B.Sc. (Honours) Part-II

Paper-IIIB

Topic: Metallic Bond Theory

UG

Subject-Chemistry

Dr. Laxman Singh

Asst. Professor

Department of Chemistry

R.R.S. College (PPU)

(Mokama, Patna)

Metallic Bond Theory

The metallic bond is a type of binding or linkage or attraction or force that holds the atoms of two or more metals together in an alloy or it is the force that links atoms of the pure metal together in a metallic crystal.

The metallic bond cannot be an ionic bond as there is no transfer of electrons from electropositive element to electronegative element. It cannot be a directional (covalent) bond since metallic properties persist even in liquid state (e.g. mercury) or in solution (e.g. sodium in liquid ammonia) etc.

Different theories have been suggested for metallic bonding from time to time .The successful theory of bonding in metals is one which can explain the following to utmost satisfaction.

a) The great mobility of electrons in metallic solids.
b) The bonding between a large numbers of identical atoms in a pure metal.
c) The bonding between widely different atoms in an alloy and
d) The non-rigid and non-directional bonding in metals which is retained even in the liquid state (say in ,mercury) or even for the metals which are dissolved in a suitable solvent e.g. sodium in liquid ammonia .

These are at present three theories to explain the metallic features

1. **Free Electron theory or Electron Gas Theory**
2. Valence Bond theory (VBT) or Pauling's Atomic orbital theory and
3. Molecular orbital Theory or Band theory

The Free Electron Theory of Metals:

As early as 1900 the free electron theory was first proposed by Drude and was further refined by Lorentz in 1932. The theory is based upon two assumptions

(a) Mutual repulsion between the negative electrons in absent.

(b) The potential field due to the positive ions is completely uniform throughout the metallic crystal.

According to Drude metal is a lattice through which electrons move as freely as molecules of a gas. This idea was used primarily to account electrical conductivity of metals. According to Lorentz metal is a lattice of rigid spheres (i.e. positive metal ions) embedded (fixed) in a gas of valence electrons which could move freely in the interstices of metal throughout the crystal .

Explanation:

We know that metals are poor in valence electrons and have low ionization energies. Hence metals lose some of their valence electrons and tend to be electropositive. The electrons so freed are not bound to any single nucleus but spread out around several nuclei. Such free electrons are referred to as non localized or delocalized or mobile electrons and their some total collection is appropriately termed as electron pool or electron cloud or electron gas according to the classical electromagnetic theory. If many metal atoms are brought close together the outer energy levels of each can merge together when they begin to overlap. The outer electrons are then in a position to move not just around one atom but around and between all the atoms. These electrons have turned to be delocalized or non localized and are therefore more stable. Thus a block of metal may be visualized as an array of positive ions located in the crystal lattice,

immersed in an ocean of mobile electrons. The metallic bond is the force of attraction between metal atoms and all the electrons under their influence.

Illustration:

Consider a simple metal such as lithium. It crystallizes in the body centred cubic form. Hence each atom of lithium is co-ordinated by eight neighboring lithium atoms. The electronic configuration of lithium is $1s^2\ 2s^1$ i.e.

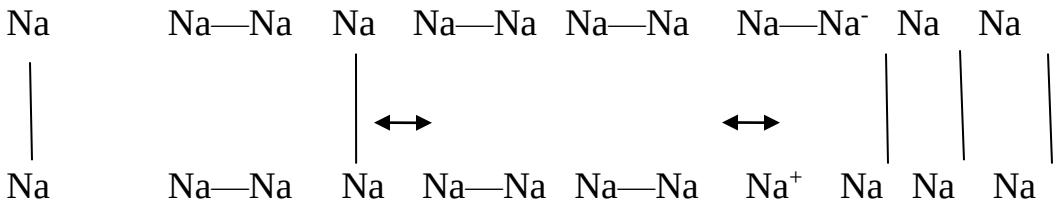
For lithium metal, one cannot expect ordinary covalent bonding which requires eight pairs of electrons as CN=8 but there is only one such electron per lithium atom. This means that the single electron utilizes all the four valence orbitals; 2s and 2p's available to it .Thus the nine electrons from (1+8) lithium atoms have freedom to move simultaneously in all the (9x4) thirty six orbitals forming the unit cell of lithium. The electrons are thus regarded as belonging to the crystal a whole and not just to any particular atom or atoms.

Since the theory accounts for electron gas or sea of mobile electrons and the non directional nature of bonding, it can successfully explain the properties of metals such as metallic lustre, malleability, ductility high thermal and electrical conductivity high melting and boiling points etc as already outlines.

But the theory fails to explain the following due to the concept of electron gas in metallic solids namely

i. Semiconductance
ii. Specific heats
iii. Calculations of cohesive energy of metallic crystals quantitatively.

(Another sincere attempt was made to explain metallic bonding by Prof. L. pauling in 1940. This is known as pauling's Atomic Orbital of Valence Bond Theory. He pictured metallic bond to be a dynamic covalent bond which oscillates through a number of positions between an atom and its nearest neighbors. e.g. sodium metal may be pictured as :



But the theory fails to explain metallic character in liquid state or in solution.

Properties of Metals can be explained by Metallic Bonding:

The properties of metals that are a consequence of metallic bonding include:

- Malleability
- Ductility
- High melting and boiling point
- High electrical and thermal conductivity
- Metallic lustre