What is normal zeeman effect?

Zeeman effect :- In 1896, Zeeman discovered that if a source of light producing line spectrum is placed in a strong magnetic field, the spectral lines are split up into components doublets or triplet or even more complex arrangements. This is called "Zeeman effect".

For the study of this effect, a gas discharge tube is placed between the pole pieces of a strong electromagnet. Light from this source is studied with the help of a spectrograph of high resolving power. The zeeman effect may be observed in two ways:-

i) **Perpendicular to the direction of the magnetic field:** In this case a single spectral line is observed when no field is applied, splits up into three components when the magnetic field is applied i.e., a triplet consisting of three spectral line is observed. The central line is found to be plane polarised. The two outer lines are also plane polarised but their vibrations are in a direction perpendicular to the field. This is known as normal transverse Zeeman effect.

ii) **Parallel to the direction of the magnetic field :-** In this case a hole is bored through one of the pole pieces and the light coming from the source through the hole is examined with the spectrograph. In this case a single spectral li[ne] is split up into two components when the magnetic field is applied i.e.; a doublet consisting of two spectral lines is observed. Both the lines are equally displaced from the original position and are circularly polarized in opposite directions. This is known as Normal longitudinal zeeman effect.

The displacement in the two cases are proportional to the strength of the magnetic field and are equal for the same value of magnetic field.

When a single spectral line is split up into four or more lines when observed in the direction perpendicular to that of the magnetic field, is known as Anomalous zeeman effect.

Normal zeeman effect is obtained from sources of element like Ca, Cu, Zn, Cd etc. and anomalous zeeman effect is obtain[ed] from elements like Na, Cr, etc.

Normal zeeman effect :-

Debye explained the normal zeeman effect without taking into account the concept of spin of electron. If we neglect the spin motion of the electron, then the orbital angular momentum of the electron is

$$L = \frac{lh}{2\pi} \quad \text{——— (1)}$$

and magnetic moment $\mu_l = \frac{lh}{2\pi} \cdot \frac{e}{2m} \vec{l}$ —— (2)

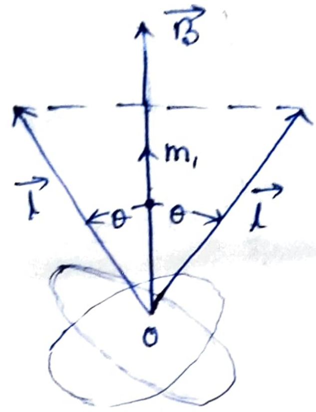

Fig - (1)

In the presence of an external magnetic field of flux density $\vec{B}$, the vector $\vec{l}$ processes around the direction of the magnetic field axis. This precession is known as Larmor precession.

The frequency of Larmor precession

$$\omega = \frac{Be}{2m} \quad \text{—— (3)}$$

Fig (1) shows two positions of the vector $\vec{l}$, as it processes about the electronic orbit.

The additional energy of the electron due to this precessional motion

$$\Delta E = \mu_l B \cos\theta = \left(\frac{e}{2m} \cdot \frac{lh}{2\pi}\right) B \cos\theta$$

$$\left[\because \mu_l = \frac{e}{2m} \cdot \frac{lh}{2\pi}\right]$$

But $\frac{Be}{2m} = \omega$ and $l\cos\theta$ = Projection of $\vec{l}$ on $\vec{B}$ $= m_l$

$$\therefore \Delta E = m_l \frac{eh}{4\pi m} \cdot B = m_l \omega \frac{h}{2\pi} \quad \text{—— (4)}$$

Zeemann Effect

Now m_l can have $(2l+1)$ values from $+l$ to $-l$. Therefore an external magnetic field will split a single energy level into $(2l+1)$ levels. The d-state $(l=2)$ is split into 5 sub-levels and the p-state $(l=1)$ is split into 3 sub-levels as shown in fig (2)

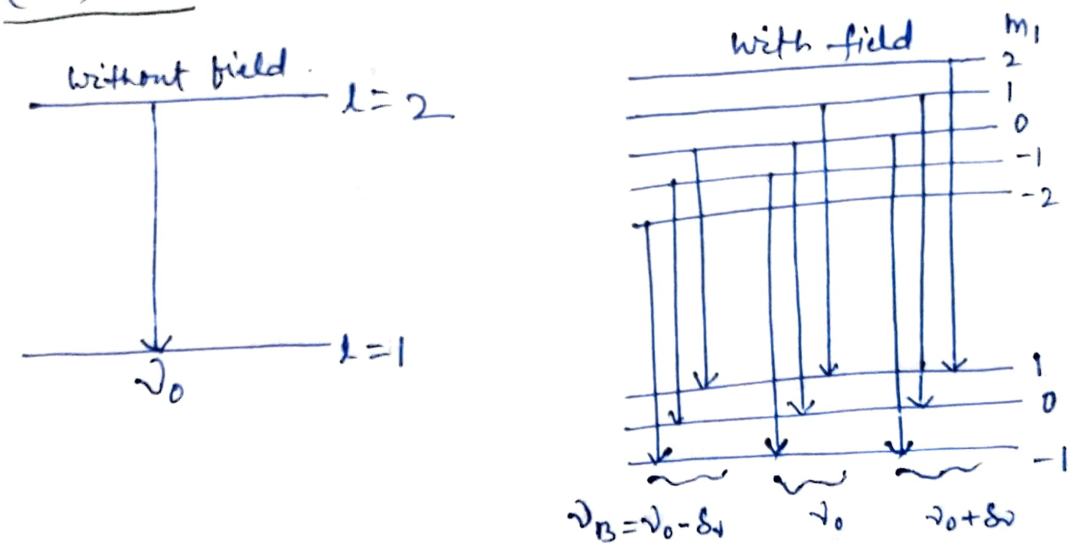

Fig (2)

Let E_0 represents the energy of the level $l=1$ in the absence of the magnetic field and E_B represents the energy of this level in the presence of magnetic field. Then

$$E_B = E_0 + \Delta E$$

$$= E_0 + m_{l0} \frac{eh}{4\pi m} \cdot B \qquad (5)$$

Similarly, if E_{01} and E_{B01} represent the energies of the level $l=2$ without and with the magnetic field respectively, then

$$E_{B01} = E_{01} + M_{l01} \frac{eh}{4\pi m} B \qquad (6)$$

The quantity of energy radiated in the presence of magnetic field is

$$E_{B01} - E_{B0} = E_{01} + E_0 = (m_{l01} - m_{01}) \frac{eh}{4\pi m} \cdot B$$

or, $h\nu = h\nu_0 + \Delta m_l \frac{ehB}{4\pi m}$

or, $\nu = \nu_0 + \Delta m_l \frac{eB}{4\pi m}$ ——— (7)

Where ν = frequency of the radiation emitted with the magnetic field and ν_0 = frequency of the radiation in the absence of the magnetic field. The selection rule for m_l is $\Delta m_l = 0$ or ± 1.

Hence, we have three possible lines,

$\nu_1 = \nu_0$ for $\Delta m_l = 0$ ——— (8)

$\nu_2 = \nu_0 + \frac{eB}{4\pi m}$ for $m_l = +1$ ——— (9)

and, $\nu_3 = \nu_0 - \frac{eB}{4\pi m}$ for $m_l = -1$ ——— (10)

Fig. (2) represents the normal zeeman effect. Though there are nine possible transitions, they are grouped, into only three different frequency components as indicated by eqns (8), (9) and (10). For three transitions in a bracket, change in the value Δm_l is the same and hence they represent the same energy and single line.