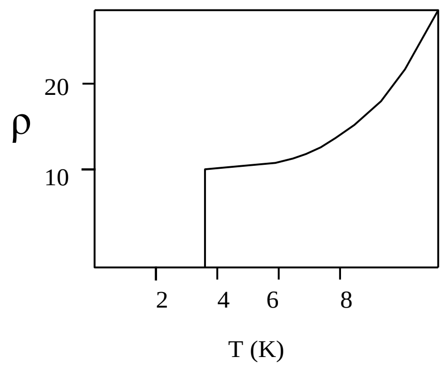
1. Superconductivity

Certain metals and alloys exhibit almost zero resistivity (i.e. infinite conductivity), when they are cooled to sufficiently low temperatures. This effect is called superconductivity. This phenomenon was first of all discovered by H. K. Onnes in 1911 when measuring the electrical conductivity of metals at low temperatures.



Critical or transition temperature

(Or)

Transition temperature (T_c)

The temperature at which the transition from normal state to superconducting state takes place on cooling in the absence of magnetic field is called critical temperature or transition temperature.

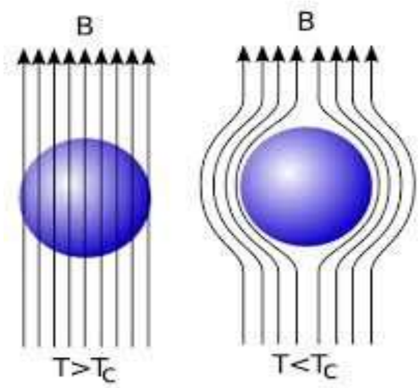
2. General properties of Superconductors:-

Properties of superconductors:-

1. It is a low temperature phenomenon.
2. The transition temperature is different for different substances.
3. Materials having high normal resistivities exhibit superconductivity.
4. Materials for which $Z\rho = 10^6$ (where Z is a atomic number and ρ is resistivity) show superconductivity.
5. For chemically pure and structurally perfect specimen, the superconductivity is very sharp.
6. Ferro magnetic and Anti ferromagnetic materials are not superconductors.
7. Below the transition temperature the magnetic flux lines are rejected out of the superconductors.
8. Superconducting elements, in general, lie in the inner columns of the periodic table.
9. Those metallic elements having their valence electrons lies between 2 to 8 exhibit superconductivity.
10. Below the transition temperature the specific heat curve is discontinuous.

3. The Meissner effect

When a weak magnetic is applied to a superconducting specimen at a temperature below transition temperature T_C ***the magnetic flux lines are expelled. This phenomenon is called Meissner effect***.



Under normal state the magnetic induction inside the specimen is

$$B = \mu_0 (H + I)$$

Where H is the external applied magnetic field and I is the magnetization produced inside the specimen.

When the specimen is in superconducting state $B = 0$ (Meissner effect)

$$0 = \mu_0 (H + I)$$

Or

$$H = -I$$

$$\chi = \frac{I}{H} = -1$$

Thus the material is act as a perfectly diamagnetic (for diamagnetic material $\chi = -1$).

Let us consider a superconducting material is in normal state. From ohms law, the electric field $E = J\rho$

On cooling the material to its transition temperature ρ tends to zero. If J is held finite E must be zero.

From Maxwell's equations

$$\nabla \times E = \frac{-dB}{dt}$$

Under superconducting condition since E is zero $\frac{dB}{dt} = 0$ or B=constant.

This means that the magnetic flux passing through the specimen should not change on cooling to the transition temperature. The Meissner effect contradicts the result.

4. Type I and type II superconductors. Or types of superconductors

Based on the diamagnetic response superconductors can be classified into two types, they are

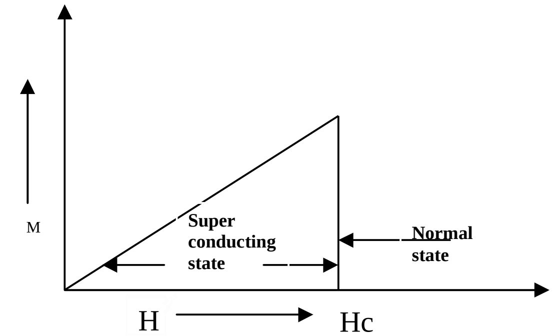
1. Type I superconductors
2. Type II superconductors

Type I superconductors

Superconductors which one follows a complete Meissner effect is called type I superconductors (also is known as soft superconductors).

When the magnetic field strength is gradually increased from its initial value $H < H_C$, $at\ H_C$ the diamagnetism is abruptly disappear and the transition from superconducting state to normal state is sharp as shown in figure. These superconductors are known as soft superconductors

Examples: - Al, Zn, Hg and Sn

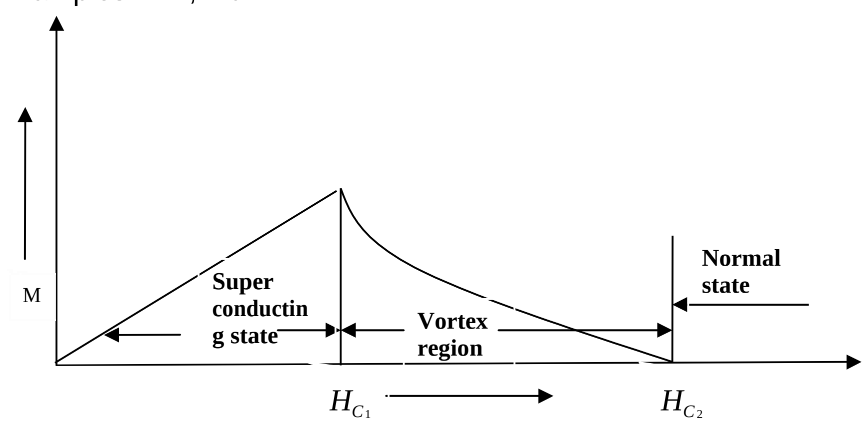


Type II superconductors: -

Superconductors which does not follow the complete Meissner effect is called type I superconductors (also is known as hard superconductors).

In type II superconductors, the specimen is in pure superconducting state up to the field H_{C_1} (lower critical field) when the field is increased beyond H_{C_2} (upper critical state) the magnetic flux lines start penetrating. The specimen is in mixed state between H_{C_1} and H_{C_2}. Above H_{C_2} , the specimen is in a normal state. This means that the Meissner effect is incomplete in the region between H_{C_1} and H_{C_2} . This region is known as vertex region. These superconductors are known as hard superconductors.

Examples: - Zr, Nb



5. Differences between type I and Type II superconductor

Type I superconductor	Type II superconductor
1. It follows complete Meissner effect.	1. It does not follow the complete Meissner effect
2. It has single critical field value H_C	2. It has two critical field values H_{C_1} and H_{C_2}
3. There no mixed state.	3. There is a mixed state
4. They are soft superconductors	4. They are hard superconductors
5. Materials with pure form are type I superconductors	5. Materials with impurities or alloys are type II superconductors
6. Examples; Zn, Al, Hg and Sn	6. Examples: Zr, Nb