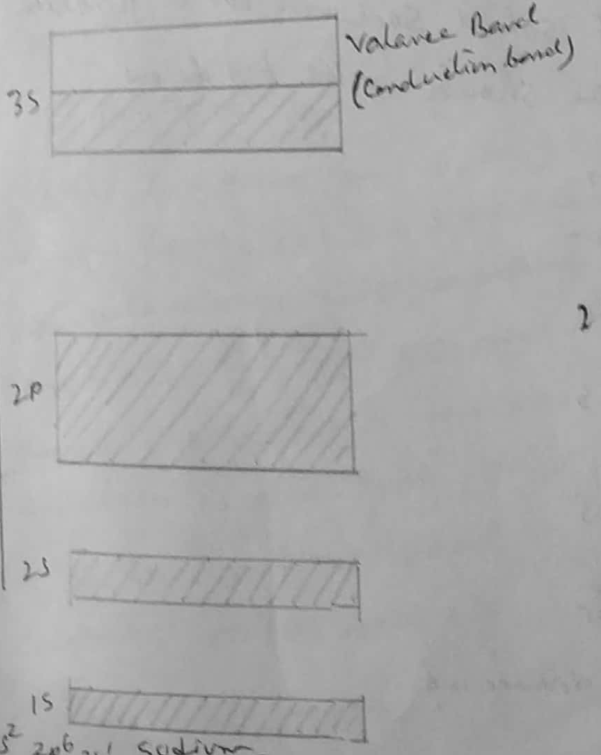
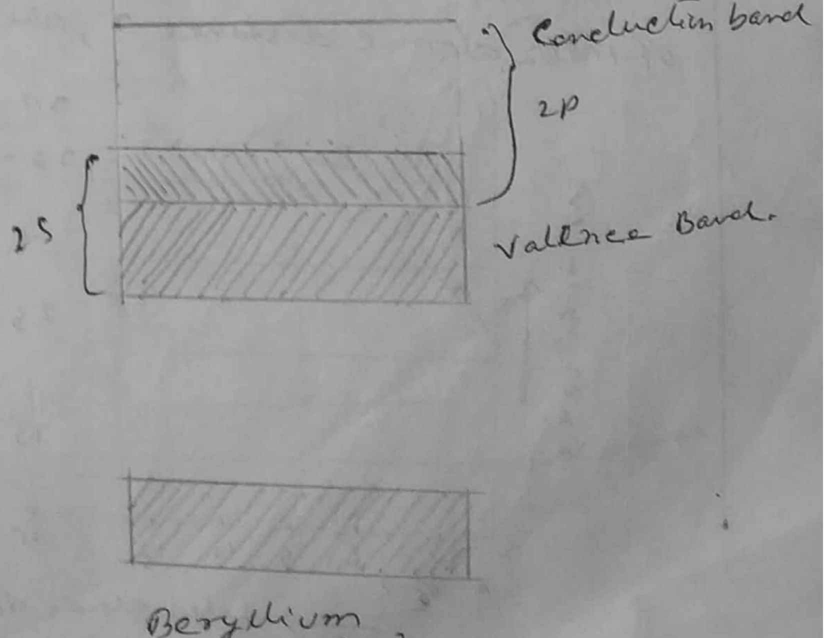
Classification of Solids:-

The electrons in a solid are distributed in different energy bands which are separated from each other by forbidden regions. The band consists of large number of energy levels. The width of the band is very small and is nearly equal to few electron volts. The two electrons having opposit spinn can occupy each energy level in a band. Generally lower energy bands will be filled by electrons. Thus solids can be classified into conductors, semiconductors and insulators on the basis of band occupation by electron and on the width of forbidden region.

Conductors:- It is found that in a certain solids above the completely filled lower bands there is partially filled band. The following fig represent the simplified digram of energy bands of sodium and Beryllium respectively.



$s^2 2s^2 2p^6 3s^1$ Sodium

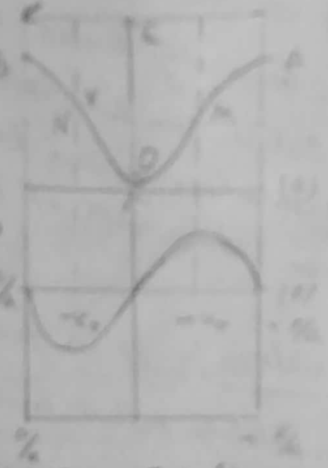


Beryllium
$1s^2 2s^2$

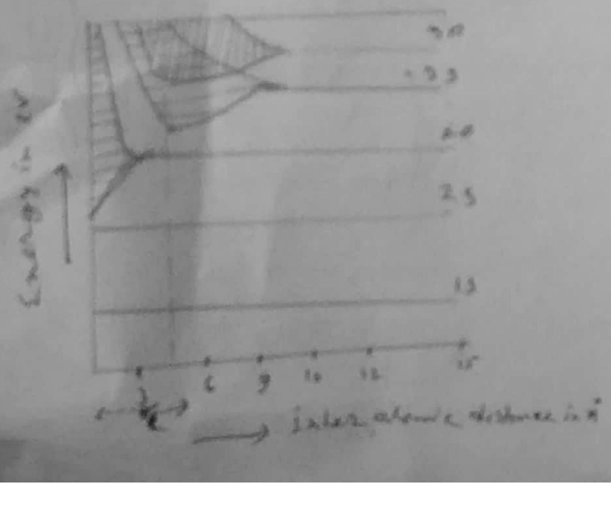
In a conductor, the effective number of free electrons N_{eff} in a band depends upon the value of $\frac{d^2E}{dk^2}$, i.e. the rate of change of electron energy with wave vector k and is given by $N_{eff} = \frac{2m_e}{\hbar^2}\left(\frac{d^2E}{dk^2}\right)$.

The value of $\left(\frac{d^2E}{dk^2}\right)$ is the maximum at the point of inflexion of $(E-k)$ curve (fig a) and hence the effective number of electrons is also maximum. Thus in a conductor with incompletely filled valence band, there are quite a large number of electrons available for conduction, i.e. they behave as free electrons and hence as charge carriers. Such a metals are good conductors for electricity.

In case of conductor, the last occupied valence band is only partially filled. For example, in sodium atom, it has 2 electrons in 1s, 2 in 2s, 6 in 2p and only 1 in 3s level. But according to pauli's exclusion principle it can contain a maximum of 2 electrons in the 3s level. Thus in the solid form of sodium the last band is only half filled and the other half is available for the free motion of valence electrons.



The energy band of solid sodium as a function of inter atomic distance r, are shown in the fig below



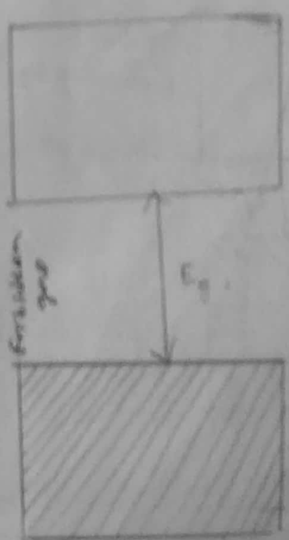
At equilibrium separation, the total potential energy is minimum and the [illegible] forces [illegible] stability. As the atoms are brought closer, the ratio of 3s decreases and that of 3p and hence the energy [illegible] in accordance with Pauli exclusion principle. [illegible] the equilibrium separation is $r_0 = 3.67$ Å. At a distance r_0, the 2p level does not spread into a band (it does not [illegible]), whereas the 3s and 3p levels spread into bands and overlap. The overlapping of 3p (conduction band) and 3s (valence) band is [illegible] provides a continuous set of unfilled levels for the valence electrons to move readily under the effect of applied electric field and thus give rise to electric current. Hence sodium like crystals are very good conductors of electricity.

INSULATORS: In case of few solids the valence band is completely filled and the higher band separated by a large energy gap is empty. These types of solids are called insulators. In these solid electric current will not flow. When an electric field is applied across the solid, the electron in the valence band would ~~move~~ not move within the band as there are no unoccupied level in the band. The electron can move to the higher band only if they gained energy E_g to cross the forbidden gap. This amount of energy can't be ~~provided~~ produced by an electric field.

Example: Diamond, NaCl etc.

In the eqn $N_{eff} = \frac{2mL}{\hbar^2}\frac{dE}{dk}$

At the top ~~[illegible]~~ (and bottom) of the band, for the E–K curve ~~the valence band is completely~~ for $K = 0, \pm \frac{\pi}{a}$, $\frac{dE}{dk} = 0$ and hence the effective number of electron is also zero. Thus when the valence band is completely filled and the



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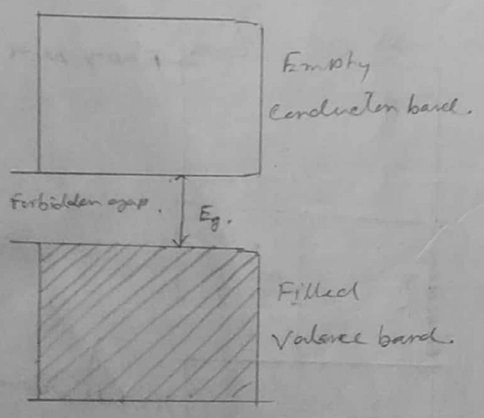
Conduction band is completely empty, the solid is perfectly insulator.

Dimond is a very good example of such an insulator. The outer most 2P energy ~~band is~~ band is completely filled with electrons and is separated from the empty band by a gap of 6eV above it. This means an additional energy of 6eV must be imparted to an electron in the diamond crystal to jump across the forbidden band. But an electron moving through a dimond crystal has a mean free path of about 10^{-6} cm, " it has a collision thereafter, in which it loses most of the energy gained by it from the electric field. So Diamond is very poor conductor of electricity.

SEMICONDUCTOR:-

A semi conductor is a solid substance whoes electrical conductivity ~~is~~ lies between the very high conductivity of conductors and very low conductivity of insulator. Germenium, Silicon etc are the example of semiconductor. In this substance the width of the forbidden gap is very small as shown in the fig below



In this substance a small portion of its electron in the valence band have sufficient kinetic energy to cross the forbidden gap and enter the empty band. (Conduction band)

When an electric field is applied across the solid, few electrons in the valence band gain some energy to move towards the conduction band.

The very small current is flowing in this case. The forbidden gap Eg for Germenium is 0.7eV and for silicon is 1.1eV.

—x—

Semiconductor is insulator at 0°K. — At 0°K the electrons in the valance band do not have sufficient energy to jump from the valance band to the conduction band across the forbidden band as the band gap is about 1 eV. Thus the conduction band being empty at 0°K, the semiconductor behaves as insulator.

How Tempr effect the conductivity of metal and semiconductor

An important distinction between metals (good conductors) and semiconductors is the tempr dependence of their conductivities. The conductivity of metals decreases with increase of tempr. This is because, as the tempr is raised more and more phonons are excited which scatter electrons and reduce their mobility. In semiconductors the decrease in mobility is more than compared by the increase in the number of charge carriers because as the temperature increases more and more electrons in the valence band have sufficient energy to jump into the conduction band. Hence the conductivity of semiconductor increases with tempr.