Insulator:-

→ VB is full and E_g is very large.
→ Thus high amount of energy is required to make an electron to jump from valence band to conduction band.
→ At such high energy insulator breaks down. The breakdown does not even take place at very high temperature or under very large electric fields.

semiconductor:

→ Intrinsic Semiconductor:- A semiconductor in its own right i.e. no impurity has been added to it. The basic semiconductors such as Si ~~or~~ Ge are under this category.

→ The valence band is full and conduction band (CB) is empty at very low temperature. The E_g is small. The electrons easily jump from valence band to conduction band by application of small thermal energy ($k_B T$).

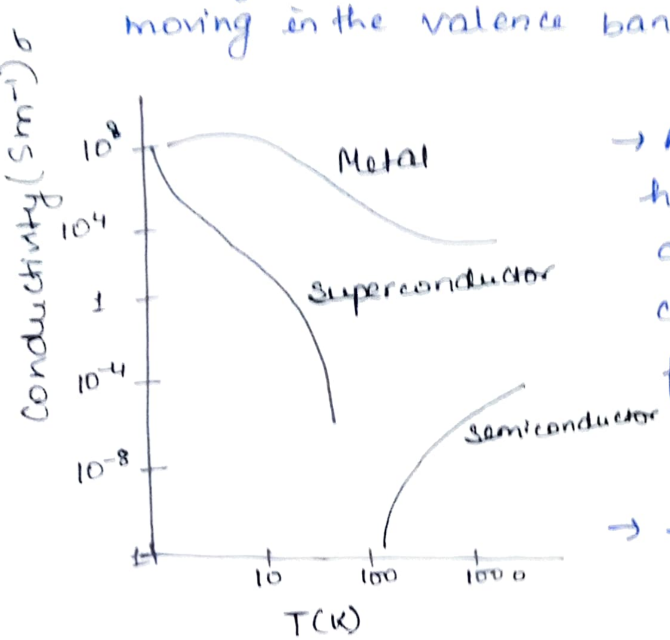
→ The electrical conductivity increases with increase in temperature as more and more electrons are liberated with increase in temperature.

→ The smaller value of E_g show semiconductor is very good. For Ge, $E_g = 0.67$ eV and Si, $E_g = 1.14$ eV. ~~Hence Silicon Ge is better~~ se

Hence Ge is better semiconductor than Si.

→ As the electron jumps from V.B to C.B, a hole is created in the valence band which is positively charged and another electron from other part of V.B. jump to hole, hence creates another hole.

→ In a way it can either be negative electrons moving between the conduction bands or holes moving in the valence band.



Temp. dependence of metal, semiconductor and superconductor in conductivity.

→ A semiconductor at RT has much lower conductivity as compared to metallic conductor because only a few electrons and holes can act as charge carriers.

→ The temperature dependence of electrical conductivity, σ, for a metallic conductor, a semiconductor and a superconductor is represented with super conductance with little or ~~high~~ negligible resistance.

→ For metals the conductivity decreases with high temperature.

→ For superconductors has zero electrical resistance below a certain temperature called critical temperature.

→ For semiconductor the

→ The conductivity of a semiconductor follows the Arhenius type temperature- dependence with activation energy E_a, approximately equal to half of the energy gap, E_g. Thus,

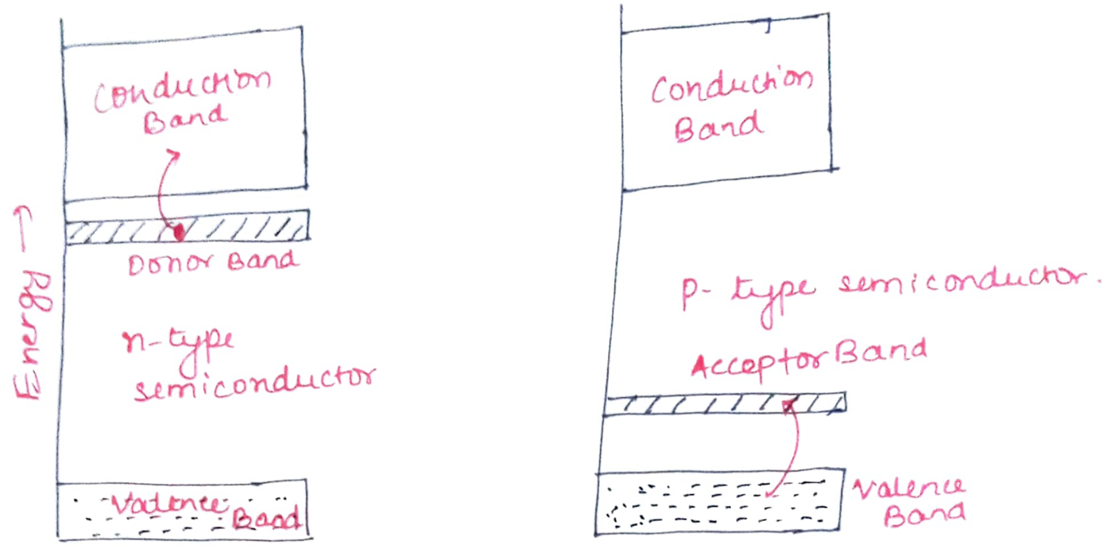
$$\sigma = \sigma_0 \exp(-E_a/kT) = \sigma_0 \exp(-E_g/2kT) \quad (1)$$

Extrinsic Semiconductor:-

* **Doping:-** If atoms with more or less electrons are added to the parent elements, there is an increase in the number of charge carriers. This is known as doping and dopant atom used is very less than parent atom (one atom of dopant per 10^9 atom of host material).

→ **p-type and n-type semiconductor:-**

- Doping of Si or Ge with trivalent atom such as Ga or In leads to p- type semiconductor where the charge carriers are positive holes.
- Doping of Si or Ge with pentavalent atoms such as P or As leads to n- type semiconductors. The charge carriers are known as n- type Semiconductor.
- The semiconductor metals are primiarily purified by zone refining method to get Impurity free & dopants are added with an extreme care as impurities.



Band type of n-type and p-type semiconductors.

- a) when As is added to Ge some atoms of Germanium are replaced by As. The four electrons of As are ~~replaced by~~ bonded to Ge atom while the fifth electron is unbonded (i.e. free). At low temperature fifth electron is localized into As atom. At normal temperatures these electrons jump to higher conduction band and hence act as charge carriers.

  b) The conduction that is generated is hereby known as extrinsic conduction. The current is carried by extra electrons i.e. negative charge and its magnitude is far much more than an intrinsic semiconductor.

  c) This type of system is labelled as <u>n-type semiconductor.</u>

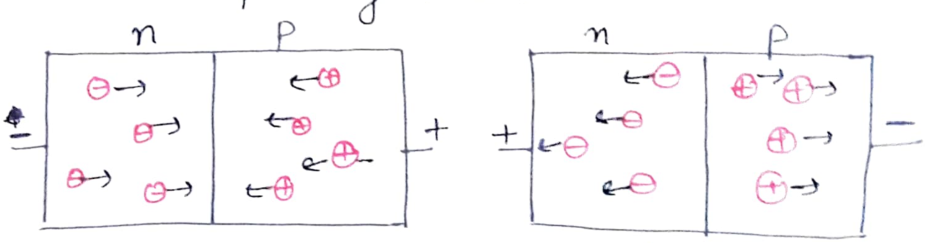
- a) A crystal of pure Si and/or Ge is doped with In or Ga. Each Ga atom has three electrons which forms bond with Ge atom/Si atom. The fourth electron of Ge/Si, however is ~~un~~ non bonded and site which remains unoccupied because of missing electron and hole is generated which leads to p-type semicond.

b) This unoccupied missing electron space is termed positive hole. The dopant atom forms a narrow acceptor band near the valence band which is empty at low values of Temp. or at T=0K. However at high temp. it accepts thermally excited electrons from valence band, which forms a positive band at Si.

c) Holes move opposite to the direction of electron. The positive holds tend to 'hop' through the band.

* As and In are ~~p~~ preffered over other 15 or 13 group elements due to their low melting point.

* A combination of n- and p-type semiconductor is termed as p-n junction.



(a) (b)

a) electrons move from left to right.
b) On reversing the voltage there is n-p separation and conduction stops.