnesium could be written $[Ne]3s^2$, rather than writing out $1s^2 2s^2 2p^6 3s^2$.

AUFBAU PRINCIPLE

The Aufbau principle dictates the manner in which electrons are filled in the atomic orbitals of an atom in its ground state.

It states that electrons are filled into atomic orbitals in the increasing order of orbital energy level. According to the Aufbau principle, the available atomic orbitals with the lowest energy levels are occupied before those with higher energy levels.



he Aufbau principle can be used to understand the location of electrons in an atom and their corresponding energy levels. For example, carbon has 6 electrons and its electronic configuration is $1s^2 2s^2 2p^2$.

It is important to note that each orbital can hold a maximum of two electrons (as per the Pauli exclusion principle). Also, the manner in which electrons are filled into orbitals in a single subshell must follow Hund's rule, i.e. every orbital in a given subshell must be singly occupied by electrons before any two electrons pair up in an orbital.

Salient Features of the Aufbau Principle

-
  -
    -
    - According to the Aufbau principle, electrons first occupy those orbitals whose energy is the lowest. This implies that the electrons enter the orbitals having higher energies only when orbitals with lower energies have been completely filled.

- The order in which the energy of orbitals increases can be determined with the help of the (n+l) rule, where the sum of the principal and azimuthal quantum numbers determines the energy level of the orbital.
- Lower (n+l) values correspond to lower orbital energies. If two orbitals share equal (n+l) values, the orbital with the lower n value is said to have lower energy associated with it.
- The order in which the orbitals are filled with electrons is: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, 7p, and so on.

PAULI'S EXCLUSION PRINCIPLE

The Pauli exclusion principle states that in a single atom no two electrons will have an identical set or the same quantum numbers (n, l, m_l, and m_s). To put it in simple terms, every electron should have or be in its own unique state (singlet state). There are two salient rules that the Pauli Exclusion Principle follows:

- Only two electrons can occupy the same orbital.
- The two electrons that are present in the same orbital must have opposite spins or they should be antiparallel.

However, Pauli's Exclusion Principle does not only apply to electrons. It applies to other particles of half-integer spin such as fermions. It is not relevant for particles with an integer spin such as bosons which have symmetric wave functions. Moreover, bosons can share or have the same quantum states, unlike fermions. As far as the nomenclature goes, fermions are named after the Fermi–Dirac statistical distribution that they follow. Bosons, on the other hand, get their name from the Bose-Einstein distribution function.

HUND'S RULE OF MAXIMUM MULTIPLICITY

Aufbau principle tells us that the lowest energy orbitals get filled by electrons first. After the lower energy orbitals are filled, the electrons move on to higher energy orbitals. The problem with this rule is that it does not tell about the three 2p orbitals and the order that they will be filled in.

According to Hund's rule:

- Before the double occupation of any orbital, every orbital in the sub level is singly occupied.
- For the maximization of total spin, all electrons in a single occupancy orbital have the same spin.

An electron will not pair with another electron in a half-filled orbital as it has the ability to fill all its orbitals with similar energy. Many unpaired electrons are present in atoms which are at the ground state. If two electrons come in contact they would show the same behaviour as two magnets do. The electrons first try to get as far away from each other as possible before they have to pair up.

Hunds Rule of Maximum Multiplicity

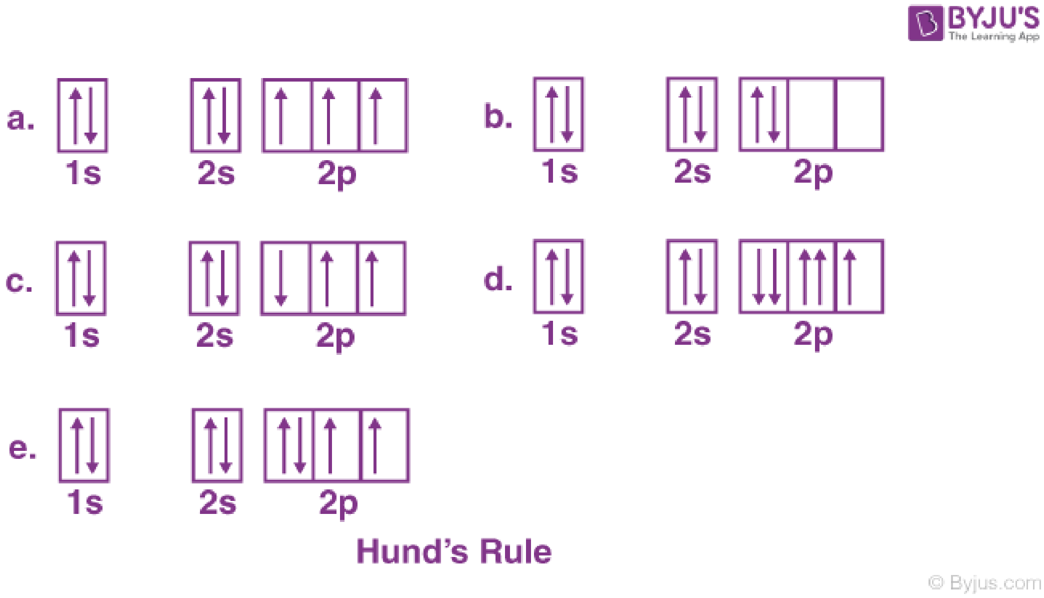
Hunds Rule of Maximum Multiplicity rule states that for a given electron configuration, the term with maximum multiplicity falls lowest in energy. According to this rule electron pairing in p, d and f orbitals cannot occur until each orbital of a given subshell contains one electron each or is singly occupied.

State Hund's Rule

It states that:

1. In a sublevel, each orbital is singly occupied before it is doubly occupied.

2. The electrons present in singly occupied orbitals possess identical spin.



Theory of Chemical Bonding

Chemical Bonding refers to **the formation of a chemical bond between two or more atoms, molecules, or ions to give rise to a chemical compound**. These chemical bonds are what keep the atoms together in the resulting compound.

The attractive force which holds various constituents (atom, ions, etc.) together and stabilizes them by the overall loss of energy is known as chemical bonding. Therefore, it can be understood that chemical compounds are reliant on the strength of the chemical bonds between its constituents; The stronger the bonding between the constituents, the more stable the resulting compound would be.

The opposite also holds true; if the chemical bonding between the constituents is weak, the resulting compound would lack stability and would easily undergo another reaction to give a more stable chemical compound (containing stronger bonds). To find stability, the atoms try to lose their energy.

Whenever matter interacts with another form of matter, a force is exerted on one by the other. When the forces are attractive in nature, the energy decreases. When the forces are repulsive in nature, the energy increases. The attractive force that binds two atoms together is known as the chemical bond.

Important Theories on Chemical Bonding

Albrecht Kössel and Gilbert Lewis were the first to explain the formation of chemical bonds successfully in the year 1916. They explained chemical bonding on the basis of the inertness of noble gases.

Lewis Theory of Chemical Bonding

- An atom can be viewed as a positively charged 'Kernel' (the nucleus plus the inner electrons) and the outer shell.
- The outer shell can accommodate a maximum of eight electrons only.
- The eight electrons present in the outer shell occupy the corners of a cube which surround the 'Kernel'.
- The atoms having octet configuration, i.e. 8 electrons in the outermost shell, thus symbolize a stable configuration.
- Atoms can achieve this stable configuration by forming chemical bonds with other atoms. This chemical bond can be formed either by gaining or losing an electron(s) (NaCl, MgCl2) or in some cases due to the sharing of an electron (F2).
- Only the electrons present in the outer shell, also known as the valence electrons take part in the formation of chemical bonds. Gilbert Lewis used specific notations better known as Lewis symbols to represent these valence electrons.
- Generally, the valency of an element is either equal to the number of dots in the corresponding Lewis symbol or 8 minus the number of dots (or valence electrons).

Lewis symbols for lithium (1 electron), oxygen (6 electrons), neon (8 electrons) are given below:

Types of Chemical Bonds

When substances participate in chemical bonding and yield compounds, the stability of the resulting compound can be gauged by the type of chemical bonds it contains.

The type of chemical bonds formed vary in strength and properties. There are 4 primary types of chemical bonds which are formed by atoms or molecules to yield compounds. These types of chemical bonds include:

- Ionic Bonds
- Covalent Bonds
- Hydrogen Bonds

These types of bonds in chemical bonding are formed from the loss, gain, or sharing of electrons between two atoms/molecules.

Ionic Bonding

Ionic bonding is a type of chemical bonding which involves a transfer of electrons from one atom or molecule to another. Here, an atom loses an electron which is in turn gained by another atom. When such an electron transfer takes place, one of the atoms develops a negative charge and is now called the anion.

The other atom develops a positive charge and is called the cation. The ionic bond gains strength from the difference in charge between the two atoms, i.e. the greater the charge disparity between the cation and the anion, the stronger the ionic bond.

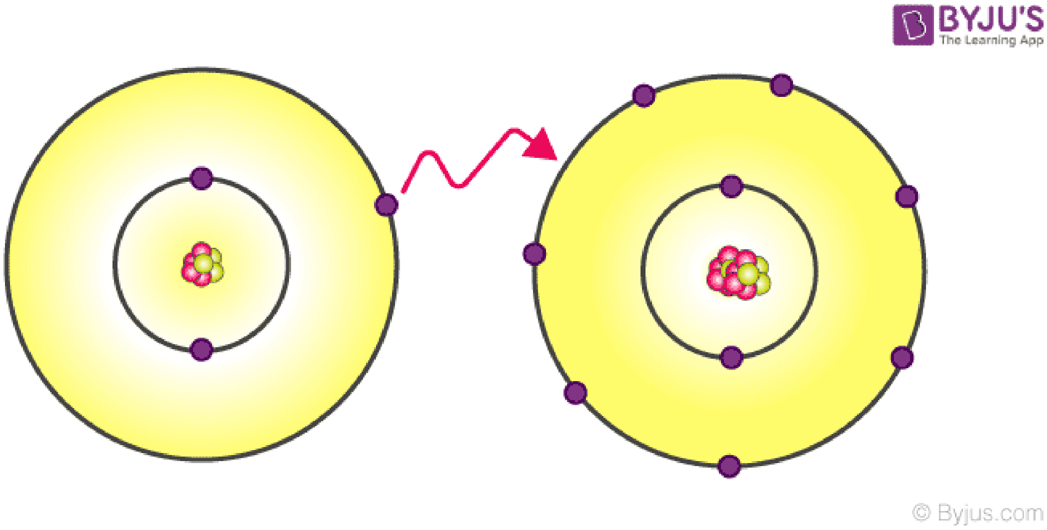
What is Ionic Bond?

The bond formed as a result of strong electrostatic forces of attraction between a positively and negatively charged species is called an electrovalent or ionic bond. The positively and negatively charged ions are aggregated in an ordered arrangement called the crystal lattice which is stabilized by the energy called the Lattice enthalpy.

Conditions for the formation of an Ionic Bond

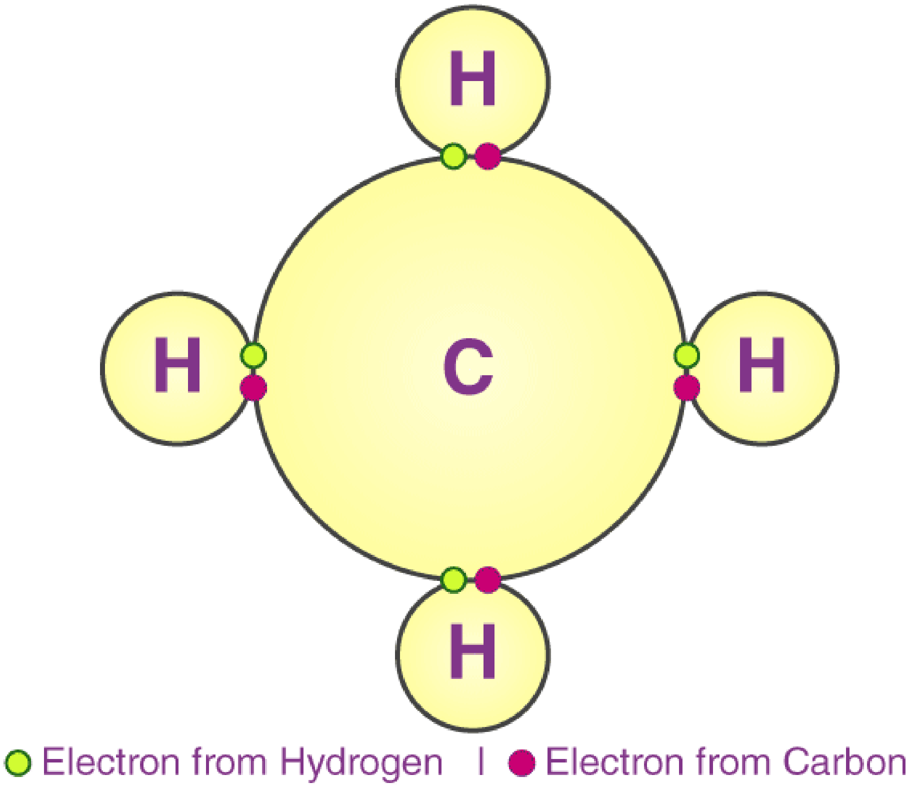
- The low ionization energy of the atom forming the cation.
- High electron gain enthalpy of the atom forming the anion.
- High negative lattice enthalpy of the crystal formed.

Generally, the ionic bond is formed between a metal cation and non-metal anion.



Covalent Bonding

A covalent bond indicates the sharing of electrons between atoms. Compounds that contain carbon (also called organic compounds) commonly exhibit this type of chemical bonding. The pair of electrons which are shared by the two atoms now extend around the nuclei of atoms, leading to the creation of a molecule.



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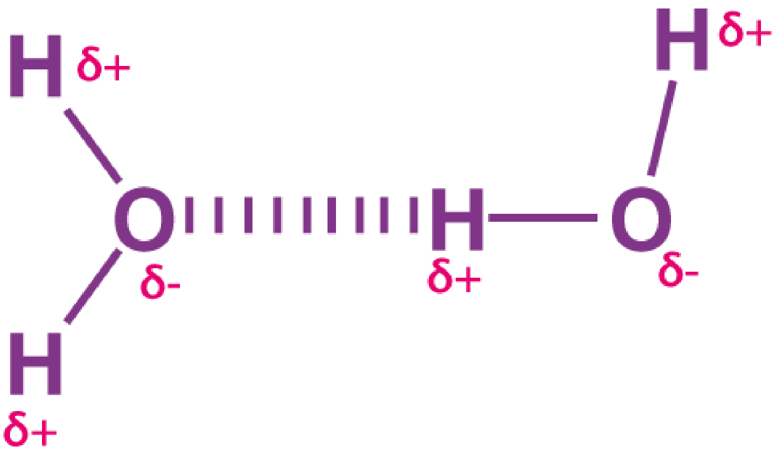
Hydrogen Bonding

Compared to ionic and covalent bonding, Hydrogen bonding is a weaker form of chemical bonding. It is a type of polar covalent bonding between oxygen and hydrogen wherein the hydrogen develops a partial positive charge. This implies that the electrons are pulled closer to the more electronegative oxygen atom.

This creates a tendency for the hydrogen to be attracted towards the negative charges of any neighbouring atom. This type of chemical bonding is called a hydrogen bond and is responsible for many of the properties exhibited by water.



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Co-ordinate Bond

Co-ordinate bond is a type of alternate covalent bond that is formed by sharing of electron pair from a single atom. Both shared electrons are donated by the same atom. It is also called dative bond or dipolar bond.

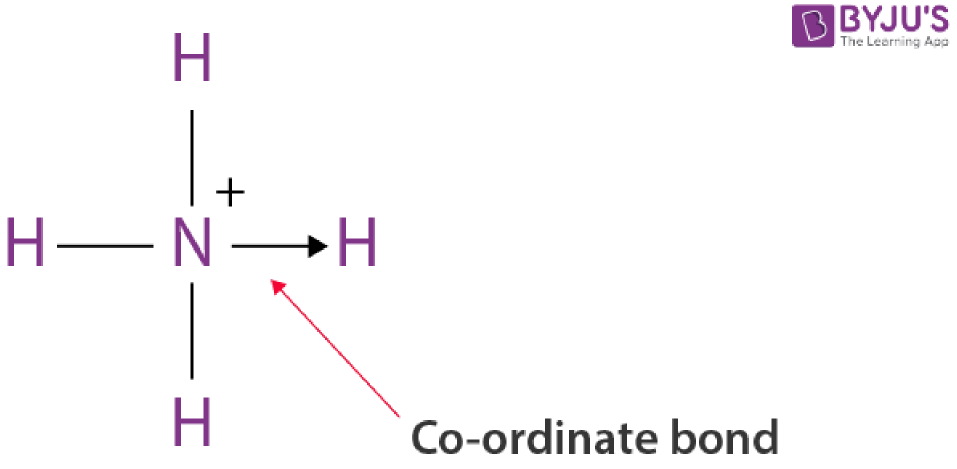
Co-ordinate covalent bonds are usually formed in reactions that involve two non-metals such as a hydrogen atom or during bond formation between metals ions and ligands.

Characteristics Of Coordinate Covalent Bond

1. In this type of bonding, the atom that shares an electron pair from itself is termed as the donor.
2. The other atom which accepts these shared pair of electrons is known as a receptor or acceptor.
3. The bond is represented with an arrow →, pointing towards acceptor from the donor atom.
4. After sharing of electron pain each atom gets stability.
5. This type of bonding is central to the Lewis theory.
6. Getting a good understanding of co-ordinate covalent bonds can help in properly designing complex organic molecules.

Coordinate Bond Diagram

Below we have given a simple diagram of a co-ordinate bond. The bond is shown by an arrow which points in the direction where an atom is donating the lone pair to the atom that is receiving it.

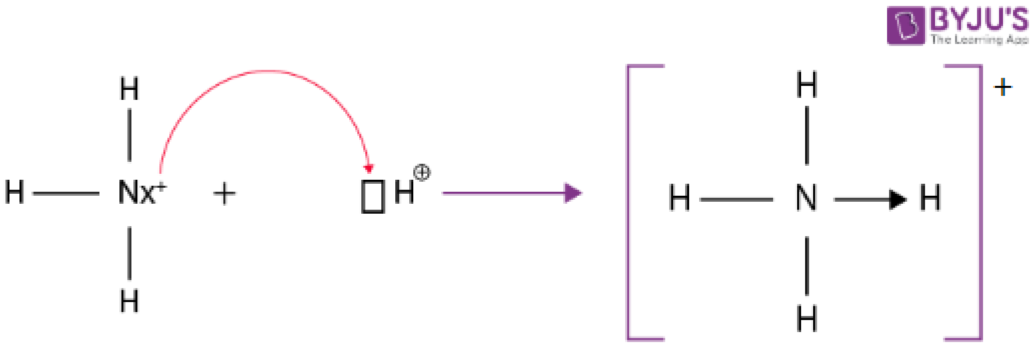


Co-Ordinate Bond Examples

Here are a few examples of the coordinate covalent bond.

Formation Of Ammonium Ion

The nitrogen atom in Ammonia donates its electron pair to the empty orbital of H^+ ion thus nitrogen is donor, H^+ is acceptor and a co-ordinate bond is formed



Ammonium ion

UNIT-2

HARNESS OF WATER

The hardness of water is due to the presence of soluble bicarbonates, chlorides and sulfates of calcium and magnesium. Water which does not give lather with soap is hard water.

Water is the most important compound that is needed for the survival of life on earth. Water is present in the oceans, rivers, ponds, lakes, glaciers, etc. Rainwater is considered pure water because it does not contain any salt dissolved in it thought there are dissolved gases present.

Water can be classified as hard water and soft water.

- Soft water: It lathers with soap. Water which is obtained from the rains is soft water. This water is suitable for household purposes for example laundry and cleaning.
- Hard water: It is known as hard water because of the presence of salts of calcium and magnesium. Hard water does not lather with soap but instead forms a precipitate.
- : Differences Between Hard Water and Soft Water
-

Hard Water

Hard water has high mineral content. It is formed when water percolates through the deposits of chalk and limestone which are made up of magnesium and calcium carbonates. It does not lather with soap, so it is not suitable for laundry purposes.

The hardness of water is harmful to the boilers as the deposition of salts occurs, which reduces the efficiency of the boiler. Hard water is safe to drink but using over a long interval of time can lead to many problems like:

- Strains in skin
- Water appliances work harder resulting in higher water bills
- Spots appear on clothes and linens

Types of Hardness of Water

The hardness of water can be classified into two types:

- Temporary Hardness
- Permanent Hardness

Temporary Hardness of Water:

The presence of magnesium and calcium carbonates in water makes it temporarily hard. In this case, the hardness in water can be removed by boiling the water.

When we boil water the soluble salts of $Mg(HCO_3)_2$ is converted to $Mg(OH)_2$ which is insoluble and hence gets precipitated and is removed. After filtration, the water we get is soft water.

Permanent Hardness of Water:

When the soluble salts of magnesium and calcium are present in the form of chlorides and sulphides in water, we call it permanent hardness because this hardness cannot be removed by boiling.

We can remove this hardness by treating the water with washing soda. Insoluble carbonates are formed when washing soda reacts with the sulphide and chloride salts of magnesium and calcium and thus, hard water is converted to soft water.

Disadvantages of Hardness

1. Wastage of soap
2. Wastage of fuel
3. Formation of scales on metallic boilers.

⇒ Also Read: Heavy Water – Methods of Preparation and Properties

Remove Hardness of Water (Temporary)

By Boiling:

Soluble bicarbonates are converted into insoluble carbonates which are removed by filtration.

Reactions: $Ca(HCO_3)_2 \rightarrow \Delta Calo_3\downarrow + H_2O + CO_2$

$\Rightarrow Mg(HCO_3)_2 \rightarrow \Delta MgCO_3\downarrow + H_2O + CO_2$

By Clarks Method:

Calcium hydroxide is Clark's reagent. It removes the hardness of water by converting bicarbonates into carbonate.

Reaction: $Ca(OH)_2 + Ca(HCO_3)_2 \rightarrow 2CaCO_3\downarrow + 2H_2O$

Harmful Effects of Hard Water

Some of the most common signs of hard water include:

- Linens and clothes look dull and feel rough.
- Ugly stains on white porcelain and scale build-up on faucets
- Low water pressure from showers due to clogged pipes.
- Chalky, white residue or spots appear on dishes.
- Strains appearing in the shower.

SOFTENING METHOD

1. LIME-SODA PROCESS

Lime-Soda Water Softening Process -Process Soda lime is a process used in water treatment to remove Hardness from water. This process is now obsolete but was very useful for the treatment of large volumes of hard water. Addition of lime (CaO) and soda (Na_2CO_3) to the hard water precipitates calcium as the carbonate, and magnesium as its hydroxide. The amounts of the two chemicals required are easily calculated from the analysis of the water and stoichiometry of the reactions. The lime-soda uses lime, Ca $(OH)_2$ and soda ash, Na_2CO_3, to precipitate hardness from solution.

Carbon dioxide and carbonate hardness (calcium and Magnesium bicarbonate) are complexed by lime. In this process Calcium and Magnesium ions are precipitated by the addition of lime ($Ca(OH)_2$) and soda ash (Na_2CO_3). Following are the reactions that takes place in this process: As slacked lime is added to a water, it will react with any carbon dioxide present as follows:

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 \downarrow + H_2O$....(1)

The lime will react with carbonate hardness as follows:
$Ca(OH)_2+Ca(HCO_3)_2\rightarrow 2CaCO_3\downarrow+2H_2O$.....(2)

$Ca(OH)_2+Mg(HCO_3)_2\rightarrow MgCO_3+CaCO_3\downarrow+2H_2O$.....(3)

The product magnesium carbonate in equation 3 is soluble. To remove it, more lime is added:
$Ca(OH)_2MgCO_3\rightarrow CaCO_3\downarrow+Mg(OH)_2\downarrow$.....(4)

Also, magnesium non-carbonate hardness, such as magnesium sulfate, is removed:
$Ca(OH)_2+MgSO_4\rightarrow CaSO_4+Mg(OH)_2\downarrow$.....(5)

Lime addition removes only magnesium hardness and calcium carbonate hardness. In equation 5 magnesium is precipitated, however, an equivalent amount of calcium is added. The water now contains the original calcium non-carbonate hardness and the calcium non-carbonate hardness produced in equation 5. Soda ash is added to remove calcium non-carbonate hardness: $Na_2CO_3+CaSO_4 \rightarrow Na_2SO+CaCO_3\downarrow$.....(6)

To precipitate $CaCO_3$ requires a pH of about 9.5; and to precipitate $Mg(OH)_2$ requires a pH of about 10.8, therefore, an excess lime of about 1.25 meq/l is required to raise the pH. The amount of lime required: lime (meq/l) = carbon dioxide (meq/l) + carbonate hardness (meq/l) + magnesium ion (meq/l) + 1.25 (meq/l) The amount of soda ash required: soda ash (meq/l) = non-carbonate hardness (meq/l) After softening, the water will have high pH and contain the excess lime and the magnesium hydroxide and the calcium carbonate that did not precipitate. Recarbonation (adding carbon dioxide) is used to stabilize the water. The excess lime and magnesium hydroxide are stabilized by adding carbon dioxide, which also reduces pH from 10.8 to 9.5 as the following: $CO_2+Ca(OH)_2 \rightarrow CaCO_3\downarrow+H_2O$

$CO_2+Mg(OH)_2 \rightarrow MgCO_3+H_2O$

Further recarbonation, will bring the pH to about 8.5 and stablize the calcium carbonate as the following: $CO_2+CaCO_3+H_2O \rightarrow Ca(HCO_3)_2$

It is not possible to remove all of the hardness from water. In actual practice, about 50 to 80

mg/lwill remain as a residual hardness.

Figure- COLD LIME-SODA PROCESS

Fig- Hot lime-soda process

ION Exchange process of Softening of water

The process of treating permanent hardness of water using synthetic resins is based on the exchange of cations (e.g., Na^+,Ca^{2+},Mg^{2+} etc) and anions (e.g., Cl^-,SO_4^{2-},HCO_3^- etc) present in water by H^+ and OH^- ions respectively.

Synthetic resins are of two types:

1) Cation exchange resins

2) Anion exchange resins

Cation exchange resins are large organic molecules that contain the $-SO_3H$ group. The resin is firstly changed to RNa (from RSO_3H) by treating it with NaCl. This resin then exchanges Na^+ ions with Ca^{2+} and Mg^{2+} ions, thereby making the water soft.

$2RNa+M^{2+}(aq) \longrightarrow R_2M(s)+2Na^+(aq)$

There are cation exchange resins in H^+ form. The resins exchange H^+ ions for Na^+,Ca^{2+}, and Mg^{2+} ions.

$2RH+M^{2+}(aq) \rightleftharpoons MR_2(s)+2H^+(aq)$

Anion exchange resins exchange OH− ions for anions like Cl−,HCO−3, and SO2+4 present in water.

During the complete process, water first passes through the cation exchange process. The water obtained after this process is free from mineral cations and is acidic in nature. This acidic water is then passed through the anion exchange process where OH− ions neutralize the H+ ions and de-ionize the water

Zeolite softening process:

- It is a method of removing the permanent as well as temporary hardness of the water.
- It involves the precipitation of Calcium and Magnesium ions present in water.
- The exchange of Ca2+ and Mg2+ ions occurs with the help of zeolite and therefore, it is known as Zeolite softening process.

Example:

- Hydrated zeolites are commonly utilized as ion exchangers in the process of hard-water softening.

Six Basic Boiler Problems

Boiler efficiency can be increased upto 90% by proper maintenance of the systems.

Some of the common problems hinder the boiler’s ability to produce output to its full capacity.

Check Our Steam Boilers Catalog

They are as under-

1. Priming:

Priming

When the steam is produced in the boiler, some droplets of water get carried away with the steam resulting in the formation of ‘wet steam’. This phenomenon is termed as priming.

Problem:

1. Deposits on the valves which may cause overheating and corrosion
2. Reduced product quality which affects the heat transfer rates
3. Higher steam consumption for the same power output
4. Life of boiler and its components are subjected to danger

Cause:

There are two main causes for priming to occur in a boiler:

Mechanical Causes:

1. Improper design of boiler shell
2. Too high a water level
3. Incorrect firing rate
4. Boiler operating at a steam pressure below the design pressure

Chemical Causes:

1. Presence of oil and organic matter in the boiler water.
2. Suspended solids in boiling water.
3. Highly alkalinity
4. Soap-like structures in boiler water

Solution:

1. Maintain low levels of salts in the water
2. Efficient filtration of water used in the boiler
3. Blow-off the sludge from time to time
4. Controlling rapid changes in the flow velocity

2. Foaming

Formation of a layer of froth or stable foam on the surface of the water is termed as foaming.

Problem:

1. Formation of soap like structures reduces the surface tension of water significantly, thus decreasing the boiler efficiency.
2. Fluctuation in water levels.
3. Water hammer problem.
4. Can lead to contamination and scaling.

Cause:

1. Presence of various chemical (especially alkalis and oils) and solid constituents in the boiling water. These oil and alkali constituents react to form soaps, which in turn lowers the surface tension thus increasing the foaming tendency.
2. The lubrication used in boilers serves as a source of oil, which is the primary source behind the effect of foaming.

3. Formation of small bubbles at the water surface, which do not break easily.

Solution:

1. Use of Anti-foaming agents such as castor oil. (Anti-foaming agents neutralize the effects of surface tension)
2. Proper treatment of water before entry into the boiler in order to remove the foaming agents (such as oil, alkali)
3. Addition of sodium aluminates has proved to be an effective way to remove oil traces by entrapping oil drops.

3. Caustic embritllment

Carrying away of water containing soluble salts into the distribution system is termed as carry-over. The salts essentially have an alkaline nature.

Problem:

1. The decrease in the efficiency of a boiler as the dissolved salts and solid particles have chances of getting carried away into the turbine blades and finally getting deposited over the blades.
2. Life of different parts of a boiler subjected to such water-soluble salts is at stake.
3. A judgment of actual height of water column becomes difficult, making maintenance procedure quite troublesome
4. Carry-over poses a serious problem to the parts such as turbine blades, steam traps, valve bodies, etc.

Cause:

1. Presence of soluble alkaline salts in the boiler water

Solution:

1. Ensure proper feed water treatment
2. Expert advice of a chemist should be considered regarding the boiler and feed water treatment
3. Main steam stop valve should be opened gradually.
4. Maintain lower water levels.
5. Use anti-priming baffles.
6. Leakage of any ‘foreign’ material into the boiler feed water system should be avoided.
7. Alignment of gauge glasses should be properly done.

4. Scale

A layer of water formed over the metal surfaces of the boiler is termed as scale. Scales are salts of Calcium and Magnesium (existing primarily in the form of sulphates or carbonates), which are highly insoluble in water.

Problem:

1. If there is scaling in the boiler, then the amount of fuel required to produce the same amount of steam may increase considerably in comparison to a boiler without scales.

2. Sodium sulphate is a strong electrolyte so it dissociates with water Its conductivity is about one hundredth to that of steel thus causing hindrance in the heat flow. Even a thin layer of this scale on the metallic surfaces may reduce the boiler efficiency by, upto 20%.

3. The scaled boiler becomes increasingly hotter due to resistance in heat flow, so this metal will become more prone to deformation and rupturing.

4. The heat transfer in the boiler is reduced due to the layers of scale that act as an insulator.

Cause:

1. Hard water is the reason for scale formation in boilers.

Solution:

1. If the scales are adhered loose to the surface, a wire brush or scraper can remove them.

2. Thermal shocks may remove the “brittle” natured scales.

3. Frequent blow-down operations can be benefic in removing scale which is loosely held on to the surface of the boiler.

4. Hard scales require chemical treatment. For e.g. Calcium Sulphate scales can be removed by adding EDTA(Ethylenediaminetetraacetic acid).

5. Corrosion:

Corrosion

The active destruction of the boiler material through pitting action is termed as corrosion. It is the process of continuous ‘decay’ or ‘disintegration’ of the boiler material due to the electrochemical action of the dissolved oxygen with the boiler metal. Corrosion leads to rusting of ferrous metals, tools which are not regularly oiled and steel windows which are not regularly painted.

Problem:

1. The boiler metal gets eaten up quickly due to the action of dissolved oxygen leading to complete failure of the boiler system.

2. Increase in cost of maintenance and repairs.

3. Leaking of rivets and joint areas.

4. Reduced boiler life and possible chances of failure of the entire system.

Cause:

1. The dissolved oxygen (about 8ppm at room temperature) sets free as the water is heated. This dissolved oxygen then reacts with the iron of the boiler to form a ferric oxide (known as rust).

Solution:

1. Addition of Hydrazine/ Sodium Sulphite/Sodium Sulphide.

1. By mechanical aeration under high temperature and vacuum conditions.

MUNCIPAL WATER TREATMENT

SEDIMENTATION-The process of the removal of suspended particles by gravitational settling is called sedimentation.

The water after screening may contain various suspended impurities like silt and clay particles. So to remove such particles sedimentation is done.

The particles whose specific gravity is greater than that of water get settles down under the action of gravity.

Sedimentation tanks are designed to reduce the velocity of the flow of water so that the suspended particles get settled under the action of gravity. Sedimentation can be achieved in two ways which are explained below.

2. Types of Sedimentation in Water Treatment

1. Plain Sedimentation

When the suspended particles are separated under the action of gravity only, it is called plain sedimentation.

2. Sedimentation with coagulation

Fine suspended particles and colloidal impurities are not removed by plain sedimentation. Particles of sizes 0.006 mm or less require 10 hours to settle in plain sedimentation.

Therefore we need certain chemicals to add in the water to remove such impurities which are not removed by plain sedimentation. These chemical are known as coagulants and the process is called sedimentation with coagulation.

Examples of coagulants are $(Al_2SO_4)_3$, $AlSO_4$, sodium aluminate, etc.

Read Also: Screening of Water

3. Advantages of Sedimentation in Water Treatment

Some advantages of sedimentation are:

a. Requirement of fewer chemicals for subsequent water treatment.

b. Cheaper than other methods.

4. Disadvantages of Sedimentation in Water Treatment

Some disadvantages of sedimentation are:

a. Slower process as required more time.

b. Shows pollution trend in a specific region over time.

Water treatment steps

Coagulation

Coagulation is often the first step in water treatment. During coagulation, chemicals with a positive charge are added to the water. The positive charge neutralizes the negative charge of dirt and other dissolved particles in the water. When this occurs, the particles bind with the chemicals to form slightly larger particles. Common chemicals used in this step include specific types of salts, aluminum, or iron.

Flocculation

Flocculation follows the coagulation step. Flocculation is the gentle mixing of the water to form larger, heavier particles called flocs. Often, water treatment plants will add additional chemicals during this step to help the flocs form.

Sedimentation

Sedimentation is one of the steps water treatment plants use to separate out solids from the water. During sedimentation, flocs settle to the bottom of the water because they are heavier than water.

Filtration

Once the flocs have settled to the bottom of the water, the clear water on top is filtered to separate additional solids from the water. During filtration, the clear water passes through filters that have different pore sizes and are made of different materials (such as sand, gravel, and charcoal). These filters remove dissolved particles and germs, such as dust, chemicals, parasites, bacteria, and viruses. Activated carbon filters also remove any bad odors.

Water treatment plants can use a process called ultrafiltration in addition to or instead of traditional filtration. During ultrafiltration, the water goes through a filter membrane with very small pores. This filter only lets through water and other small molecules (such as salts and tiny, charged molecules).

Reverse osmosisexternal icon is another filtration method that removes additional particles from water. Water treatment plants often use reverse osmosis when treating recycled waterexternal icon (also called reused water) or salt water for drinking.

Disinfection/STERILIZATION

After the water has been filtered, water treatment plants may add one or more chemical disinfectants (such as chlorine, chloramine, or chlorine dioxide) to kill any remaining parasites, bacteria, or viruses. To help keep water safe as it travels to homes and businesses, water treatment plants will make sure the water has low levels of the chemical disinfectant when it leaves the treatment plant. This remaining disinfectant kills germs living in the pipes between the water treatment plant and your tap.

In addition to or instead of adding chlorine, chloramine, or chlorine dioxide, water treatment plants

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

Biochemical oxygen demand (BOD) is the amount of oxygen microorganisms require to break down organic materials. In contrast, chemical oxygen demand (COD) is the amount of oxygen required to break down the organic material via oxidation.

Read: Biological Oxygen Demand

Let us look at the differences between BOD and COD.

Biological Oxygen Demand	Chemical Oxygen Demand

Definition

It is the amount of oxygen the microbes require to decompose the organic matter under aerobic conditions.	It is the total amount of oxygen required to break down the organic matter by chemical oxidation.

Test

It can be determined by putting a sealed water sample under specific temperature conditions for five days.	It can be determined by placing a water sample with a strong oxidising agent under specific temperature conditions for a short period.

Value

Lower than COD.	Higher than BOD.

Use

- It is used to waste loadings in treatment plants.
- Evaluation of BOD removal efficiency of the waste plants.
- To quantify the amount of oxidisable pollutants found in water bodies.
- It provides a measurement on how an effluent will affect the water body.

POLYMER

Polymers are all created by the process of polymerization wherein their constituent elements, called monomers, are reacted together to form polymer chains, i.e., 3-dimensional networks forming the polymer bonds.

The type of polymerization mechanism used depends on the type of functional groups attached to the reactants. In the biological context, almost all macromolecules are either completely polymeric or are made up of large polymeric chains.

Classification of Polymers

Polymers cannot be classified under one category because of their complex structures, different behaviours and vast applications. We can, therefore, classify polymers based on the following considerations.

Classification of Polymers based on the Source of Availability

There are three types of classification under this category, namely, Natural, Synthetic, and Semi-synthetic Polymers.

Natural Polymers:

They occur naturally and are found in plants and animals. For example, proteins, starch, cellulose, and rubber. To add up, we also have biodegradable polymers called biopolymers.

Semi-synthetic Polymers:

They are derived from naturally occurring polymers and undergo further chemical modification. For example, cellulose nitrate, and cellulose acetate.

Synthetic Polymers:

These are man-made polymers. Plastic is the most common and widely used synthetic polymer. It is used in industries and various dairy products. For example, nylon-6, 6, polyether’s etc.

Also Read: Natural Polymers vs Synthetic Polymers

Classification of Polymers based on the Structure of the Monomer Chain

This category has the following classifications:

Linear Polymers

The structure of polymers containing long and straight chains falls into this category. PVC, i.e. poly-vinyl chloride, is largely used for making pipes and electric cables is an example of a linear polymer.

Branched-chain Polymers

When linear chains of a polymer form branches, then such polymers are categorized as branched chain polymers. For example, Low-density polythene.

Cross-linked Polymers

They are composed of bifunctional and trifunctional monomers. They have a stronger covalent bond in comparison to other linear polymers. Bakelite and melamine are examples in this category.

Other Ways to Classify Polymers

Classification Based on Polymerization

- Addition Polymerization: For Example, poly ethane, Teflon, Polyvinyl chloride (PVC)
- Condensation Polymerization: Example, Nylon -6, 6, perylene, polyesters.

Classification Based on Monomers

- Homomer: In this type, a single type of monomer unit is present. For example, Polyethene
- Heteropolymer or co-polymer: It consists of different types of monomer units. For example, nylon -6, 6

Classification Based on Molecular Forces

- Elastomers: These are rubber-like solids weak interaction forces are present. For example, Rubber.
- Fibres: Strong, tough, high tensile strength and strong forces of interaction are present. For example, nylon -6, 6.
- Thermoplastics: These have intermediate forces of attraction. For example, polyvinyl chloride.
- Thermosetting polymers: These polymers greatly improve the material’s mechanical properties. It provides enhanced chemical and heat resistance. For example, phenolics, epoxies, and silicones.

Structure of Polymers

Most of the polymers around us are made up of a hydrocarbon backbone. A Hydrocarbon backbone is a long chain of linked carbon and hydrogen atoms, possible due to the tetravalent nature of carbon.

A few examples of a hydrocarbon backbone polymer are polypropylene, polybutylene, and polystyrene. Also, there are polymers which, instead of carbon, have other elements in their backbone. For example, Nylon, contains nitrogen atoms in the repeated unit backbone.

Types of Polymers

On the basis of the type of the backbone chain, polymers can be divided into:

- Organic Polymers: Carbon backbone.
- Inorganic Polymers: Backbone constituted by elements other than carbon.

On the basis of their synthesis:

- Natural Polymers
- Synthetic Polymers

Biodegradable Polymers

The polymers which are degraded and decayed by microorganisms like bacteria are known as biodegradable polymers. These types of polymers are used in surgical bandages, capsule coatings and in surgery. For example, Poly hydroxybutyrate co vel [PHBV]

High-Temperature Polymers

These polymers are stable at high temperatures. Due to their high molecular weight, these are not destroyed even at very high temperatures. They are extensively used in the healthcare industries, for making sterilization equipment and in the manufacturing of heat and shock-resistant objects.

Few of the important polymers are:

Polypropylene: It is a type of polymer that softens beyond a specific temperature allowing it to be moulded, and on cooling, it solidifies. Due to its ability to be easily moulded into various shapes, it has a lot of applications.

A few of which are in stationary equipment's, automotive components, reusable container speakers and much more. Due to its relatively low energy surface, the polymer is fused with the welding process and not using glue.

Polyethene: It is the most common type of plastic found around us. Mostly used in packaging from plastic bags to plastic bottles. There are different types of polyethene, but their common formula is $(C_2H_4)_n$.

Properties of Polymers

Physical Properties

- As chain length and cross-linking increase, the tensile strength of the polymer increases.
- Polymers do not melt, and they change state from crystalline to semi-crystalline.

Chemical Properties

- Compared to conventional molecules with different side molecules, the polymer is enabled by hydrogen bonding and ionic bonding resulting in better cross-linking strength.
- Dipole-dipole bonding side chains enable the polymer for high flexibility.
- Polymers with Van der Waals forces linking chains are known to be weak but give the polymer a low melting point.

Optical Properties

- Due to their ability to change their refractive index with temperature, as in the case of PMMA and HEMA: MMA, they are used in lasers for applications in spectroscopy and analytical applications.

Some Polymers and their Monomers

- Polypropene, also known as polypropylene, is made up of monomer propene.
- Polystyrene is an aromatic polymer, naturally transparent, made up of monomer styrene.
- Polyvinyl chloride (PVC) is a plastic polymer made of monomer vinyl chloride.

- The urea-formaldehyde resin is a non-transparent plastic obtained by heating formaldehyde and urea.

- Glyptal is made up of monomers ethylene glycol and phthalic acid.

- Bakelite or polyoxybenzylmethylenglycolanhydride is a plastic which is made up of monomers phenol and aldehyde.

Types of Polymerization Reactions

Addition Polymerization

This is also called as chain growth polymerization. In this, small monomer units join to form a giant polymer. In each step, the length of the chain increases. For example, Polymerization of ethane in the presence of Peroxides

Condensation Polymerization

In this type small molecules like H2O, CO, NH3 are eliminated during polymerization (step growth polymerization). Generally, organic compounds containing bifunctional groups such as idols, -dials, diamines, dicarboxylic acids undergo this type of polymerization reaction. For example, Preparation of nylon -6, 6.

What is Copolymerization?

In this process, two different monomers join to form a polymer. Synthetic rubbers are prepared by this polymerization. For example, BUNA – S.

Uses of Polymers

Here we will list some of the important uses of polymers in our everyday life.

- Polypropene finds usage in a broad range of industries such as textiles, packaging, stationery, plastics, aircraft, construction, rope, toys, etc.

- Polystyrene is one of the most common plastic actively used in the packaging industry. Bottles, toys, containers, trays, disposable glasses and plates, tv cabinets and lids are some of the daily-used products made up of polystyrene. It is also used as an insulator.

- The most important use of polyvinyl chloride is the manufacture of sewage pipes. It is also used as an insulator in electric cables.

- Polyvinyl chloride is used in clothing and furniture and has recently become popular for the construction of doors and windows as well. It is also used in vinyl flooring.

- Urea-formaldehyde resins are used for making adhesives, moulds, laminated sheets, unbreakable containers, etc.

- Glyptal is used for making paints, coatings, and lacquers.

- Bakelite is used for making electrical switches, kitchen products, toys, jewellery, firearms, insulators, computer discs, etc.

Commercial Uses of Polymers

Polymer	Monomer	Uses of Polymer
Rubber	Isoprene (1, 2-methyl 1 – 1, 3-butadiene)	Making tyres, elastic materials
BUNA – S	(a) 1, 3-butadiene (b) Styrene	Synthetic rubber
BUNA – N	(a) 1, 3-butadiene (b) Vinyl Cyanide	Synthetic rubber
Teflon	Tetra Fluoro Ethane	Non-stick cookware – plastics
Terylene	(a) Ethylene glycol (b) Terephthalic acid	Fabric
Glyptal	(a) Ethylene glycol (b) Phthalic acid	Fabric
Bakelite	(a) Phenol (b) Formaldehyde	Plastic switches, Mugs, buckets
PVC	Vinyl Cyanide	Tubes, Pipes
Melamine Formaldehyde Resin	(a) Melamine (b) Formaldehyde	Ceramic plastic material
Nylon-6	Caprolactam	Fabric

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Types of rubber

There are two primary types of rubber, namely natural rubber and synthetic rubber.

Natural rubber

These are the elastomers which are obtained naturally. Natural rubber is made up of solid particles suspended in a milky white liquid (called latex) that drips from the bark of certain tropical and subtropical trees. This latex rubber is mainly found in countries like Brazil, India, Indonesia, Malaysia, and Sri Lanka. It is made by the polymerization of isoprene (2 methyl-1, 3-butadiene) which has a chemical formula ($C5H8$) n and it is known as cis- 1, 4- polyisoprene. In simple words, we can say that they are made by loosely joining the monomers of isoprene ($C5H8$) in the form of a long tangled chain.

Preparation of Natural Rubber:

- Rubber tapping – The milky white liquid latex is collected from the rubber trees in a cup by making a slight V-cut on the tree bark. The collected latex is washed, filtered and reacted with acids to congeal the rubber particles.

- Mastication – The rubber obtained from the tapping process is still not ready to be used. When it is cold it is very brittle in nature and when warmed up it becomes very gluey. To remove the brittle nature and strong odour of the rubber, it is allowed to pass through the rollers and is pressed to make it softer and flexible to work. This process is repeated based on the properties that are required for the rubber. In this process, extra chemical ingredients are also added to enhance the properties of rubber.

- Calendering is a process which is mainly performed to provide shape to the rubber using rollers (after proper mixing of the chemical ingredients).

- The final product obtained is then extruded to make hollow tubes by passing them through specially designed holes in an extrusion machine.

- Vulcanization – Performing all the steps listed above will not yield rubber that is strong or hard enough to be used in items like car tires and machinery. To enhance all these properties, sulphur is added to the rubber and it is heated at a temperature ranging from 373 K to 415 K. This process is known as vulcanization. The sulphur acts as a cross-linking agent and after vulcanization, rubber gets cross-linked and becomes hard.

Synthetic rubbers

Synthetic rubbers are produced from petroleum and natural gas. It is obtained by polymerization of 1, 3 – butadiene derivatives or by copolymerization of 1, 3 – butadiene along with an unsaturated monomer.

Preparation of synthetic rubbers:

Neoprene (Polychloroprene): –

The monomer of Neoprene is 2-chloro-1,3-butadiene, it is commonly known as chloroprene. Neoprene is a polymer of chloroprene, which is formed by joining together the monomers of chloroprene.

Buna- N:-

It is a copolymer of 1, 3 – butadiene and acrylonitrile, it is formed in the presence of a peroxide catalyst.

Uses of Rubber

Rubber can be used for various rubber and across various platforms, a few of them are mentioned below;

- It is used for lining chutes, bins and industrial mixers. Because of its water-proof and resilient property, it can be made into a good insulator.
- In the clothing industry, it can be used as wetsuits and expandable clothes such as gym and cycling shorts etc.
- Rubbers are also used for flooring purposes it gives padding and prevents fatigue along with being waterproof and slip-resistant.
- In the automobile industry, its use can be witnessed in tires, padding in brakes, airbags, seats, roofs etc.
- VALCANIZATION OF RUBBER
- vulcanization, chemical process by which the physical properties of natural or synthetic rubber are improved. it is the process of converting natural rubber to more strong and elastic form. Natural rubber is mixed with 3 to 5% sulphur and heated at 100 to 150oC to form cross linking of cis−1,4−polyisopropene chains through disulphide bonds.
- The process was discovered in 1839 by the U.S. inventor Charles Goodyear, who also noted the important function of certain additional substances in the process. Such a material, called an accelerator, causes vulcanization to proceed more rapidly or at lower temperatures. The reactions between rubber and sulfur are not fully understood, but in the product, the sulfur is not simply dissolved or dispersed in the rubber; it is chemically combined, mostly in the form of cross-links, or bridges, between the long-chain molecules.

Unit – 3

In this type of titration, upon the continuous addition of the titrant (and the continuous recording of the corresponding change in electrolytic conductivity), a sudden change in the conductivity implies that the stoichiometric point has been reached. The increase or decrease in the electrolytic conductivity in the conductometric titration process is linked to the change in the concentration of the hydroxyl and hydrogen ions (which are the two most conducting ions).

The strength of an acid can be determined via conductometric titration with a standard solution of a base. An example of a curve plotted for such a titration process is given below.

Electrical Insulators are materials that restrict the free flow of electrons from one particle to the other. If some amount of charge is transferred to an element at any point, the charge stays at the initial location and is not distributed across the surface. The process of charging of such elements involves Charging by Rubbing and **Charging by Induction**.

Electrical Insulator materials do not allow free flow of Electric currents or charges. The Electrical Insulator materials give very little freedom for the electrons to drift from atom to atom. Thus, Electrical Insulators are a poor Conductor of Electricity. You can get a better understanding with the help of an Electrical Conductor example. You must have observed that the outer covering of your phone charger plug is made from plastic so that the Electric charges do not pass on to human skin. The following is a list of Electrical Insulator examples.

- Styrofoam
- Plastic
- Wax
- Rubber
- Dry air
- Glass
- Ceramics
- Rubber

- Teflon
- Mica
- Quartz
- Porcelain
- Asphalt

Uses of Insulators

You must be wondering why are Electrical Insulators important for us when Electric charges cannot be passed through it? Generally, Electrical Insulators are highly useful at home, offices, streets, etc. They are used in Electrical appliances and equipment. Unfortunately, human skin is one of the best Conductors of Electric charges. Furthermore, the presence of Electrical Insulator materials prevents and protects Electrical devices from generating high voltage. There are innumerable uses of Insulators. They are listed below.

- It prevents the passing of high-voltage in an Electric circuit.
- It helps in reducing the cost of energy.
- It helps in saving the environment by controlling the emission of pollutants.
- It improves process performances.
- It protects from Electric shock or electrocution.
- It allows the soundproofing of appliances.

Application of Insulator

Since the Electrical Insulator materials bind the electrons tightly, it prevents the electrons from floating from atom to atom. Thus, they prevent the conduction of Electric charges. Given the benefits of there are multifold applications of the Electrical Insulator. They are applied to-

- Circuit boards
- Coating of Electric wires
- High voltage appliances
- Coating of cables
- Coating for Electric poles on the streets

Types of Electrical Insulation in Overhead Lines

Electrical Insulators can withstand the charges from Electricity. They are broadly classified into three types of Electrical insulation based on their operating voltage levels and applications.

Pin Type Electrical Insulator

A pin Insulator is best for supporting low voltage line Conductors. A single piece of pin Insulator is used in 11kV, and the double piece is applied to 25kV. Above 44kV, three or four pieces of pin Insulators can be used. An Electrical Insulator has a porcelain shell. So even if the outer surface of an Electrical appliance gets wet, the inner surface is dry to keep it leakage resistant.

(Image will be uploaded soon)

Suspension Type Electrical Insulator

Suspension Electrical Insulators are best to handle high-voltage transmission lines. This type of Electrical Insulator has porcelain discs inside arranged in a series through metal links such that they have a string-like appearance. The arrangement of Insulators highly depends upon the weather condition, voltage, the size of the Insulator, etc.

(Image will be uploaded soon)

Strain Type Electrical Insulator

Another name for strain Insulator is tension Insulator. They are best for high voltages when the Electrical line is subject to change in the direction of the line, and at higher-tension areas at sharp curves, river crossings, etc. It is useful in minimizing the excessive tension in the line. Strain Electrical Insulators have diElectric properties. Additional strings can be added when the tension begins to aggravate.

Fun Facts

1. You would be surprised to know that the diamond necklace you wear on a special occasion is an excellent Electrical Insulator material.
2. A high-voltage area, which is dangerous, is enclosed in fiberglass or glass to prevent the conductivity of charges to pass.
3. Your Electrician uses a special screwdriver with a plastic coating to check the passage of Electrical charges without getting electrocuted.

Difference between Conductor and Insulator

Conductor	Insulator
These substances help to flow the Electric current	These substances prevent the flow of Electric current
The Electrical resistance of the Conductor is very low	The Electrical resistance of Insulators is high
They contain a large number of free electrons	Insulators do not have free electrons
The thermal Conductivity is high as compared to Insulators	The thermal conductivity is low as compared to Conductors
The Electrical field in Conductors is present only on the surface and not inside the material	The Electrical field is not present in Insulators
Most metals are Conductors	Mostly non-metals are Insulators
Some of the examples of the Conductor are copper, Aluminium, iron, etc.	Examples of Insulators are wood, rubber, plastic, etc.

Quick Summary

Here’s a quick summary of the topic of Electrical Insulators and their examples.

Type of the material	Insulator
Some examples	are wood, plastic, rubber, etc.
Conductivity	Conductivity is low in Insulators

Electrical resistance	Electrical resistance is high in Insulators.
Materials possessing property	Mostly non-metals
Electric field	Absent
Free electrons	No free electrons present
Types of Insulators In overhead lines	Pin type, suspension type, and strain type

This was all about Electrical Insulators, properties and their types. For more such information, access free resources available on the Vedantu website useful for the state board, CBSE, ICSE, and competitive examinations. All NCERT Solutions for all subjects are available on the Vedantu website.

Is this page helpful?

All metals have different properties; characteristics that set them apart from each other. With a thermocouple, we use these innate differences to help determine the temperature difference that we’re trying to measure. It is important to remember that there are always two dissimilar metals within thermocouples; it is intrinsic to how they work.

Some common metals used in thermocouples are **iron** (Fe), **copper** (Cu), **nickel** (Ni), and **platinum** (Pt). Metal alloys, or combinations of metals, are also used in thermocouples. **Nichrome** is an alloy consisting of nickel and chromium (Cr). **Constantan**, a mixture of copper and nickel, is also prevalent. There is even **alumel**, which is a trademarked alloy consisting of mostly nickel with small percentages of aluminum, manganese, and silicon.

Each type of metal brings certain advantages to thermocouple temperature measurement. Some combinations of metal may work well for relatively hot temperatures, but not for cold ones. Other combinations might give very accurate temperature readings but only within a specific and narrow range of measurements. Still another combination can be resilient to the corrosive environment where it is employed; therefore adding a longer lifespan to the thermocouple before it needs replacement.

Different Thermocouple Types

When a certain pair of metals are discovered to cooperatively produce a reliable voltage signal they are standardized and given their own classification. This way a specific "type" of thermocouple has properties that are now regulated. Meaning, those voltage measurements are reproducible exactly the same from one thermocouple to another. Let's take a look at some common thermocouples types, the metals that they consist of, and areas where they excel.

Type J:

The J is the most common thermocouple out there. Made from the common metals iron and constantan (Fe-Con), the type J thermocouple is a low-cost option. The temperature range is from 0ºC to +750ºC and is accurate to within a few degrees. This type is most accurate in the mid to low ranges since iron will rapidly oxidize toward the higher measurable temperatures and the standard voltage readings can be permanently altered. You'll find type J thermocouples in a wide variety of manufacturing processes.

Type K:

Also a common thermocouple, type K can measure from -270ºC to +1200ºC, and is most accurate to within a couple of degrees towards the higher side. It is comprised of nichrome-nickel (NiCr-Ni) or nichrome-alumel (NiCr-Alumel). These metals are common, relatively inexpensive, and typically used above the 600ºC mark. It is comparable to a type J in price but with a less refined voltage to temperature output. Type K thermocouples are arguably the most widely used type and are found throughout many different industries.

Type T:

A thermocouple that is often used to measure colder temperatures, type T is comprised of copper and constantan (Cu-Con). This combination of metals gives a reliably measurable voltage from -270ºC to +350ºC, perfect for food-related uses and scientific research, like cryogenics. Below -200ºC even the type T thermocouple begins to lose its accuracy. You may remember from high school science class; that the coldest known temperature possible is -273ºC; otherwise known as 0 Kelvin or absolute zero. It's pretty impressive that our simple thermocouple can plumb those depths of temperature measurability.

Type B:

Let's go the other way and measure something extremely hot. The type B thermocouple can measure from 200ºC all the way up to 1700ºC. To put that in perspective, steel and iron melt at around 1400ºC and 1500ºC, respectfully, so this type of thermocouple would be an ideal fit for specialized industrial use. Unlike, type J or K materials which would be at their melting points at this high of a temperature. The two very rare elements of rhodium (Rh) and platinum (Pt) are used in type B, and these metals don't come cheap. Also, depending on the spot price, platinum is around the same price as gold. Rhodium, on the other hand, is currently worth twice the price of gold. Due to this, along with its specialized use, means you won't see too many type B thermocouples out there.

UNIT -4

Define the terms:
(i) mineral
(ii) ore
(iii) gangue
(iv) charge
(v) flux
(vi) slag

Solution

(i) Minerals: The naturally occurring metals or their compounds present on the earth surface along with sand and rocks are called minerals.

(ii) Ore: Minerals from which metals can be profitably extracted are known as ores.

(iii) Gangue: Gangue constitutes impurities like sand, mud and rocky substances like SiO_2; it is present along with metals in an ore.

(iv) Charge: The combination of substances that are supplied to a furnace during the extraction of metals from their ores is called charge.

(v) Flux: The material that is added to remove gangue is called flux.

(vi) Slag: The product obtained by combining gangue and flux is called slag.

Extraction Of Iron: Application Of Metallurgy

Extraction of Iron

Extraction of iron from its ore is the third and the penultimate process in the Metallurgy. The extraction of metals and its isolation occurs over a few major steps:

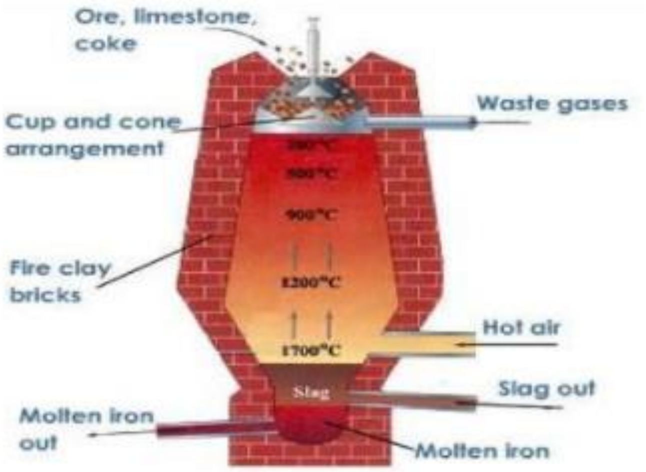
1. Concentration of Ore
2. Extraction of metal from concentrated Ore
3. Purification of the metal

How is iron extracted from its ore? It's a long process which begins with Concentration through calcination roasting. Concentration removes the water and other volatile impurities such as sulphur and carbonates. This concentrated ore is mixed with limestone ($CaCO_3$) and Coke and fed into the blast furnace from the top. It is in the blast furnace that extraction of iron occurs. The extraction of iron from its ore is a long and subdued process, that helps in separating the useful components from the waste materials such as slag.

What happens in the Blast Furnace?

The purpose of a Blast Furnace is to reduce the concentrated ore chemically to its liquid metal state. A blast furnace is a gigantic, steel stack lined with refractory brick where the concentrated iron ore, coke, and limestone are dumped from the top, and a blast of hot air is blown into the bottom. All the three ingredients are crushed into small round pieces and mixed and put on a hopper which controls the input.

Hot air is blown from the bottom and coke it burned to yield temperatures up to about 2200K. Burning coke provides the majority of the heat required for this process. At such high temperatures, Coke reacts with the oxygen in the hot air to form Carbon Monoxide (CO). The CO and heat now move upwards and meet the raw material running down from the top. The temperature in the upper parts of the Blast Furnace is considerably lower than the 2200K at the bottom. In this part, Haematite (Fe_2O_3) and Magnetite (Fe_3O_4) are reduced to Ferrous Oxide (FeO).



Reactions in the Blast furnace at 500 – 800 K, In the upper parts with lower temperatures,

$$3Fe2O3+CO=2Fe3O4+CO23$$

$$Fe3O4+4CO=3Fe+4CO2$$

$$Fe2O3+CO=2FeO+CO2$$

At 900 – 1500 K, In the lower sections of the furnace,

$$C+CO2=2CO$$

$$3FeO+CO23$$

=

$$Fe+CO2$$

The limestone also decomposes to CaO which removes the silicate impurity of the ore in the form of Slag. It can be easily separated out of molten iron. The iron manufactured in Blast Furnaces contain about 3 – 4 % of Carbon and smaller quantities of many other impurities such as sulphur, Silicon, etc. This is called Pig Iron. It is a hard but brittle metal and the impurities severely hamper its strength. Carbon seems to play a significant role in influencing the brittleness and hardness balance in iron. To further reduce the carbon content of pig iron, it is melted again with scraps of iron and coke and subjected to the blast of hot air. This kind of iron is called Cast Iron and has a slightly lower carbon content 2 – 3 %. This is even harder than pig iron.

Wrought Iron/ Malleable Iron

Wrought iron is the purest form of iron available commercially available and is prepared from cast iron by heating cast iron in a furnace lined with Haematite (Fe_2O_3). The Haematite reacts with Carbon in the cast iron to give pure iron and carbon monoxide gas which escapes.

Limestone is then added as flux, and it creates the slag. Impurities such as S, Si pass into the slag and the slag later can be easily separated to yield pure iron.

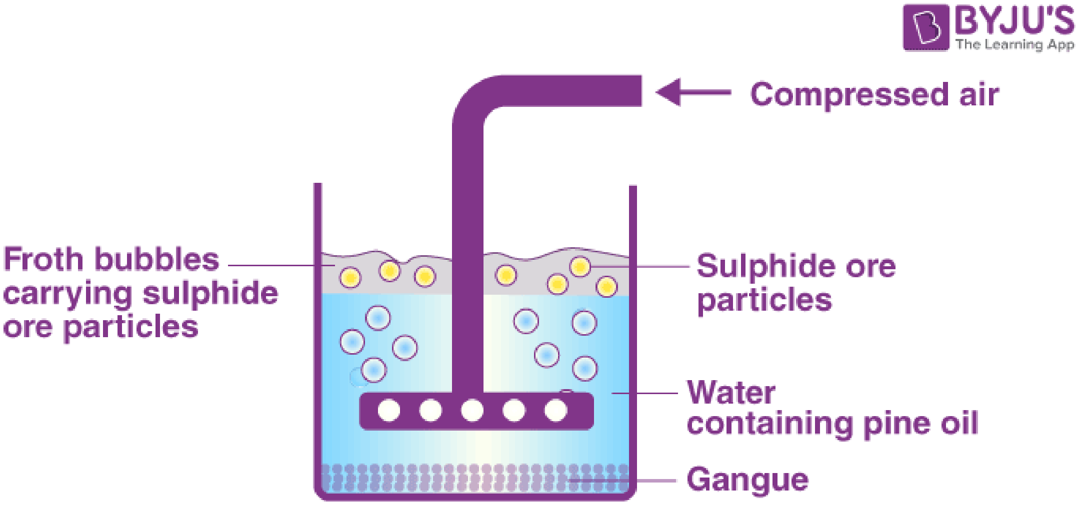
Extraction Of Copper: Application Of Metallurgy

Copper Mining:

The commonest ore used in the extraction of copper is **Chalcopyrite** ($CuFeS_2$) also known as Copper Pyrites and other such sulphides. The percentage of copper in the actual ore is too low for direct extraction of copper to be viable. The concentration of ore is required and it is done by the Froth Flotation method.

Concentration of Ore:

The ore is crushed into a fine powder and a suspension is created in water. To this are added, Collectors and Froth Stabilizers. Collectors (pine oils, fatty acids etc) increase the non-wettability of the metal part of the ore and allow it to form froth and Froth Stabilizers (cresols, aniline etc) sustain the froth. The oil wets the metal and the water wets the gangue. Paddles and air constantly stir up the suspension to create the froth. This frothy metal is skimmed off the top and dried to recover the metal.



Copper Smelting:

Smelting is a metallurgy technique to extract base metals from their ores with the help of heat and a chemical reducing agent. (Click here for extraction process). Copper Smelting means that the concentrated ore is heated strongly with silicon dioxide (silica), calcium carbonate ($CaCO_3$) and air in a furnace. The major steps in the extraction of copper are

- Copper in Chalcopyrite is reduced to copper sulphide.

- Just like in Blast Furnaces, calcium carbonate is added as a flux to create the slag.
- Iron in Chalcopyrite is removed as iron silicate slag.
- Most of the sulphur in Chalcopyrite turns into Sulphur dioxide (SO_2).

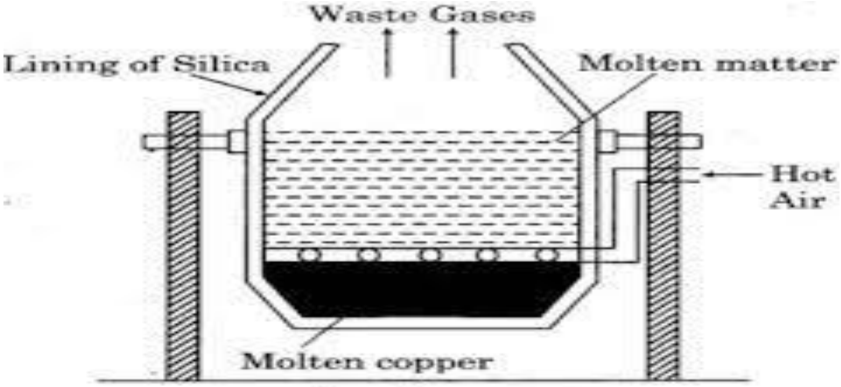
The reaction of these processes can be written as:

$2CuFeS_2+2SiO_2+4O_2 \rightarrow Cu_2S+2FeSiO_3+3SO_2$

The copper extracted from this process is mixed with the slag and is called Matte Copper due to its texture and appearance. This mainly consists of Cu2S which is reduced to pure metal by blasting Matte Copper with air.

$Cu_2S+O_2 \rightarrow 2Cu+SO_2$

The sulphur dioxide escapes the copper and this causes bubbles to appear and burst as SO2 leaves. This causes the final product to have a very blistery appearance and hence it is called Blister Copper; 98 – 99.5 % pure.



Bessemer convertor

Copper is an outstanding conductor of electricity and combined with its ductility, it is the perfect metal to make electrical wiring, both domestic and industrial. The electronic Age would have been just a dream without this metal.

<u>Properties of following metal</u>

1. Nickel-

2. Tungeston

3. Platinium

4. Copper

5. Iron

Physical Properties of Iron

- It rusts in damp air, but not in the dry air.
- It dissolves readily in dilute acids.

- At room temperature, this metal is in the form of ferrite or α-form.
- At 910°C, it changes to γ-iron, which is much softer in nature.
- It melts at 1536°C and boils at 2861°C.
- Being a metal is magnetic in nature.

Properties of COPPER

It is a soft, malleable, and ductile metal with very high thermal and electrical conductivity. A freshly exposed surface of pure copper has a pinkish-orange color. Copper is a reddish metal with a face-centered cubic crystalline structure It is malleable, ductile, and an extremely good conductor of both heat and electricity.

melting point	1,083 °C (1,981 °F)
boiling point	2,567 °C (4,653 °F)
density	8.96 at 20 °C (68 °F)
valence	1, 2

Copper does not react with water, but it does slowly react with atmospheric oxygen to form a layer of brown-black copper oxide which, unlike the rust that forms on iron in moist air, protects the underlying metal from further corrosion

Properties of Platinum

- Physically, platinum is a soft, lustrous, silver-coloured metal.
- It is highly dense (21.5 g/cc), malleable and ductile (there is an ongoing debate if it is the most ductile).
- It is also highly corrosion resistant and has a high boiling point (around 1700 degrees Celsius or 3220 degrees Fahrenheit).
- Chemically, platinum is one of the most stable elements in nature. It is often referred to as Noble metal because of its high stability.
- It is immune to nitric and hydrochloric acids but can be dissolved by aqua regia at a high temperature.
- It reacts with oxygen and fluorine but at very high temperatures. Platinum has six isotopes that occur in nature- 190Pt, 192Pt, 194Pt, 195Pt, 196Pt, and 198Pt.

Properties Of Nickel

- Nickel is a silvery-white, hard, malleable, and ductile metal.
- It is a good conductor of heat and electricity.
- It is bivalent, that is it has a valency of two.

- The metal dissolves slowly in dilute acids.
- Its melting point is 1453 °C and its boiling point is 2913 °C.

Tungsten is a greyish-white lustrous metal, which is a solid at room temperature. Tungsten has the highest melting point and lowest vapor pressure of all metals, and at temperatures over 1650°C has the highest tensile strength. It has excellent corrosion resistance and is attacked only slightly by most mineral acids.

Alloy and its properties

When a metal is mixed with another element, which may be a metal or a non metal such that a new substance of homogeneous composition is obtained, the substance obtained is known as an alloy. An alloy is thus a homogeneous mixture of two or more metals, or a metal and a non metal. The properties of an alloy are different from that of combining elements. For example when iron is mixed with Carbon, nickel and chromium, stainless steel is obtained which is hard and does not rust. Other examples of alloys include brass, bronze, solder etc.

1. Alloys are stronger than the metals from which they are made.
2. Alloys are harder than the constituents metals.
3. Alloys ere more resistant to corrosion.
4. Alloys have lower melting points than the constituent metals.
5. Alloys have lower electrical conductivity than pure metals.

Alloys are classified into two different types. These are listed below..

- Ferrous Alloy
- Non-ferrous Alloy

Ferrous Alloy:– A ferrous alloy is the alloy that contains the iron, carbon and the other elements like manganese, nickel, chromium, copper, vanadium, molybdenum, tungsten, etc.

Non-ferrous Alloy:– A non-ferrous alloy is the alloy that contains no iron in combination of mixture.

If the percentage of the carbon in the alloy is below 0.1, the formed alloy is the iron alloy. If it is above 0.1, the formed alloys are called steels.

Some Important Alloys with composition and uses.

Below are some important alloys already created for our useful equipments and materials. Some metals are hardest some are good in electrical conductivity. Check these alloys and the metals used to create these alloy.

Name of Alloy	**Alloy Composition**	**Uses of Alloy**
Brass	• Copper(Cu): 60-80% • Zinc(Zn): 20-40%	• Utensils • Condenser Tubes • Electrical Goods • Cartridge shell
Bronze	• Copper(Cu): 75-90% • Tin(Sn): 10-25%	• Coins • Statues • Utensils
German Silver	• Copper(Cu): 56% • Zinc(Zn): 24%	• Coins • Statues • Utensils
Gun Metal	• Copper(Cu): 56% • Tin(Sn): 24%	• Machine Parts • guns

Duralumin	- Aluminium(Al): 95% - Copper(Cu): 4% - Manganese(Mn): 0.5% - Magnesium(Mg): 0.5%	- Making Aeroplanes
Solder	- Lead(Pb): 50-70% - Tin(Sn): 30-50%	- Soldering Machine
Britannia	- Tin(Sn): 93% - Antimony(Sb): 5% - Copper(Cu): 2%	- Use in making Tableware
Wood’s metal	- Bi: 50% - Lead(Pb): 25% - Tin(Sn): 12.5% - Cadmium(Cd): 12.5%	- Use in Electric fuses and other safety devices
Nichrome	- Nickel(Ni): 60% - Chromium(Cr): 15% - Iron(Fe): 25%	- Electrical resistances
Stainless steel	- Iron(Fe): 89.4% - Chromium(Cr): 10% - Manganese(Mn): 0.35% - Carbon(Cr): 0.25%	- Utensils - Ornamental pieces

Types of carbon steel

Low-carbon steel

Usually have a carbon content of between 0.04% and 0.30%. The largest category of carbon steel is this one. The shapes it covers range greatly, from Flat Sheets to Structural Beams. Other elements are decreased or increased based on the desired qualities required. It is flexible, malleable, and soft. Steel bars, stamping-resistant components, specific steels, etc., are among the things it mostly produces. The surface hardness of low-carbon steel can be improved through the carburizing process, making it more abrasion resistant and boosting its strength even further.

Properties of low carbon steel

- High toughness
- Low tensile strength
- High weldability
- Low cost
- High ductility
- Low hardness
- High machinability

Medium carbon steel

It has a typical carbon value between 0.31% and 0.60% and a manganese content between.060% and 1.65%. Although this product is more difficult to mold, weld, and cut than low-carbon steel, it is stronger. Heat treatment is a common method for hardening and tempering medium carbon steels. It is ideal for producing products like gears and studs that will endure a lot of wear and tear. Medium carbon steel can be heated and maintained at a constant temperature until it reaches the desired hardness, then soaked and cooled if more hardening is required. The production of stainless steel is the primary goal.

Properties of medium carbon steel

- Medium strength
- Moderate toughness
- Medium weldability
- Medium ductility
- Moderate machinability

High-carbon steel

It is frequently referred to as “carbon tool steel” and usually contains carbon content between 0.61% and 1.50%. Cutting, bending, and welding high-carbon steel is particularly challenging. It gets exceedingly hard and brittle after being heated. High-carbon steel can be made with chromium and manganese alloys added to assist the material resists corrosion. The primary applications are steel doors, rails, knives, general bearings, and steel frame molds (used to shape steel).

Properties of high carbon steel

- High toughness
- Low machinability
- High strength
- Moderate weldability
- Low ductility

Definition of Portland Cement

A cement is any substance which binds together other materials by a combination of chemical processes known collectively as setting. Cements are dry powders and should not be confused with concretes or mortars, but they are an important constituent of both of these materials. Cement act as the 'glue' that gives strength to structures. Mortar is a mixture of cement and sand whereas concrete also includes rough aggregates. Cement is a powdered material with water forms a paste that hardens slowly. It has an important property that when mixed with water a chemical reaction (hydration) takes place.

Raw Materials

1. Calcareous rocks such as limestone, marl, chalk.
2. 2. Argillaceous rocks (silica and alumina) such as in clay and shale.

Portland cement production must contain, in proper form and proportions of lime, silica and alumina.

2.3.2 Chemical Composition of Portland Cements

The raw materials used in the manufacture of Portland cement consist mainly of lime, silica, alumina and iron oxide .The oxides account for over 90% of the cement. The oxide composition of (ordinary) Portland cement may be expressed as follows:

Common Name Oxide & Approximate composition limits (%)

Lime CaO 60-66

Silica $SiO2$ 19-25

Alumina $Al2O3$ 3-8

İron oxide $Fe2O3$ 1-5

Magnesia MgO 0-5

Alkalies: -soda -potassa $Na2O$ $K2O$ 0.5-1 0.5-1

Sulfur trioxide $SO3$ 1-3

Production Steps of Portland Cement

1- Crushing, screwing, and stockpiling the raw materials.

2- Calculating the proportions of raw materials.

3- Preparing the raw mix by blending.

4- Feeding the raw mix into rotary kiln.

5- 100oC: Free water is evaporated.

6- 150-300oC: Loosely bound water is evaporated.

7- 500oC: More firmly bound water is evaporated.

8- 600oC: MgCO3 MgO + CO2

9- 900oC: CaCO3 CaO + CO2

10- Reaction between lime and clay starts.

11- 1300oC: Major compound formation starts.

12- 1400-1600oC: Output temperature.

13- (Around 1600oC clinker forms C3A, C2S, C3S, C4AF)

14- Clinker cooled and stored.

15- Clinker is ground with gypsum.

16- Storing and marketing.

Physical Properties of Cement

1. Hydration: The chemical combination of cement and water known as hydration produces a very hard and strong binding medium for the aggregate particles in the concrete. At the end of hydration normally a heat is liberated which is expressed as calories per gram. The rate of hydration depends on the relative properties of silicates and aluminate compounds, the fineness of the cement, and the ambient temperature. Time taken to achieve 80% hydration and heat of hydration of the main chemical compounds of Portland cement.

2. Setting and Hardening: Setting and hardening of the cement paste are the main physical characteristics associated with hydration of cement. The setting times: The time from the addition of the water to the initial and final set are known as the setting times. The initial set: The beginning of noticeable stiffening in the cement paste is known as the initial set. The final set: The final hardening process which is responsible for its strength known as the final set. Setting time is affected by cement composition, cement fineness, rate of hydration, and the ambient temperature.

3. Strength: The strength of hardened cement is its most important property. The rate of hardening of cement depends on the chemical and physical properties of the cement, the curing conditions and the water/cement ratio.

4. Soundness: Soundness is a physical property of cement paste, which determines the ability of the cement paste to retain its volume after setting is completed. The unsoundness is due to the presence of free CaO (lime) and free MgO (magnesia) in cement. These constituents hydrate very

slowly after setting of cement. Since Ca(OH)2 and Mg(OH)2 occupy larger volume, expansion takes place.

The unsoundness may be reduced by;

1- limiting MgO content to less than 5%,

2- 2- fine grinding,

3- 3- thorough mixing,

4- 4- Allow cement to aerate for several days (lime may have hydrated or carbonated in cement).

Unit-5

NMDC DAV POLYTECHNIC DANTEWADA

Education City, Jawanga-Geedam

Coal

- Also called **black gold**.
- Found in sedimentary strata [layers of soil].
- Contains **carbon, volatile matter, moisture** and **ash** [in some cases **Sulphur** and **phosphorous**]
- Mostly used for power generation and metallurgy.
- Coal reserves are six times greater than oil and petroleum reserves.

✓ Type of Coal

This division is based on carbon, ash and moisture content.

1. Peat
2. Lignite
3. Bituminous
4. Anthracite

Peat Coal

- First stage of transformation.
- Contains **less than 40 to 55 per cent carbon == more impurities.**
- Contains sufficient volatile matter and **lot of moisture** [more smoke and more pollution].
- Left to itself, it burns like **wood**, gives less heat, emits more smoke and leaves a **lot of ash.**

Lignite Coal

- **Brown coal.**
- Lower grade coal.
- **40 to 55 per cent carbon.**
- Intermediate stage.
- Dark to black brown.
- Moisture content is high (over 35 per cent).
- It undergoes **SPONTANEOUS COMBUSTION** [Bad. Creates fire accidents in mines]

Bituminous Coal

- Soft coal; most widely available and used coal.
- Derives its name after a liquid called bitumen.
- **40 to 80 per cent carbon.**
- Moisture and volatile content (15 to 40 per cent)
- Dense, compact, and is usually of black colour.
- **Does not have traces of original vegetable material.**
- Calorific value is **very high** due to high proportion of carbon and low moisture.
- Used in production of **coke and gas**.

Anthracite Coal

- **Best quality**; hard coal.
- **80 to 95 per cent carbon**.
- Very little volatile matter.
- Negligibly small proportion of moisture.
- Semi-metallic lustre.
- **Ignites slowly** == less loss of heat == highly efficient.
- Ignites slowly and burns with a nice short **blue flame. [Complete combustion == Flame is BLUE == little or no pollutants. Example: LPG]**
- In India, it is found only in Jammu and Kashmir and that too in small quantity.

Proximate and Ultimate analysis of Coal

What is meant by Fuel Characterization?

Fuel characterization concerns with the “analysis” and “energy content of fuel” (also known as calorific value). Fuel analysis comprises of “proximate” and “ultimate”.

(A)Proximate analysis:

In the proximate analysis, moisture (M), Ash (A) and volatile matter (VM) are determined. Fixed carbon (FC) is obtained from the following equation:

FC= 100 – (%M + %A + %VM) − (1)

There are standard tests to determine proximate analysis. Moisture is determined by drying 1gm of sample at 105^{o}C for 1hr. Weight loss is expressed in %of initial weight of sample ; i.e.

%M = (weight loss/weight of sample) ×100 − (2)

Ash is weight of residue obtained after complete combustion of 1 g of coal at 700-750^{o}C. Ash in % is

%A= (weight of residue/weight of sample)×100 −(3)

Volatile matter is the weight loss obtained on heating 1 gm sample of coal at 950oC for 7 minutes in the absence of air.

Total weight loss of a moist coal= Weight loss due to Volatile matter + Moisture

Weight loss due to VM = Total weight loss – moisture

If coal sample is dry then weight loss is due to VM only.

% VM = (weight loss due to VM/ weight of sample) ×100. − (5)

Fixed carbon can be calculated by eq. 1.

(B) Ultimate Analysis

The main chemical elements in coal (apart from associated mineral matter) are C, O, H, N and S. The chemical analysis is very important to calculate material balance accurately and calorific value of coal. For the ultimate analysis C, H, S and N are determined by chemical analysis and expressed on a moisture free basis. Ash is determined as in proximate analysis and is calculated on moisture free basis. Then,

$$\%O = 100 \quad (\%C + \%H + \%N + \%S + \% \text{ ash}) \tag{6}$$

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Proximate Analysis of Coal

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Ultimate Analysis of Coal

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[illegible] ([illegible]) [illegible], [illegible], [illegible], [illegible] C, H, N [illegible] S [illegible] Ash [illegible],

$\%O = 100 \quad (\%C + \%H + \\%N + \%S + \% ash)$ (6)

Octane Number

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Cetane number (**cetane rating**) is an indicator of the combustion speed of diesel fuel and compression needed for ignition. It plays a similar role for diesel as octane rating does for gasoline. The CN is an important factor in determining the quality of diesel fuel, but not the only one; other measurements of diesel fuel's quality include (but are not limited to) energy content, density, lubricity, cold-flow properties and sulphur content.

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Fractional Distillation of Crude Petroleum

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Gaseous Fuel (Natural Gas)

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[illegible]

[illegible]– biogenic [illegible]

[illegible]– thermogenic [illegible]

Biogenic [illegible], bogs, landfills [illegible] methanogenic [illegible]

thermogenic [illegible], [illegible], [illegible] (process) [illegible], [illegible], butanes, pentanes [illegible], [illegible], [illegible], [illegible], [illegible]

LPG (Liquefied Petroleum Gas)

[illegible] **LPG** [illegible] ([illegible]) [illegible], [illegible] (Liquefied petroleum gas / LPG) [illegible], [illegible] ([illegible]) [illegible]

CNG (Compressed Natural Gas)

[illegible] ([illegible]) [illegible] ([illegible])

[illegible]

[illegible]

[illegible] ([illegible] – **C***ompressed* **N***atural* **G***as*, [illegible] CNG, [illegible]) [illegible]

[illegible]

[illegible]