B.Sc - IIIrd

Unit-4

ATOM IN AN EXTERNAL FORCE FIELD

In General, the spectral line is split into several components. splitting of spectral lines into several components by application of magnetic field was first of all discovered by Zeeman in 1896 and hence is called Zeeman effect.
The effect of larger value of magnetic field on the spectrum of an element is called Paschen-Back effect.
The effect of electric field on spectrum of an element was studied by stark in 1913 and is called Stark effect.

Zeeman effect:-

Splitting of spectral line into several components by application of magnetic field is called zeeman effect

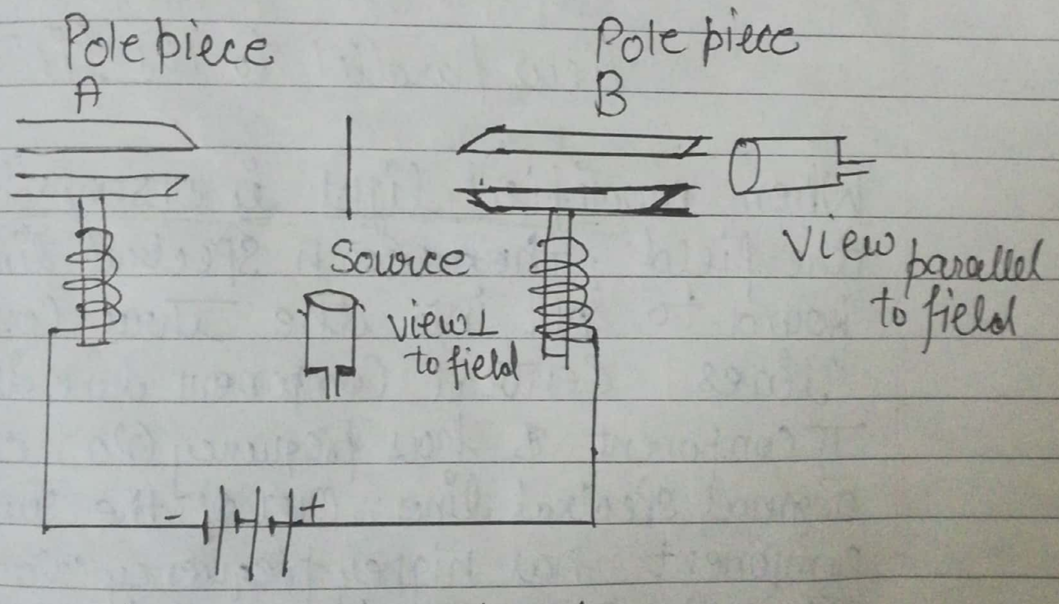
It is of two types;
① Normal zeeman effect
② Anomalous zeeman effect

It is observed that change in the frequency of lines is directly proportional to the magnitude of applied field magnetic field.
This shows that in an atom, there are some

additional discrete energylevels

Experimental Arrangement of Zeeman Effect

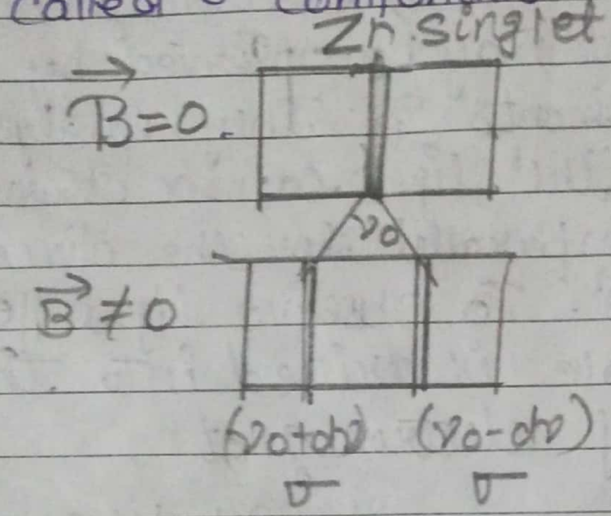
Consider a Source of light ray sodium lamp (S), placed b/w 2 pole pieces A & B of a strong (magnetic field) electromagnet. The modified light may be observed by high resolving Instruments & They analysed by Nicol prism the light can be observed both perpendicular & parallel to the direction of applied field $\vec{B}$. To observe light ||el to the field a hole is drilled into the pole pieces A & B of electromagnet.



* Normal zeeman effect

When modified light is observed parallel to the field, then each spectral line is found to split into the two Components lines. One component line has higher frequency ($\nu_0 + d\nu$) and other component line have lower frequency

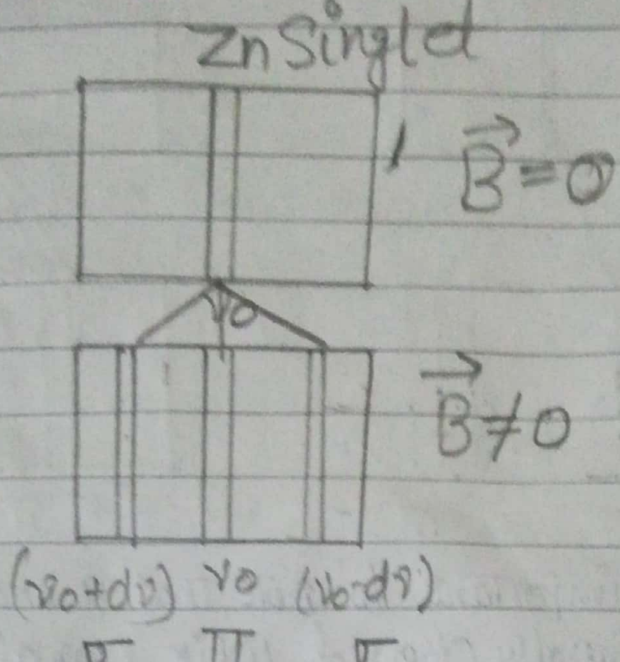
$(\nu_0 - d\nu)$ than the frequency (ν_0) of the original line. Original line is not observed in presence of $\vec{B}$. Though the original light is unpolarized, the 2 components are found to be circularly polarized. The two component lines are called σ components.



View parallel to the field

When modified light is observed ⊥er to the field, then each spectral line is found to split into the three component lines. Central component line is called π component & has frequency (ν_0) of the original spectral line. Out of the two remaining component has higher frequency $(\nu_0 + d\nu)$ & other component of lower frequency $(\nu_0 - d\nu)$ than the frequency (ν_0) of the original line. These two components on either side of central component are separated by equal distance pair from the central component and are called σ components. Though the original line is unpolarized while all the three

Component lines are found to be Polarized



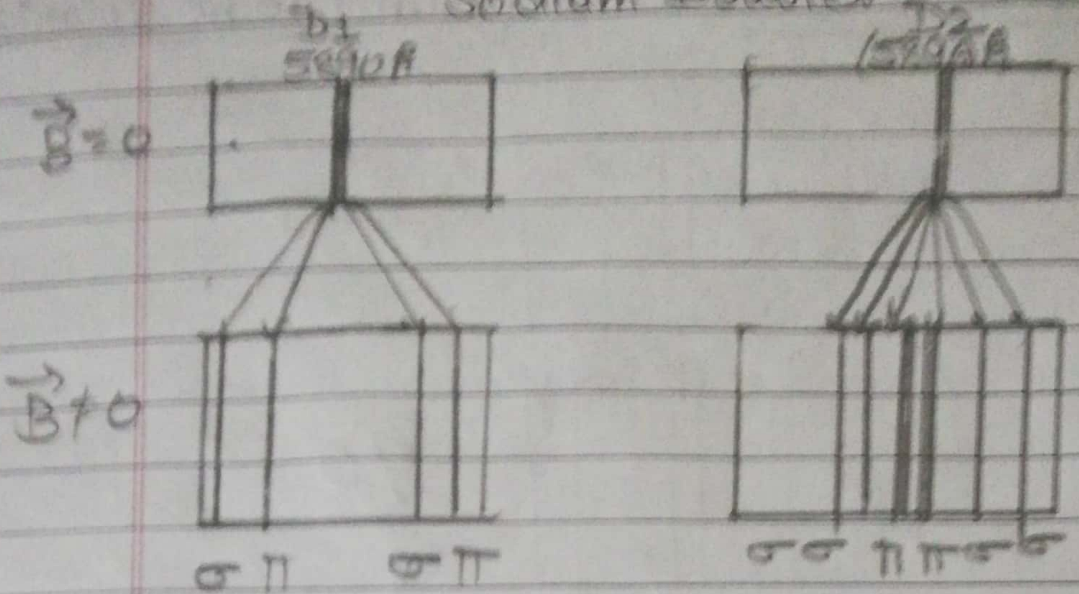
view ⊥er to the field

The phenomenon of splitting of a spectral line into three components (original line absent in parallel view) in presence of strong is called normal Zeeman effect

* Anomalous Zeeman effect :-

The splitting of spectral line into a number of components lines (i.e more than three components) in the presence of external magnetic field is called anomalous Zeeman effect

Sodium Doublet



It is important to note that anomalous Zeeman effect is generally observed while normal zeeman effect rarely occurs. However Normal zeeman effect is called Normal because it explained from classical theory while anomalous Zeeman effect can not be explained from classical theory and that is why they called Normal and anomalous effects.

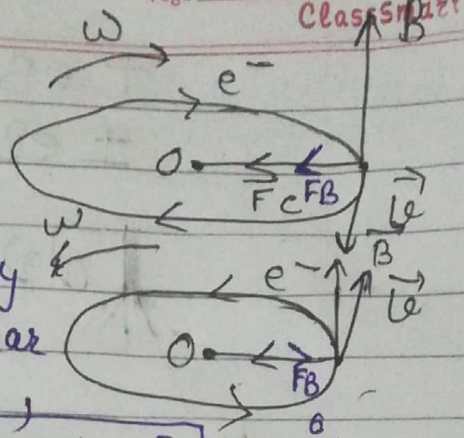
* Classical theory of Normal Zeeman Effect

This theory was given by lorentz.

Consider an electron of mass m & charge e moving in a circular path of radius r and velocity $\vec{v}$. The necessary centripetal force required for the motion of the e^- is given by

$$F_c = \frac{mv^2}{r} = \frac{m(r\omega)^2}{r} \qquad \boxed{v = r\omega}$$

$$F_c = \frac{m r^2 \omega^2}{r} \Rightarrow \boxed{F_c = m r \omega^2} \quad (1)$$



~~when~~
Where ω is angular velocity of electron.
If v is the linear velocity of electron and perpendicular magnetic field $\vec{B}$ is applied, and additional force $\boxed{F_B = evB}$ → (2) is experienced by electron

Let dω be change in angular velocity of e^- due to applied magnetic field $(\vec{B})$

In Equilibrium the eq^n of motion is given by ($\omega \to \omega + d\omega$)
By using eq^n (1) & (2)

$$F_C \pm |F_B| = mr(\omega + d\omega)^2 \pm evB$$

$$F_C \pm F_B = mr(\omega + d\omega)^2$$

$$mr\omega^2 \pm evB = mr\omega^2 + mr(d\omega)^2 + 2mr\omega d\omega \rightarrow (3)$$

$$\pm evB = mr(d\omega)^2 + 2mr\omega d\omega$$

Since dω is small, so the term containing $(d\omega)^2$ is neglected

$$\pm evB = 2m(r\omega)d\omega$$

$$\pm evB = 2mv\,d\omega \rightarrow (4)$$

We know $r\omega = v$

$$\pm eB = 2m\,d\omega \rightarrow (5)$$

As $\omega = 2\pi\nu$
so, $d\omega = 2\pi d\nu \rightarrow (6)$
By using (6) in (5)

$$\pm eB = 2m(2\pi d\nu)$$

$$\pm eB = 4\pi m d\nu$$

$$d\nu = \frac{\pm eB}{4\pi m} \longrightarrow (7)$$

Know convert ν into λ term

As $\nu = \frac{c}{\lambda}$

$$d\nu = -\frac{c}{\lambda^2} d\lambda \longrightarrow (8)$$

Comparing eq^n (7) & (8)

$$\frac{\pm eB}{4\pi m} = -\frac{c}{\lambda^2} d\lambda$$

$$\mp \frac{\lambda^2 eB}{c 4\pi m} = d\lambda \longrightarrow (9)$$

eq^n (9) represent the change in wavelength called Zeeman shift of the spectral line.