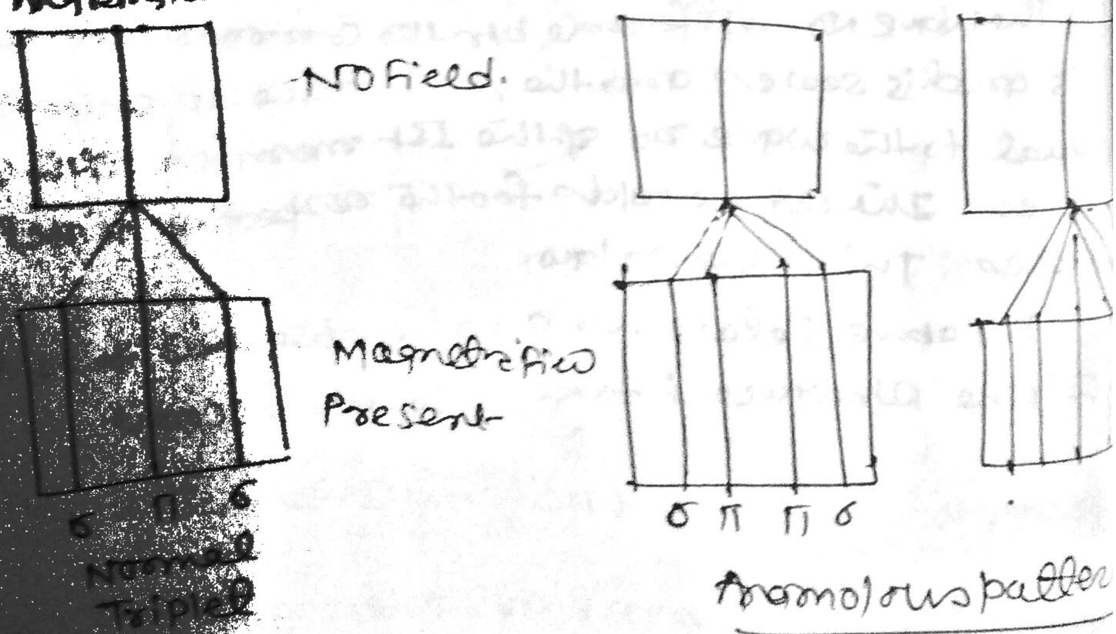
The ZEEMAN EFFECT:-

Normal and anomalous effects:-

Zeeman in 1896, observed that, when the atom is (light source) is placed in an external magnetic field, the spectral lines it emits are split into several polarised components. For fields less than several tenths of 1 tesla, the splitting is proportional to the strength of the field. The effect of magnetic field on the atomic spectral lines is called Zeeman effect.

A single spectral lines viewed normal to the field is split into three plane polarised components, a central unshifted line with the electric vector vibrating parallel to the field (called π component) and two other lines equally displaced one on either side with electric vector perpendicular to the field (called σ component). This is called normal triplet and the effect is called the normal Zeeman effect.

any singlet



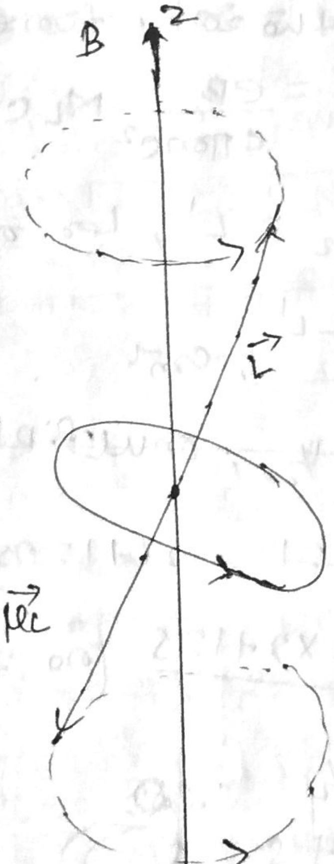
Explanation of normal zeeman effect :-

The normal zeeman effect which is shown by all lines due to transitions b/w the singlet ($S=0$) states of an atom, can be explained from the classical electron theory and also from the quantum theory without taking note of electron spin.

In quantum theory, a polyelectronic atom possesses an orbital angular momentum $\vec{L}$ and an orbital magnetic moment $\vec{\mu_L}$, with gyromagnetic ratio,

$$\boxed{\frac{|\vec{\mu_L}|}{|\vec{L}|} = \frac{e}{2mc}}$$

$e \rightarrow$ charge of the $\bar{e}$
$m \rightarrow$ mass of the $\bar{e}$
$c \rightarrow$ velocity of light



Vector $\vec{\mu_L}$ is directed opposite to the vector $\vec{L}$ b/cz the $\bar{e}$ is -ve charged.

When the atom is in external Mag. field B. say along the z-axis, vector $\vec{L}$ precesses around the field direction with quantised components,

$$\boxed{L_z = M_L \frac{h}{2\pi}}$$

The Magnetic orbital quantum no. M_L is

$M_L = L, L-1, \ldots -L$

angular velocity. $\boxed{\omega = \frac{|\vec{\mu_L}| B}{|\vec{L}|} = \frac{e}{2mc} B}$

The interaction energy of such a precession is equal to the product of the angular velocity and projection of $\vec{L}$ along the field is

$$\boxed{\Delta E = \omega L_z = \frac{e}{2mc} B M_L \frac{h}{2\pi}}$$

or $\Delta E = \frac{eh}{4\pi mc} B M_L$

In wavenumbers, the interaction energy is

$$-\Delta T = \frac{\Delta E}{hc} = \frac{eB}{4\pi mc^2} M_L \, cm^{-1}$$

or, $\boxed{\frac{eB}{4\pi mc^2} = L', \text{ Lorentz unit}}$

Thus, $\boxed{-\Delta T = M_L L'}$ cm^{-1}

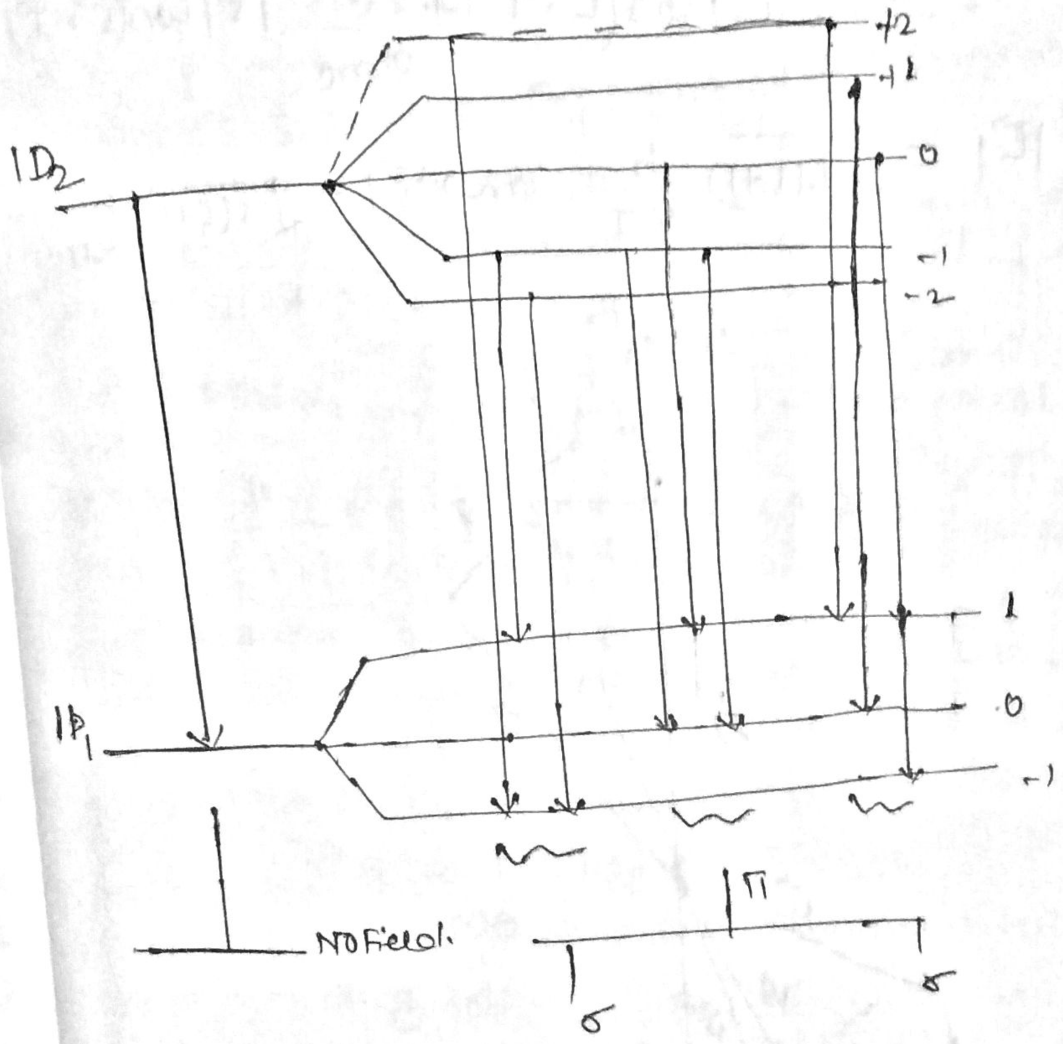
~~$^1D_2$ $l = 2$ $s = 1/2$, multiplicity $2s+1 = 2$~~

1D − 1P $L = 2$, $L = 1$, $2L+1 = 2\times1+1 = 3$. (no. of lines)

$2L+1 = 2\times2+1 = 5$ (no. of lines)

$L = 2$, $s = 1/2$ $\therefore$ ^2D

$J = L + S = 5/2$



→ The selection for the magnetic quantum Number as derived by Quantum mechanics

$$\boxed{\Delta M_L = 0, \pm 1}$$

Explanation of Anomalous Zeeman effect :-

The spectral lines which arise from transitions b/n components of multiplet levels produce a complex zeeman pattern. The explanation of this anomalous zeeman effect is found in the spin of the electron.

$$\text{angular momentum} = M_J \frac{h}{2\pi}$$

where $M_J = J, \; J-1 \; \ldots -J+1$

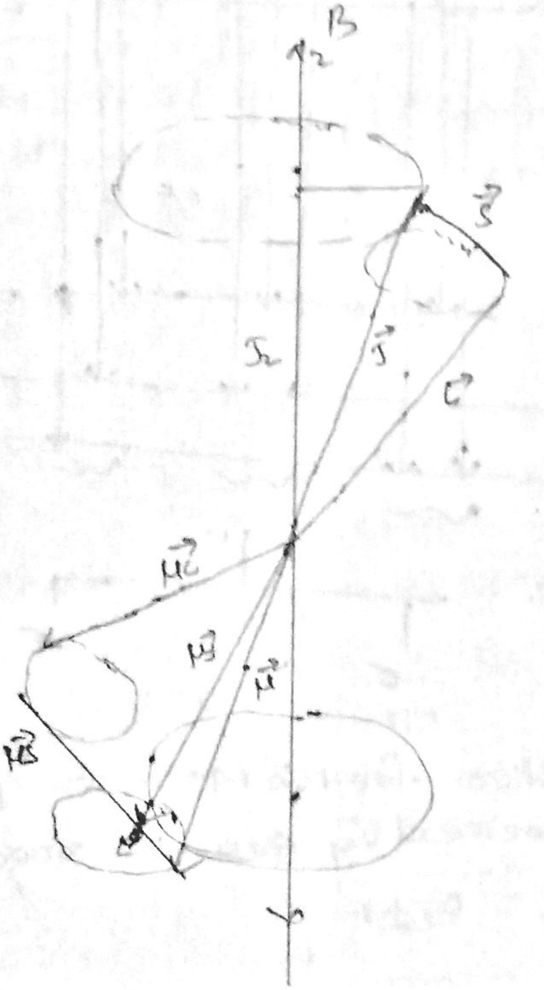
that is in all $2J+1$ values

μ_J = Component of $\vec{\mu}_L$ along $\vec{J}$ + Component of $\vec{\mu}_S$ along $\vec{J}$

$$= |\vec{\mu}_L| \cos(\vec{L}, \vec{J}) + |\vec{\mu}_S| \cos(\vec{S}, \vec{J})$$

$$= \frac{e}{2mc} |\vec{L}| \cos(\vec{L}, \vec{J}) + \frac{2e}{2mc} |\vec{S}| \cos(\vec{S}, \vec{J})$$

But $\boxed{|\vec{L}| = \sqrt{L(L+1)} \frac{h}{2\pi}}$ and $\boxed{|\vec{S}| = \sqrt{S(S+1)} \frac{h}{2\pi}}$



$$\therefore \mu_J = \frac{e}{2mc} \left[\sqrt{L(L+1)} \cos(\vec{L}, \vec{J}) + 2\sqrt{S(S+1)} \cos(\vec{S}, \vec{J}) \right] \frac{h}{2\pi}$$

Using Cosine law

$$\cos(\vec{L}, \vec{J}) = \frac{J(J+1) + L(L+1) - S(S+1)}{2\sqrt{J(J+1)}\sqrt{L(L+1)}}$$

and
$$\cos(\vec{S}, \vec{J}) = \frac{J(J+1) + S(S+1) - L(L+1)}{2\sqrt{J(J+1)}\sqrt{S(S+1)}}$$

$$\therefore \mu_J = \frac{e}{2mc} \left[\frac{J(J+1) + L(L+1) - S(S+1)}{2\sqrt{J(J+1)}} + \frac{J(J+1) + S(S+1) - L(L+1)}{\sqrt{J(J+1)}} \right] h/2\pi$$

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

$$\underset{\text{Total Mag. moment}}{\underset{\downarrow}{M_J}} = g \frac{e}{2mc} \sqrt{J(J+1)} \frac{h}{2\pi} = g \frac{e}{2mc} |\vec{J}|$$

and $\boxed{\frac{M_J}{|\vec{J}|} = g \frac{e}{2mc}}$

Larmore precession $\boxed{\omega = \frac{M_J}{|\vec{J}|} B = g \frac{e}{2mc} B.}$

$$\Delta E = \omega J_z$$

$$= g \frac{e}{2mc} B M_j \frac{h}{2\pi}$$

$$= g M_j \frac{eh}{4\pi mc} B.$$

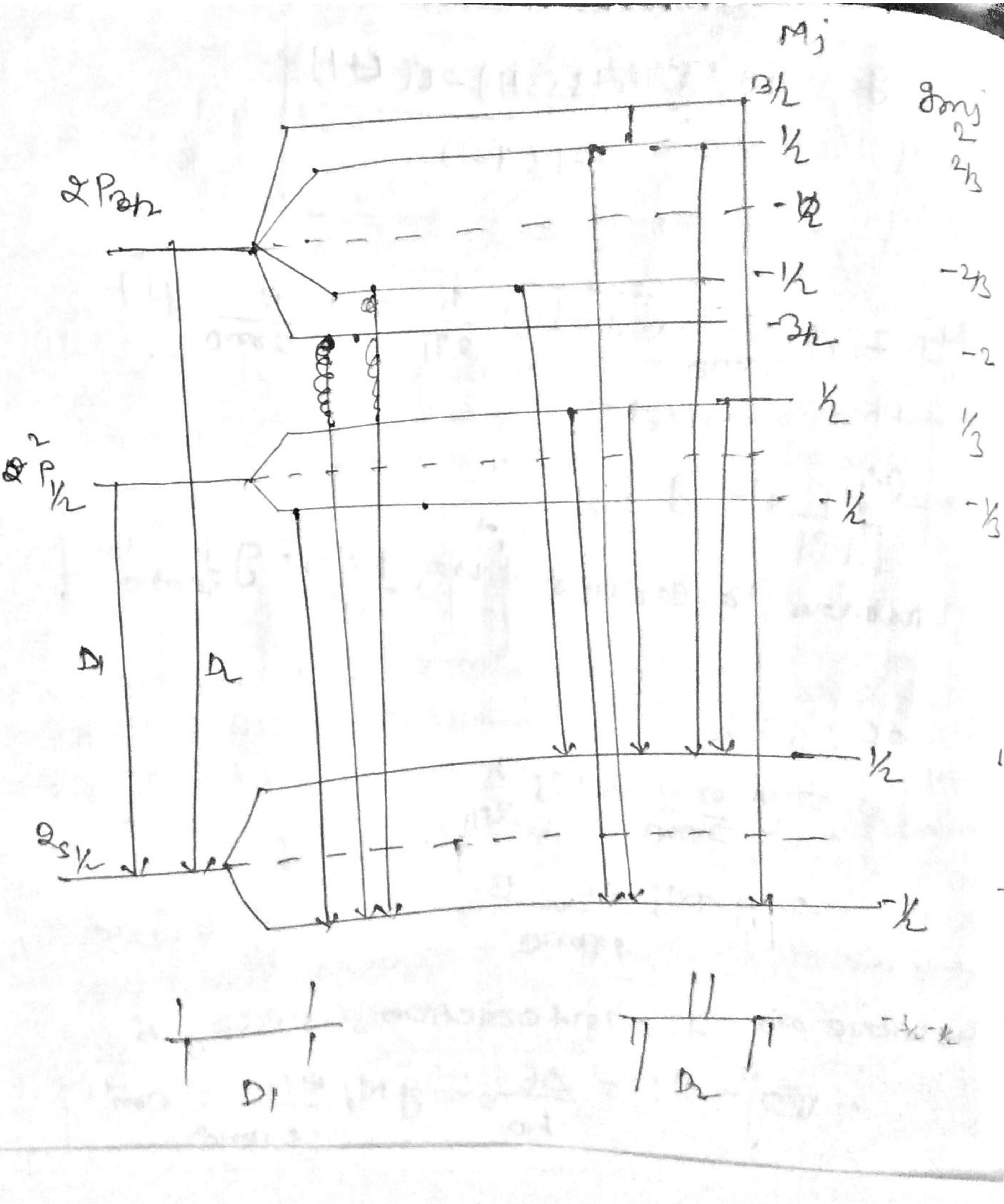
The wave no. the interaction energy is

$$-\Delta T = \boxed{\frac{\Delta E}{hc} = g M_j \frac{eB}{4\pi mc^2} \text{ cm}^{-1}.}$$

$\frac{eB}{4\pi mc^2}$ → Lorentz unit

so $\boxed{-\Delta T = g M_j L' \text{ cm}^{-1}}$

Term	No of Zeeman levels $2J+1$	g	M_j $+J \to -J$	Shift in Lorent unit gM_j
$2S_{1/2}$ $L=0, S=\frac{1}{2}$ $J=\frac{1}{2}$	$2 \times \frac{1}{2} + 1 = 2$	2	$\pm \frac{1}{2}$	$2 \cdot \frac{1}{2} = \pm 1$
$2P_{1/2}$ $L=1, S=\frac{1}{2}$ $J=\frac{1}{2}$	$2 \times \frac{1}{2} + 1 = 2$	$\frac{1}{3}$	$\pm \frac{1}{2}$	$\frac{1}{3} \pm \frac{1}{2} = \pm \frac{1}{6}$



Mj
gmj
3/2
1/2
-1/2
-1/2
-3/2
2
2/3
-2/3
-2
1/3
-1/3
²P3/2
²P1/2
²S1/2
D1
D2
1/2
-1/2
1/2
-1/2
D1
D2