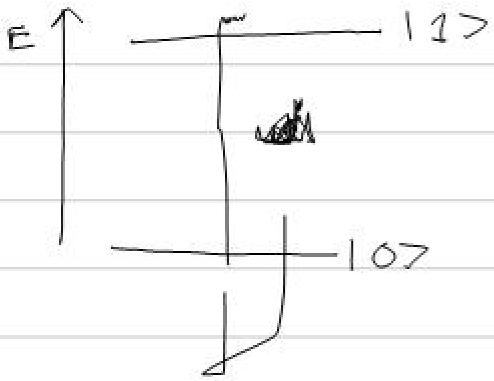
NMR - Spectroscopy

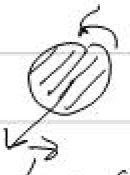
$\Delta E = h\nu$ ↖ frequency in rf range (10-900 MHz)

↑ change b/w two states

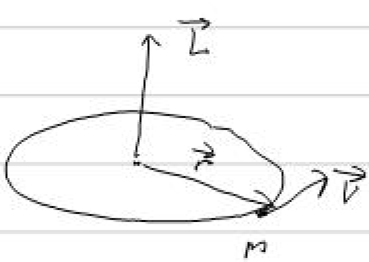


Angular momentum (classical), $\vec{L}$

- rotating object



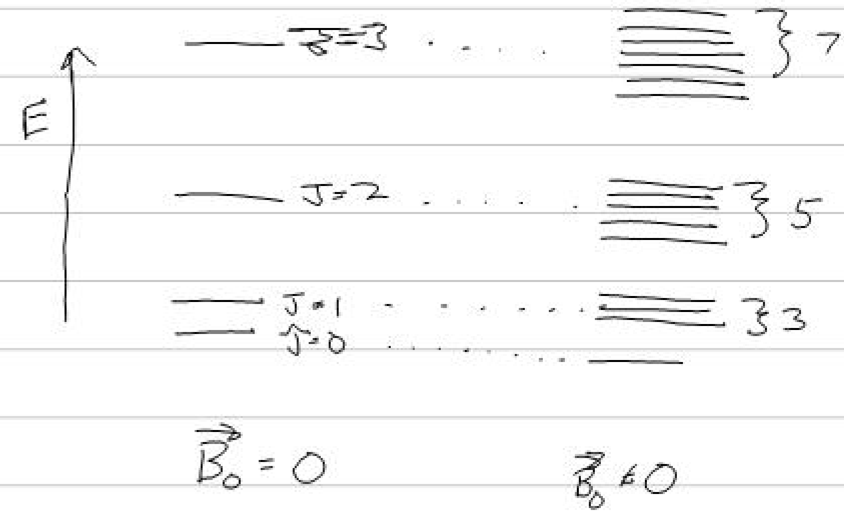
$\vec{L}$, right hand rule



$\vec{L} = m\vec{v} \times \vec{r}$? ← check

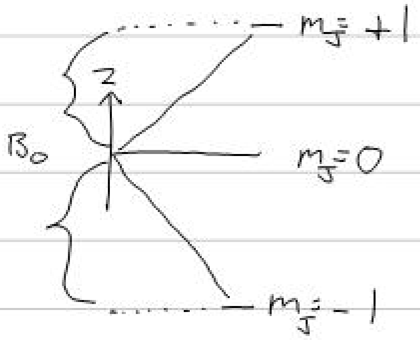
Quantum mechanics

$L_{tot} = \sqrt{J(J+1)}\hbar$ $J = 0, 1, 2, 3, 4, ..$



2J+1 sublevels
Zeeman Effect leads to removal of degeneracy

Quantization of angular momentum → quantize energy, specified by appropriate quantum numbers



1924 - Fine structure in atomic spectra couldn't be explained by quantum numbers n, ℓ, m_ℓ

Pauli - hypothesized that the nuclei possess magnetic moment~~s~~

Electrons spin quantum number $s = \frac{1}{2}$
(γ is negative)

Nuclear spin quantum number $I = \Big(\overset{\text{half integer}}{\underset{\text{(common)}}{\frac{1}{2}}},\ \overset{\text{integer}}{\overbrace{0,\ 1,\ \frac{n}{2}}}$

$^{13}C \rightarrow I = \frac{1}{2}$ $\qquad$ $^{1}H \rightarrow I = \frac{1}{2}$

$^{12}C \rightarrow I = 0$ $\qquad$ $^{2}H \rightarrow I = 1$

$^{69}Ga \rightarrow I = \frac{3}{2}$

Rules

Examples

- even # protons / even # neutrons } $I = 0$ $\qquad$ ^{12}C, ^{16}O

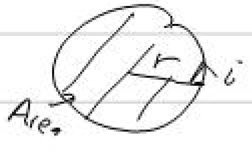
- odd # protons / odd # neutrons } $I =$ integer $\qquad$ ~~^{10}B~~ ^{2}H, $I = 1$
^{10}B, $I = 3$

- even # protons / odd # neutrons / or vice versa } $I =$ half integer $\qquad$ ^{13}C, $I = \frac{1}{2}$

$I > \frac{1}{2}$ (special), Quadrupolar nuclei

Relationship between magnetic moments and angular moment

Circulating charge in a loop of wire



$\mu = iA$ (amps m^2)

For a circle, $v = \frac{\text{circumference}}{\text{time}} = \frac{2\pi r}{t} \Rightarrow t = \frac{2\pi r}{v}$

$\mu = iA = \frac{q}{t} \cdot \pi r^2 = \frac{qv}{2\cancel{\pi r}}(\cancel{\pi} r^{\cancel{2}}) = \frac{qvr}{2}$

Recall $L = mvr$

So, $\vec{\mu} = \frac{q}{2m}\vec{L}$

→ So, angular momentum and magnetic moment are related.

$\vec{\mu} = \gamma \vec{L}$

gyromagnetic ratio, proportionality constant

$\gamma \doteq$ gyromagnetic ratio
units appear to be $\frac{\text{charge}}{\text{mass}}$
typical units $\frac{\text{rad}}{\text{s} \cdot \text{T}}$

^1H: $\gamma = 26.75 \cdot 10^7 \frac{\text{rad}}{\text{s} \cdot \text{T}}$ (high)

^{109}Ag: $\gamma = -1.250 \cdot 10^7 \frac{\text{rad}}{\text{s} \cdot \text{T}}$ (low)

e^-: $\gamma =$ big, negative