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# Magnetic Properties of Transition metal Complexes

Unit III Inorganic chem

- Magnetic properties of substance explain distribution of electrons in atoms or ions.
- Magnetic moment and magnetic susceptibility arises due to presence of unpaired electrons.
- High spin and low spin complexes can be differentiated on the basis of magnetic properties
- Transition metals have unpaired electron and show magnetic properties.
- The unpaired e⁻ spin about its axis and acts as tiny magnet.
- The molecules with paired e⁻ are diamagnetic

The paired e⁻ have opp spin in opposite direction and cancel their magnetic field.

- In unpaired e⁻ produce magnetic field

Two type of magnetic behaviour :-

- Paramagnetic substances: They have unpaired electron. They are attracted to magnetic field
- Greater the no of unpaired e⁻ greater is the ~~extent~~ paramagnetic character. eg transition metal
- Diamagnetic substances: They donot possess unpaired e⁻. They donot show magnetic moment.
- They are ~~attracted~~ repelled by external magnetic field.

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## Paramagnetic moments:

- Magnetic properties of substance arise from electron and nucleus.
- The magnetic moment is mainly because of electron this is due to mass of proton that is 1850 times of $e^-$.
- The $e^-$ is treated as small sphere of negative charge spinning on its axis. The spinning of charge produce magnetic moment.
- $e^-$ travelling in closed path create magnetic moment. (around a nucleus)
- The magnetic moment due to spin of $e^-$ on its axis is called spin magnetic moment of $e^-$.
- Magnetic moment due to motion of $e^-$ around the nucleus is called orbital magnetic moment.
- The observed magnetic moment is due to sum of spin magnetic moment and orbital magnetic moment.
- Magnetic moment is expressed in terms of units called Bohr Magneton. B.M.
- Magnetic moment of $e^-$ having charge e and mass m

$$\mu_s = \frac{eh}{4\pi mc}$$

h = Plank's constant
c = Velocity of light

$\mu_s = 9.274 \times 10^{-21}$ erg/gauss. One unit of magnetic ~~mag~~ moment called Bohr Magneton.

$$1\,B.M = \frac{eh}{4\pi mc}$$

- $\mu_s$ for single electron

$$\mu_s = 2\sqrt{s(s+1)}$$

s is spin quantum number $= \frac{1}{2}$, $s = \frac{1}{2}$

$$\mu_s = 2\sqrt{\frac{1}{2}\left(\frac{1}{2}+1\right)} = \sqrt{3} = 1.732 \text{ B.M.}$$

- for atom or ion having multiple unpaired electron, the overall spin moment is given by

$$\mu_s = 2\sqrt{S(S+1)}$$

S is the sum of the spin quantum numbers for the individual electrons.

- $Ti^{+3}$ it has one unpaired $e^-$ $S = \frac{1}{2}$
- $Cr^{+3}$ four unpaired $e^-$ $S = 4 \times \frac{1}{2} = 2$

$$\mu_s = \sqrt{4S(S+1)}$$

$$\mu_s = \sqrt{4 \times \frac{1}{2}\left(\frac{1}{2}+1\right)} = \sqrt{3} = 1.732 \text{ BM}$$

$Ti^{+3}$

$Cr^{+3}$

$$\mu_s = \sqrt{4 \times 2(2+1)}$$

$$= \sqrt{8 \times 3} = \sqrt{24} = 2\sqrt{6}$$

$$= 4.90 \text{BM}$$

$$\mu_s = \sqrt{n(n+2)} \text{ B.M}$$

~~Here~~ $n$ = number of unpaired $e^-$.

- But value changes because $\mu_s$ is because ~~of spin quantum no. and~~ orbital magnetic and spin magnetic moment.

- Magnetic moment is $M_{S+L}$

$$= \sqrt{4S(S+1) + L(L+1)}$$

S = is resultant spin angular momentum
L = resultant orbital angular quantum momentum

- $M_{S+L}$ is greater than $M_S$ because there is contribution of magnetic moment due to orbital motion.
- The orbital moment is quenched (neutralised)
- The electric field of ligand surrounding the metal ion restrict the orbital motion of $e^-$.
- For ~~Ba~~ lanthanides unpaired electrons occupy 4f orbitals which is shielded by 5s and 5p Subshell.
- Both spin and orbital motion of the $e^-$ contribute to total magnetic moment.

- Measurement of magnetic properties:

* it cannot be measured directly.
* Magnetic susceptibility (χ) is measured first.

- Magnetic susceptibility is a measure of the capacity of a substance to take up magnetisation in an applied magnetic field.
- Substance placed in a magnetic field of strength H, magnetic induction or magnetic flux density

$$B = H + 4\pi I$$

I = intensity of magnetisation, extent to which sample can be magnetised when placed in magnetic field.

I is defined as the magnetic moment per unit volume of the magnet.

$$I = \frac{\text{magnetic moment}}{\text{volume}}$$

a is area of cross section of magnetic substance
2l is the length of substance I

$$I = \frac{m \times 2l}{a \times 2l} = \frac{m}{a}$$

Intensity of magnetisation is the pole strength per unit area of cross section of material

B/H magnetic permeability

$$\frac{B}{H} = 1 + 4\pi \frac{I}{H}$$

$$\frac{B}{H} = 1 + 4\pi K \qquad K \text{ (kappa)}$$

K is called magnetic susceptibility per unit volume

magnetic permeability is the ability of a material to permit the passage of magnetic lines of force through it.

- Magnetic permeability (B/H) gives the ratio of density of lines of force within the substance to the density of such lines in the same region in the absence of the substance.

- The volume susceptibility of vacuum is zero because in vacuum $B/H = 1$

$$1 = 1 + 4\pi K \quad , \quad K = 0$$

- Susceptibility of a diamagnetic substance is negative because lines of force from induced dipole cancel out the lines of force due to applied field $B/H$ is less than 1.
- Paramagnetic substance have flux is greater within the substance than it would be in vacuum and paramagnetic substances have positive susceptibilities.

Susceptibility is in two form.

- Specific Susceptibility $\chi = \frac{K}{\rho}$ $\quad \rho$ = density

- Molar Susceptibility $\chi_M = \frac{K \cdot M}{\rho}$

$M$ = molecular mass of the substance.