B.SC-III, Paper-VII, group-A

Electron spin:-

(i) Sommerfeld could not explain the fine structure of hydrogen spectral lines. (i) Sommerfeld's relativistic explanation of fine structure was not accepted for alkalies whose spectral lines are doublets. In alkali atoms the (single) optical ē moves in a Bohr-like orbit of large radius at low velocity. Therefore, the relativity effect would be too small to account for the large (compared with hydrogen) fine structure splitting observed in alkali lines.

(II) The simple quantum theory failed to explain anomalous zeeman effect i.e the splitting of atomic spectral lines into four, six or more components, when the light source was placed in an external magnetic field.

In view of these drawbacks of the theory, Goudsmit and Uhlenbeck proposed in 1925 that the ē must be looked upon a charged sphere spinning about its own axis. Thus it has an intrinsic angular momentum and an intrinsic magnetic moment.

These are called spin angular momentum $\vec{S}$ and spin magnetic moment $\vec{\mu_s}$.

(These are besides the orbital angular momentum $\vec{l}$ and orbital magnetic moment $\vec{\mu_l}$).

The magnitude of the spin angular momentum is

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

[s → spin Q.No. & Its value is $\frac{1}{2}$]

$$|\vec{S}| = \sqrt{\frac{1}{2}\left(\frac{3}{2}\right)}\,\frac{h}{2\pi} = \frac{\sqrt{3}}{2}\,\frac{h}{2\pi}$$

The component of $\vec{S}$ along a magnetic field parallel to the z-direction is

$$S_z = m_s\, h/2\pi$$

where m_s is the spin magnetic quantum no.

i.e. $m_s = (2S+1)$, gives 2 values $+S$ & $-S$

i.e. $m_s = \pm 1/2$

& $S_z = \pm \frac{1}{2} \frac{h}{2\pi}$

The Gyromagnetic ratio of for electron spin $\frac{|\vec{\mu_s}|}{|\vec{s}|}$ is twice the corresponding ratio $\frac{|\vec{\mu_l}|}{|\vec{l}|} \left(= \frac{e}{2mc}\right)$ for the electron orbital motion.

Thus Spin magnetic moment $\vec{\mu_s}$ of electron is related to the spin angular momentum $\vec{s}$

$$\vec{\mu_s} = -2 \frac{e}{2mc} \vec{s}$$

−ve sign means $\vec{\mu_s}$ is opposite in direction to $\vec{s}$ b'cz electron is Negatively charged.

Thus $\vec{\mu_s} = -g_s \frac{e}{2mc} \vec{s}$ where $g_s = 2$

$g_s \rightarrow$ spin g factor.

$$\vec{\mu_s} = -g_s \frac{e}{2m} \vec{s}$$

The Magnitude of the spin Magnetic moment is

$$|\vec{\mu_s}| = 2 \frac{e}{2mc} |\vec{s}| \qquad \left\{ |\vec{S}| = \sqrt{S(S+1)}\, h/2\pi \right\}$$

$$= \frac{e}{mc} \frac{\sqrt{3}}{2} \frac{h}{2\pi}$$

$$|\vec{\mu_s}| = \sqrt{3} \frac{eh}{4\pi mc} = \sqrt{3}\, \mu_B.$$

$\mu_B \rightarrow$ Bohr Magneton.

The spinning $\bar{e}$ proved to be successful in explaining not only fine structure and the anomolous Zeeman effect but other atomic effects also.

In 1928 Dirac proved on the basis of relativistic quantum mechanics that an electron must have an intrinsic angular momentum and an intrinsic Magnetic moment which were just the same as attributed to it by Goudsmit and Uhlenbeck.