Part IV B.Sc phy(H) Paper VII C

Atomic, molecular & Nuclear physics

Q: Discuss and explain the Paschen - Back effect.

Ans: The anomalous Zeeman effect is observed when the external magnetic field is weak as compared to internal fields due to spin and orbital motions of the valence electron. Paschen and Back observed "Whatever be the anomalous Zeeman pattern of a given spectral line in a weak magnetic field, the pattern always approximates the normal Zeeman triplet as the strength of magnetic field is progressively increased". This phenomenon is known as Paschen - Back effect.

Explanation: When the external magnetic field is very strong, the coupling between $\vec{L}$ and $\vec{S}$ breaks down and it is no longer reasonable to think of their resultant $\vec{J}$.

Therefore, we must consider that $\vec{L}$ and $\vec{S}$ precess independently about the external magnetic field $\vec{B}$, shown in fig (1). The magnitudes of these components along the field direction Z are

$$L_z = m_l \frac{h}{2\pi}$$

and $S_z = m_s \frac{h}{2\pi}$

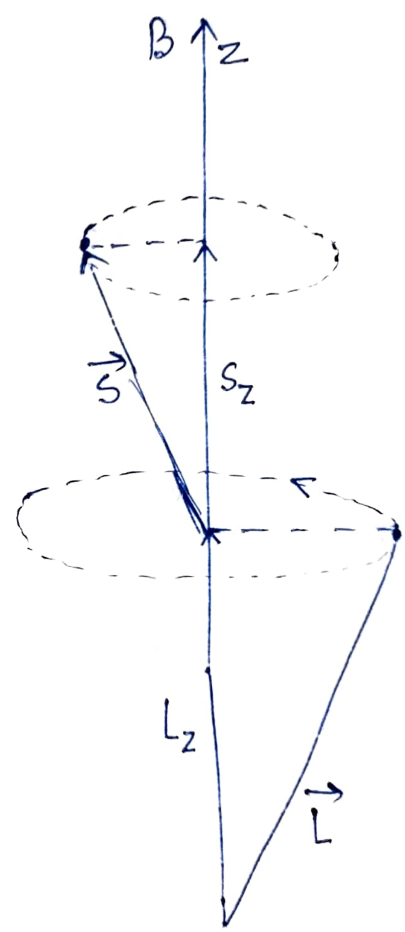

Fig-(1).

where, m_l is the orbital quantum number takes $(2l+1)$ values from $-l$ to $+l$ with a difference of unity and m_s is the spin quantum number takes $(2s+1)$ values from $-s$ to $+s$ with a difference of unity.

By Larmor's theorem the angular velocities of precession of $\vec{L}$ and $\vec{S}$ about the field direction $\vec{B}$ are given by

$$\omega_L = \frac{\mu_L}{|\vec{L}|} B = \frac{e}{2m} B$$

and

$$\omega_S = \frac{\mu_S}{|\vec{S}|} B = 2 \cdot \frac{e}{2m} B$$

The change in energy due to magnetic interaction is equal to

$$\Delta E = \Delta E_L + \Delta E_S$$

$$= \omega_L \cdot L_z + \omega_S \cdot S_z$$

$$= \frac{e}{2m} B \frac{m_l h}{2\pi} + 2 \cdot \frac{e}{2m} B \frac{m_s h}{2\pi}$$

$$= (m_l + 2m_s) \frac{eh}{4\pi m} B$$

The shift in terms of wave-numbers is

$$\Delta T = \frac{\Delta E}{hc}$$

$$= (m_l + 2m_s) \frac{eB}{4\pi mc}$$

i.e.

$$\boxed{\Delta T = (m_l + 2m_s) L'}$$

Where $L' = \frac{eB}{4\pi mc}$ is Lorentz unit and

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$(m_l + 2m_s)$ is called the strong field quantum number and is always an integer even though m_s can assume half-integral values.

Selection Rules :- As $\Delta m_l = 0, \pm 1$, $\Delta m_s = 0$; therefore the selection rule takes the form

$$\Delta(m_l + 2m_s) = 0 \text{ or } \pm 1.$$

This means that in a strong magnetic field a given line will be splitted into three components only, which is the usual characteristics of normal Zeeman effect.

Kbsin