Dr. Ranjana Singh
Assistant Professor, Physics
Har Prasad Das Jain college
Ara, Bihar, India

Date: 21/02/2025
Time: 01 pm

MPHYCC10-15

Nuclear spin & hyperfine splitting:→

Isotope effect failed to explain the hyperfine splitting in many cases. It was seen that the number of hyperfine components is often greater than the number of isotopes. It was also observed that certain element having single isotope, still have hyperfine structure. Pauli in 1924 pointed out that hyperfine structure can be explained by assuming the atomic nucleus contain an intrinsic spin angular momentum I. Magnetic dipole moment $\vec{\mu}_I$ is associated with $\vec{I}$.

magnitude of nuclear angular momentum is

$$|\vec{I}| = \sqrt{I(I+1)}\,\frac{h}{2\pi} \quad (1)$$

I = nuclear spin quantum number.

Angular momentum has different magnitude for different nuclei. Also it is different ~~from~~ for different isotopes of the same element.

Just as $\vec{L}$, $\vec{S}$ & $\vec{J}$ have quantized component along an axis in space, the component of $\vec{I}$ along the z axis is

$$I_z = M_I \frac{h}{2\pi} \quad - (2)$$

possible values of magnetic quantum number M_I is $2I+1$

where $M_I = I, I-1, I-2 \;---\; -I$

Nuclear proton/neutron motions produces magnetic moment $\vec{\mu}_I$.

$$\vec{\mu}_I = g_I\left(\frac{e}{2m_p}\right)\vec{I} \quad (3)$$

e = charge on proton, m_p = mass of proton, g_I = nuclear g factor.

$$\mu_I = g_I\left(\frac{e}{2m_p}\right)\sqrt{I(I+1)}\,\frac{h}{2\pi} \quad -- (4)$$

$$\mu_I = g_I \frac{eh}{4\pi m_p}\sqrt{I(I+1)} = g_I\sqrt{I(I+1)}\,\mu_N \quad -- (5)$$

Assistant Professor, Physics
HarPrasad Das Jain college
Ara, Bihar, India

MPHYCC10_13

$\mu_N = \frac{eh}{4\pi m_p}$ = (6) nuclear magneton

proton mass = 1836 times mass of electron

hence $\mu_N = \frac{1}{1836} \times \mu_e$ - (7) μ_e = Bohr magneton.

component of ~~the~~ μ_I along z axis

$$\mu_{IZ} = g_I M_I \mu_N \quad - (8)$$

maximum value of M is I

Improved atomic vector model :→

Now ~~for~~ the atomic vector model constructed taking the nuclear spin into account. The total angular momentum of the atom is the vector sum of three angular momenta

(a) electron orbital angular momentum $\vec{L}$
(b) electron spin angular momentum $\vec{S}$
(c) Nuclear spin angular momentum $\vec{I}$

Total angular momentum $\vec{F}$ is

$$\vec{F} = \vec{L} + \vec{S} + \vec{I} = \vec{J} + \vec{I}$$

Due to interaction between electron orbit and spin, $\vec{L}$ & $\vec{S}$ precess rapidly around resultant $\vec{J}$.

Further, the interaction between the nuclear magnetic moment and magnetic field produced by the orbital and spin motion of the atomic electrons couples $\vec{I}$ with $\vec{J}$ causes these vectors to precess around their resultant $\vec{F}$.

Precession of $\vec{I}$, & $\vec{J}$ is 1000 times smaller than $\vec{L}$ & $\vec{S}$ about $\vec{J}$ hence the energy difference are very much smaller.

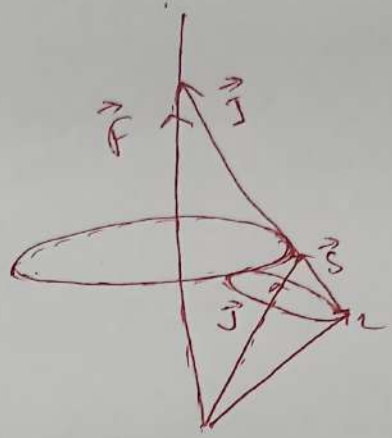
Dr. Ranjana Singh
Assistant Professor Physics
HarPrasad Das Jain College
Ara, Bihar, India.

Date: [illegible]
Time: 01 pm

MPHYCC10_15

The quantized values of the angular momentum $\vec{F}$ are

$\sqrt{F(F+1)}\,\frac{h}{2\pi}$ F = hyperfine splitting quantum number



$F = J+I,\ J+I-1 \ \cdots\cdots\ |J-I|$

$I \geq J$ then $F = 2J+1$

$I \leq J$ then $F = 2I+1$

Interaction energy:→ The interaction energy due to $\vec{I}$ & $\vec{J}$ can be given as

$$E_{I,J} = \frac{1}{2}A'\left[F(F+1) - I(I+1) - J(J+1)\right] \quad -(1)$$

$A' = $ constant

The various hyperfine splited level of a given term value for the given atom have same I & J value but different F value.

Hence the sepration between two hyperfine splited levels can be obtained by substituting first F+1 then F. The energy sepration between F+1 & F values

$$\boxed{\Delta E' = A'(F+1)} \quad --- (2)$$

The order of hfs levels in some hypermultiplets is normal i.e smallest F level deepest while in some it is inverted i.e. largest F level is deepest.

selection rule for F, $\Delta F = 0, \pm 1$ but $F=0 \not\leftrightarrow F=0$

Dr. Ranjana Singh
Assistant Professor Physics
HarPrasad Das Jain College
Ara, Bihar, India

Date: 21/02/2025
Time: 01 pm

MPHYCC10_15

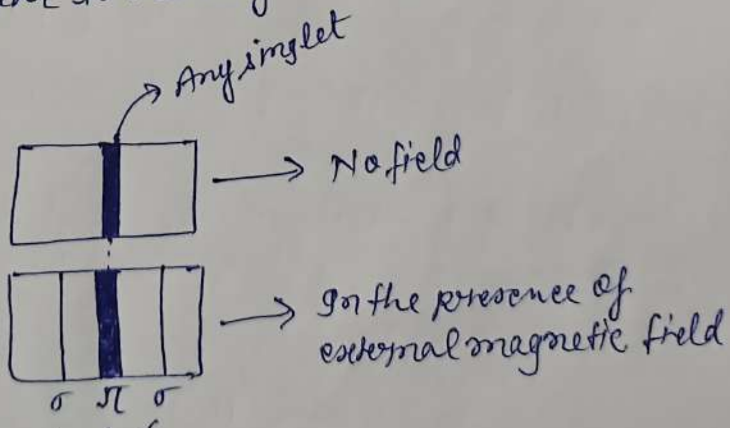
Zeeman effect : It was envented by Zeeman in 1896. He obsorved that light source giving line spectrum placed in external magnetic field, the spectral lines emitted by the atomic source split into a number of polarised components. This effect of magnetic field on the atomic spectral lines is called "Zeeman effect".

There are two types of 'Zeeman effect' obsorved in the presence of external magnetic field.

Normal Zeeman effect :- In the presence of external magnetic field a singlet spectral line viewed at right angles to the external magnetic field direction split into three plane-polarised components.

A central unshifted line with electric vector vibrating parellel to the magnetic field is known as π component.

Two other lines epually displaced on either side with electric vector vibrating perpendicular to the magnetic field is known as σ component.



Normal triplet