Superconductivity :-

It can be categorized into two types
→ low temperature superconductivity (LTSC)
→ High temperature superconductivity (HTSC)

Low Temperature superconductivity : (LTSC)

- According to H. Kamerligh-Onnes, down to 4.15 K, the resistance of mercury decreases with decreases in temperature. This rule applied to most of the metals.

- At critical temperature T_c = 4.15 K, the resistance fell sharply closely to zero. At or below T_c, Hg becomes superconductors.

- At very low temperature, many metals, alloys & certain compounds become superconductors, the critical temperature for superconductivity lying between 0.1 K and 10 K.

- Since a superconductor has almost zero resistance it can carry an electric current without losing energy and current can flow forever.

- Meisner effect:- Superconductor do not allow magnetic field to pass through it. In other words, it can be said that superconductors act as perfect diamagnetics. This effect gives rise to levitation.

→ levitation occurs due to mutual repulsion between a permanent magnet and a super conductor. A superconductor is a diamagnet because it expels all internal magnetic field arising from unpaired electrons.

BCS Theory of superconductivity:

- Proposed by J. Bardeen, L. Cooper and J. Schreifer in 1957.

- According to the theory, Cooper pair are the main cause of superconductivity. Cooper pairs are formed by interaction between ~~ions~~ two electrons that form bounde state in superconductor despite Coulombic repulsion.

- The cooper pair of electrons exist ~~without~~ on account of the indirect interaction of two electrons could interact via nuclei of atoms in lattice. The lattice is slightly deformed as an electron moves through it, with positive ions in the path of electrons being displaced towards it.

- The deformation produces a region of increased positive charge. Another electron passing through this polarized region will be attracted by the greater concentration of positive charge there. If the attraction is stronger than the repulsion between the electrons, the electrons are effectively coupled together into Cooper pair with deformed lattice as intermediary.

- A Cooper pair undergoes less scattering than an individual electron as it travels through the lattice because the distortion caused by one electron can attract back the other electron should be scattered out of the path in a collision.

- Since Cooper pair is stable against scattering, it can carry charge freely through the solid thereby giving rise to superconduction. The BCS theory, which shows that two e- of cooper pair must be moving in opposite direction and their correlations may persist over length as large as 10^{-6} m. The binding energy of Cooper pair is of order 10^{-3} eV.

- When $h\nu >>$ binding energy, strong absorption occurs as cooper pairs break down. The binding energy of electron at zero K, $E_g(0)$ is given by

$$E_g(0) = 3.53 \; kT_c$$

At $T > 0K$, only few the Cooper pair breakdown. The resulting individual electrons interact with the remaining Cooper pairs break down. The resulting individual electrons interact with the remaining Cooper pairs breakdown & reduce E_g.

- At T_c, E_g disappears, there are no more Cooper pairs and the material ceases to be superconductor.
- As the electrons are having opposite spins, the resultant spin value is zero.

High Temperature superconductivity (HTSC) :-

Because of the very low temperatures at which most materials become superconducting which ~~most materials become~~ implies that T_c is very low, LTSC has not found widespread use.

- The highest value of T_c known until 1986 was about 23K. G. Bednorz and A. Muller (1986) discovered a cuprate viz a mixed oxide Ba - La - Cu - O system which has T_c of about 35K.

- Another high T_c superconductor $YBa_2Cu_3O_{7-x}$ ($x \lesssim 0.1$) have $T_c = 93K$.

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$CuBaO_3$
$CuYO_3$
$CuBaO_3$

This temperature is significant because it allows liquid nitrogen (boiling point 77K) to be used as coolant rather than more expensive liquid Helium. This superconductor is called Yttrium-Barium-Cuprate. It is 1-2-3 system because of the ratio of metals present.

- The major requirement for HTSC is proved to be neccesary ~~for~~ ~~its~~ the presence of non-stoichiometry.

- Replacement of copper with other elements ~~is~~ showed the absence of superconductivity. That mean Copper ~~mean~~ is an important part of the superconductivity.

- The cuprate has perskovite structure.

- Oxygen deficiency is very important for the HTSC.

Liquid Crystals :-

- There are some solids which undergo two sharp tranformations one after the other when heated.

- First they fuse sharply yielding turbid liquids and then equally sharply at higher temperature to yield clear liquids. These changes are reversed on cooling these liquids at the same temperature.

- The turbid or translucent liquid shows anisotropy especially in the optical properties. They exhibit double refraction and hence give interference patterns in polarized light. True liquid on the contrary are isotropic

- The anisotropic properties are here associated with the turbid liquid and the properties are mainly double refraction. Such turbid liquids are called liquid crystals.

- The substance do not have crystal property like solids. They are more like liquid in having mobility, surface tension, viscosity etc. They are thus mostly refered as mesomorphic state.

- Substances showing the above behavior are usually some long chain organic molecules either terminating in groups such as $-OR, -COOR$ or having groups like $-C{=}N-$, $-N{=}O-$, $-C{=}C-$, in the middle.

- The first solid to show such a feature was discovered in 1888 as Cholesteryl benzoate, $C_6H_5COOC_{27}H_{45}$. ~~If~~ It fuses sharply at 145°C to give a turbid liquid which on further heating changing suddenly into liquid at 178°C. The above changes are reversed on the cooling. The clear liquid when cooled first changes into turbid state at 178°C and then into solid state 145°C.

- The basic essential requirement for mesomorphism to occur is that molecule must be anisotropic in shape i.e. mesomorphic state like a rod or a disc.

- Most of the industrial lubricants are liquid crystals which is ~~mesop~~ mesomorphic state. The system may pass through one or more mesophases before it changes to isotropic liquid. Transformation into liquid intermediate states may be brought either through thermotropic meso-morphism (by thermal processes) or by the lyotropic mesomorphism (by intervention of the solvent).

- The first temperature at which solid changes into turbid liquid is known as transition point and the second temperature at which turbid liquid changes into clear liquid is known as melting point. For p-cholesteryl benzoate, the changes may be represented as

$$\underset{\text{Solid}}{A} \underset{}{\overset{145^\circ C}{\rightleftharpoons}} \underset{\text{Liquid crystal}}{A} \overset{178^\circ C}{\rightleftharpoons} \underset{\text{Liquid}}{A}$$

- The substance showing liquid crystal character are highly stable and do not decompose on heating.

- It can be concluded that there are 4 phases or 4 states of matter. Besides solid, liquid and gaseous states, the fourth state is the mesomorphic state.

Vapor Pressure - Temperature Diagrams:-

(1) The phase changes involved in the conversion of an ordinary solid into liquid and vapor state is usually represented as

$$\text{solid} \rightleftharpoons \text{liquid} \rightleftharpoons \text{vapour}$$

(2) For liquid crystals

$$\text{solid} \rightleftharpoons \text{liquid crystal} \rightleftharpoons \text{liquid} \rightleftharpoons \text{vapor}$$