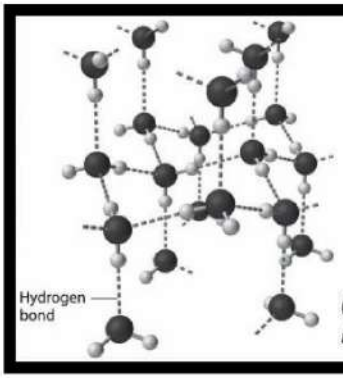


CHAPTER 4

STRUCTURE OF MOLECULES

SUBJECTIVE PART
LONG QUESTION ANSWERS

Q.1 What is a chemical bond and why do atoms form chemical bonds? (Ex. Q.10)

Ans: *A chemical bond is defined as force of attraction between atoms that holds them together in a substance.*

Example: A bond formed between H and Cl atoms in a molecule of HCl.

Why do atoms form chemical bonds? (Atoms form bands to get stability)

It is a universal rule that everything in this world tends to become more stable.

Atoms achieve stability by attaining electronic configuration of inert gases (He, Ne or Ar etc) i.e. ns^2 np^6 having 2 or 8 electrons in the valence shell is sign of stability.

Duplet rule: Attaining two electrons in the valence shell is called duplet rule.

Octet Rule: An atom having eight electrons in the valence shell is called octet rule.

Why noble gases are non reactive?

The noble gases do .have 2 or 8 electrons in their valence shells. It means all the noble gases have their valence shells completely filled. Their atoms do not have vacant space in their valence shell to accommodate extra electrons. Therefore, noble gases do not gain, lose or share electrons. That is why they are non-reactive.

Importance of the noble gas electronic configuration:

The importance of the noble gas electronic configuration lies in the fact that all other atoms try their best to have the noble gas electronic configuration. For this purpose atoms combine with one another, which is called chemical bonding. In other words, atoms form chemical bonds to achieve stability by acquiring inert gas electronic configuration.

Q.2 What is octet rule? Why do atoms always struggle to attain the nearest noble gas electronic configuration? (Ex. Q.11)

Ans: Octet Rule:

The attaining of 8 electrons configuration in the valence shell, either by sharing, by losing or by gaining electrons is called octet rule.

Examples:

All noble gases except helium follow octet rule.

Explanation:

Atoms always struggle to attain the nearest noble gas electronic configuration in order to become more stable.

An atom can accommodate 8 electrons in its valence shell in three ways:

i. By giving valence shell electrons (if they are less than four) to other atoms.

ii. By gaining, electrons from other atoms (if the valence shell has five or more electrons in it)

iii. By sharing valence electrons with other atoms.

It means every atom has a natural tendency to achieve 2 or 8 electrons in its valence shell. The atoms having less than 2 or 8 electrons in their valence shells are unstable.

How can we identify the way an atom reacts?

The position of an atom in the periodic table indicates its group number. The group number is assigned on the basis of valence shell electrons.

Examples:

i. Group 1 has only 1 electron in its valence shell.
ii. Group 17 has 7 electrons in its valence shell.
iii. Mode of reaction of an atom depends upon its number of valence shell electrons.

Bond Formation

If the bond formation is between ions, it is due to an electrostatic force between them. But if bond formation is between similar atoms or between the atoms that have comparable electro negativities, then the chemical bond formation is by 'sharing' of electrons. This sharing of electrons may be mutual or one sided.

Effect of attractive and repulsive forces on bond formation:

When two approaching atoms come closer, the attractive as well as repulsive forces become operative. The formation of a chemical bond is a result of net attractive forces which dominate. The energy of that system is lowered and molecule is formed. Otherwise if repulsive forces become dominant no chemical bond will be formed. In that case there will be increase in the energy of the system due to creation of repulsive forces.

Q.3 Name the types of chemical bonds.

Ans: Types of chemical bond:

Bonding electrons:

The valence electrons, which are involved in chemical bonding, are termed as bonding electrons. They usually reside in the incomplete or partially filled outermost shell of an atom.

There are four types of chemical bonds depending upon the way how valence electrons are involved in bonding.

i. Ionic Bond
ii. Covalent Bond
iii. Dative Covalent or Coordinate Covalent Bond
iv. Metallic Bond

Q.4 What is ionic bond? Discuss the formation of ionic bond between sodium and chlorine atoms.

Ans: Ionic Bond:

The type of Chemical bond which is formed due to complete transfer of electron from one atom to another atom is called ionic bond.

OR

The electrostatic force of attraction between positive and negative ions is called ionic bond.

Explanation:

If the difference of electronegativity between two elements is more than 1.7 the bond between them will be permanently ionic bond.

The elements of Group-l and Group-2 being metals have the tendency to lose their valence electrons forming positively charged ions whereas non-metals of Group-15 to Group-17 have tendency to gain or accept electrons. They are electronegative elements with high electron affinities. If atoms belonging to these two different groups, metals and non-metals, are allowed to react and chemical bond is formed.

Conditions of ionic bond formation:

i. It is to be noted that only valence shell electrons take part in this type of bonding while other electrons are not involved.

ii. In such type of reaction heat is usually given out.

iii. The compounds formed due to this type of bonding are called ionic compounds.

Example: (Formation of sodium chloride, NaCl)

The formation of NaCl is a good example of this type of bond.

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

Sodium chloride is a simple compound formed from Sodium (Z=11) and Chlorine (Z= 17). The ground state electronic configuration of these elements is shown below:

$_{11}Na = 1s^2, 2s^2\ 2p^6, \boxed{3s^1}$ or $Na^{\bullet}$

$_{17}Cl = 1s^2, 2s^2\ 2p^6, \boxed{3s^2\ 3p^5}$ or $:\ddot{Cl}\cdot$

The frame indicates electrons in valence shells of the elements; sodium has only one electron and chlorine has seven electrons. Sodium being electropositive element has the tendency to lose electron and chlorine being an electronegative element, has the tendency to gain electron. Therefore, they form positive and negative ions by losing and gaining electrons respectively, and their electronic configuration resembles with the nearest noble gases. $1S^2$, $2S^2$, $2p^6$, $3s^2$, $3p^6$ (Ar)

Formation of Na^+ ion:

Sodium atom loses one electron from the outermost shell and becomes sodium (Na^+) ion. Now the second shell becomes valance shell with 8 electrons.

Formation of Cl^- ion:

Chlorine atom gains one electron in the outermost shell and become Cl^- ion with 8 electrons.

$$Na^{\bullet} \longrightarrow Na^+ + e^-$$

$1s^2, 2s^2, 2p^6$ (Ne)

$$:\ddot{Cl}\cdot + e^- \longrightarrow :\ddot{Cl}:^- \text{ or } Cl^-$$

$1s^2, 2s^2, 2p^6, 3s^2, 3p^6$ (Ar)

Na^+ and Cl^- ions stabilize themselves by combining with each other due to electro static force of attraction between them.

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

Q.5 Define the covalent bond. Explain the types of covalent bond.

OR

Explain the types of covalent bond with at least one example of each. (Ex. Q.5)

Ans: Covalent Bond:

"The type of bond, which is formed due to mutual sharing of electrons, is called covalent bond."

Explanation:

When bonding atoms have comparable values of electronegativity they share their electrons and form covalent bonds.

The elements of Group-13 to Group-I when allowed to react with each other, they form a chemical bond by mutual sharing of their valence shell electrons.

Formation of covalent bond (Energy changes during bond formation):

The energy changes during the covalent bond formation are of considerable value. When two atoms approach each other attractive forces develop between electrons of

one atom and nucleus of other atom. Simultaneously repulsive forces between electrons of the two atoms as well as between their nuclei are also created. When the attractive forces dominate due to decrease in distance between those two atoms, a chemical bond is formed between them. By this mutual sharing of valence shell electrons each of the contributing atom attains the 'Octet' or nearest inert gas configuration

Bond pair:

The covalent bond is formed by mutual sharing of electrons between two atoms. The electrons that pair up to form a chemical bond are called 'bond pair' electrons.

Examples: Hydrogen chlorine, Nitrogen, Oxygen gases etc.

Types of covalent bonds:

Depending upon the number of bond pairs, covalent bond is classified into following three types:

i. Single Covalent bond.

ii. Double Covalent bond.

iii. Triple Covalent bond

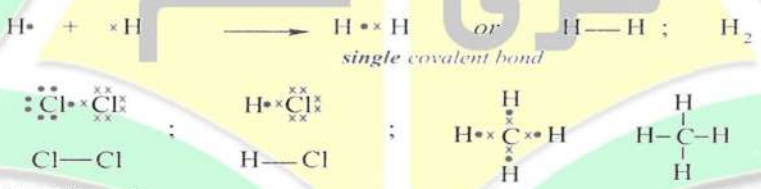
i. Single Covalent Bond (–)

When one electron is contributed by each bonded atom, one bond pair is formed and it forms a single covalent bond.

Representation:

It is indicated by single line (–) between two atoms.

Example: Hydrogen (H_2), Chlorine (Cl_2), Hydrochloric acid (HCl) and Methane (CH_4).



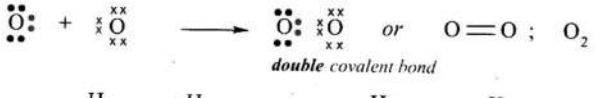
ii. Double Covalent Bond:

When two electrons are contributed by each bonded atom two bond pairs are formed and it forms a double covalent bond.

Representation:

It is indicated by two lines (=) between two bonded atoms.

Example: Oxygen (O_2) gas, Ethane (C_2H_4).



iii. Triple Covalent Bond (≡)

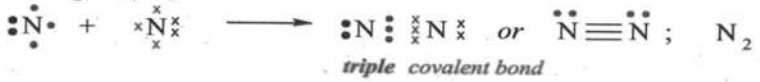
When three electrons are contributed by each bonded atom, three bond pairs are formed and it forms a triple covalent bond.

Representation:

It is indicated by three lines (≡) between two bonded atoms.

Examples:

a. Nitrogen (N_2)



b. Ethyne (C_2H_2)

By this mutual sharing of valence shell electrons, each of the contributing atom attains the 'octet' or nearest inert gas configuration.

Q.6 Define the coordinate covalent bond. Explain coordinate covalent bond with the help of example.

Ans: Dative covalent or coordinate covalent bond:

"Coordinate covalent or dative covalent bonding is a type of, covalent bonding in which the bond pair of electrons is donated by one bonded atom only."

Donor:

An atom which donates the electron pair is called donor

Acceptor:

An atom which accepts the electron pair is called acceptor.

Representation:

A small arrow (–) is usually used to indicate the atom and pair of electron being donated. The head of arrow is towards the acceptor atom

Lone pair of electrons:

The non bonded electron pair available on an atom in a molecule is called lone pair of electrons.

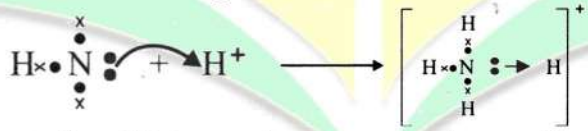
Example:

The electron pair available on nitrogen atom in ammonia (NH_3) molecule is called lone pair of electrons.

Examples:

i. Formation of ammonium radical (NH_4^{+1}):

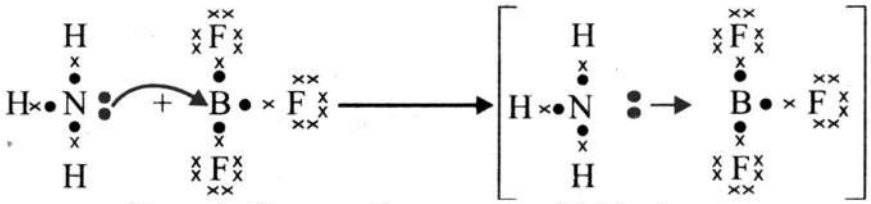
In the formation of ammonium ion, the nitrogen of NH_3 is the donor atom while hydrogen ion H^+ is the acceptor atom.



Ammonia (Donor) Hydrogen ion (Acceptor) Ammonium ion (Adduct)

ii. Formation of co-ordinate covalent bond between ammonia and boron tri-fluoride:

In the formation of BF_3 (boron tri fluoride) molecule, three valence electrons of boron atom (Z = 5) pair up with three electrons, one from each three fluorine atoms. The boron atom even after this sharing of electrons (covalent bond formation), remains short or deficient of two electrons in its outermost shell. Now if a molecule with a lone pair approaches this molecule, it accepts lone pair from that donor and forms a coordinate covalent bond. The one pair on nitrogen of ammonia molecule makes it a good donor molecule to form a coordinate covalent bond.



(Donor) (Acceptor) (Adduct)

Q.7 Explain in detail the Polar and non polar Covalent bond.

Ans: Polar and Non-polar Covalent Bond.

i. Non-Polar Covalent Bond:

A covalent bond formed between two similar atoms (homo-atoms) in shared pair of

electrons is attracted by both the atoms equally, called non-polar covalent bond.

Explanation:

These bonds are formed by equal sharing of electron pair between the two bonding atoms. This type of bond is called a pure covalent bond.

Examples: Bond formation in H_2, Cl_2, O_2, N_2 and F_2

ii. Polar Covalent Bond

A covalent bond formed between two atoms of different elements (hetero-atom) in which shared pair of electrons is attracted by both the atoms unequally is called polar covalent bond.

Examples: Water, hydrogen fluoride, hydrogen chloride etc.

Formation of polar bond:

The difference between electro negativities of hydrogen and chlorine is 1.0. As the electro-negativity of chlorine is more, it attracts the shared pair of electron towards itself with a greater force. A partial negative charge is therefore created on chlorine and in turn a partial positive charge on hydrogen due to electro negativity difference. It creates polarity in the bond and is called polar covalent bond.

Delta (δ) sign:

The delta (δ) sign indicates partial positive or partial negative charge that is developed due to unequal sharing of shared pair or bonded pair of electrons.

The compounds resulting from polar covalent bonds are called polar compounds.

Determination of Nature of Chemical bond:

By using electro negativity values, it is possible to predict whether a chemical bond will be ionic or covalent in nature.' A bond formed between elements of high electro negativity (halogen group) and elements of low electro negativity (alkali metals) are ionic in nature there is complete transfer of electrons between them.

If the difference of electro negativities between two elements is more than 1.7 the bond between them will be predominantly ionic bond and if it is less than 1.7, the bond between two atoms will be predominantly covalent.

Q.8 What is metallic bond? Explain metallic bonding with the help of diagram. (Ex. Q7)

Ans: Metallic Bond:

The metallic bond is defined as a bond formed between metal atoms (positively charged ions) due to mobile or free electrons.

Properties:

i. They have high melting and boiling points.

ii. They show good conductions of heat and electricity.

iii. They are hard and of heavy nature.

Reason for the formation of metallic bond in metals:

i. In case of metals, the hold of nucleus over the outermost electrons is weak because of large sized atoms and greater number of shells in between nucleus and valence electrons.

ii. Because of low ionization potentials, metals have the tendency to lose their outer electrons easily. The loose 'or free electrons of all metal atoms move freely in the spaces between atoms of a metal. None of these electrons is attached to any particular atom. They belong to a common pool or belong to all the atoms of that metal. Nuclei of metal atoms appear submerged in sea of these free mobile electrons. The mobile electrons are responsible for holding the atoms of metals together forming a metallic bond.

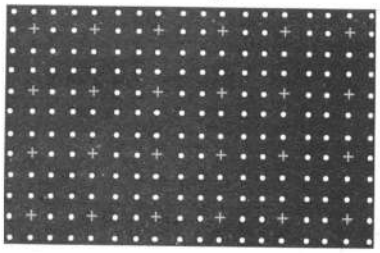


Fig. 4.2 A schematic diagram of Copper wire showing its positive nuclei (+) embedded in sea of free electrons (o) making 'Metallic Bonding'

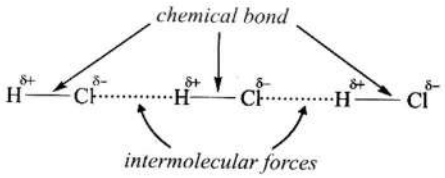
Example: The bond found in Na, Ca, Mg etc.

Q.9 What are intermolecular forces? Explain their types in detail.

Ans: Intermolecular forces:

"*The forces of attraction presence between molecule of a substance are called inter molecular forces.:*

The forces that hold atoms in a compound are chemical bonds. In addition to these strong bonding forces, relatively weak forces also exist in between the molecules, which are called intermolecular forces.



Comparison of strength of intermolecular and intermolecular forces:

It requires about 17 kJ energy to break these intermolecular forces between one mole of liquid hydrogen chloride molecules to convert it into gas whereas, about 430 kJ are required to break the chemical bond between hydrogen and chlorine atoms in 1 mole of hydrogen chloride.

Types of Inter molecular forces:

All intermolecular forces, which are collectively called van der Waals forces, are electrical in nature. Following are types of intermolecular forces

i. Dipole-Dipole Forces
ii. Hydrogen Bonding
iii. Dipole - Induced Dipole Forces
iv. Ion Dipole Forces
v. London Forces

i. Dipole - Dipole Interaction:

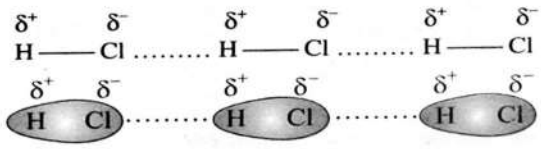
The force of attraction present between partial positive end of one polar molecule and partial negative and of other polar molecule is called dipole - dipole force.

Explanation:

i. They result from the attractions of opposite charges which may be temporary or permanent.
ii. The unequal sharing of electrons between two different types of atoms make one end of molecule slightly positive and other end slightly negatively charged.
iii. As shared pair of electron is drawn towards more electronegative atom, it is partially negatively charged, as chlorine in hydrogen chloride. The other end automatically becomes partially positively charged.

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

iv. When partial positive and partial negative charges exist at different positions in a molecule, the adjacent molecules will arrange themselves in such a way that negative portion of that molecule comes near to positive portion of other molecule.



ii. Hydrogen Bonding:

The forces of attraction present between partially positive hydrogen atom of one molecule and highly electronegative atom (N, O or F) of another molecule is called

hydrogen bonding.

Partially positively hydrogen of one molecule attracts and forms a bond with the partially negatively charge atom of the other molecule, the bonding is called hydrogen bonding

Explanation:

Occurrence: Hydrogen bonding is a special type of intermolecular forces present in the permanently polar molecules. This bonding can be considered unique dipole-dipole attraction.

Development of hydrogen bonding: This force of attraction develops between molecules that have a hydrogen atom bonded to a small, highly electronegative atom with lone pairs-of electrons such as nitrogen, oxygen and fluorine. The covalent bond between hydrogen atom and other atom becomes polar enough to create a partial positive charge on hydrogen atom and a partial negative charge on the other atom. The small size and high partial positive charge on the hydrogen atom enables it to attract highly electronegative (N, O or F) atom of the other molecule.

Representation:

This force of attraction is represented by a dotted line (……) between the molecules as shown below:

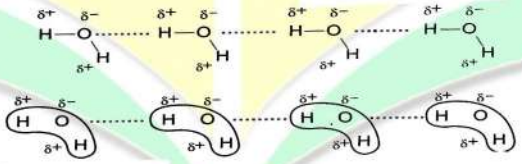
Hydrogen bonding and physical properties:

a. Boiling Points:

i. Due to this, boiling points of the compounds are affected greatly.

ii. It enhances the force of attraction between molecules.

Boiling point of water (100°C) is higher than that of alcohol (78°C) because of more and stronger hydrogen bonding in water.



b. Floating of Ice:

The important phenomenon of floating of ice over water is because of hydrogen bonding. The density of ice at 0 ^{0}C (0.917 gcm^{-3}) is less than that of liquid water at 0°C (1.00 g/cm^3). In the liquid state water molecules move randomly, however. When water freezes the molecules arrange themselves in an ordered form that gives them open structure. This process expands the molecules. That results in ice being less dense as compared to water.

4.5 Nature Of Bonding and Properties:

Q.10 Write down the properties of ionic compounds.

Ans: Ionic Compounds:

"The compounds which contain ionic bond in them are called ionic compounds."

Examples: NaCl, KCl, KNO_3, $CaCO_3$ etc.

Composition:

Ionic compounds are made up of positively and negatively charged ions. Thus they consist of ions and not the molecules.

Attractive forces:

These positively and negatively charged ions are held together in a solid or crystal form with strong electrostatic attractive forces.

Order arrangement of ions:

The orderly arrangement of Na+ and Cl^{-1} ions in a solid crystal of sodium chloride is

given below.

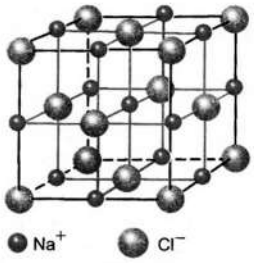


Figure 4.3 Regular arrangement of Na^+ and Cl^- ions in solid crystal of NaCl

Properties of Ionic Compounds:

The ionic compounds have following properties:

i. Crystalline Solids: Ionic compounds are mostly crystalline solids.

ii. Electrical conductivity: Ionic compounds in solid state have negligible electrical conductance but they are good conductors in solution and in the molten form. It is due to presence of free ions in them.

iii. Melting and boiling points: Ionic compounds have high melting and boiling points. **For example,** sodium chloride has melting point 800°C and a boiling point 1413 °C. As ionic compounds are made up of positive and negative ions, there exist strong electrostatic forces of attraction between oppositely charged ions. So, a great amount of energy is required to break these forces.

iv. Solubility: They dissolve easily in polar solvents like water. Water has high dielectric constant that weakens the attraction between ions.

Q.11 What are covalent compounds?

Ans: Covalent Compounds:

"The compounds which contain covalent bond in them are called covalent compounds."

Composition:

The covalent compounds are made up of molecules that are formed by sharing of electrons between their atoms.

Strength of bond:

A covalent bond is generally regarded as weaker than an ionic bond. Covalent compounds are made up of two or more non-metals.

Physical states:

Lower molecular mass covalent compounds are gases or low boiling liquids. Contrary to it, higher molecular mass covalent compounds are solids.

Example: H_2, Cl_2, CO_2, H_2SO_4, $C_6H_{12}O_6$ etc.

Properties of Covalent Compounds:

i. Melting and boiling points: They have usually low melting and boiling points.

ii. Electrical conductivity: They are usually bad conductors of electricity. The compounds having polar character in their bonding are conductor of electricity when they dissolve in polar solvents.

iii. Solubility: They are usually insoluble in water but are soluble in non-aqueous solvents like benzene, ether, alcohol and acetone.

iv. Crystal formation: Bigger molecules with three dimensional bonding form covalent crystals which are very stable and hard. They have high melting and boiling points.

Q.12 Write down the properties of polar and non-polar compounds.

Ans: a. Polar Compounds:

"A compound having polar molecule is called polar compound."

Examples: HF, HCl, H_2O, NH_3 etc

Development of polarity in chemical:

Polarity in a chemical bond is due to difference in electro negativities of the bonding atoms.

Scale:

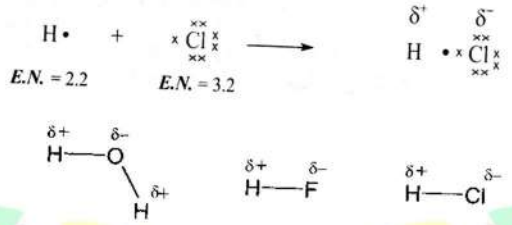
On the Pauling Scale fluorine has been given an electronegativity value of 4. The values for other elements are calculated relative to it.

Properties:

i. Properties of non-polar and polar covalent compounds differ to some extent.

ii. Polar covalent compounds usually dissolve in water while non polar do not dissolve.

iii. An aqueous solution of a polar compound usually conducts electricity due to the formation of ions as a result of its reaction with water.



b. Non-Polar Compounds:

"A compound having non polar molecule is called non polar compound."

Examples: CO_2, CH_4, C_6H_6, C_2H_2, CCl_4 etc.

Properties:

i. Non-polar covalent compounds usually do not dissolve in water

ii. Similarly non-polar compounds do not conduct electricity

Q.13 Write down the properties of coordinate covalent compounds.

Ans: Coordinate Covalent Compounds:

The compounds which contain coordinate covalent bond in them are called coordinate covalent compounds.

Examples: $NH_3 - BF_3$, NH_4Cl , NH_3AlCl_3 etc.

Properties:

i. Their properties are mostly similar to those of covalent compounds.

ii. As the nuclei in these compounds are held by shared electrons, therefore, they do not form ions in water.

iii. Due to their covalent nature they form solutions in organic solvents and are very less soluble in water.

iv. Usually they are rigid compounds with a dipole.

Q.14 Write down the properties of metals.

Ans: Metals:

"The elements which are usually hard, are good conductors of heat and electricity and are malleable and ductile are called metals."

Metals have common property of conducting heat and electricity. It gives them prime role in many technologies.

Examples: Iron, cobalt, nickel, gold, silver etc.

Properties:

i. They show **metallic luster.**

ii. They are usually **malleable and ductile.** Malleability is the property by virtue of which a metal can be drawn into sheets, while ductility is the property by virtue of which a metal can be drawn into wires.

iii. They have usually **high melting and boiling** points.

iv. Being greater in size they have **low ionization energies and form cations** (M) very easily.

v. They are **good conductors of heat and electricity** in solid and liquid state due to

mobile electrons

vi. Metals have **shining surface**.

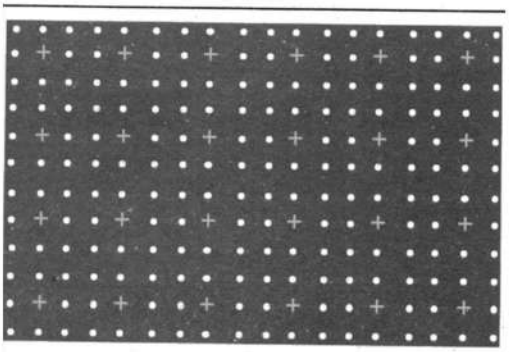


Fig. 4.2 A schematic diagram of Copper wire showing its positive nuclei (+) embedded in sea of free electrons (o) making 'Metallic Bonding'

Q.15 What are synthetic adhesives? Describe properties of epoxy adhesives.

Ans: Synthetic Adhesives:

"The synthetically produced substances which are used to stick the surfaces are called synthetic adhesives"

Properties:

i. Although natural adhesives are less expensive to produce,

ii. But most important adhesives used nowadays are synthetic.

iii. Adhesives based on synthetic resins and rubbers excel in versatility and performance.

iv. Synthetics adhesives can be produced in a constant supply with uniform properties and they can be modified in many ways.

v. The polymers or resins used in synthetic adhesives fall into two general categories-thermoplastics and thermosetting.

Example: One form of polymer used industrially is epoxy adhesive.

Epoxy adhesive:

"Epoxy is polymer that is formed from two different chemicals. These are referred to as resin and the hardener. Epoxy adhesives are called structural adhesives."

Uses:

i. These high-performance adhesives are used in the construction of aircraft, automobiles, bicycles, boats, golf clubs, where high strength bonds are required.

ii. Epoxy adhesives can be developed to suit almost any application.

Properties:

i. They can be made flexible or rigid, transparent or opaque even colored as well as fast or slow setting.

ii. Epoxy adhesives are good heat and chemical resistant

iii. They are stable to heat up to temperatures 177°C.

Because of these properties, they are given the name of engineering adhesives.