Magnetic properties of transition metal ions and their complexes

- The electron while revolving around the nucleus has two types of motions namely orbital motion and spin motion.
- The spin magnetic moment is due to the spin of the electrons about their own axes whereas the orbital magnetic moment is due to the motion of electrons around the nucleus in various orbitals.
- Both these motions produce magnetic fields when a substance is placed between the poles of a horse-shoe magnet.

Types of Magnetic Substances

Paramagnetic

- Attracted by the magnetic field due to the presence of permanent magnetic dipoles (unpaired electrons). In magnetic field, these tend to orient themselves parallel to the direction of the field and thus, produce magnetism in the substances.
- At least one unpaired electron

↑↓	↑	↑

- O_2, Cu^{2+}, Fe^{3+}, TiO, Ti_2O_3, VO, VO_2, CuO
- Electronic appliances

Types of Magnetic Substances

Diamagnetic

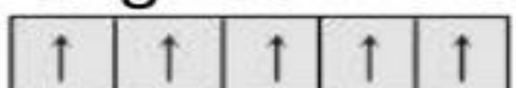
- Feebly repelled by the magnetic fields. Non-metallic elements (excepts O_2, S) inert gases and species with paired electrons are diamagnetic
- All paired electrons

- TiO_2, V_2O_5,NaCl, C_6H_6(benzene)
- Insulator

Types of Magnetic Substances

Ferromagnetic

- Permanent magnetism even in the absence of magnetic field, Above a temperature called **Curie** temperature, there is no ferromagnetism.
- Dipoles are aligned in the same direction



- Fe, Ni, Co, CrO_2
- CrO_2 is used in audio and video tapes

Types of Magnetic Substances

Antiferromagnetic

- This arises when the dipole alignment is zero due to equal and opposite alignment.

↑	↓	↑	↓	↑	↓

- MnO, MnO_2,Mn_2O, FeO, Fe_2O_3; NiO, Cr_2O_3, CoO, Co_3O_4,

Types of Magnetic Substances

Ferrimagnetic

- The dipoles are antiparallel as shown in Fig. 8. However, the dipoles are not equal in magnitude.

- Net magnetization is larger even for a small external field.
- The susceptibility is positive and vary large when the temperature is higher than T_N.

$$\chi = \frac{C}{T \pm \theta}$$

- They behave as paramagnetic and ferromagnetic materials respectively above and below Curie temperature.

Curie Law

- The susceptibility of paramagnetic substances is inversely proportional to their temperature that means that materials become more magnetic at lower temperatures.

Curie Equation

$$M = \chi H \text{ with } \chi = \frac{C}{T}$$

where

$\chi > 0$ is the (volume) magnetic susceptibility,

M is the magnitude of the resulting magnetization in amperes/meter (A/m),

H is the magnitude of the applied magnetic field (A/m),

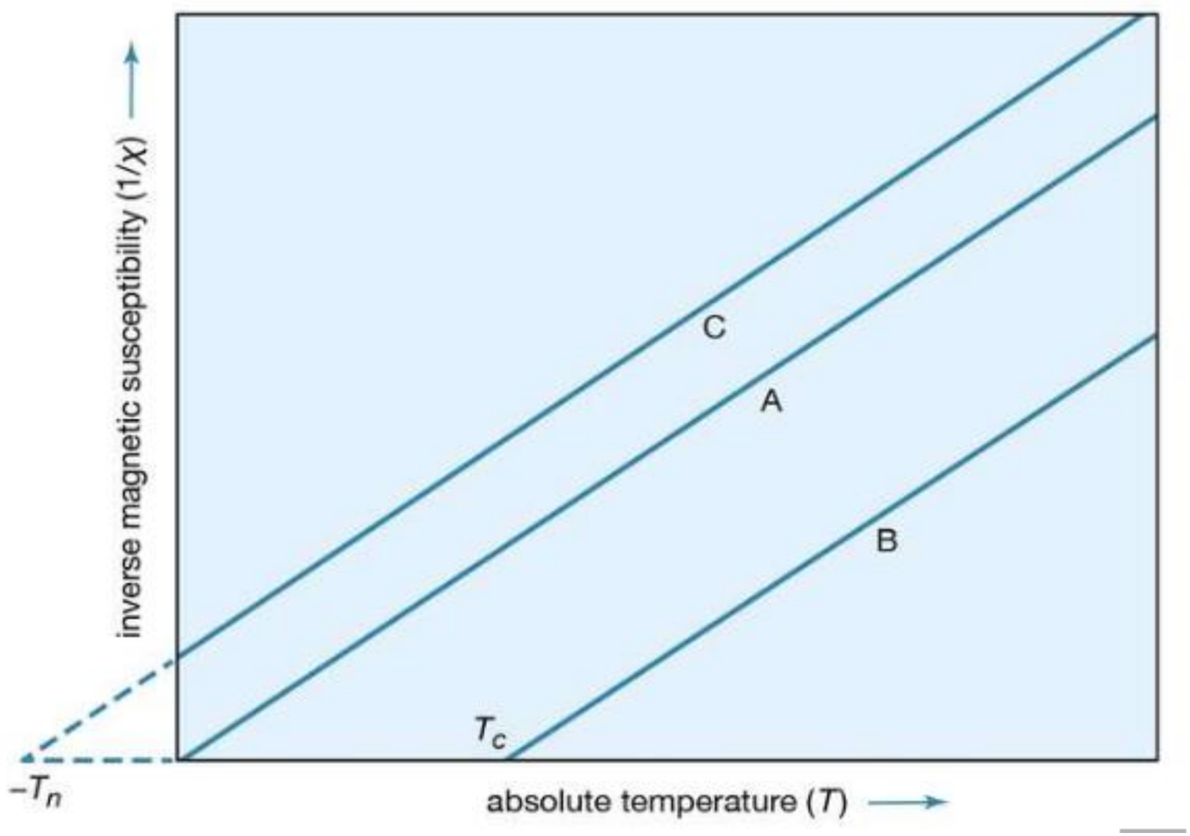
T is absolute temperature, measured in kelvins (K),

C is a material-specific Curie constant (K).

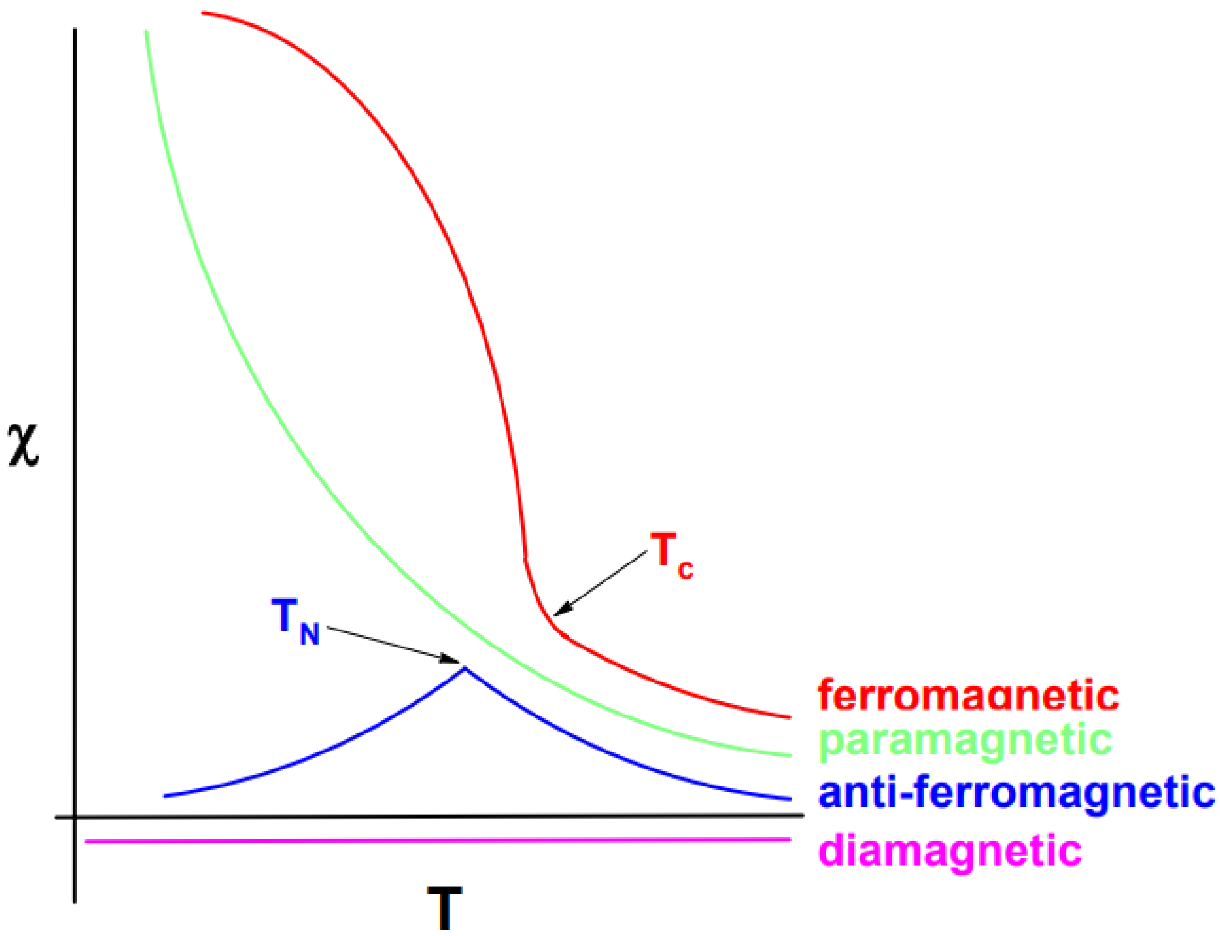
Curie–Weiss Law

- The Curie–Weiss law describes the magnetic susceptibility χ of a ferromagnetic substances in the paramagnetic region above the Curie Temperature.

Magnetic Curves



Magnetic Susceptibility vs Temperature plot



Curie Temperature
&
Neel Temperature

- A ferromagnetic substances has a characteristic Curie Temperature (TC) above which it behaves like a paramagnet and below which it’s magnetic susceptibility increases rapidly.
- An antiferromagnetic substances has a characteristic Neel Temperature (TN) above which it behaves like a paramagnet and below which it’s magnetic susceptibility decreases with decreasing temperature.