Classification of magnetic materials and their properties.

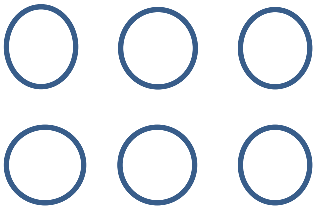
The basic reason of magnetization is the unpaired number of the valence electrons in a given magnetic material and on the effect of magnetic dipoles in a material ,specifically the orientation of these dipoles is responsible for the magnetic properties of the material.

The magnetic materials are classified as

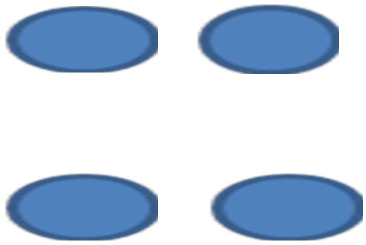
1. Diamagnetic 2. Parmagnetic 3. Ferromagnetic 4. Anti –Ferromagnetic and 5. Ferrimagnetic

   Materials from 2-5 are due to the interaction of the diploes in the material while the 1 is characterized by the absence of dipoles.

1. Diamagnetism.



H=0 Absence of external no dipoles as C.G of + & - charge of molecules magnetic field is same



H≠0 Dipoles occur as C.G of + & - charge of molecules changes

As shown in the figures above in absence of external field (H = 0) the molecules are spherical in shape as **C.G** (center of gravity) of **+ve** and **–ve** charges coincide. But in presence of external field the molecules develop dipoles. These induced dipoles vanish as soon as the external field is removed.

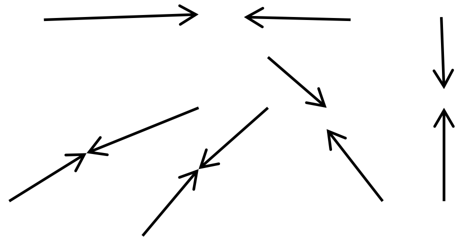
PROPERTIES.

1. These do not have permanent dipoles in normal state.
2. The induced magnetic property due to occurrence of dipoles in presence of external field is lost as soon as the external applied field is removed.
3. The induced magnetic field is aligned opposite to the applied external field i.e. these are repelled by the magnetic field.
4. The relative permeability of these materials is positive and but $<$ unity.
5. Susceptibility of diamagnetic materials is a).independent of applied magnetic field b). Independent of temperature and c). It is small and negative.
6. Superconductors exhibit ideal diamagnetism.

7. Eg. Organic crystals napthelene, benzene and metals such as silver , gold, copper etc. These materials have effective orbitals moments as zero and electronic spins are paired.

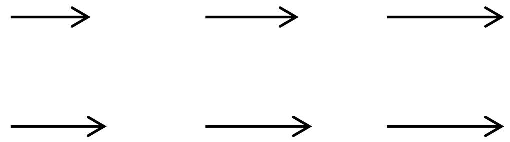
2. Paramagnetism

$\overrightarrow{H}=0$



H=0 in absence of external field dipoles are aligned so as to have net dipole moment as zero.

$\overrightarrow{H} \neq 0$



In presence of external magnetic field the dipoles align in direction of this field resulting in induces magnetism.

PROPERTIES.

1.The materials have permanent dipoles which in absence of external magnetic field are oriented randomly so that net dipole moment is zero

2. In presence of applied field tend to align parallel to the applied field giving rise to a feeble induced magnetism.

3. When the field is removed it looses its induced magnetic property.

3. The relative permeability of these materials is positive and always> unity.

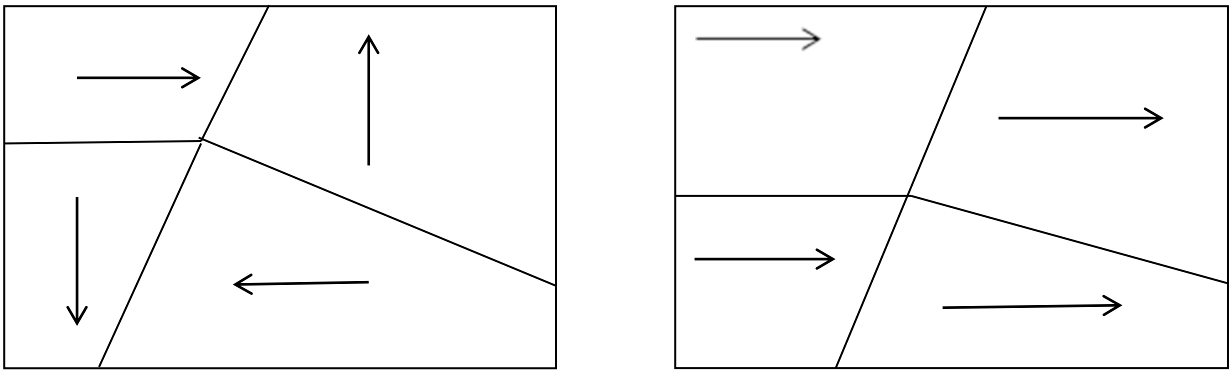
4. Susceptibility of paramagnetic materials is a).small positive. B). inversely proportional to absolute temperature.

5.when suspended freely a paramagnetic rod aligns itself parallel to the applied uniform external magnetic field

6. e.g. Atoms or molecules having odd number of electrons as total spin is non zero like nitric oxide, elements having partially filled inner shells of atoms rare earth and transition elements and metals like chromium platinum and aluminum.

3. Ferromagnetism

$\overrightarrow{H}=0$ $\overrightarrow{H}\neq 0$



These are like paramagnetic substances having dipoles , their strong affinity towards magnetism is explained on basis of DOMAIN theory . This theory assumes that these dipoles are grouped together in small –small regions or DOMAINS. Within each domain all the dipoles have the same direction of alignment due to mutual cohesiveness.

In absence of external magnetic field these regions align randomly so that net dipole moment is zero. In presence of external magnetic field all the domains align parallel to the applied field.(***refer notes on Weiss domain theory)***

PROPERTIES.

1.The materials have permanent dipoles which in absence of external magnetic field are oriented randomly so that net dipole moment is zero

2. In presence of applied field the domains tend to align parallel to the applied field giving rise to a strong induced magnetism.

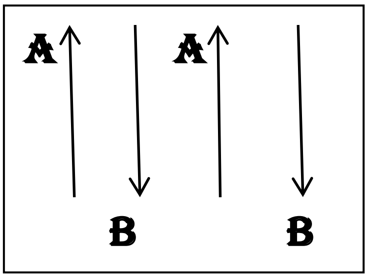
3. When the field is removed it retains its induced magnetic property.

4. Susceptibility of paramagnetic materials is a).large positive value. B). decreases with rise in temperature eas per Curie –Weiss law $\chi = \frac{C}{T-\theta}$,

C is curie constant θ is Curie temperature. Also at curie temperature ferromagnetism reduces to paramagnetic.

5. e.g. iron , nickel, cobalt and certain alloys fabricated to manufacture strong magnets

4. AntiFerromagnetism



These were discovered by Neel and Bitter. These materials can be supposed to be made up of two inter linked sub lattice **A(↑)** and **B(↓) such that the spin of both are aligned antiparallel to each other as shown.**

In absence of external field the net magnetic moment is zero and on the application of external field a small induced magnetism occurs in the direction of the applied field. At Neel temperature it attains its maximum value above which its magnetism decreases and attains paramagnetic state.

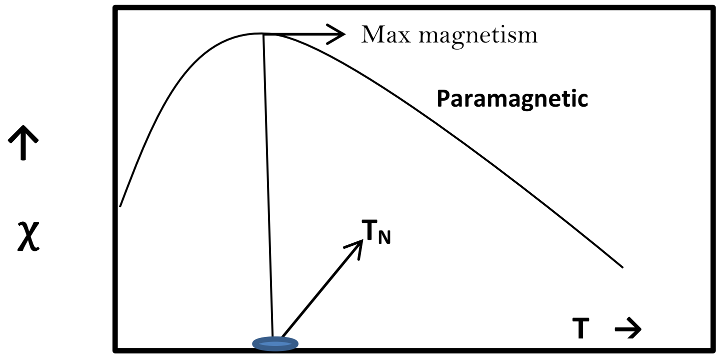
PROPERTIES.

1. The materials have spins of neighboring atoms as antiparallel.

2. In presence of strong field these get feebly magnetized.

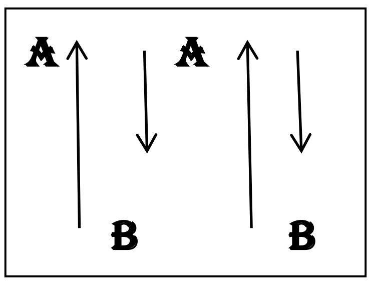
3. Susceptibility of these materials depend on rise in temperature per the equation $\chi = \frac{C}{T+\theta}$, and above Neel T_N temperature the material becomes paramagnetic

4. e.g. MnO, MnF_2, FeO,Cr_2O_3



5. Ferrimagnetism

These material exhibit similar characteristics as that of Antiferromagnetic materials with the diference that the two sub-lattice spins **A(↑)** and **B(↓) are not of equal magnitude**



PROPERTIES.

1.The materials have spins of neighboring atoms as antiparallel but possess net magnetic moment as both the spins are unequal in strength.

2. These materials become or behave as paramagnetic above Curie temperature.

3. Their induced magnetism is less than the antiferromagnetic materials.

4. These magnetic compounds consist of two or more different kind of atoms e.g

$MO.Fe_2O_3$ where M is di-valent metal atom such as Mn , Ni, Zn , Cd……Yttrium iron garnet (YIG) $Y_3Fe_2O_{12}$ is an important material of this kind.

BASIC ORIGIN OF MAGNETISM IN CASE OF MATERIALS

The origion of magnetism lies in the magnetic field produced by the angular motion of an electron about the nucleus wherein the revolving electron is considered as constituting a current and the next cause is the spin of the electron about its own axis.

As far as the orbital motion is concerned the magnetic field can be calculated as the distribution of the electron charge about the nucleus is known but in case of electron spin it has been observed that it is twice as given by angular moment. Further more these orbital and spin angular moments couple together to form Total angular momentum and their corresponding magnetic fields also couple as per the rules of coupling

L (0_p) S = J