Physics 2D Lecture Slides
Lecture 31: March 11th 2005
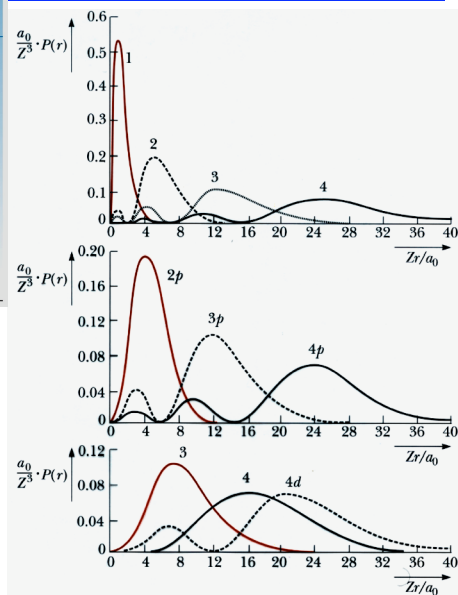
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Radial Probability Distribution $P(r) = r^2 R(r)$

TABLE 7-2 Radial functions for hydrogen

$n = 1$	$l = 0$	$R_{10} = \dfrac{2}{\sqrt{a_0^3}} e^{-r/a_0}$
$n = 2$	$l = 0$	$R_{20} = \dfrac{1}{\sqrt{2a_0^3}}\left(1 - \dfrac{r}{2a_0}\right) e^{-r/2a_0}$
	$l = 1$	$R_{21} = \dfrac{1}{2\sqrt{6a_0^3}} \dfrac{r}{a_0} e^{-r/2a_0}$
$n = 3$	$l = 0$	$R_{30} = \dfrac{2}{3\sqrt{3a_0^3}}\left(1 - \dfrac{2r}{3a_0} + \dfrac{2r^2}{27a_0^2}\right) e^{-r/3a_0}$
	$l = 1$	$R_{31} = \dfrac{8}{27\sqrt{6a_0^3}} \dfrac{r}{a_0}\left(1 - \dfrac{r}{6a_0}\right) e^{-r/3a_0}$
	$l = 2$	$R_{32} = \dfrac{4}{8\sqrt{30a_0^3}} \dfrac{r^2}{a_0^2} e^{-r/3a_0}$

Because $P(r) = r^2 R(r)$

No matter what R(r) is for some n

The prob. Of finding electron

inside nucleus = 0

TABLE 7-1 Spherical harmonics

$l = 0$	$m = 0$	$Y_{00} = \sqrt{\dfrac{1}{4\pi}}$
$l = 1$	$m = 1$	$Y_{11} = -\sqrt{\dfrac{3}{8\pi}}\,\sin\theta\;e^{i\phi}$
	$m = 0$	$Y_{10} = \sqrt{\dfrac{3}{4\pi}}\,\cos\theta$
	$m = -1$	$Y_{1-1} = \sqrt{\dfrac{3}{8\pi}}\,\sin\theta\;e^{-i\phi}$
$l = 2$	$m = 2$	$Y_{22} = \sqrt{\dfrac{15}{32\pi}}\,\sin^2\theta\;e^{2i\phi}$
	$m = 1$	$Y_{21} = -\sqrt{\dfrac{15}{8\pi}}\,\sin\theta\cos\theta\;e^{i\phi}$
	$m = 0$	$Y_{20} = \sqrt{\dfrac{5}{16\pi}}\,(3\cos^2\theta - 1)$
	$m = -1$	$Y_{2-1} = \sqrt{\dfrac{15}{8\pi}}\,\sin\theta\cos\theta\;e^{-i\phi}$
	$m = -2$	$Y_{2-2} = \sqrt{\dfrac{15}{32\pi}}\,\sin^2\theta\;e^{-2i\phi}$

Excited States (n>1) of Hydrogen Atom : Birth of Chemistry !

Features of Wavefunction in θ & ϕ :

Consider $n = 2,\ l = 0 \implies \psi_{200} = $ Spherically Symmetric (last slide)

Excited States (3 & each with same E_n) :

$\psi_{211}, \psi_{210},\ \psi_{21\text{-}1}$ are all 2p states

$\psi_{211} = R_{21}Y_1^1 = \left(\dfrac{1}{\pi}\right)\left(\dfrac{Z}{a_0}\right)^{3/2}\left(\dfrac{Z}{8}\right)\left(\dfrac{r}{a_0}\right)e^{\frac{-Zr}{a_0}}.\sin\theta.e^{i\phi}$

$\boxed{|\psi_{211}|^2 = |\psi_{211}^{*}\psi_{211}|\ \propto \sin^2\theta}$ Max at $\theta = \dfrac{\pi}{2}$, min at θ=0; Symm in ϕ
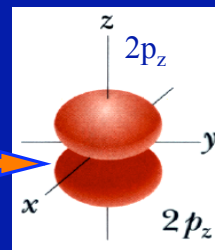
What about (n=2, ℓ=1,m_l = 0)

$\psi_{210} = R_{21}(r)\,Y_1^0(\theta,\phi);$

$Y_1^0(\theta,\phi) \propto \dfrac{1}{2}\sqrt{\dfrac{3}{\pi}}\cos\theta;$

Function is max at θ=0, min at $\theta = \dfrac{\pi}{2}$

We call this $2p_z$ state because of its extent in z

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Excited States (n>1) of Hydrogen Atom : Birth of Chemistry !

Remember Principle of Linear Superposition

for the TISE which is basically a simple differential equation:

$$-\frac{\hbar^2}{2m}\nabla^2\psi + U\psi = E\psi$$

Principle of Linear Superposition $\Rightarrow$ If ψ_1 and ψ_2 are sol. of TISE
then a "designer" wavefunction made of linear sum
$\psi' = a\psi_1 + b\psi_2$ is also a sol. of the diff. equation !
To check this, just substitute ψ' in place of ψ
& convince yourself that

$$-\frac{\hbar^2}{2m}\nabla^2\psi' + U\psi' = E\psi'$$

The diversity in Chemistry and Biology DEPENDS
on this superposition rule

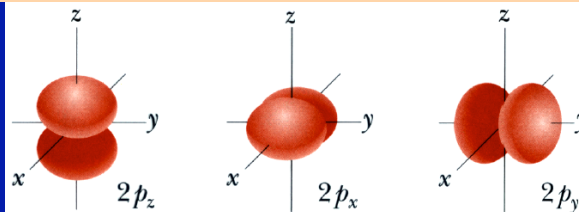## Designer Wave Functions: Solutions of S. Eq !

Linear Superposition Principle means allows me to "cook up" wavefunctions

$$\psi_{2p_x} = \frac{1}{\sqrt{2}}\left[\psi_{211} + \psi_{21-1}\right] \dots\dots\text{has electron "cloud" oriented along x axis}$$
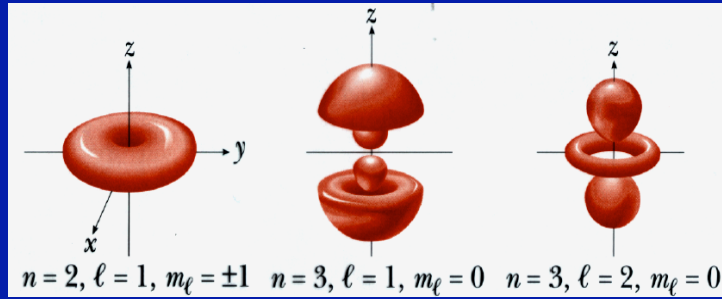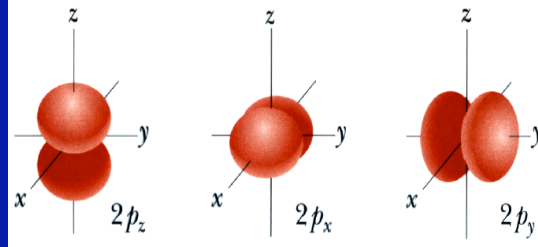
$$\psi_{2p_y} = \frac{1}{\sqrt{2}}\left[\psi_{211} - \psi_{21-1}\right] \dots\dots\text{has electron "cloud" oriented along y axis}$$

So from 4 solutions $\psi_{200}, \psi_{210}, \psi_{211}, \psi_{21-1} \rightarrow 2s, 2p_x, 2p_y, 2p_z$

Similarly for n=3 states ...and so on ...can get very complicated structure
in θ & ϕ.......which I can then mix & match to make electrons "most likely"
to be where I want them to be !

$2p_z \qquad 2p_x \qquad 2p_y$

$$2p_z \qquad 2p_x \qquad 2p_y$$

$$n = 2, \ell = 1, m_\ell = \pm1 \qquad n = 3, \ell = 1, m_\ell = 0 \qquad n = 3, \ell = 2, m_\ell = 0$$

$$\frac{d^2\Phi}{d\phi^2} + m_l^2\Phi = 0 ....(1)$$

TYPO FIXED

$$\left[\frac{1}{\sin\theta}\frac{d}{d\theta}\left(\sin\theta\frac{d}{d\theta}\right) + \left[l(l+1) - \frac{m_l^2}{\sin^2\theta} \right] \right]\Theta(\theta) = 0 .....(2)$$

$$\left[\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{\partial}{\partial r}\right) + \left[\frac{2mr^2}{\hbar^2}(E + \frac{ke^2}{r}) - \frac{l(l+1)}{r^2} \right] \right]R(r) = 0 ....(3)$$

These 3 "simple" diff. eqn describe the physics of the Hydrogen atom.

The hydrogen atom brought to you by the letters

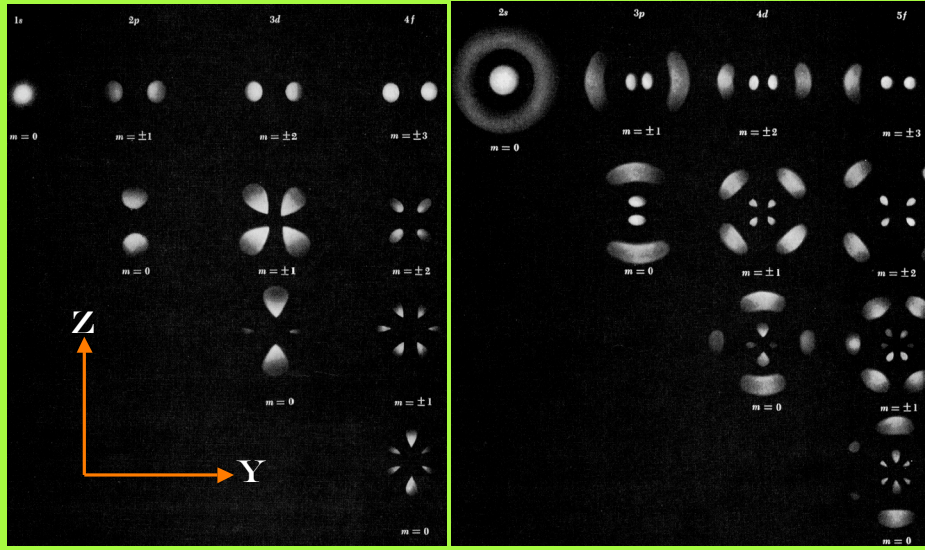$$n = 1,2,3,4,5,....\infty$$
$$l = 0,1,2,3,,4....(n-1)$$
$$m_l = 0, \pm1, \pm2, \pm3,...\pm l$$

The Spatial Wave Function of the Hydrogen Atom

$$\Psi(r,\theta,\phi) = R_{nl}(r) \cdot \Theta_{lm_l}(\theta) \cdot \Phi_{m_l}(\phi) = R_{nl}Y_l^{m_l} \text{ (Spherical Harmonics)}$$
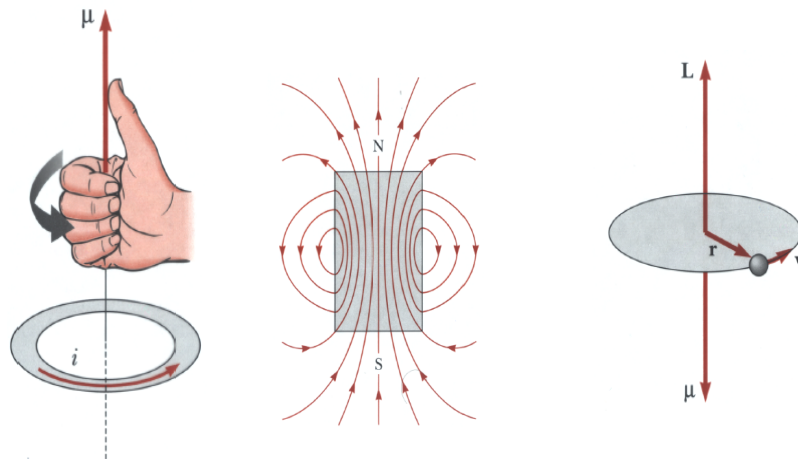
Cross Sectional View of Hydrogen Atom prob. densities in r,θ,φ

Birth of Chemistry (Can make Fancy Bonds→ Overlapping electron "clouds")

What's the electron "cloud" : Its the Probability Density in r, θ,φ space!
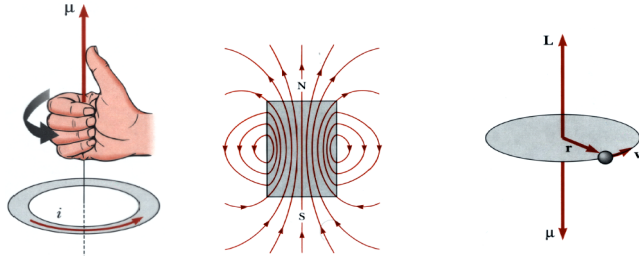

What's So "Magnetic" ?

Precessing electron→ Current in loop → Magnetic Dipole moment μ

The electron's motion ➔ hydrogen atom is a dipole magnet

The "Magnetism" of an Orbiting Electron

Precessing electron → Current in loop → Magnetic Dipole moment μ

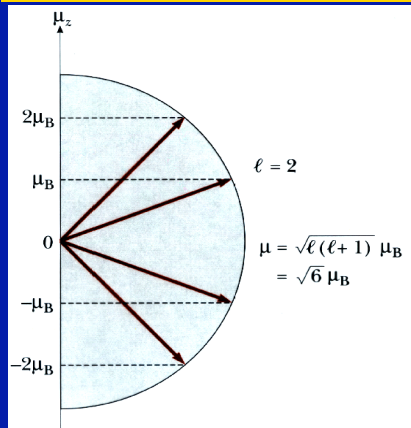Electron in motion around nucleus $\Rightarrow$ circulating charge $\Rightarrow$ curent i

$$i = \frac{-e}{T} = \frac{-e}{\frac{2\pi r}{v}} = \frac{-ep}{2\pi mr};$$ Area of current loop A=πr^2

Magnetic Moment $|\mu|$=iA=$\left(\frac{-e}{2m}\right)rp$; $\boxed{\vec{\mu} = \left(\frac{-e}{2m}\right)\vec{r} \times \vec{p} = \left(\frac{-e}{2m}\right)\vec{L}}$

Like the $\vec{L}$, magnetic moment $\vec{\mu}$ also precesses about "z" axis

$\boxed{\text{z component, } \mu_z = \left(\frac{-e}{2m}\right)L_z = \left(\frac{-e\hbar}{2m}\right)m_l = -\mu_B m_l = quantized\,!}$

Quantized Magnetic Moment

$$\mu_z = \left(\frac{-e}{2m}\right)L_z = \left(\frac{-e\hbar}{2m}\right)m_l$$

$$= -\mu_B m_l$$

$$\mu_B = \text{Bohr Magnetron}$$

$$= \left(\frac{e\hbar}{2m_e}\right)$$

ℓ = 2

$\mu = \sqrt{\ell(\ell+1)}\ \mu_B$
$= \sqrt{6}\ \mu_B$

Why all this ? Need to find a way to break the Energy Degeneracy & get electron in each (n, l, m_l) state to identify itself, so we can "talk" to it and make it do our bidding:
" Walk this way, talk this way!"

"Lifting" Degeneracy : Magnetic Moment in External B Field
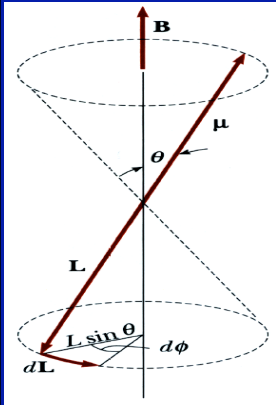
Apply an External $\vec{B}$ field on a Hydrogen atom (viewed as a dipole)

Consider $\vec{B} \parallel \vec{Z}$ axis (could be any other direction too)

The dipole moment of the Hydrogen atom (due to electron orbit)

experiences a Torque $\vec{\tau} = \vec{\mu} \times \vec{B}$ which does work to align $\vec{\mu} \parallel \vec{B}$

but this can not be (same Uncertainty principle argument)

$\Rightarrow$ So, Instead, $\vec{\mu}$ precesses (dances) around $\vec{B}$... like a spinning top

The Azimuthal angle ϕ changes with time : calculate frequency
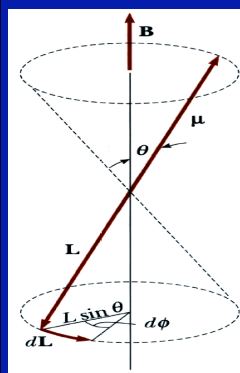
Look at Geometry: |projection along x-y plane : $|dL| = L\sin\theta . d\phi$

$\Rightarrow d\phi = \dfrac{|dL|}{L\sin\theta}$; Change in Ang Mom. $|dL| = |\tau| \, dt = \left| \dfrac{q}{2m} LB\sin\theta \right| dt$

$\Rightarrow \boxed{\omega_L = \dfrac{d\phi}{dt} = \dfrac{1}{L\sin\theta} \dfrac{|dL|}{dt} = \dfrac{1}{L\sin\theta} \dfrac{q}{2m} LB\sin\theta = \dfrac{qB}{2m_e}}$ Larmor Freq

ω_L depends on B, the applied external magnetic field

"Lifting" Degeneracy : Magnetic Moment in External B Field

WORK done to reorient $\vec{\mu}$ against $\vec{B}$ field: $\boxed{dW = \tau d\theta = -\mu B\sin\theta d\theta}$

$dW = d(\mu B\cos\theta)$: This work is stored as orientational Pot. Energy U

$$dW = -dU$$

Define Magnetic Potential Energy $U = -\vec{\mu}.\vec{B} = -\mu\cos\theta . B = -\mu_z B$

Change in Potential Energy $U = \dfrac{e\hbar}{2m_e} m_l B = \boxed{\hbar\omega_L m_l}$

Zeeman Effect in Hydrogen Atom

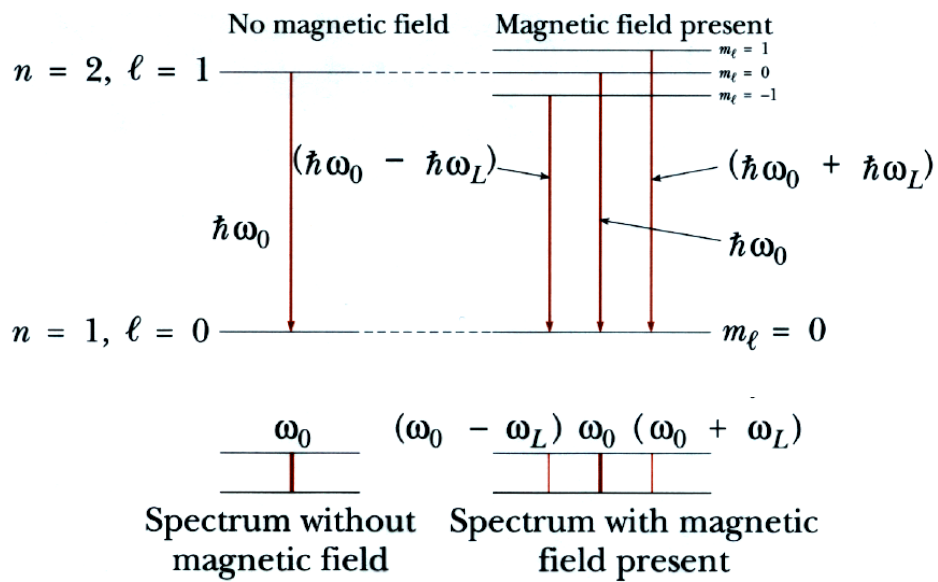In presence of External B Field, Total energy of H atom changes to
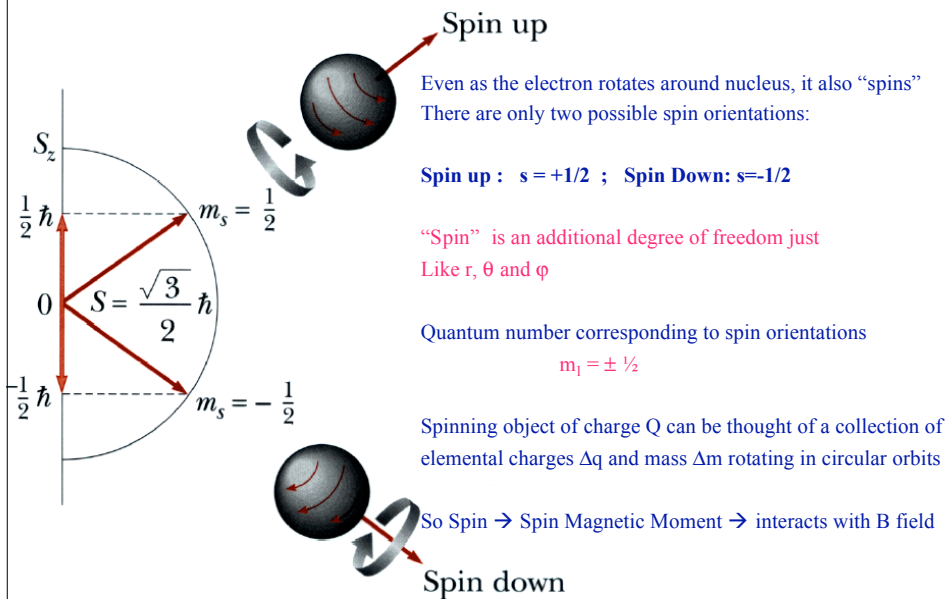
$$\boxed{E = E_0 + \hbar\omega_L m_l}$$

So the Ext. B field can break the E degeneracy "organically" inherent in the H atom. The Energy now depends not just on n but also m_l

## Zeeman Effect Due to Presence of External B field

Energy Degeneracy Is Broken

No magnetic field   Magnetic field present

$n = 2, \ell = 1$ $m_\ell = 1$ $m_\ell = 0$ $m_\ell = -1$

$(\hbar\omega_0 - \hbar\omega_L)$ $(\hbar\omega_0 + \hbar\omega_L)$

$\hbar\omega_0$ $\hbar\omega_0$

$n = 1, \ell = 0$ $m_\ell = 0$

ω_0 $(\omega_0 - \omega_L)\ \omega_0\ (\omega_0 + \omega_L)$

Spectrum without   Spectrum with magnetic
magnetic field   field present

Electron has "Spin": An additional degree of freedom

Spin up

S_z

$\frac{1}{2}\hbar$ $m_s = \frac{1}{2}$

0 $S = \frac{\sqrt{3}}{2}\hbar$

$-\frac{1}{2}\hbar$ $m_s = -\frac{1}{2}$

Spin down

Even as the electron rotates around nucleus, it also "spins"
There are only two possible spin orientations:

Spin up : s = +1/2 ; Spin Down: s=-1/2

"Spin" is an additional degree of freedom just
Like r, θ and φ

Quantum number corresponding to spin orientations
$m_l = \pm\ \frac{1}{2}$

Spinning object of charge Q can be thought of a collection of
elemental charges Δq and mass Δm rotating in circular orbits

So Spin → Spin Magnetic Moment → interacts with B field

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Stern-Gerlach Expt⟹ An additional degree of freedom: "Spin" for lack of a better name

$\vec{\mu}$ in inhomogenous $\vec{B}$ field, experiences force $\vec{F}$

$\vec{F} = -\nabla U_B = -\nabla(-\vec{\mu}.\vec{B})$

When gradient only along z, $\dfrac{\partial B}{\partial z} \neq 0; \dfrac{\partial B}{\partial x} = \dfrac{\partial B}{\partial y} = 0$

$F_z = m\mu_B(\dfrac{\partial B}{\partial z})$ moves particle up or down

(in addition to torque causing Mag. moment to precess about B field direction
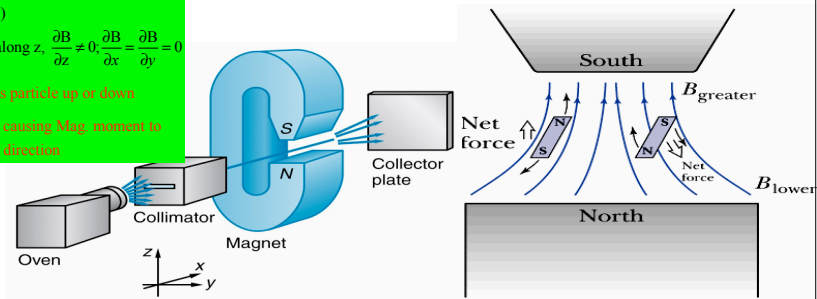
In an inhomogeneous field, magnetic moment μ experiences a force F_z whose direction depends on component of the net magnetic moment & inhomogeneity dB/dz. Quantization means expect *(2l+1)* deflections. For l=0, expect all electrons to arrive on the screen at the center (no deflection)

$m_\ell = +1$
$m_\ell = 0$
$m_\ell = -1$

Silver   Hydrogen (l=0)
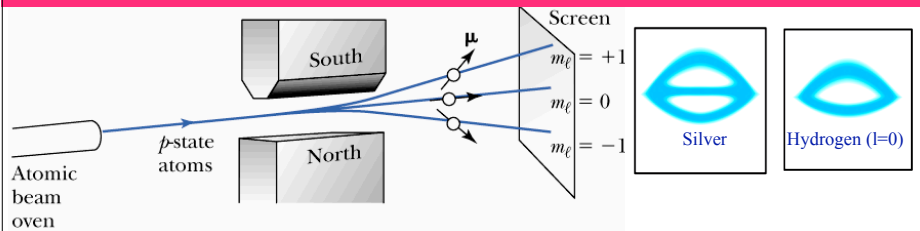
Four (not 3) Numbers Describe Hydrogen Atom → n,l,m$_l$,m$_s$

"Spinning" charge gives rise to a dipole moment $\vec{\mu}_s$:

Imagine (semi-clasically, incorrectly!) electron as sphere: charge q, radius r

Total charge uniformly distributed: $q = \sum_i \Delta q_i$;

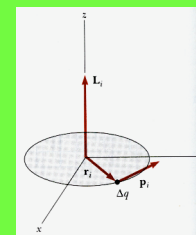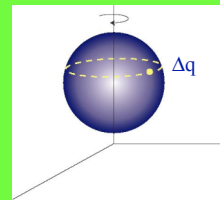as electron spins, each "chargelet" rotates ⟹ current ⟹ dipole moment $\vec{\mu}_{s_i}$

$$\vec{\mu}_s = \left(\frac{q}{2m_e}\right)\sum_i \vec{\mu}_{s_i} = g\left(\frac{q}{2m_e}\right)\vec{S}$$

In a Magnetic Field $\vec{B}$ ⟹ magnetic energy due to spin $U_S = \vec{\mu}_s.\vec{B}$

Net Angular Momentum in H Atom $\vec{J} = \vec{L} + \vec{S}$

Net Magnetic Moment of H atom: $\vec{\mu} = \vec{\mu}_0 + \vec{\mu}_s = \left(\frac{-e}{2m_e}\right)(\vec{L} + g\vec{S})$
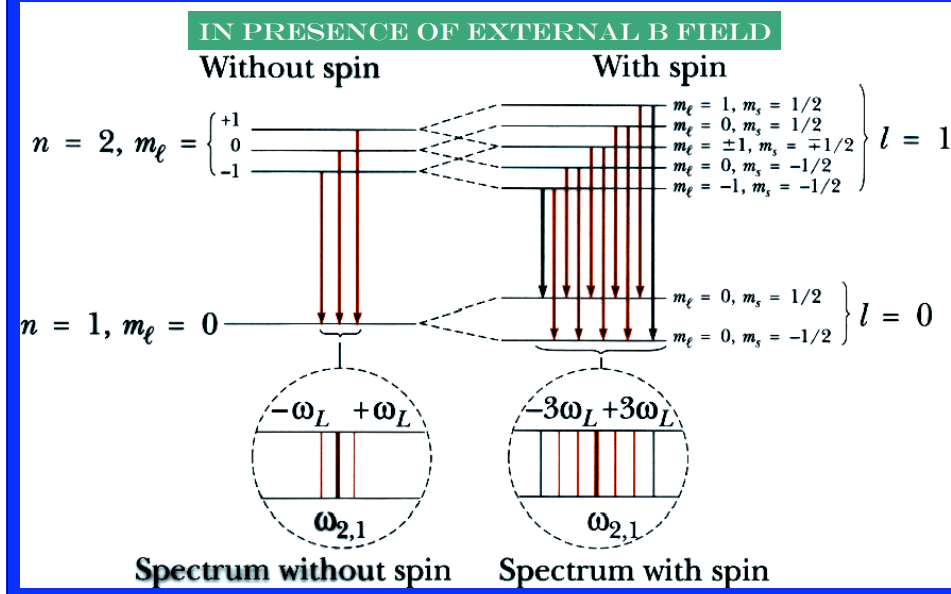
Notice that the net dipole moment vector $\vec{\mu}$ is not ‖ to $\vec{J}$

(There are many such "ubiquitous" quantum numbers for elementary particle but we won't teach you about them in this course !)

Doubling of Energy Levels Due to Spin Quantum Number

Under Intense B field, each {n , m_l} energy level splits into two depending on spin up or down

IN PRESENCE OF EXTERNAL B FIELD

Without spin   **With spin**

$$n = 2, \; m_\ell = \begin{cases} +1 \\ 0 \\ -1 \end{cases}$$

$$\left. \begin{array}{l} m_\ell = 1, \; m_s = 1/2 \\ m_\ell = 0, \; m_s = 1/2 \\ m_\ell = \pm 1, \; m_s = \mp 1/2 \\ m_\ell = 0, \; m_s = -1/2 \\ m_\ell = -1, \; m_s = -1/2 \end{array} \right\} l = 1$$

$$n = 1, \; m_\ell = 0 \qquad\qquad \left. \begin{array}{l} m_\ell = 0, \; m_s = 1/2 \\ m_\ell = 0, \; m_s = -1/2 \end{array} \right\} l = 0$$

$-\omega_L \quad +\omega_L$ $-3\omega_L \quad +3\omega_L$

$\omega_{2,1}$ $\omega_{2,1}$

Spectrum without spin   **Spectrum with** spin

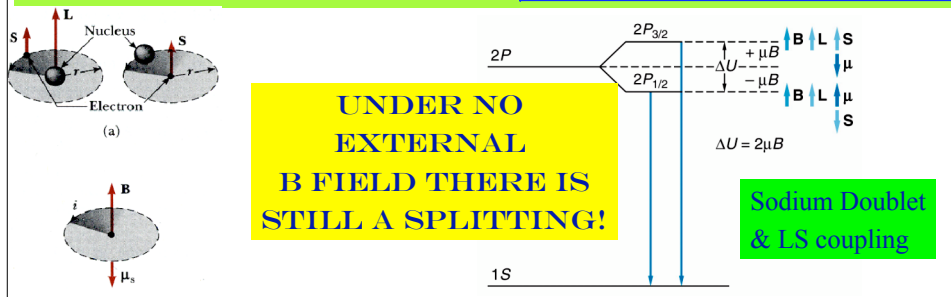## Spin-Orbit Interaction: Angular Momenta are Linked Magnetically

Electron revolving around Nucleus finds itself in a "internal" B field because in its frame of reference, the nucleus is orbiting around it.

-e

+Ze

B   B   B

Equivalent to

+Ze

-e
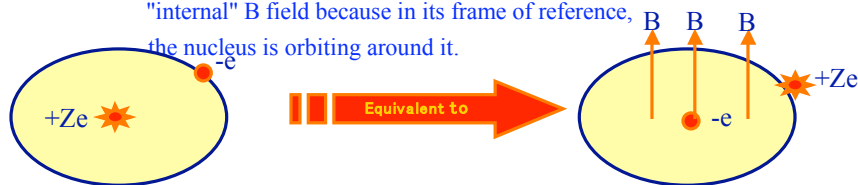
This B field, due to orbital motion, interacts with electron's spin dipole moment $\vec{\mu}_s$

$U_m = -\vec{\mu}.\vec{B} \Rightarrow$ Energy larger when $\vec{S} \parallel \vec{B}$, smaller when anti-parallel

$\Rightarrow$ States with same (n, l, m_l) but diff. spins $\Rightarrow$ energy level splitting/doubling due to $\vec{S}$

L
S   Nucleus   S
Electron
(a)

B
μ_s

2P

$2P_{3/2}$
$2P_{1/2}$

$+\mu B$
$-\Delta U--$
$-\mu B$

B   L   S
μ

B   L   μ
S

$\Delta U = 2\mu B$

UNDER NO EXTERNAL B FIELD THERE IS STILL A SPLITTING!

Sodium Doublet & LS coupling

1S

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Vector Model For Total Angular Momentum **J**

Coupling of Orbital & Spin magnetic moments $\Rightarrow$

Neither Orbital nor Spin angular Momentum are conserved seperately!

$\vec{J} = \vec{L} + \vec{S}$ is conserved so long as there are no external torques present

Rules for Total Angular Momentum Quantization :

$$|J| = \sqrt{j(j+1)}\ \hbar \quad \text{with} \quad j = |l+s|,\ l+s-1,\ l+s-2......,....,|l-s|$$

$$J_z = m_j \hbar \quad \text{with} \quad m_j = j,\ j-1,\ j-2......,\ -j$$

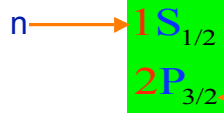Example: state with $(l = 1, s = \frac{1}{2})$

$j = 3/2 \Rightarrow m_j = -3/2, -1/2, 1/2, 3/2$

$j = 1/2 \Rightarrow m_j = \pm 1/2$
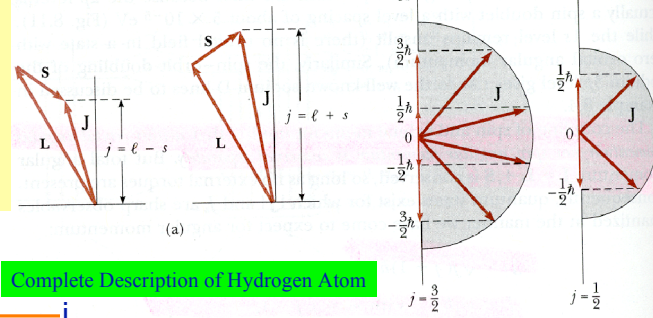
In general m_j takes $(2j+1)$ values
$\Rightarrow$ Even # of orientations

Spectrographic Notation: Final Label

n $\longrightarrow$ $1S_{1/2}$

$2P_{3/2}$ $\longleftarrow$ j

Complete Description of Hydrogen Atom

Complete Description of Hydrogen Atom

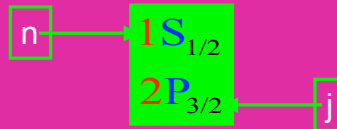Full description
of the Hydrogen atom:

$\{n, l, m_l, m_s\}$

$\Downarrow$

LS Coupling

$\Downarrow$

$\{n, l, j, m_s\}$

corresponding

to 4 D.O.F.

n $\longrightarrow$ $1S_{1/2}$

$2P_{3/2}$ $\longrightarrow$ j

How to describe multi-electrons atoms like He, Li etc?

How to order the Periodic table?

- Four guiding principles:
  - Indistinguishable particle & Pauli Exclusion Principle
  - Independent particle model (ignore inter-electron repulsion)
  - Minimum Energy Principle for atom
  - Hund's "rule" for order of filling vacant orbitals in an atom

Multi-Electron Atoms : >1 electron in orbit around Nucleus

In Hydrogen Atom $\psi(r,\theta,\phi)=R(r).\Theta(\theta).\Phi(\phi) \equiv \{n,l,j,m_j\}$

In n-electron atom, to simplify, ignore electron-electron interactions
complete wavefunction, in "independent"particle approx" :

$$\psi(1,2,3,..n)=\psi(1).\psi(2).\psi(3)...\psi(n) \quad ???$$

Complication $\rightarrow$ Electrons are identical particles, labeling meaningless!
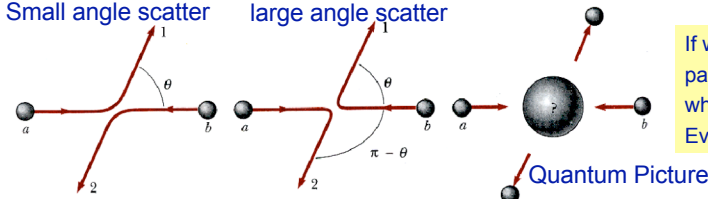Question: How many electrons can have same set of quantum #s?
Answer: No two electrons in an atom can have SAME set of quantum#s
(if not, all electrons would occupy 1s state (least energy)... no structure!!
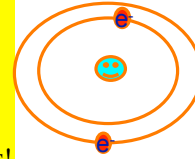
Example of Indistinguishability: electron-electron scattering

Small angle scatter   large angle scatter

Quantum Picture

If we cant follow electron
path, don't know between
which of the two scattering
Event actually happened

Helium Atom: Two electrons around a Nucleus

In Helium, each electron has : kinetic energy + electrostatic potential energy
If electron "1" is located at r_1 & electron "2"is located at r_2 then TISE has terms like:

$$H_1 = -\frac{\hbar^2}{2m}\nabla_1^2 + k\frac{(2e)(-e)}{r_1}; \quad H_2 = -\frac{\hbar^2}{2m}\nabla_2^2 + k\frac{(2e)(-e)}{r_2} \quad \text{such that}$$

$$\boxed{H_1\psi + H_2\psi = E\psi}; \quad H_1 \& H_2 \text{ are same except for "label"}$$

Independent Particle Approx $\Rightarrow$ ignore repulsive $U=k\dfrac{e^2}{|r_2-r_1|}$ term

Helium WaveFunction: $\psi=\psi(r_1,r_2)$; Probability $P=\psi^*(r_1,r_2)\psi(r_1,r_2)$
But if we exchange location of (identical, indistinguishable) electrons $\Rightarrow |\psi(r_1,r_2)|=|\psi(r_2,r_1)|$
In general, when $\psi(r_1,r_2)=\psi(r_2,r_1)$.....................Bosonic System (made of photons, e.g)
$\quad\quad\quad\quad$ when $\psi(r_1,r_2)=-\psi(r_2,r_1)$.....................fermionic System (made of electron, proton e.g)
$\Rightarrow$ Helium wavefunction must be ODD; if electron "1" is in state a & electron "2" is in state b
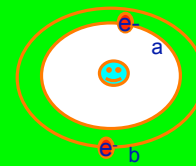Then the net wavefunction $\psi_{ab}(r_1,r_2)=\psi_a(r_1).\psi_b(r_2)$ satisfies
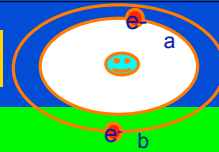
$$H_1\psi_a(r_1)\psi_b(r_2) = E_a\psi_a(r_1)\psi_b(r_2)$$
$$H_2\psi_a(r_1)\psi_b(r_2) = E_b\psi_a(r_1)\psi_b(r_2)$$
$$\text{and the sum} \quad [H_1+H_2]\psi_a(r_1)\psi_b(r_2) = (E_a+E_b)\psi_a(r_1)\psi_b(r_2)$$
$$\text{Total Helium Energy } E \simeq E_a+E_b =\text{sum of Hydrogen atom like E}$$

Helium Atom: Two electrons around a Nucleus

Helium wavefunction must be ODD $\Rightarrow$ anti-symmetric: $\psi_{ab}(r_1,r_2)=-\psi_{ab}(r_2,r_1)$

So it must be that $\psi_{ab}(r_1,r_2)=\psi_a(r_1)\psi_b(r_2)-\psi_a(r_2)\psi_b(r_1)$

It is impossible to tell, by looking at probability or energy which particular electron is in which state

If both are in the same quantum state $\Rightarrow$ a=b & $\psi_{ab}(r_1,r_2)=\psi_{bb}(r_1,r_2)=0...$ Pauli Exclusion principle

General Principles for Atomic Structure for n-electron system:

1. n-electron system is stable when its total energy is minimum

2. Only one electron can exist in a particular quantum state in an atom...not 2 or more !

3. Shells & SubShells In Atomic Structure :

(a) ignore inter-electron repulsion (crude approx.)

(b) think of each electron in a constant "effective" mean Electric field

(Effective field: "Seen" Nuclear charge (+Ze) reduced by partial screening due to other electrons "buzzing" closer (in r) to Nucleus)

Electrons in a SHELL: have same n, are at similar <r> from nucleus, have similar energies

Electons in a SubShell: have same principal quantum number n

- Energy depends on l, those with lower l closer to nucleus, more tightly bound

- all electrons in sub-shell have same energy, with minor dependence on m_l, m_s

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Shell & Sub-Shell Energies & Capacity

ENERGY

6p
5d
4f
6s

5p
4d
5s

4p
3d
4s

3p
3s

2p
2s

1s
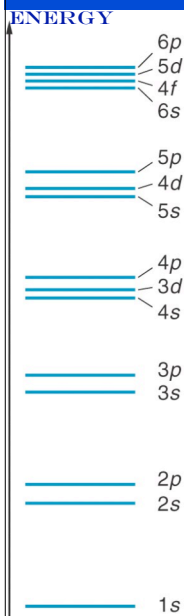
1. Shell & subshell capacity limited due to Pauli Exclusion principle

2. Shell is made of sub-shells (of same principal quantum # n)

3. Subshell $\Leftarrow (n,l)$, given $n \Rightarrow l = 0,1,2,3,..(n-1)$,

for any $l \Rightarrow m_l = 0, \pm 1, \pm 2, .. \Rightarrow (2l+1), m_s = \pm\frac{1}{2}$

$\Rightarrow$ Max. # of electrons in a shell = $\sum$ subshell capacity

$$N_{MAX} = \sum_{l=0}^{n-1} 2.(2l+1) = 2[1+3+5+..2(n-1)+1] = 2(n)\left[\frac{1}{2}(1+(2n-1))\right] = 2n^2$$

4. The "K" Shell (n=1) holds 2 electrons, "L" Shell (n=1) holds 8 electrons, M shell (n=3) holds 18 electrons ......

5. Shell is closed when fully occupied

6. Sub-Shell closed when

(a) $\sum_i \vec{L}_i = 0, \sum_i \vec{S}_i = 0, \Rightarrow$ Effective charge distribution= symmetric

(b) Electrons are tightly bound since they "see" large nuclear charge

(c) Because $\sum_i \vec{L}_i = 0 \Rightarrow$ No dipole moment $\Rightarrow$ No ability to attract electrons

$\Rightarrow$ *Inert*!*Noble* gas!

6.Alkali Atoms: have a single "s" electron in outer orbit; nuclear charge heavily shielded by inner shell electrons

$\Rightarrow$ very small binding energy of "valence"electron

$\Rightarrow$ large orbital radius of valence electron

Electronic Configurations of n successive elements from Lithium to Neon

Hund's Rule: Whenever possible
-electron in a sub-shell remain unpaired
- States with spins parallel occupied first
- Because electrons repel when close together
- → electrons in same sub-shell (l) and same spin
    -Must have diff. m_l
    -(very diff. angular distribution)
- Electrons with parallel spin are further apart
    -Than when anti-parallel⇒lesser E state
        -Get filled first

Periodic table is formed →

Atom	1s	2s		2p		Electron configuration
Li	↑↓	↑				$1s^2 2s^1$
Be	↑↓	↑↓				$1s^2 2s^2$
B	↑↓	↑↓	↑			$1s^2 2s^2 2p^1$
C	↑↓	↑↓	↑	↑		$1s^2 2s^2 2p^2$
N	↑↓	↑↓	↑	↑	↑	$1s^2 2s^2 2p^3$
O	↑↓	↑↓	↑↓	↑	↑	$1s^2 2s^2 2p^4$
F	↑↓	↑↓	↑↓	↑↓	↑	$1s^2 2s^2 2p^5$
Ne	↑↓	↑↓	↑↓	↑↓	↑↓	$1s^2 2s^2 2p^6$

That's all I can teach you this quarter; Rest is all Chemistry !