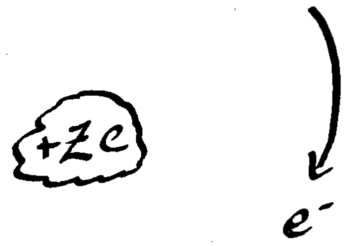


Bohr quantized 1 thing

Schrödinger's eqn for atom is a bit nasty

Separates into 3 partial differential eqns

Solve in spherical Polar Coordinates r, θ, ϕ

$\Rightarrow$ Get 3 separate things quantized

$\rightsquigarrow$ one for r
one for θ
one for ϕ

Quantum # for $r \rightarrow$ Principle quantum #
(very similar to Bohr's #)
$n = 1, 2, 3 \ldots$

Energy level

Quantum # for θ $\rightsquigarrow$ orbital quantum #
$l = 0, 1, \ldots n-1$

Angular Momentum

Quantum # for ϕ $\rightsquigarrow$ Magnetic quantum #

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

Z component of Angular Momentum

Electron orbiting nucleus is in an "attractive Potential"
General Result Schrödinger's eqn for "Potential well"
<u>Discrete</u> <u>Energy</u> <u>levels</u>

Will see this later ... nuclear
Particle Physics
TOO!

~~For Atoms w/ More than 1 e^-~~

Exact soln of $1e^-$ ATOM

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

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

$\psi_{n\ell m}$ ~ must specify

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

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

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

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

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

$n=3$	$\ell = 0$	S	$m_\ell = 0$
	1	P	$= -1\ 0\ +1$
	2	D	$= -2, -1, 0, +1, +2$

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

— from Krane
Modern Physics

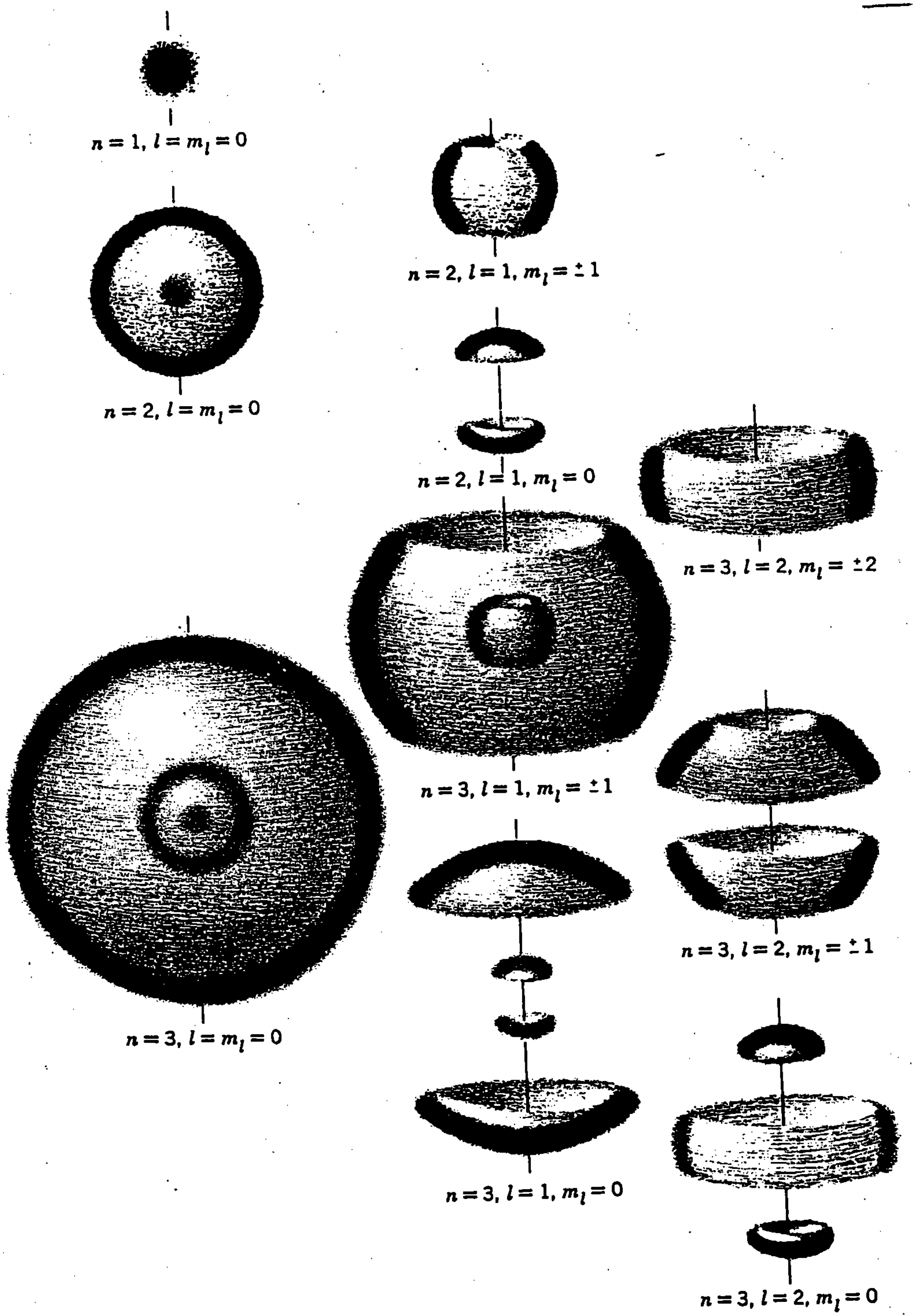


FIGURE 7.10 Representations of $|\psi|^2$ for different sets of quantum numbers. The intensity of each diagram at any point is proportional to the probability of locating an electron in a small volume element at that point. [*Source.* R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids,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

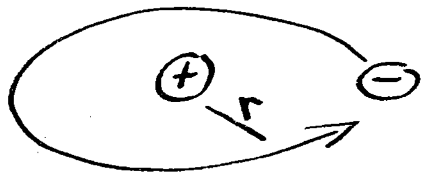
represent different possible states of existance

(As opposed to the pre-quantum infinite continuum)

for the e^- in the atom

before I discuss possible states need one More ingredient

<u>Intrinsic Spin Quantum #</u>



Current loop $\Rightarrow$ Magnetic Moment

$\Big\downarrow$ Quantum Mechanics

$$|\vec{\mu}| = \mu_b \sqrt{\ell(\ell+1)}$$

$\mu_B \equiv \dfrac{e\hbar}{2m_e} \equiv$ Constant called Bohr Magneton

Quantum Mechanics allows you to

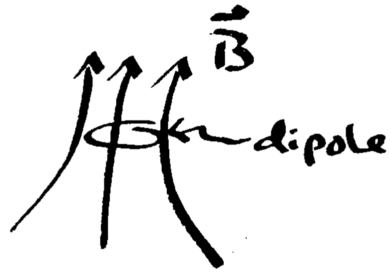
determine one vector component of $\vec{\mu}$ (Not all 3)

$$|\vec{\mu}|_z = -\mu_B m_\ell$$

↑ Quant # for ϕ

Magnetic dipole in non-uniform Magnetic field

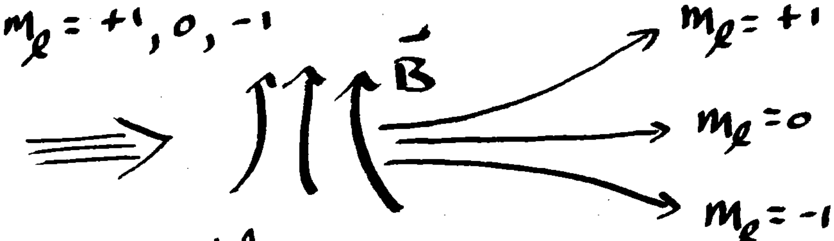
$$\vec{F}_z = \frac{\partial B_z}{\partial z} |\vec{\mu}_z|_z$$



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

So

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



A way to Measure orbital Angular Momentum

and Magnetic quantum Numbers!

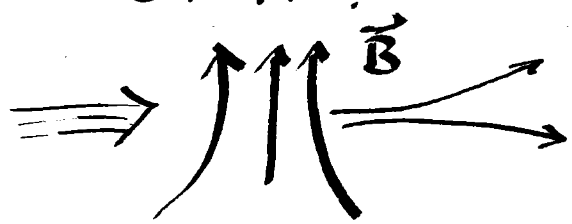
Stern-Gerlach expT

Trouble

$l=0 \quad m_l = 0$

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

$s = 1/2$

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

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 $\frac{1}{2}, \frac{3}{2}, \frac{5}{2} \cdots \Rightarrow$ Fermions

integral Spins $0, 1, 2, \cdots \Rightarrow$ 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

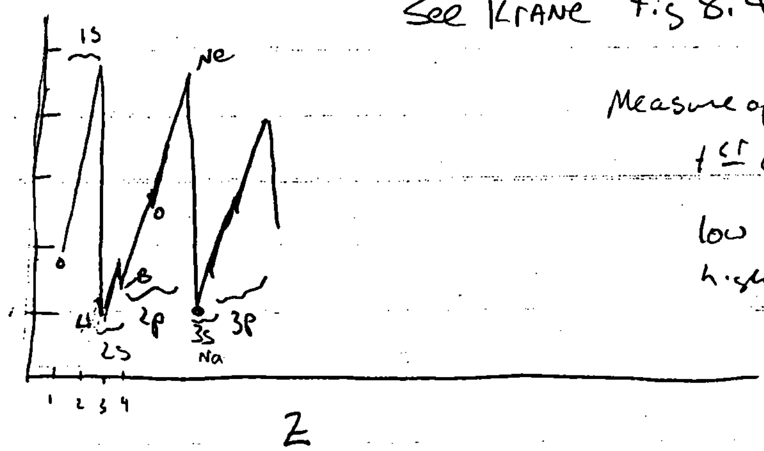
Periodic Chart reflects This Structure:

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)

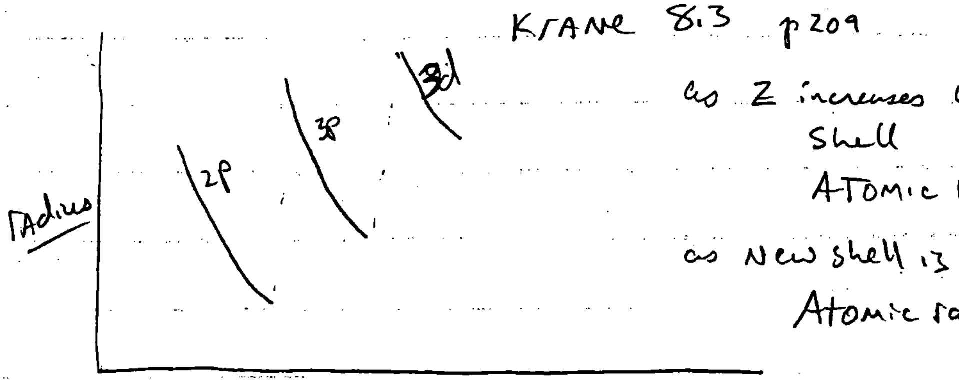


See KRANE Fig 8.4 p210

Measure of ease w/ which 1^{st} e^- given up

low ≡ easy
high ≡ hard

Atomic Radii



KRANE 8.3 p209

as Z increases within a shell
Atomic radius decreases

as new shell is added
Atomic radius increases

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

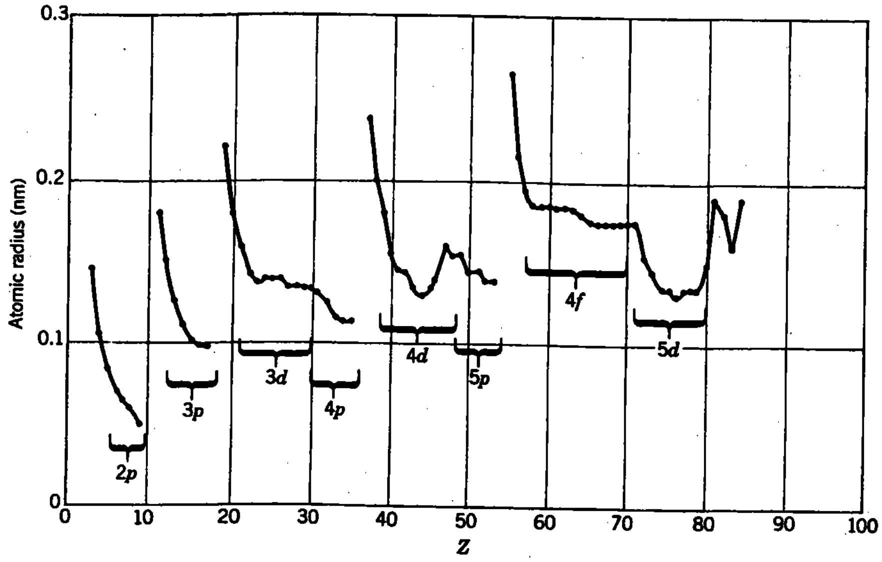


FIGURE 8.3 Atomic radii, determined from ionic crystal atomic separations. These radii are different from the mean radii of the electron cloud for free atoms.

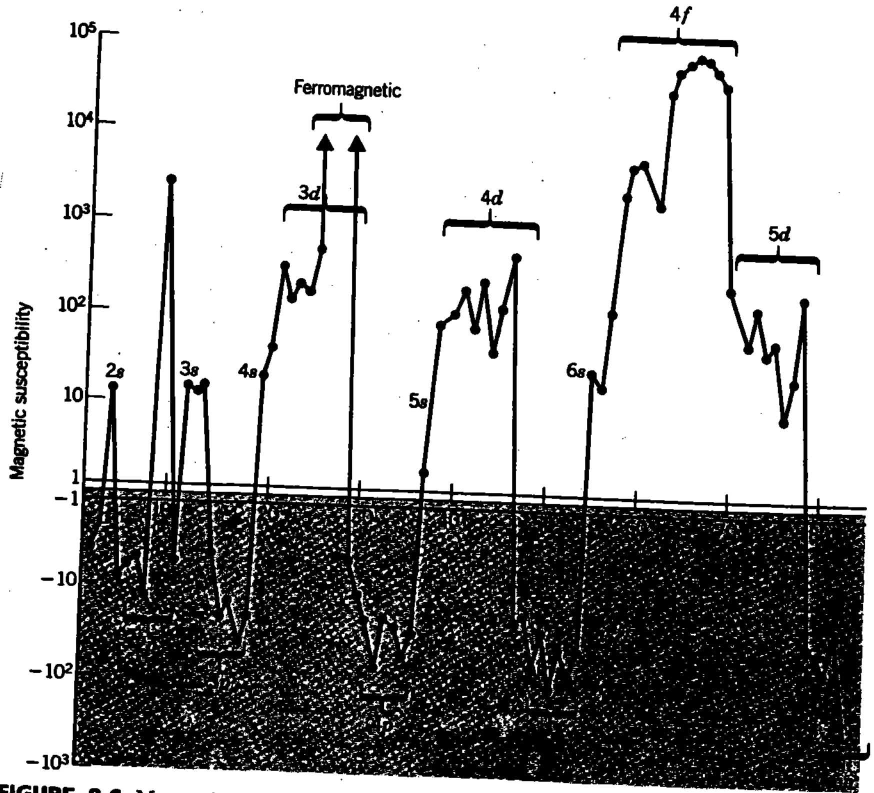


FIGURE 8.6 Magnetic susceptibilities of the elements.

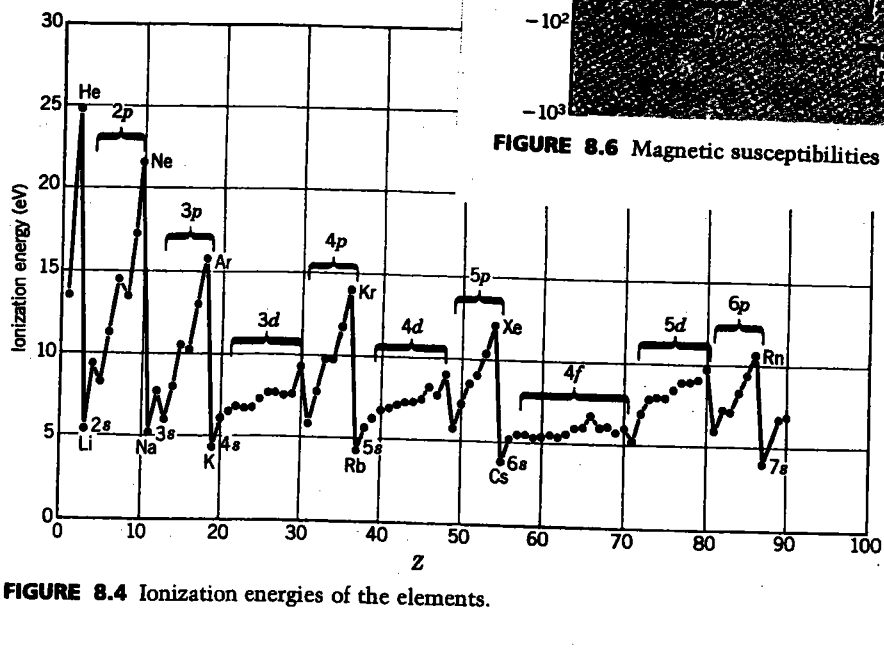


FIGURE 8.4 Ionization energies of the elements.

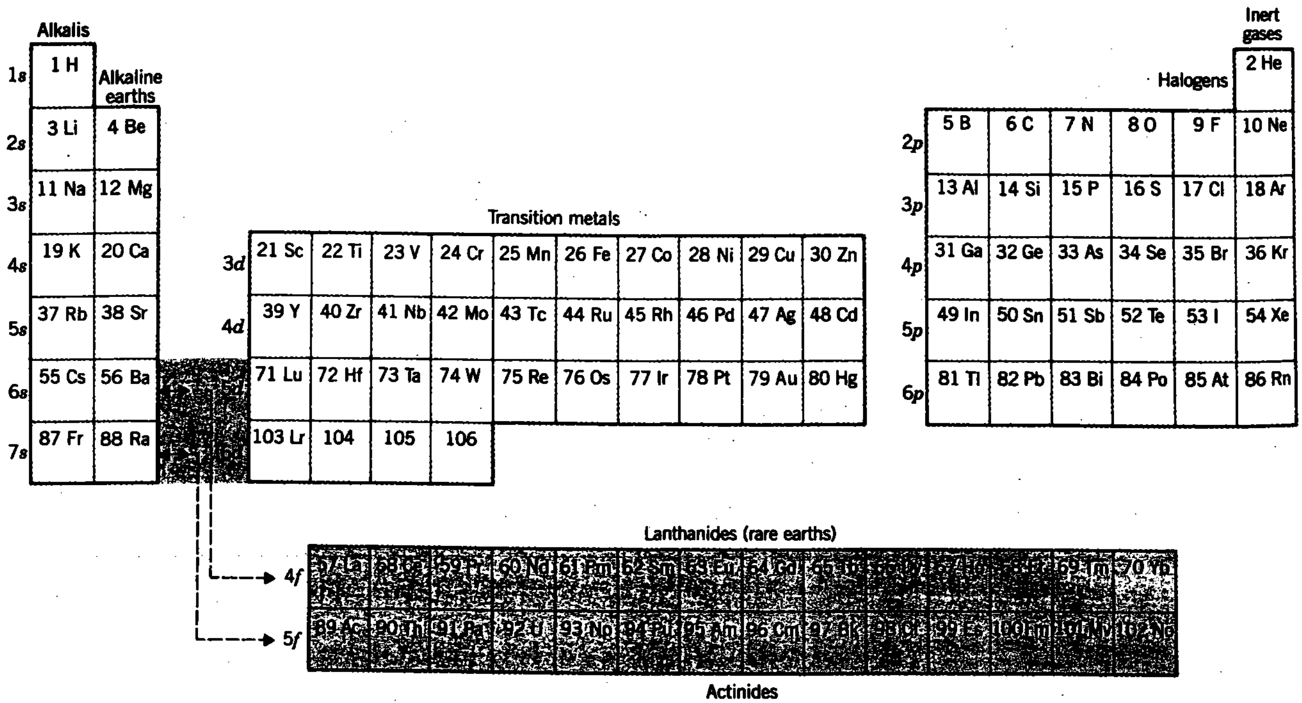


FIGURE 8.2 Periodic table of the elements.