HYDROGEN BOND and METALLIC BOND

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HYDROGEN BOND

Hydrogen bonds are a special class of attractive intermolecular forces that arise between a hydrogen atom and highly electronegative small atom like O, N and F of the same or different molecule.

TYPES OF HYDROGEN BOND

There are two types of H bonds

- **Intermolecular Hydrogen Bonding**
- **Intramolecular Hydrogen Bonding**

Intermolecular Hydrogen Bonding

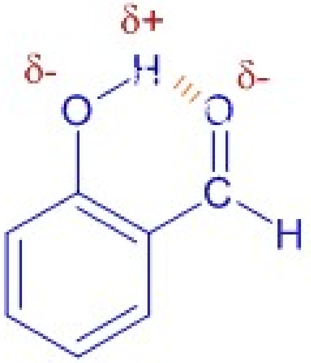
When hydrogen bonding takes place between different molecules of the same or different compounds, it is called **intermolecular hydrogen bonding.**

eg. hydrogen bonding in water, alcohol, ammonia etc.

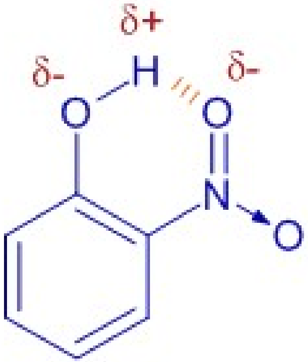
Intramolecular Hydrogen Bonding

The hydrogen bonding which takes place within a molecule itself is called **intramolecular hydrogen bonding.**

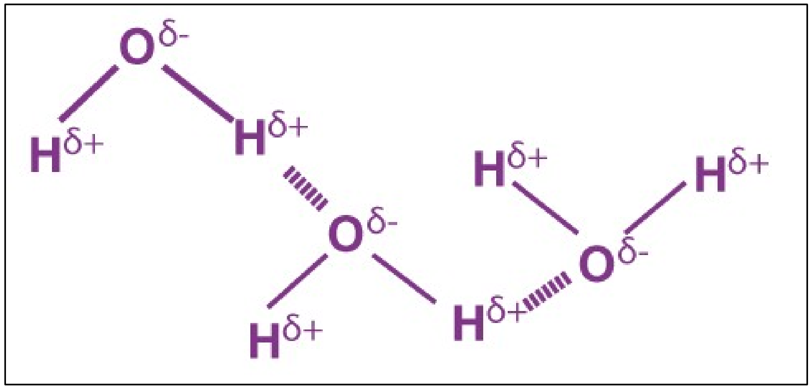
eg. Hydrogen bonding in o-nitrophenol, salicylaldehyde etc.



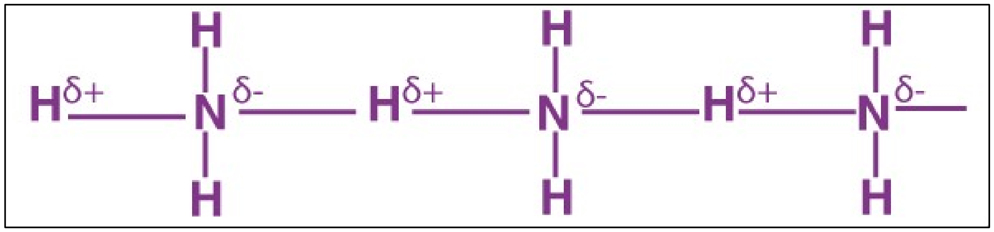
Intramolecular hydrogen bonding in ortho hydroxy benzaldehyde (salicylaldehyde)



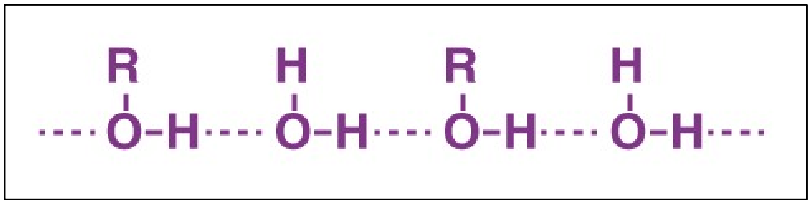
Intramolecular hydrogen bonding in ortho nitrophenol



Intermolecular Hydrogen Bond in Water



Intermolecular Hydrogen Bond in amonia



Intermolecular Hydrogen Bond in alcohol

CONSEQUENCES OF HYDROGEN BOND

DENSITY OF ICE IS LESS THAN LIQUID WATER

In liquid state water molecules are very disordered due to their mobility and weak hydrogen bonds between them. But in solid state water molecules have less mobility due strong hydrogen bonding between them. It gives ice a rather open type structure with wide holes whereas; structure of water didn't give any free space in the molecular structure. This gapping in the structure reduces density and increases volume. Hence, the density of ice is less than that of water and therefore it floats on water.

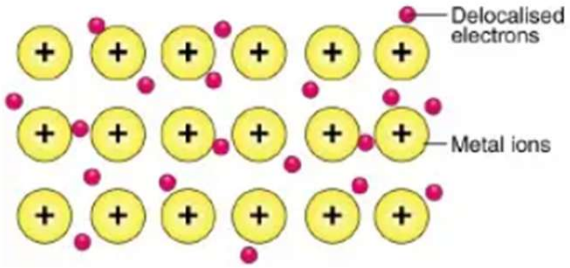
Alcohol and water are miscible because of **hydrogen bonding**. The polar hydroxyl (-OH) group on the alcohol molecule can form hydrogen bonds with the polar water molecules. This strong intermolecular attraction allows them to mix completely, creating a stable, homogeneous solution.

METALLIC BOND

Metal possesses free electrons. In solids atoms are closely packed hence the orbitals are overlap each other. So the valence electron can jump from one orbital to the another orbital of the other atom and continuously move on the surface of the metals with certain energy. It is called conduction electron. When metal atom loss an electron it converted into positive ion and it holds an electron with an electrostatic force for the surface of the metal.

Metallic bonding is formed by the sharing of free electrons among a lattice of positively charged metal ions. It formed a “sea” of electrons that surrounds the positively charged atomic nuclei of the interacting metal ions. The electrons then move freely throughout the space between the atomic nuclei. Metallic bonding is a type of chemical bonding and is responsible for several characteristic properties of metals such as their shiny lustre, their malleability, and their conductivities for heat and electricity.

Metallic bond is a term used to describe the collective sharing of a sea of valence electrons between several positively charged metal ions.



CONDUCTORS, SEMICONDUCTORS AND INSULATORS

Classification of Energy Bands

Valence Band

The electrons in the outermost shell are known as valence electrons. These valence electrons contain a series of energy levels and form an energy band known as the valence band. The valence band has the highest occupied energy.

Conduction Band

The valence electrons are not tightly held to the nucleus due to which a few of these valence electrons leave the outermost orbit even at room temperature and become free electrons. The free electrons conduct current in conductors and are therefore known as conduction electrons. The conduction band is one that contains conduction electrons and has the lowest occupied energy levels.

Forbidden Energy Gap

The gap between the valence band and the conduction band is referred to as the forbidden gap. As the name suggests, the forbidden gap doesn’t have any energy and no electrons stay in this band. If the forbidden energy gap is greater, then the valence band electrons are tightly bound or firmly attached to the nucleus. We require some amount of external energy that is equal to the forbidden energy gap.

Conductors

Gold, Aluminium, Silver, Copper, all these metals allow an electric current to flow through them.

There is no forbidden gap between the valence band and conduction band which results in the overlapping of both the bands. The number of free electrons available at room temperature is large.

Insulators

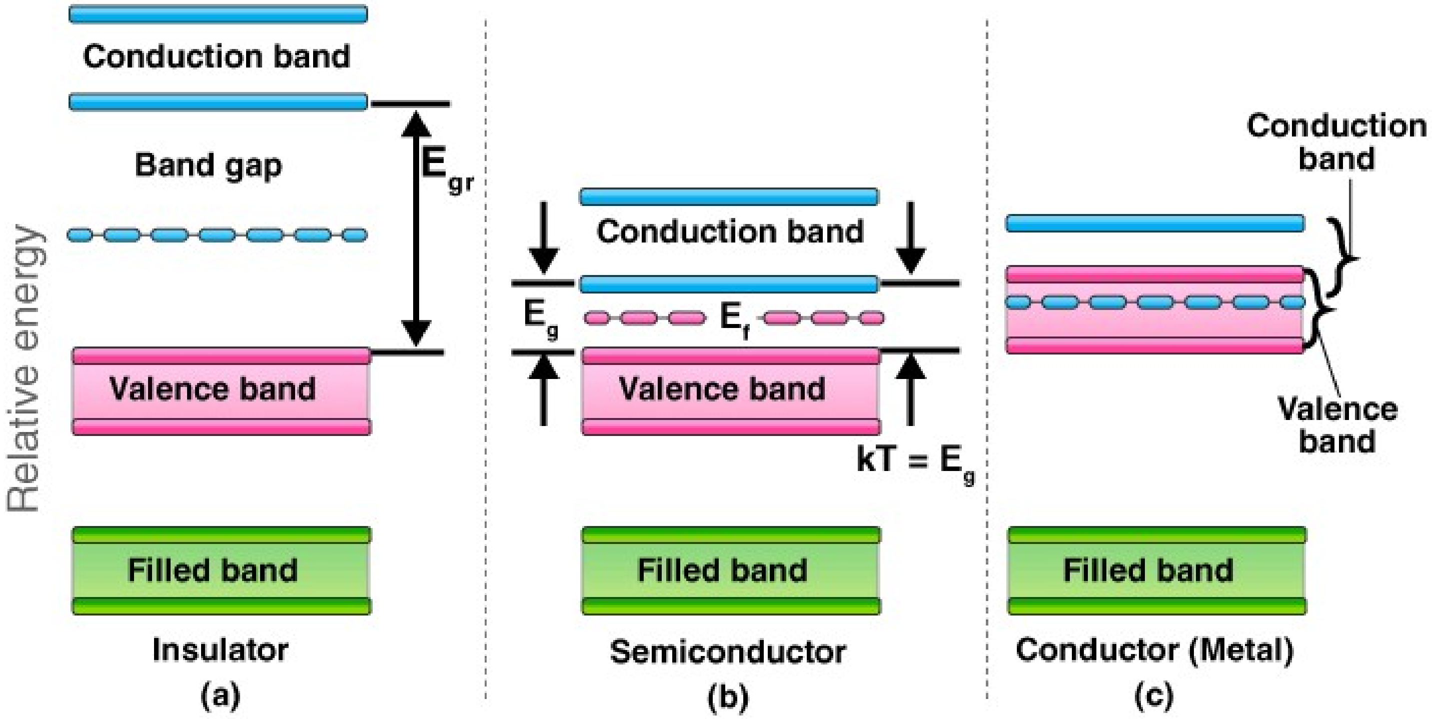
Glass and wood are examples of the insulator. These substances do not allow electricity to pass through them. They have high resistivity and very low conductivity.

The energy gap in the insulator is very high up to 7eV. The material cannot conduct because the movement of the electrons from the valence band to the conduction band is not possible.

Semiconductors

Germanium and Silicon are the most preferable material whose electrical properties lie in between semiconductors and insulators. The energy band diagram of semiconductors is shown where the conduction band is empty and the valence band is completely filled but the forbidden gap between the two bands is very small that is about 1eV. For Germanium, the forbidden gap is 0.72eV and for Silicon, it is 1.1eV. Thus, semiconductor requires small conductivity.

ENERGY BAND GAPS IN MATERIALS



DEFECTS IN SOLIDS

In an ideal crystal, there is no irregularities of arrangement of the atoms. But, sometimes, irregularities in the arrangements of constituent particles in a solid crystal occurs. This is called defects in crystal. If the defect is around any point or any atom, it is said to be a deviation point defect. Likewise, when there is any deviation of arrangement in the entire row of lattice points of crystals, such type of defect will be a line defect.

Types of Defects in Solids

As we know, according to the third law of thermodynamics, at absolute 0 K temperature, any substance will be perfectly crystalline, but on increasing temperature, defects in solids are created, which are classified into the following three types:

- Stoichiometric defects
- Non-Stoichiometric defects
- Impurity Defects

Stoichiometric Defects

The defect in which the stoichiometry of the compound remains the same, as shown by their chemical formula. It is also called an intrinsic or thermodynamic defect. They are further classified into two types:

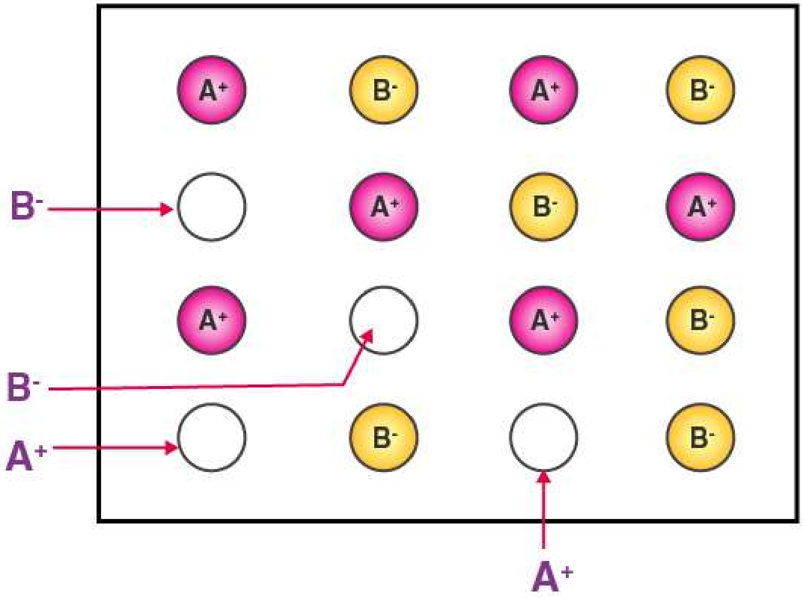
- Vacancy defect: (Vacant sites in the lattice)
- Interstitial defect: (Constituent particles move to the interstitial site of the lattice)

Both vacancy and interstitial defects are only for non-ionic solids. Ionic solids, which maintain the neutrality of the crystal, are shown by Frenkel and Schottky defects.

Schottky Defects

This defect occurs due to the missing of the same number of cations and anions from the lattice site. This type of defect is shown by that substance, which has high coordination number.

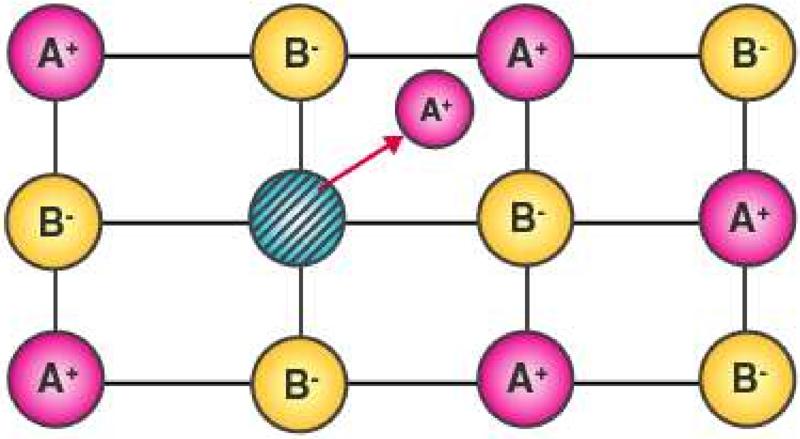
Schottky defect generally occurs in ionic compounds in which the radius ratio of cation and anion [r^+/r^-] is not far below unity. It is a kind of vacancy defect where an equal number of cations and anions are missing but maintain the neutrality of the crystal. The density of such crystal decreases. Due to the presence of ions, this crystal can conduct electricity to a small extent. For example, NaCl, CsCl, KCl, AgBr etc.



Frenkel Defect

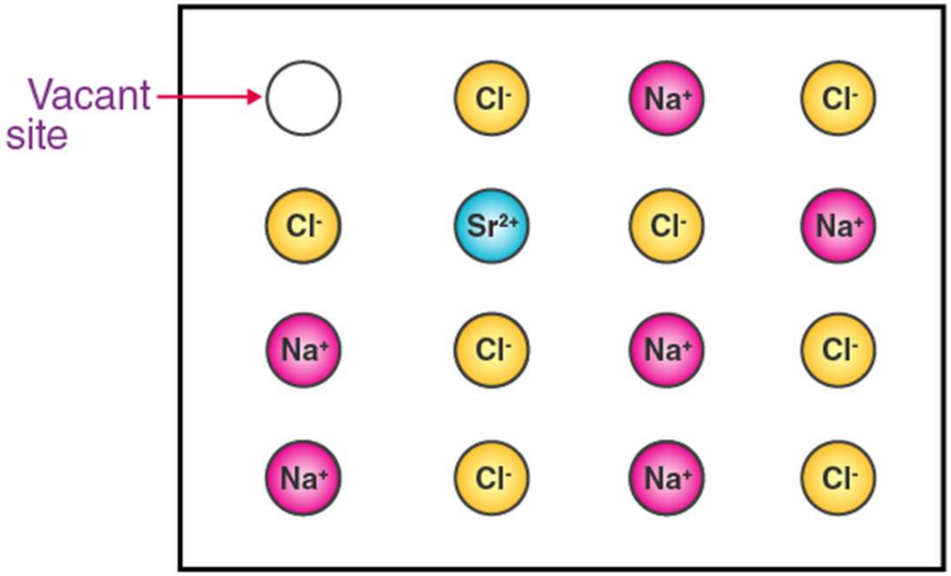
In this type of defect, some cations are missing from their lattice site and occupy the interstitial site of the lattice. This type of defect is shown by those substances which have low coordination numbers. The closeness of like charges tends to increase the dielectric constant of the crystal.

Frenkel defect is a kind of dislocation defect or interstitial defect in which the smaller ion generally cation dislocate from their position to occupy the interstitial site of the lattice or crystal. The density of these types of crystals remains the same because there is no movement of ions outside the crystal. This defect is exhibited in those ionic compounds in which the radius ratio[r^+/r^-] is low. For example, ZnS, AgBr, AgI, AgCl etc.
Note: AgBr shows both Frenkel and Schottky defects.



Impurity Defects

In the molten state, NaCl contains a small amount of $SrCl_2$ in the form of impurity in the crystal. Due to the presence of $SrCl_2$, some site of Na^+ ion is occupied by Sr^{2+}. To maintain the neutrality of the crystal, one Sr^{2+} replaces two ions of Na^+, and the remaining site of Na^+ will be vacant.



Non-stoichiometric Defects

This defect is shown by compounds of d-block elements of the periodic table. These defects are classified as metal excess defects and metal deficiency defects.

Metal excess defect is of two types.

(1) Metal excess defect due to anionic vacancy

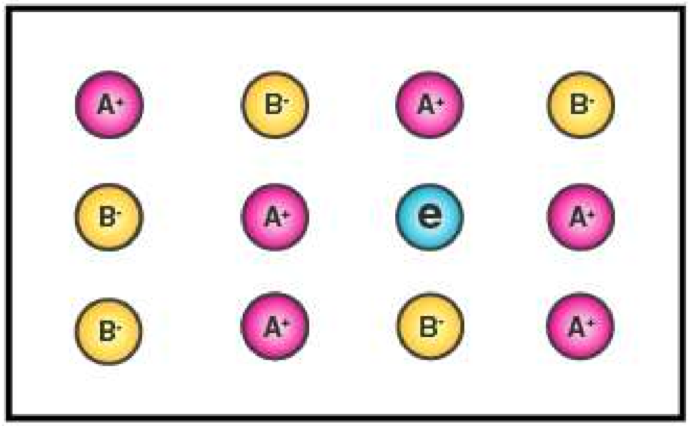
When a compound has excess metal ions, if an anion is absent from the lattice site there, it creates a void while is there occupied by an electron. This type of defect is shown by alkali metal halides like NaCl, KCl, and LiCl.

When alkali metal halides are heated in an atmosphere of vapour of the alkali metal, anion vacancies are created. This anion is then diffused to the surface of the crystal and combined with newly generated metal cations. The electron is lost by the metal atom, which then diffuses the crystal and occupies the anionic vacancy site, and forms F-centres inside the crystal. These F-centres give different colours, like NaCl gives a yellow colour. KCl gives a violet colour, and HCl gives pink colour.

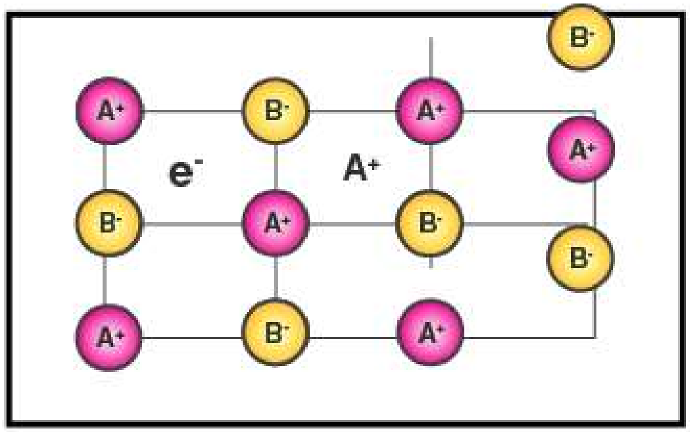
(2) Metal excess defect due to the presence of interstitial cation

It is when an excess positive ion is located in the interstitial site. This type of defect is shown by ZnO. When ZnO is heated, it loses oxygen reversibly. The excess Zn2+ ions are occupied in the interstitial sites to for maintaining neutrality, electrons are enclosed in the neighbouring interstitial sites. On heating, ZnO turns yellow colour by losing oxygen.

$$2\ ZnO \xrightarrow{\text{Heat}} 2\ Zn^{2+} + O_2 + 4e^-$$



Metal excess defect due to anionic vacancy

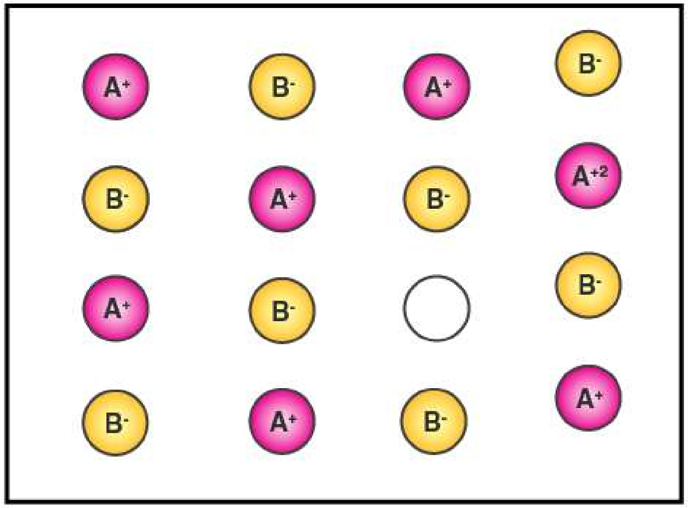


Metal excess defect due to the presence of interstitial cation:

Metal Deficiency Defect

In this defect, some cations are missing from the lattice site, and to maintain its electrical neutrality, another remaining cation increases its valency. For example, FeO, which is found with a composition of $Fe_{0.95}$ O, may actually range from $Fe_{0.93}O$ to $Fe_{0.96}O$.

In the crystal of FeO, some Fe^{2+} cations are missing, and the loss of positive charge is made up by the presence of the required number of Fe^{3+} ions.



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