MAGNETISM AND MATTER.

Classification of magnetic materials based on the magnetic behaviour.

DIAMAGNETIC MATERIALS

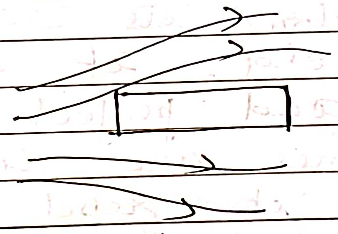
* The induced dipole moment is due to orbital motion of electrons

* develop feeble magnetisation in a direction opp. to that of magnetising field.

* they are weakly repelled by magnets.

* they tend to move from stronger to weaker parts of field.

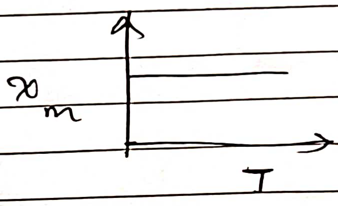
* Magnetic field lines tend to repel when it is placed in a magnetising field as shown in fig (i)



* value of magnetic susceptibility (χ_m) is small and negative.

* Eg Cu, Pb, Bi, Sn, Au, H_2O, Si etc

* Magnetic susceptibility is independent of temp.



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* Relative permeability $\mu_r < 1$.

Origin of diamagnetism

In diamagnetic substances, like Bi, Cu, Pb etc magnetic moments due to different electrons cancel out. As they occur in pairs, net mag. moment of atom is zero. When such an atom is placed in a magnetising field, the mag. moment of the electrons in the same direction as that of the field get slowed down while those opp. to the field get speeded up. As a result, the substance develops a mag. moment in a direction opp. to the external field and hence repulsion.

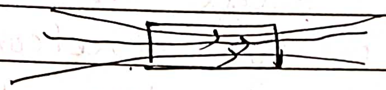
Diamagnetism and superconductivity

When a metal is cooled to a temperature below its critical temperature in a mag. field, it attains perfect diamagnetism and perfect conductivity. The mag. field lines are completely repelled from it and it repels a magnet. This effect is called "Meissner effect".

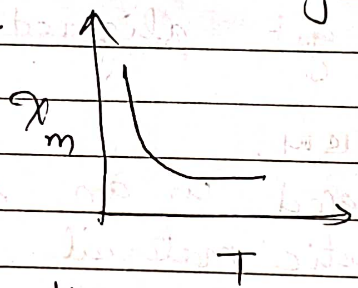
→ principle of magnetic levitation. The phenomenon of perfect diamagnetism in super conductors is known as Meissner effect.

PARAMAGNETISM MATERIALS

* Develops feeble magnetisation in the direction of magnetising field.
* tend to move from weaker to stronger parts of a mag. field.
* Weakly attracted by magnets
* χ_m is small and positive.
* when placed in an ext. mag. field, mag. field lines prefer to pass through the material as shown in fig (ii)



* Mag. susceptibility of a paramagnetic material varies inversely as the absolute temp.



* $\mu_r > 1$ but small.

* The intensity of magnetisation or magnetisation M of a paramagnetic material is directly proportional to magnetising field H and inversely proportional to temp.

$$M \propto \frac{H}{T}$$

$$M = \frac{CH}{T}$$

$$\frac{M}{H} = \chi_m = \frac{C}{T}$$ → known as Curie's Law

where C is a constant called Curie constant

Eg of paramagnetic materials Mn, Al, Cr, Pt, Na, Copper chloride etc.

ORIGIN

Atoms or molecules of paramagnetic substances possess a permanent mag. moment. In the absence of external field, the dipoles are randomly directed due to random motion and hence no magnetisation. When a strong magnetic field is applied, and temperature is low enough, the external field tends to align the mag. dipoles in the direction of ext. field.

As the field is increased or temperature is lowered magnetisation increases until it reaches saturation value M_s at which all dipoles get aligned with the field.

FERROMAGNETISM.

* When placed in an ext. mag. field, a ferro magnetic material develops strong magnetisation in the direction of applied field.

* The magnetic field lines concentrate greatly into the material so that mag. induction will be greater than the magnetising field.

ie $B > H$

* It moves from weaker to stronger parts of magnetic field.

* When a rod of ferromagnetic material is suspended freely in a uniform magnetic field, it aligns itself parallel to the field.

* Relative permeability $\mu_r = 1+\chi_m$ is large value and so is the mag. susceptibility — large and positive.

* Eg: Iron, Co, Ni, steel, Alnico, etc.

* Paramagnetism and ferromagnetism is associated with intrinsic magnetic moment of spinning electrons

* $\mu_r >> 1$

ORIGIN:

Individual atoms of ferromagnetic substances have large mag. moments which interact among neighbouring atoms and align themselves in a particular direction over macroscopic regions called domains (size ~1mm – 10^{11} atoms). So each domain possess a strong mag. moment. In the absence of field, these domains are randomly oriented and net mag. moment is zero.

When a ferro magnetic material is placed in a magnetic field, all the domains align themselves along the direction of external field. When the external field is strong the domain rotate until their mag. moment get aligned in the direction of ext. field.

Curie - Weiss Law

When a ferromagnetic substance is heated, its magnetisation decreases due to increase in randomisation of domains. At a sufficiently high temp, the domain structure disintegrates and ferromag. substance become paramagnetic. The temperature at which a ferromagnetic substance become paramagnetic is called curie temperature or Curie point T_c. Above Curie point, in the paramagnetic phase, the susceptibility is given as

$$\chi_m = \frac{C}{T - T_c} \quad (\text{for } T > T_c)$$

The above equation is called Curie-Weiss Law.

Hysteresis

When a ferromagnetic sample is placed in a magnetising field, the sample gets magnetised by Induction. As the magnetising field H varies, mag. induction B also varies linearly with H.

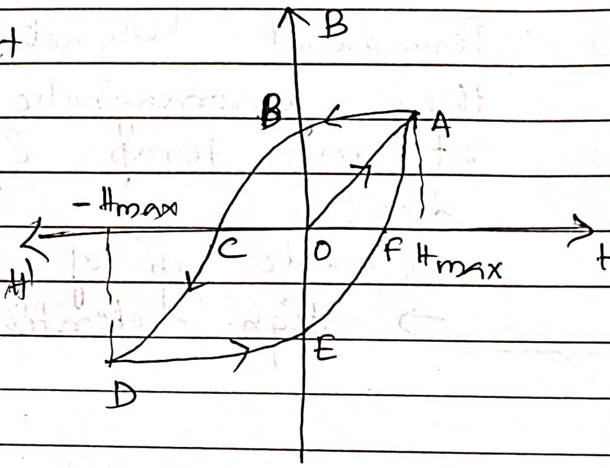
Fig (iv) shows variation of B with H. Point O represents initial state of a ferromagnetic substance. As H increases, B first increases and attaints a constant value ~~Hmax~~ B at Hmax. Now if H is ~~increased~~ decreased gradually to zero, B decreases but along a new path AB and it is seen that B does not become zero for H = 0 ie sample is not demagnetised even when the magnetising field has been removed.

The magnetic induction OB left behind in the substance when H = 0 is called residual magnetism or remanence or retentivity.

To bring $\vec{B}$ to zero, H is gradually increased in the reverse direction and B becomes zero at a value of H = OC.

The value of reverse magnetising field required to completely demagnetise a sample is known as the "Coercivity" of the sample.

On further increasing H in the reverse direction to a value $-H_{max}$ again a saturation point D is reached symmetrical to A. If H is decreased gradually the point A is reached through DEFA.



Through out the cycle, mag. induction $\vec{B}$ lags behind magnetising field H. This lagging of B behind H is called hysteresis

Significance- area of hysteresis loop is the energy dissipated per unit volume in the material when it is carried through a cycle of magnetisation. It appears in the form of heat.

Date :

Soft Ferro magnets - magnetism disappears on the removal of H. Used as core of electromagnets, due to → narrow hysteresis loop
solenoids.
→ low retentivity,
low coercivity
high permeability

Eg: Soft Iron.

Hard ferromagnets - retains magnetic field.
* can be used for making permanent magnets.

Permanent Magnets : substance that retain their ferromagnetic property for a long time at room temp. Eg: Iron, Cobalt, steel, Nickel, Alnico.

→ made up of ferromagnetic material
→ High retentivity, High permeability,