

+Ze

e⁻

Bohr quantized 1 thing

Schrödinger's eqn for atom is a bit nasty

separates into 3 partial differential eqns

Solve in spherical polar coordinates r, θ, ϕ

⇒ Get 3 separate things quantized

↪ one for r
one for θ
one for ϕ

Quantum # for r → Principle quantum #

(very similar to Bohr's #)

$$n = 1, 2, 3 \dots$$

Energy level

Quantum # for θ

↪ orbital quantum #

$$l = 0, 1, \dots, n-1$$

Angular Momentum

Quantum # for ϕ ↪ Magnetic quantum #

$$m = -l, (-l+1), \dots, 0, 1, 2, \dots, (l-1), l$$

z component of
Angular Momentum

Electron orbiting nucleus is in an "attractive Potential"

General Result Schrödinger's eqn for "Potential well"

Discrete Energy levels

Will see this later in nuclear
Particle

Physics
TAD!



~~For Atoms with more than 1 e⁻~~

Exact soln of 1e⁻ ATOM

$$E_n = - \frac{mk^2 e^4 Z^2}{2\hbar^2 n^2} = - \frac{Z^2 E_0}{n^2} \quad n = 1, 2, 3, \dots$$

↑ Energy levels the same as for Bohr ATOM!

E does NOT depend on l, m_l quantum #'s

Soln to Schrödinger eqn is called the wave function

ψ_{nlm} must specify

$$\psi_{1,0,0} = C e^{-Zr/a_0}$$

$|\psi|^2 dv \approx$ probability of finding e⁻ in state ψ in dv

$$\int |\psi|^2 dv = 1$$

$$\psi_{2,1,0} = C_{210} \left(\frac{Zr}{a_0} \right)^2 e^{-Zr/a_0} \cos^2 \theta$$

H atom ~~$n=3$~~ - Possible states for $n=3$

$n=3$	$l=0$	S	$m_l=0$
	1	P	$= -1, 0, +1$
	2	D	$= \del{-2, -1, 0, +1, +2}$

⇒ You should be very familiar w/ this stuff
from chemistry (NOT ψ)

— From KRANE
Modern Physics

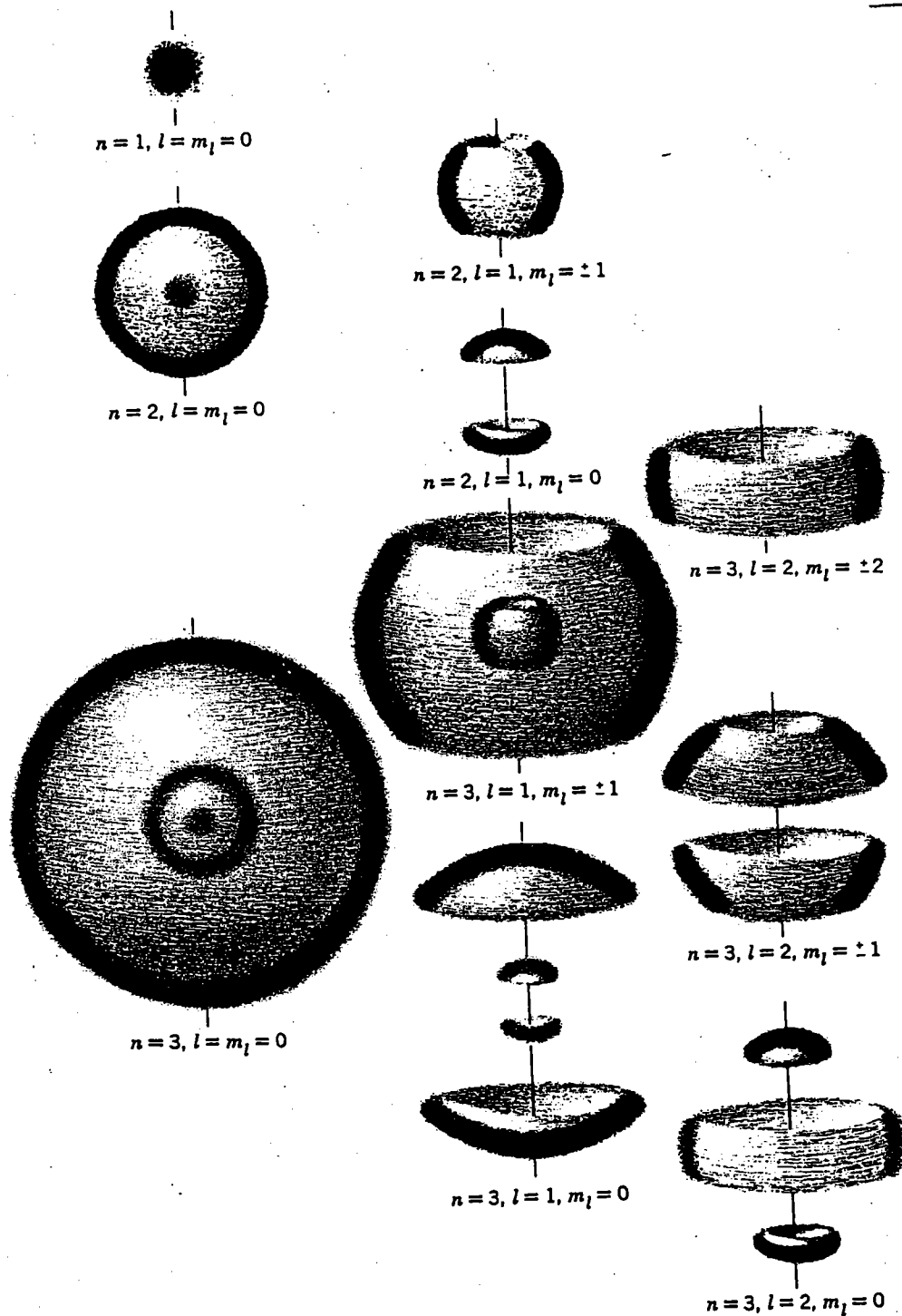


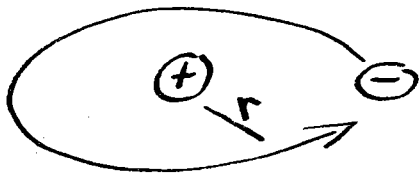
FIGURE 7.10 Representations of $|\psi|^2$ for different sets of quantum numbers. The intensity of each diagram at any point is proportional to the probability of locating an electron in a small volume element at that point. [Source: R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles* (New York, Wiley, 1974)].

Atoms w/ more than 1 e^- cannot be solved exactly
Can be solve w/ high degree of accuracy Numerically

different sets of allowed quantum #'s
represent different possible states of existence
(As opposed to the pre-quantum
infinite continuum)
for the e^- in the atom

before I discuss possible states need one more ingredient

Intrinsic Spin Quantum



Current loop \Rightarrow Magnetic Moment

\Downarrow Quantum Mechanics

$$|\vec{\mu}| = \mu_B \sqrt{l(l+1)}$$

$$\mu_B \equiv \frac{e\hbar}{2m_e} \equiv \text{constant called Bohr Magnetron}$$

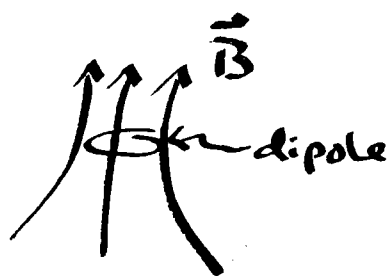
Quantum Mechanics allows you to
determine one vector component of $\vec{\mu}$ (not all 3)

$$|\vec{\mu}|_z = -\mu_B m_l$$

\uparrow quant # for ϕ

Magnetic dipole in non-uniform Magnetic field

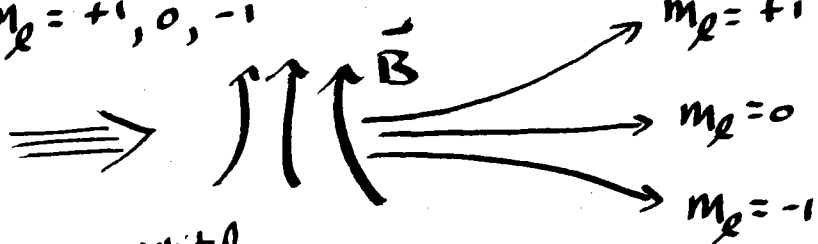
$$\vec{F}_z = \frac{\partial B_z}{\partial z} \mu_z$$



$$\propto \frac{\partial B_z}{\partial z} m$$

S

$$l=1 \quad m_l = +1, 0, -1$$



A way to Measure ^{orbital} Angular Momentum
and Magnetic Quantum Numbers!

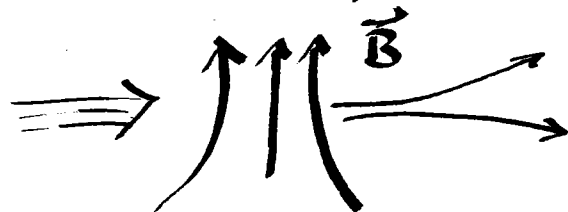
Stern-Gerlach expt

Trable

$$l=0 \quad m_l=0$$

Expect No force! ... Expect one spot

Get two!



One interpretation (other evidence helps Bolster Argument)
is that the e^- has an intrinsic magnetic moment
mechanical model

is that of
a spinning charge
distribution



Intrinsic Spin

$$s = \frac{1}{2}$$

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

intrinsic spin gives e^- a magnetic moment independent of that coming from orbital Angular Momentum!

Turns out all particles + nuclei have an Intrinsic Spin. Sometimes it is zero.

Spins of $\frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \dots \Rightarrow$ Fermions

integral spins ~~like~~ $0, 1, 2, \dots \Rightarrow$ Bosons

The two categories obey slightly different quantum Mechanical rules

So Back to our Atoms

full set of quantum #'s to describe a state

n, l, m_l, m_s (s already determined to be $\frac{1}{2}$)

after all it is an e^-

Multi electron ATOMS

Rules for determining the electronic structure :

(Which, in turn, determines the chemistry)

- ① Pauli Exclusion Principle - No two e^- in the same atom can have the same quantum #'s
... be in same state
Consequence of e^- being a fermion *would NOT be true for Bosons*
- ② Aufbau Principle - electrons go into the state with the lowest energy available to them
- ③ Within a sublevel - Electrons must have their spins "unpaired" as much as possible

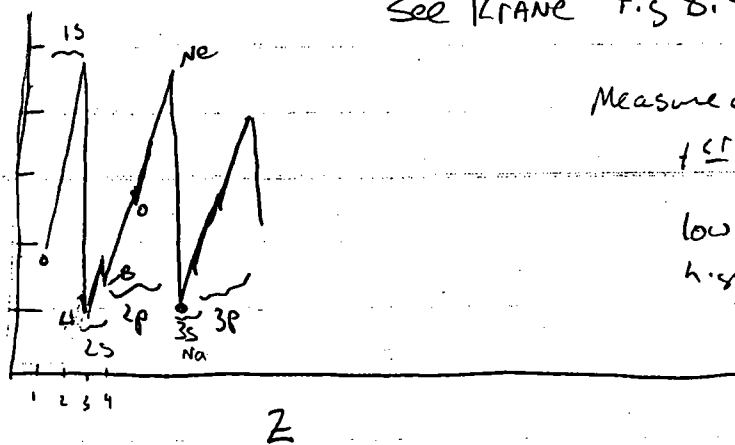
Periodic Chart reflects This structure:

Show chart from KRANE

Properties of chemical elements can be understood in terms of the Atomic level structure we are discussing

- Filled subshells, very stable configurations
Normally do NOT contribute to "chemistry"
- Atoms having 1 e⁻ over a filled shell will readily give that e⁻ up in a chemical reaction (lowers overall energy)
Atoms lacking 1 e⁻ from a filled shell will react to gain that e⁻ to form a filled shell (more stable)

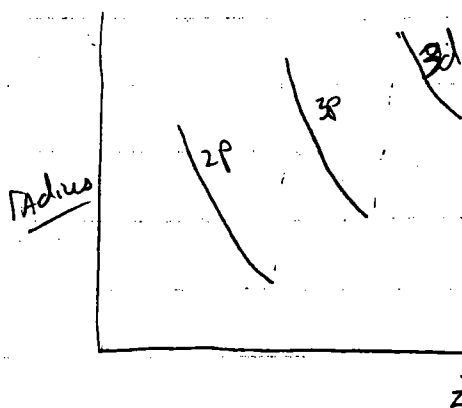
Ionization energy
(eV)



See KRANE Fig 8.4 p210

Measure of ease w/ which
1st e⁻ given up
low \equiv easy
high \equiv hard

Atomic Radius



KRANE 8.3 p209

as Z increases within a shell
Atomic radius decreases
as new shell is added
Atomic radius increases

Bohr Atom $R \sim \frac{n^2}{Z}$

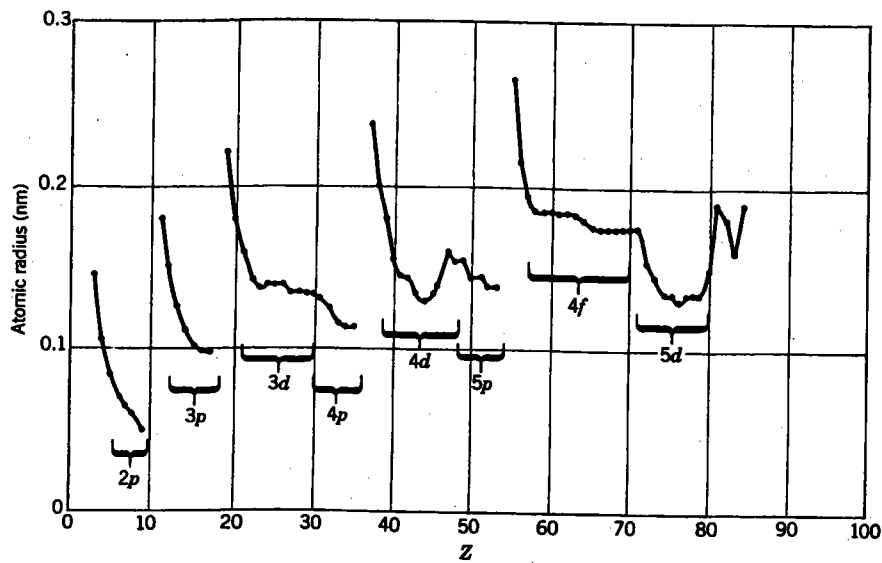


FIGURE 8.3 Atomic radii, determined from ionic crystal atomic separations. These radii are different from the mean radii of the electron cloud for free atoms.

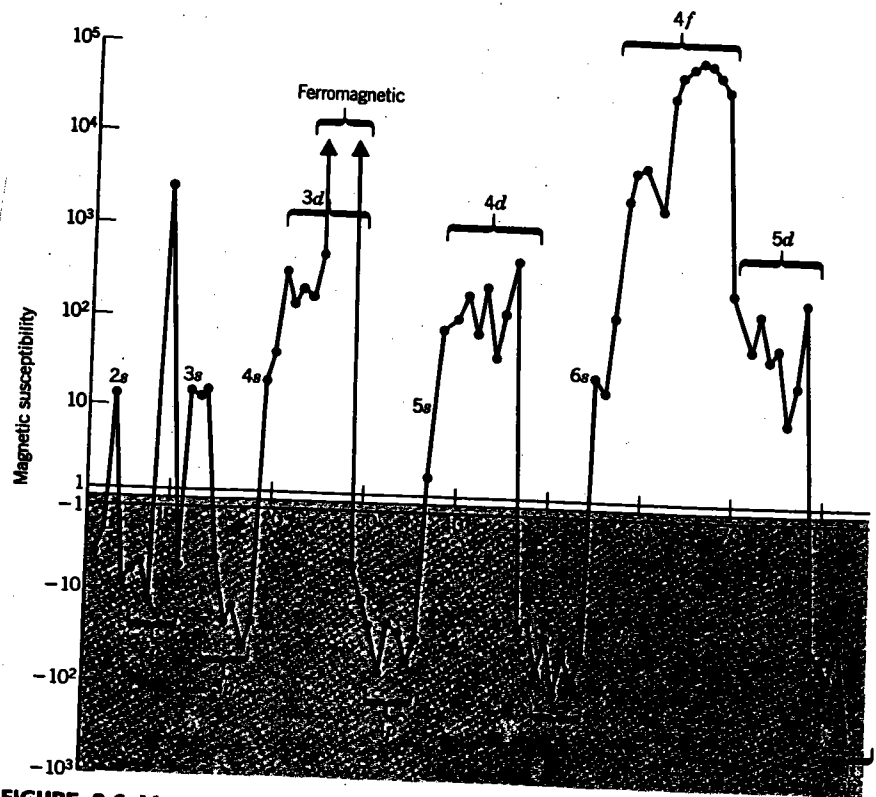


FIGURE 8.6 Magnetic susceptibilities of the elements.

210 Many-Electron Atoms

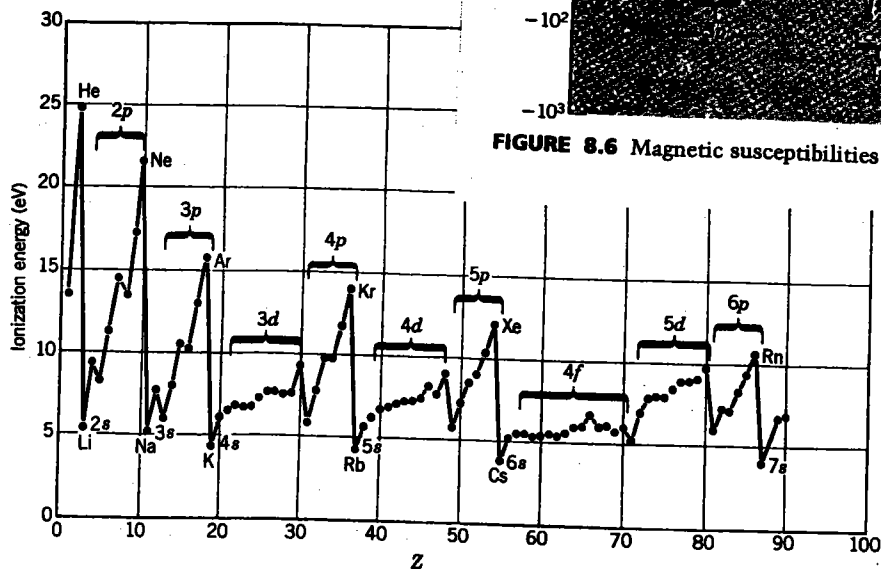


FIGURE 8.4 Ionization energies of the elements.

Alkalis		Transition metals										Halogens					Inert gases												
1s	1 H																2 He												
2s	3 Li 4 Be																												
3s	11 Na 12 Mg																												
4s	19 K 20 Ca	3d	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn																	
5s	37 Rb 38 Sr	4d	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd																	
6s	55 Cs 56 Ba		71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg																	
7s	87 Fr 88 Ra		103 Lr	104	105	106																							
															Lanthanides (rare earths)														
															4f	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
															5f	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No
															Actinides														

FIGURE 8.2 Periodic table of the elements.