B.Sc. VI - Chemistry

(Mahesh Kathal)

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Magnetic Moment

The moment of electron in the atomic orbit is similar to the flow of electric current in circular wire. Hence, the moment of electron produces a magnetic field perpendicular to the surface of orbit having electrons. The axial motion of electron on its axis produces magnetic moment. The magnetic moment in atom is calculated with the help of quantum numbers.

Spin only magnetic Moment (μ_s) —

Electron spin on its own axis. Magnetic moment associated with the spin of electron is called spin magnetic moment and produces spin angular moments. This motion of electron produces magnetic field also. The spin angular momentum (S) is

$$(S) = \sqrt{S(S+1)}\,\frac{h}{2\pi}$$

h = planck's constant
S = Spin Quantum No.

In 1926 Uhlenbeck and Gouldsmit assumed spin angular momentum, they also calculated the ratio of spin magnetic moment (μ_s) and spin angular momentum (S) i.e. the value of Lande splitting factor (g). The value of

$$\frac{\mu_s}{(S)} = g = 2$$

Spin angular momentum $(S) = \sqrt{S(S+1)}\,\frac{h}{2\pi}$, then

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

[where $\frac{h}{2\pi}$ = unit = 1]

$$\therefore \mu_s = 2\sqrt{S(S+1)} \text{ or } g\sqrt{S(S+1)}$$

This is the value of spin magnetic moment of the system having one electron. In the atom having more then one electron, then resultant spin magnetic moment (μ_s) is

$$\mu_s = 2\sqrt{S(S+1)} \text{ or } \mu_s = \sqrt{4S(S+1)}$$

To determine spin angular momentum, number of electron (unpaired) is multiplied by ½.

$$S = n \times \tfrac{1}{2} \quad \text{or} \quad n = 2S$$

Then, $\mu_s = 2\sqrt{S(S+1)} = 2\sqrt{\frac{n}{2}\left(\frac{n}{2}+1\right)} = \sqrt{n(n+2)}$

Orbital Magnetic Moment (μ_l) —

When motion of electron in its orbit, then magnetic moment of magnetic field produced by electron will be equal to the product of electric current and surface area of orbit.

$$\mu_L = iA = \frac{e\omega}{2\pi c} \times \pi r^2 = \frac{e}{2c}\omega r^2$$

where, i = electric current, A = surface area, e = charge of electron, ω = angular velocity of electron, c = velocity of light and r = radius of orbit.

Same way, the orbital angular momentum of electron is expressed in the following —

$$(l) = mr^2\omega = \sqrt{l(l+1)}\frac{h}{2\pi}$$

(l) = orbital angular moment of free electron
m = mass of electron, h = Planck's constant and
l = azimuthal quantum number of electron.

From the abov eq.

$$\omega r^2 = \sqrt{l(l+1)}\frac{h}{2\pi m}$$

From eq. $\mu_l = \frac{e}{2c}\omega r^2$, put the value of ωr^2

$$\mu_l = \sqrt{l(l+1)}\frac{eh}{4\pi mc}$$

$$\frac{eh}{4\pi mc} = \text{Bohr Magneton (B.M)}$$

$$1BM = 0.9273 \times 10^{-20} \text{ erg gauss}^{-1}$$

$$\therefore \quad \mu_l = \sqrt{l(l+1)} \text{ B.M.}$$

This is the orbital magnetic moment of atom or ion having one electron. If having more than one electron then resultant orbital angular momentum quantum number (L) is used in place of azimuthal quantum no. The resultant orbital magnetic moment (μ_L) is

$$\mu_L = \sqrt{L(L+1)} \text{ B.M.}$$

Ratio of orbital magnetic moment and orbital angular momentum is called Lande splitting factor

$$g = \frac{\sqrt{l(l+1)}\ B.M}{\sqrt{l(l+1)}\ \frac{h}{2\pi}}$$

If the unit of orbital magnetic moment is assumed to be B.M. and the unit of orbital angular moment is $\frac{h}{2\pi}$ the value of g is one, but in spin moment is 2 (two).

The resultant magnetic moment of any system will be –

$$\mu_{L+S} = \sqrt{L(L+1) + 4S(S+1)}\ B.M.$$

It is called effective magnetic moment (μ_{eff}).

Effective magnetic moment of a system, which has zero value of L is equal to only spin magnetic moment.

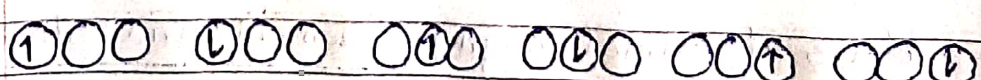
L–S Coupling
or Russel-Saunders Coupling

In a system having more than one electron, the magnetic effect of L and S also interacts. This interaction or coupling is called L-S coupling or Russel-Saunders coupling.

To learn L-S coupling, knowledge of following terms is essential.

Energy levels in an atom –

If there is only one electron in the sub-orbit of an atom, energy level depends on azimuthal quantum number. This is due to degeneracy of orbitals of sub orbital. For example, on the basis of difference in orbital and spin an electron present in 2p suborbit can have six configuration.



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