BSc IIIrd year (N.M) Unit 4 Physics (Atom In External field)

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ClassSmart

Imp Quantum Theory Of Anomalous Zeeman effect

when external applied magnetic field $\vec{B}$ is weaker than the internal magnetic field due to spin and orbital motion of the electron and to splitting of spectral line into more than three component line is called anomalous Zeeman effect

Anomalous Zeeman effect can be explained by using the concept of spin.
Acc. to vector atom model, the orbital angular momentum vector l^* & spin angular momentum vector s^* of the valence e^- in an atom precess with a uniform speed around their resultant j^*

$$j^* = l^* + s^*$$

where $l^* = \sqrt{l(l+1)}$
l is orbital quantum no & $l = 0, 1, 2 \ldots$
$s^* = \sqrt{s(s+1)}$, s is spin quantum No.
& $j^* = \sqrt{j(j+1)}$, j is total quantum no $j = l \pm s$

The magnetic moment $\vec{\mu_l}$ due to Orbital motion is given by

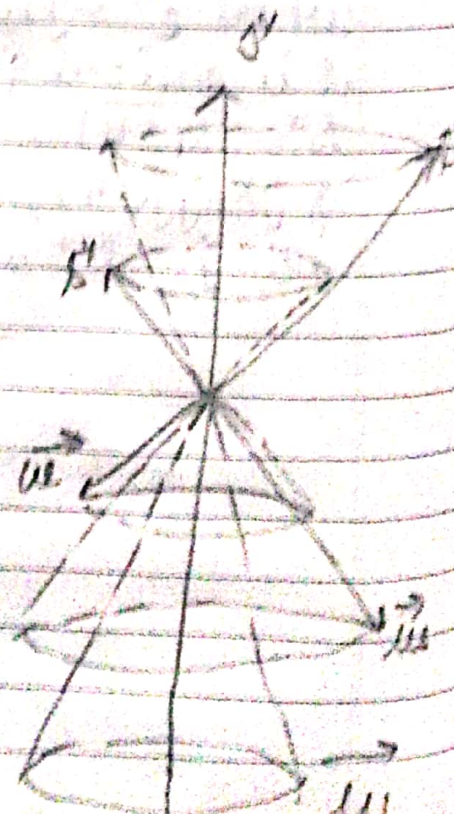
$$\vec{\mu_l} = \frac{eh}{4\pi m} l^* \longrightarrow (1)$$

The spi magnetic moment $\vec{\mu_s}$ due to spin motion is a spin magnetic moment is given as

$$\vec{\mu_s} = \frac{eh}{4\pi m}(2s^*) \longrightarrow (2)$$

The Total magnetic moment μ_j of the atom is the vector sum of Orbital magnetic moment μ_l and spin magnetic moment μ_s (i.e $\vec{\mu_j} = \vec{\mu_l} + \vec{\mu_s}$) and magnitude of $\vec{\mu_j}$ is given by

i.e $\vec{\mu_j} = \vec{\mu_l} + \vec{\mu_s}$



The magnitude of m_j is given by $\mu_j = \left(\frac{eh}{4\pi m}\right) j^* g$

where g is a called a lande's g factor

$$g = 1 + \frac{J^{*2} + S^{*2} - L^{*2}}{2J(J+1)}$$

or $\boxed{\mu_J = \mu_B J^* g} \rightarrow (3)$ $\boxed{\mu_B = \frac{eh}{4\pi m}}$

when a magnetic dipole is placed in a uniform external weak magnetic field $\vec{B}$ Potential energy acquired by the dipole is,

$$V_m = \mu_J \vec{B} \cos\theta \rightarrow (4)$$

Now put value of μ_J in eq (4)

$$V_m = (\mu_B J^* g) B \cos\theta$$

$$V_m = \mu_B g B (J^* \cos\theta)$$

Now put value of $\cos\theta$ $\left[\because \cos\theta = \frac{m_j}{\sqrt{J(J+1)}}\right]$

$$V_m = \mu_B g B J^* \frac{m_j}{\sqrt{J(J+1)}}$$

$$V_m = \mu_B g \sqrt{J(J+1)} \frac{m_j}{\sqrt{J(J+1)}}$$

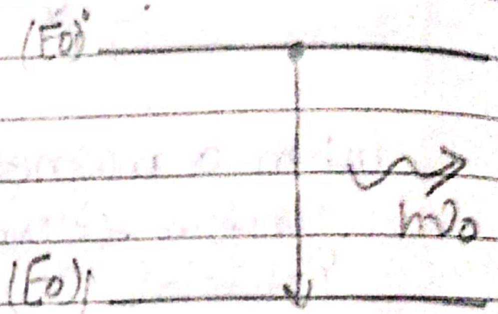
$$V_m = \mu_B g m_j \vec{B}$$

$$\boxed{V_m = g m_j \mu_B \vec{B}} \rightarrow (5)$$

If no magnetic field is applied $\vec{B}=0$
In that case electron jump from initial higher energy $(E_0)_i$ to final lower state $(E_0)_f$
The frequency of emitted spectral line is given by

$$h\nu_0 = (E_0)_i - (E_0)_f$$

$$\nu_0 = \frac{(E_0)_i - (E_0)_f}{h}$$

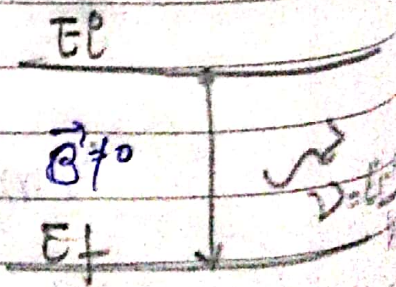


If magnetic field is applied ; The total energy E of atom is
[put Vm value]

$$E = E_0 + V_m$$
$$E = E_0 + g m_j \mu_B B$$

Now
$$E_i = (E_0)_i + g_i (m_j)_i \mu_B B$$
$$E_f = (E_0)_f + g_f (m_j)_f \mu_B B$$

Now, If electron jump from higher energy state E_i to lower energy state E_f



The frequency of emitted spectral line is given by

$$\nu = \frac{E_i - E_f}{h}$$

$$\nu = \frac{(E_0)_i - (E_0)_f}{h} + \frac{\mu_B B}{h}\left[g_i (m_j)_i - g_f (m_j)_f\right]$$

$$\boxed{\nu = \frac{\nu_0}{h} + \Delta\nu\left[g_i (m_j)_i - g_f (m_j)_f\right]}$$

$$\Delta\nu = \frac{\mu_B B}{h} = \frac{e\hbar B}{2mh} \qquad \left(\mu_B = \frac{e\hbar}{4\pi m}\right)$$

$$\boxed{\Delta\nu = \frac{eh}{4\pi m} B}$$

The anamalous Zeeman effect is Observed when the applied field is weak and the spectral line split into four or more lines