-The Bohr Model
-The Quantum Mechanical Model

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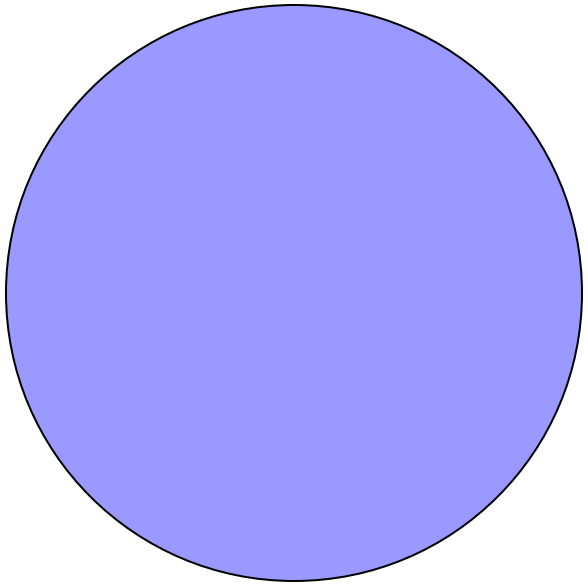
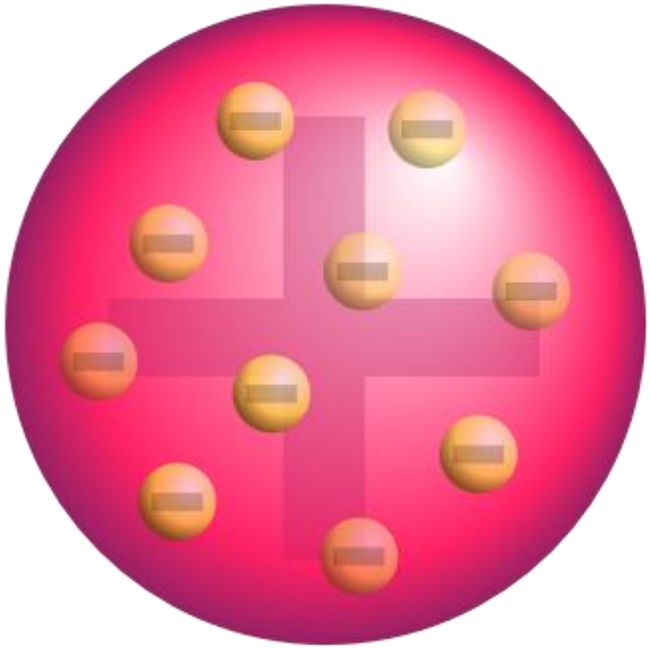
a) The Bohr Model

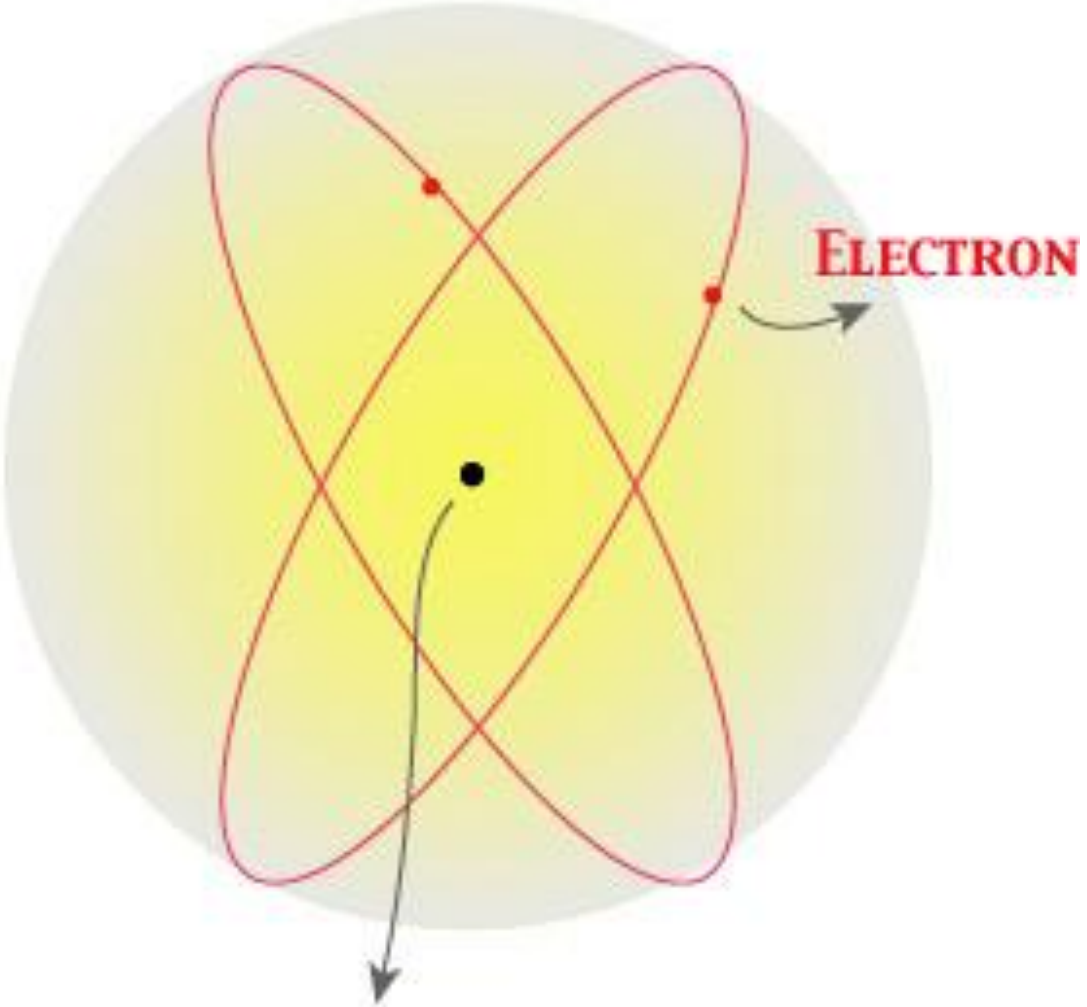
Dalton’s Atomic Model



Plum Pudding Model (Thomson)

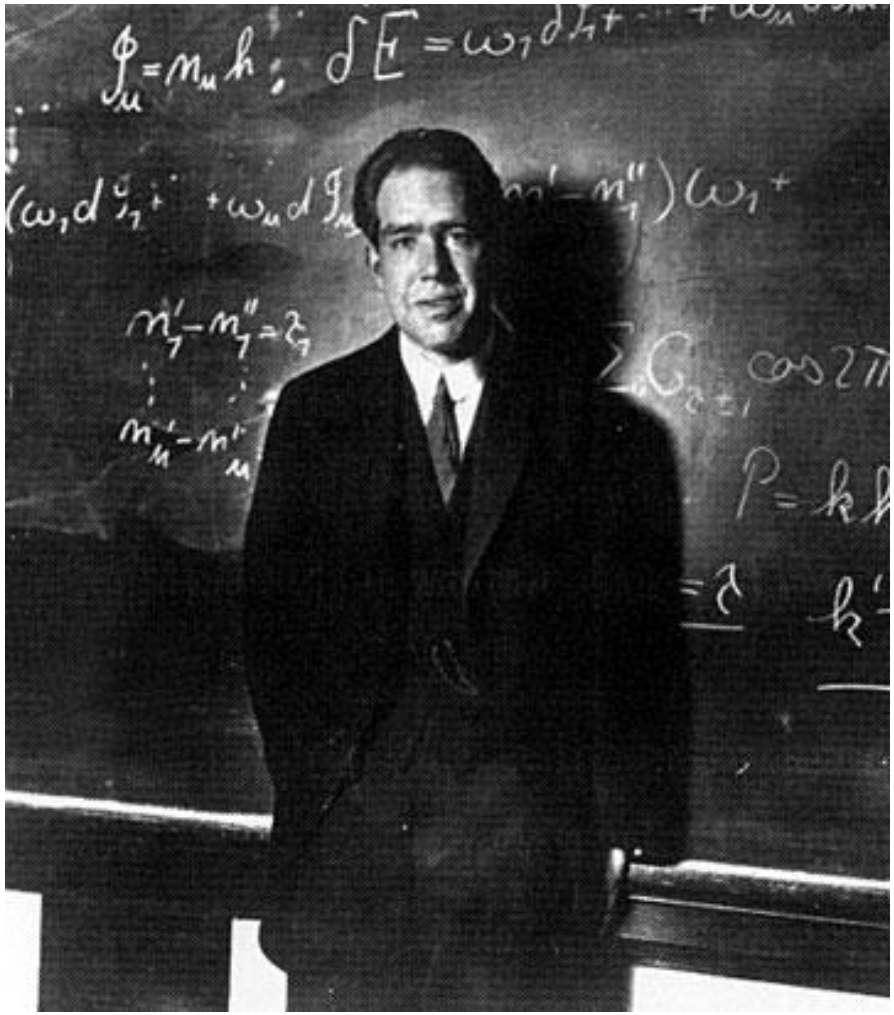


RUTHERFORD'S MODEL OF ATOM



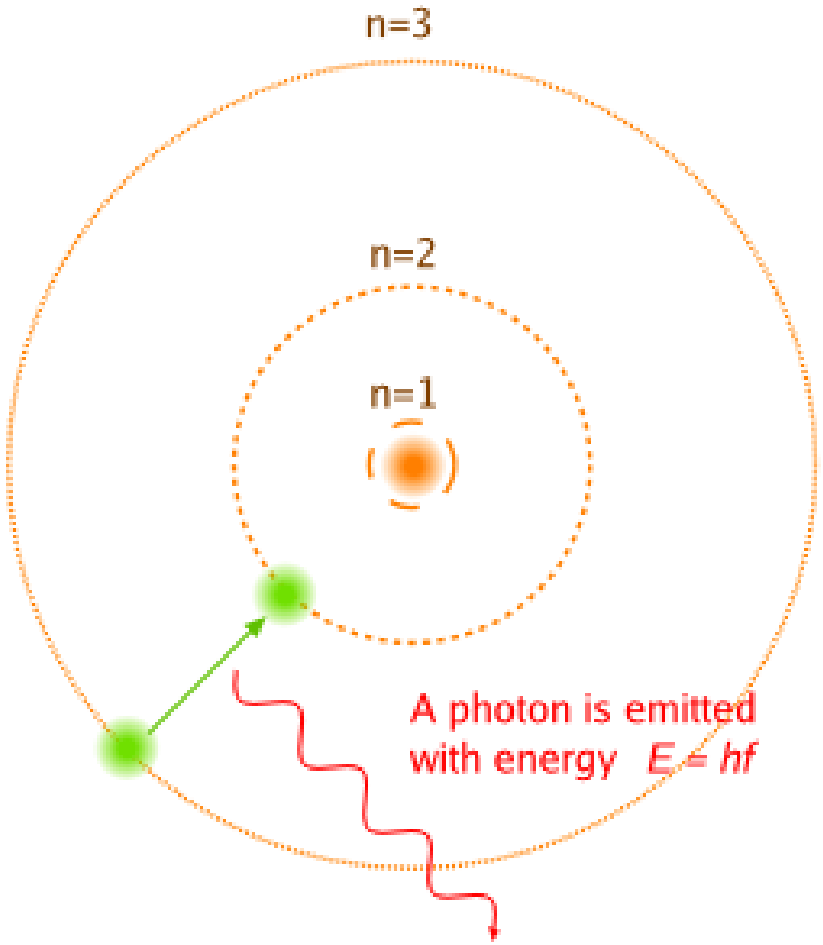
Niels Bohr
(Born in Denmark 1885-1962)

- Student of Rutherford



Niels Bohr's Model (1913)

- Electrons orbit the nucleus in circular paths of fixed energy (energy levels).



Max Plank

$$E=h\nu$$

E=energy

ν=frequency

h=Plank's constant 6.7×10^{-34}Js

Energy of Emitted Photon

Energy of the emitted photon =

Difference in energy between two states

- Energy emitted by the electron as it leaps from the higher to the lower energy level is proportional to the frequency of the light wave.
- Frequency define the color of visible light.

Bohr Atom

- http://higheredbcs.wiley.com/legacy/college/halliday/0471320005/simulations6e/index.htm?newwindow=true

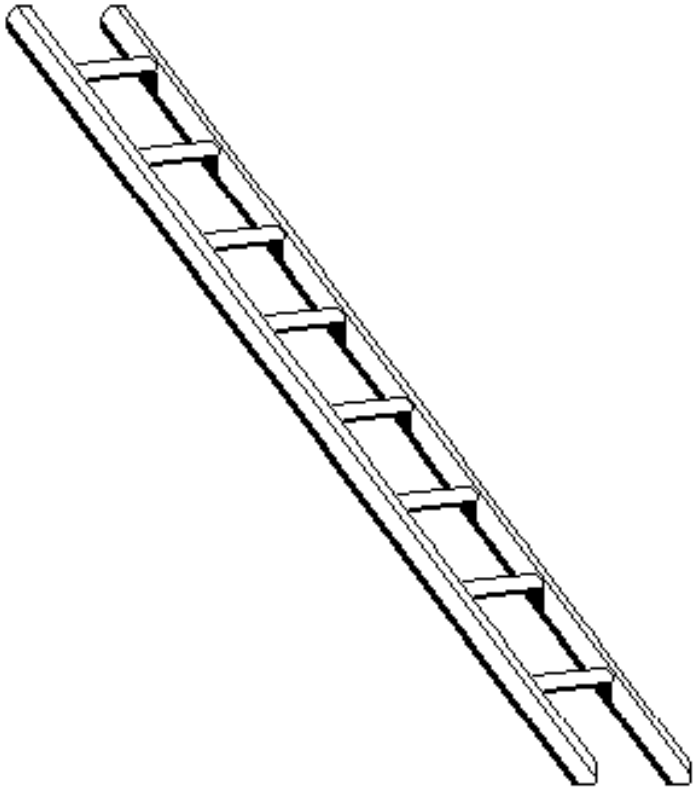
Niels Bohr's Atom Cont'd

- Electrons can jump from energy level to energy level.
- Electrons absorb or emit light energy when they jump from one energy level to another.

Quantum

- A quantum of energy is the amount of energy required to move an electron from one energy level to another.

The energy levels are like the rungs of a ladder but are not equally spaced.



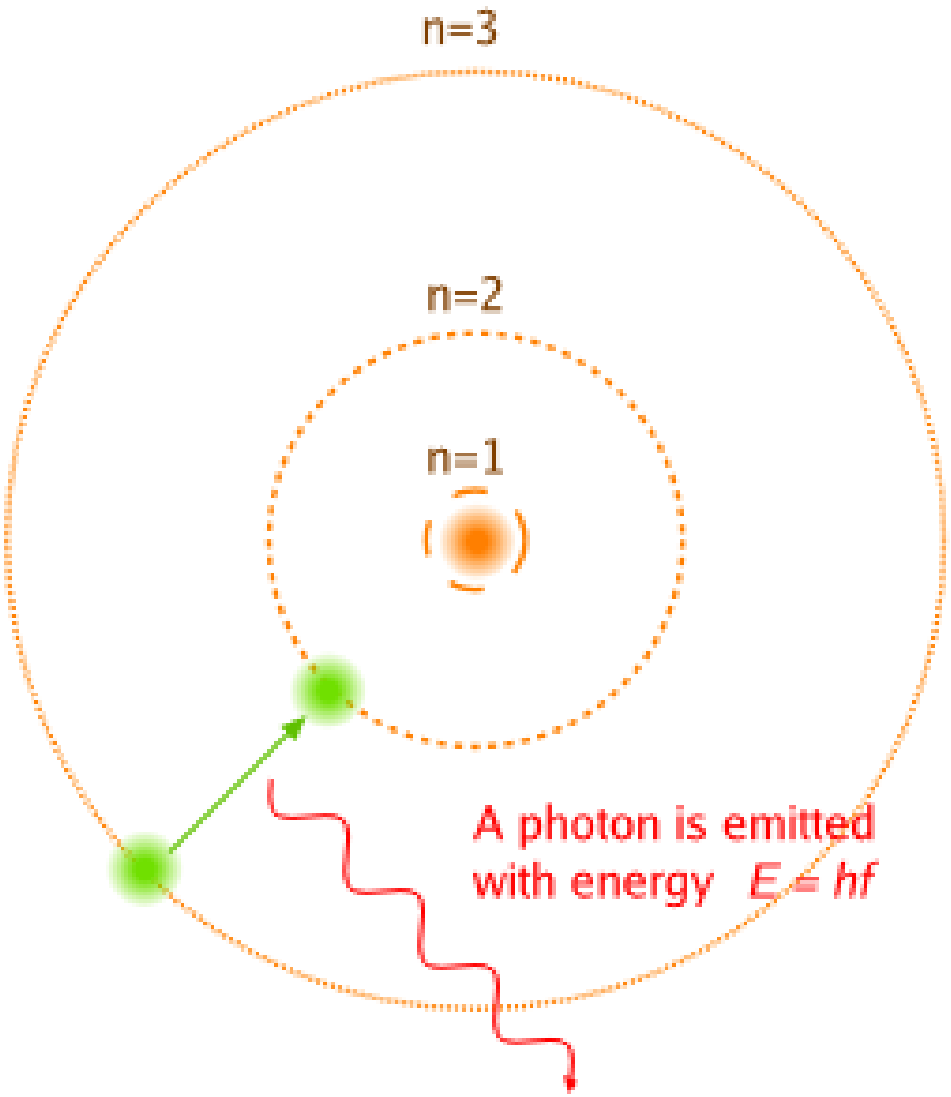
Photons

- Photons are bundles of light energy that is emitted by electrons as they go from higher energy levels to lower levels.

Excited State and Ground State

- Ground state: the lowest possible energy level an electron be at.

- Excited state: an energy level higher than the ground state.


n=3
n=2
n=1
A photon is emitted
with energy E = hf

Emission Spectrum

- Light emitted produces a unique emission spectrum.

Hydrogen Emission Spectrum

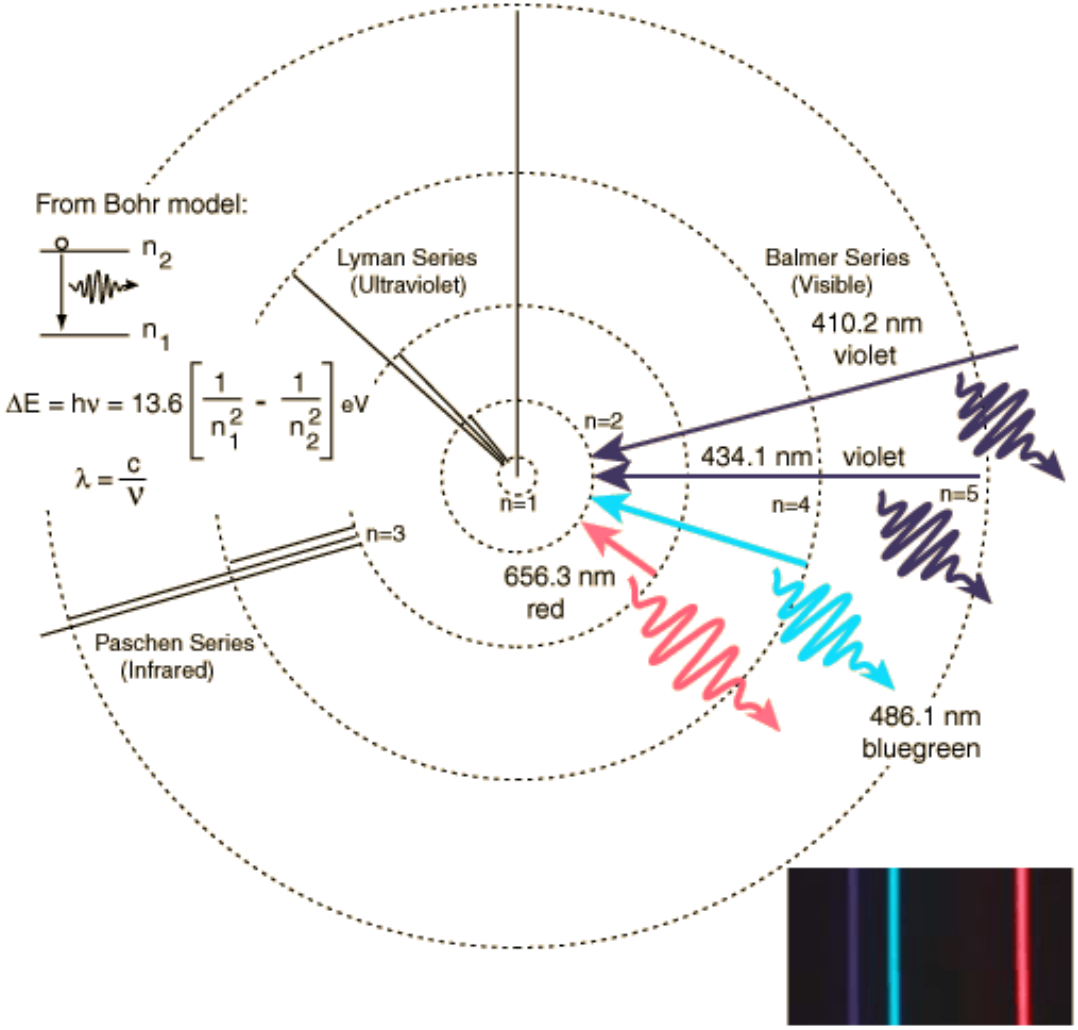
Violet

Blue

Red

Balmer Series

Bohr Model for Hydrogen



- The Bohr model explained the emission spectrum of the hydrogen atom but did not always explain those of other elements.

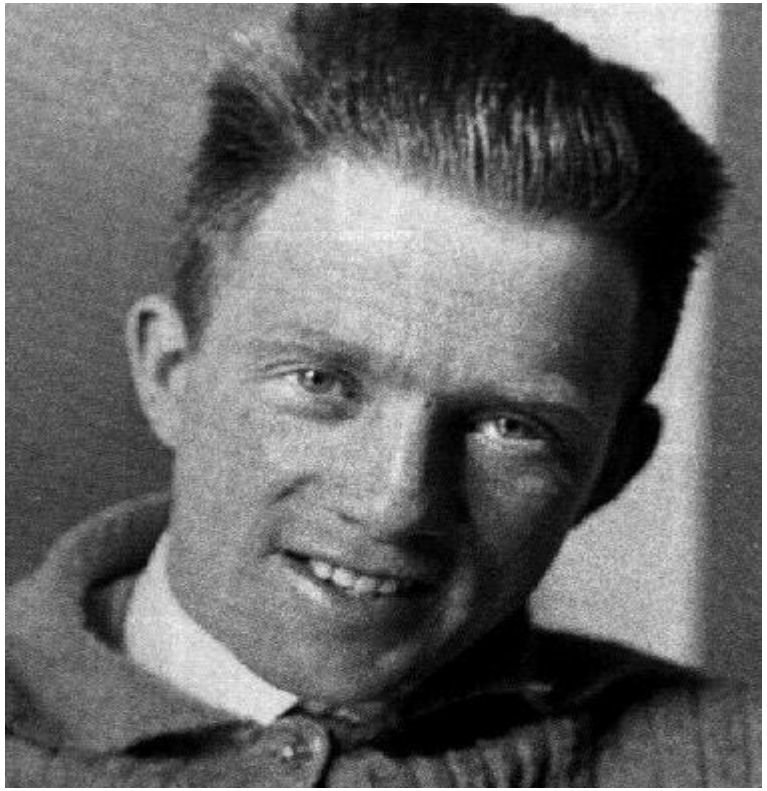
b)The Quantum Mechanical Model

Quantum Mechanical Model

- 1920's
- Werner Heisenberg (Uncertainty Principle)
- Louis de Broglie (electron has wave properties)
- Erwin Schrodinger (mathematical equations using probability, quantum numbers)

Werner Heisenberg: Uncertainty Principle

- We can not know both the position and momentum of a particle at a given time.

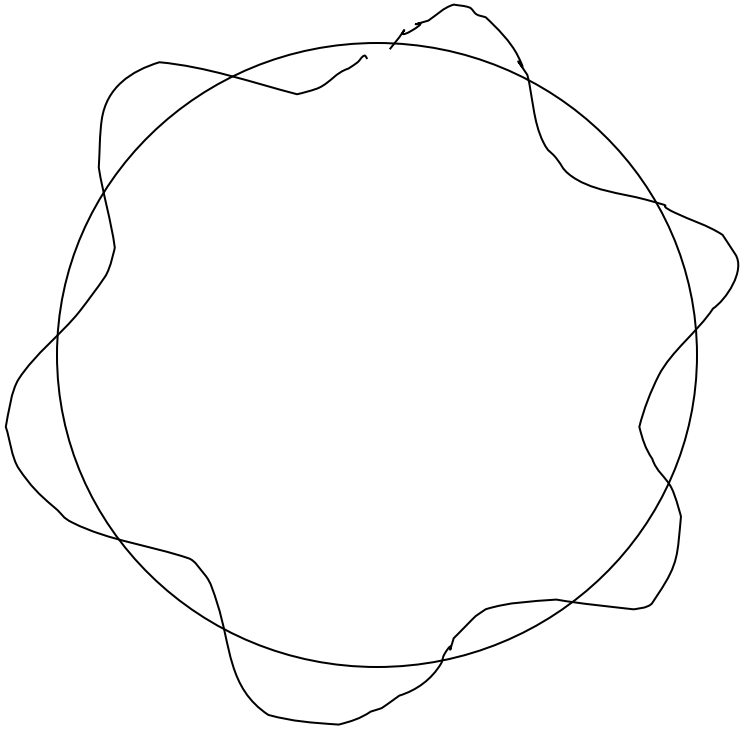


Louis de Broglie, (France, 1892-1987) Wave Properties of Matter (1923)

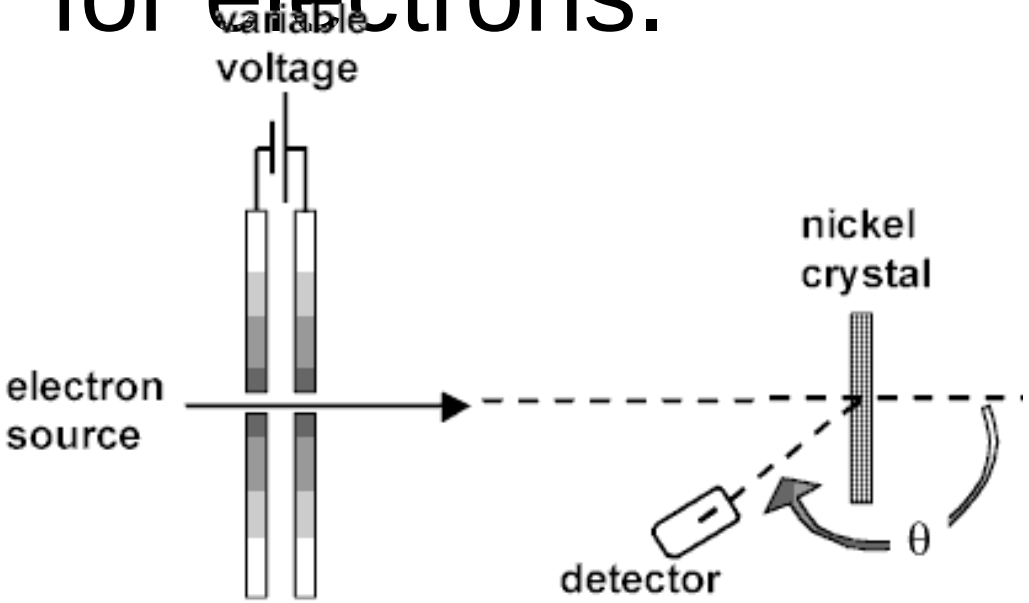
- Since light waves have a particle behavior (as shown by Einstein in the Photoelectric Effect), then particles could have a wave behavior.
- de Broglie wavelength

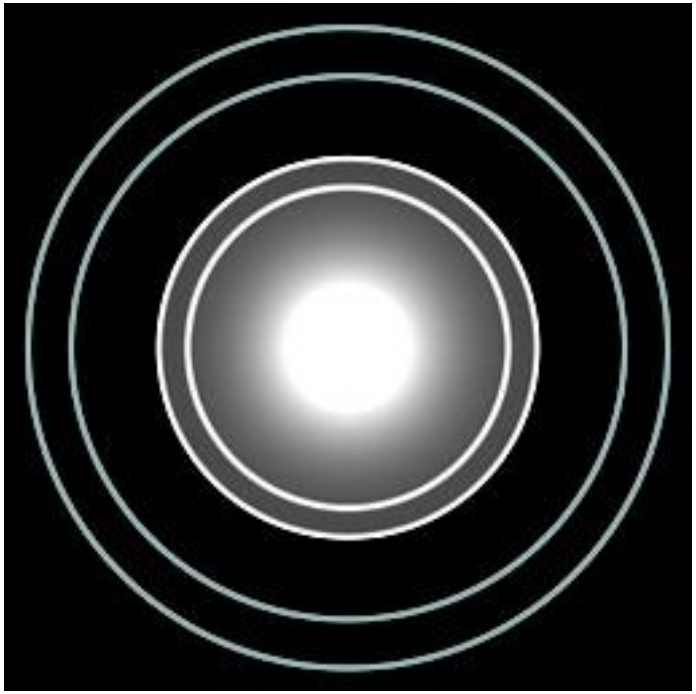
$$\lambda = \frac{h}{mv}$$

Electron Motion Around Atom Shown as a de Broglie Wave



Davisson and Germer (USA, 1927) confirmed de Broglie's hypothesis for electrons.





Electrons produced a diffraction pattern similar to x-rays.

Example:

- Determine the de Broglie wavelength for an electron moving at a speed of 9. x 10^{6}m/s.

  (m_e= 9.1 x 10^{-31} kg)

  Answer: 8.09 x 10^{-11} m

Erwin Schrodinger, 1925
Quantum (wave) Mechanical Model of the Atom

- Four quantum numbers are required to describe the state of the hydrogen atom.

Atomic Orbital:

A region in space in which there is high probability of finding an electron.

Quantum Numbers:

specify the properties of atomic orbitals and their electrons.

Four Quantum Numbers

1. Principal Quantum Number
2. Orbital Quantum Number
3. Magnetic Quantum Number
4. Spin Quantum Number

Principal Quantum Number, n

- Indicates main energy levels

  n = 1, 2, 3, 4…

- Each main energy level has sub-levels

The maximum number of electrons in a principal energy level is given by:

Max # electrons = $2n^2$

n= the principal quantum number

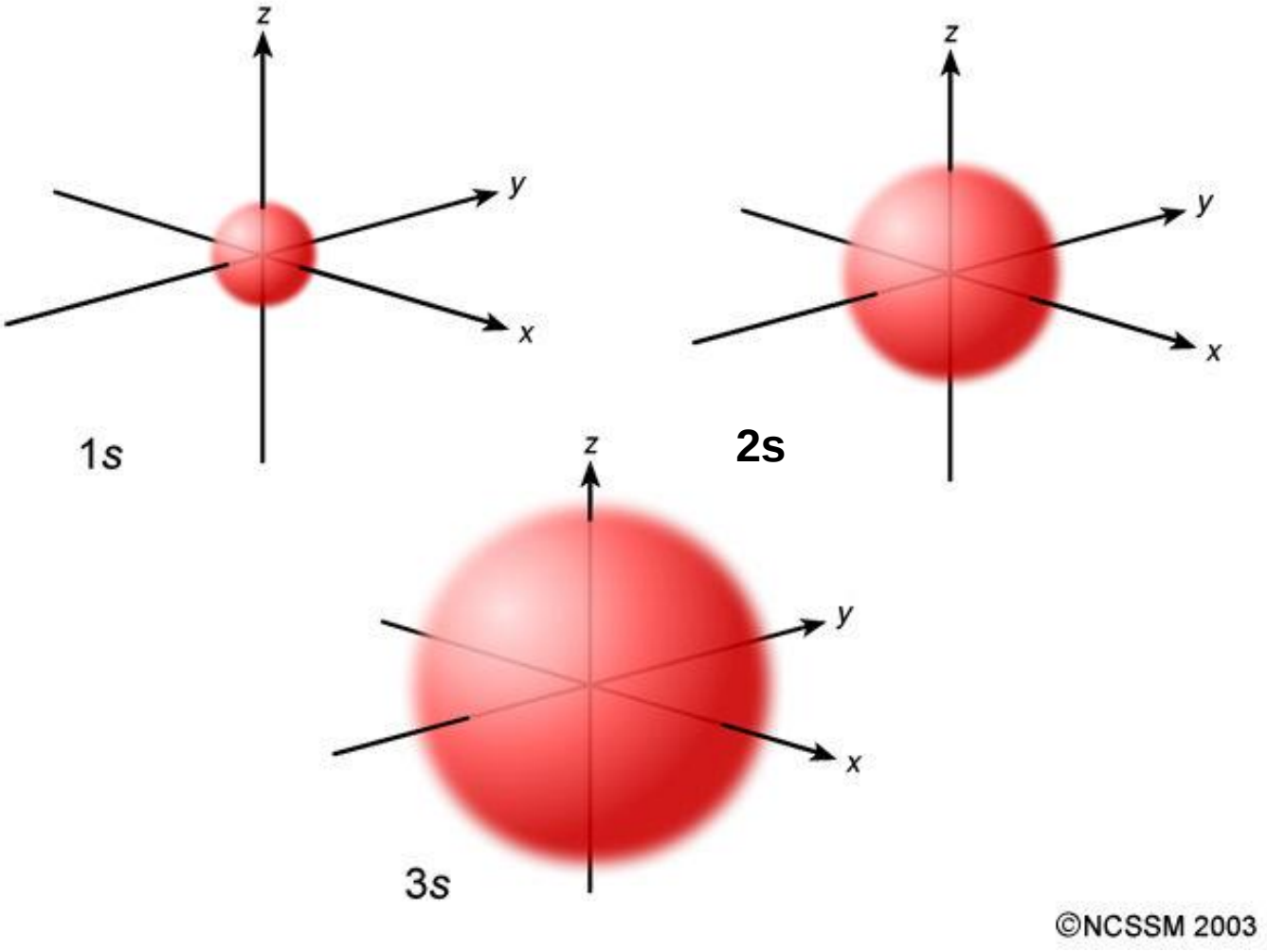
Orbital Quantum Number, ℓ

(Angular Momentum Quantum Number)

- Indicates shape of orbital sublevels
- ℓ = n-1

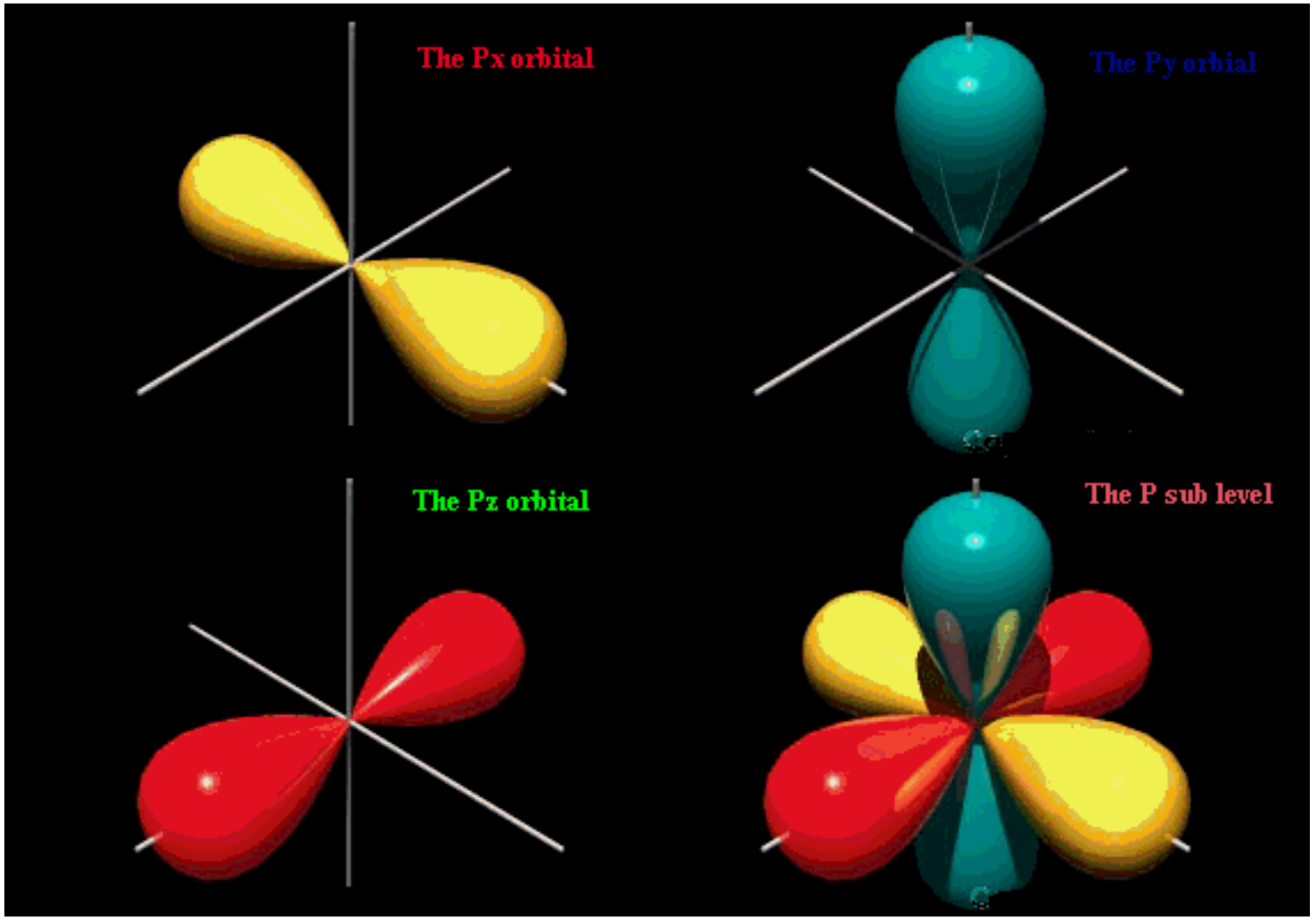
ℓ	sublevel
0	s
1	p
2	d
3	f
4	g

Atomic Orbital s



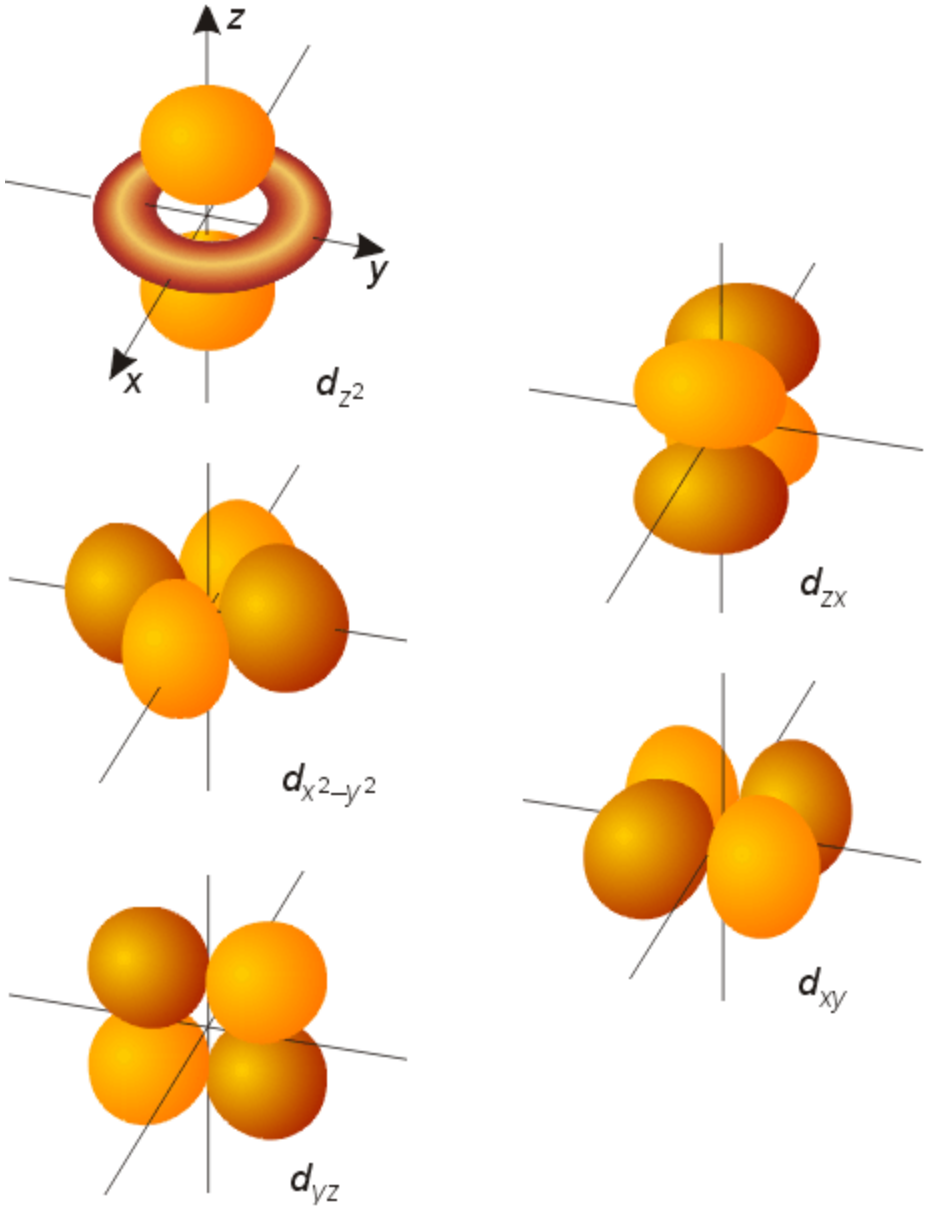
Degenerate Orbitals

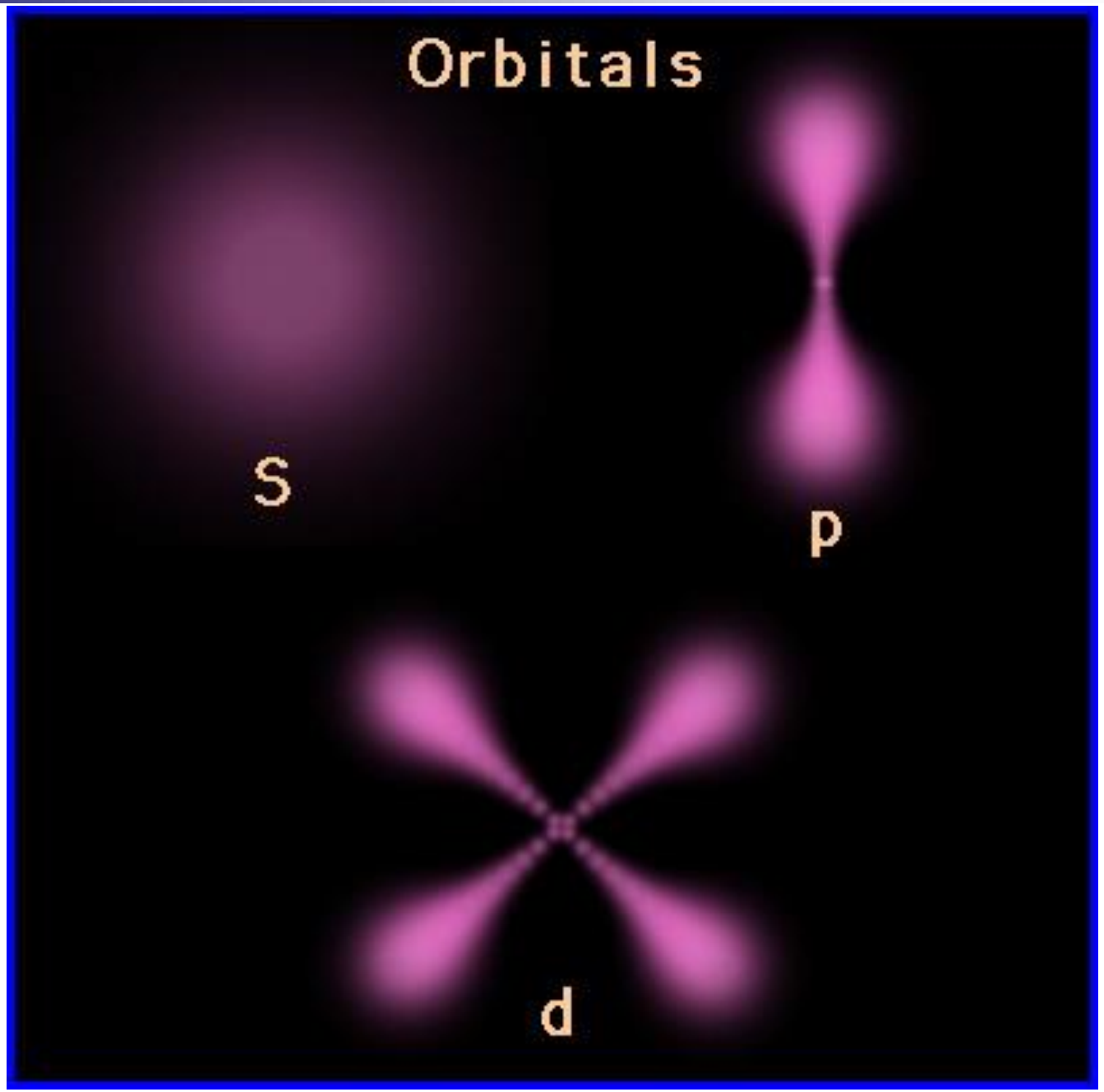
The 3 p orbitals



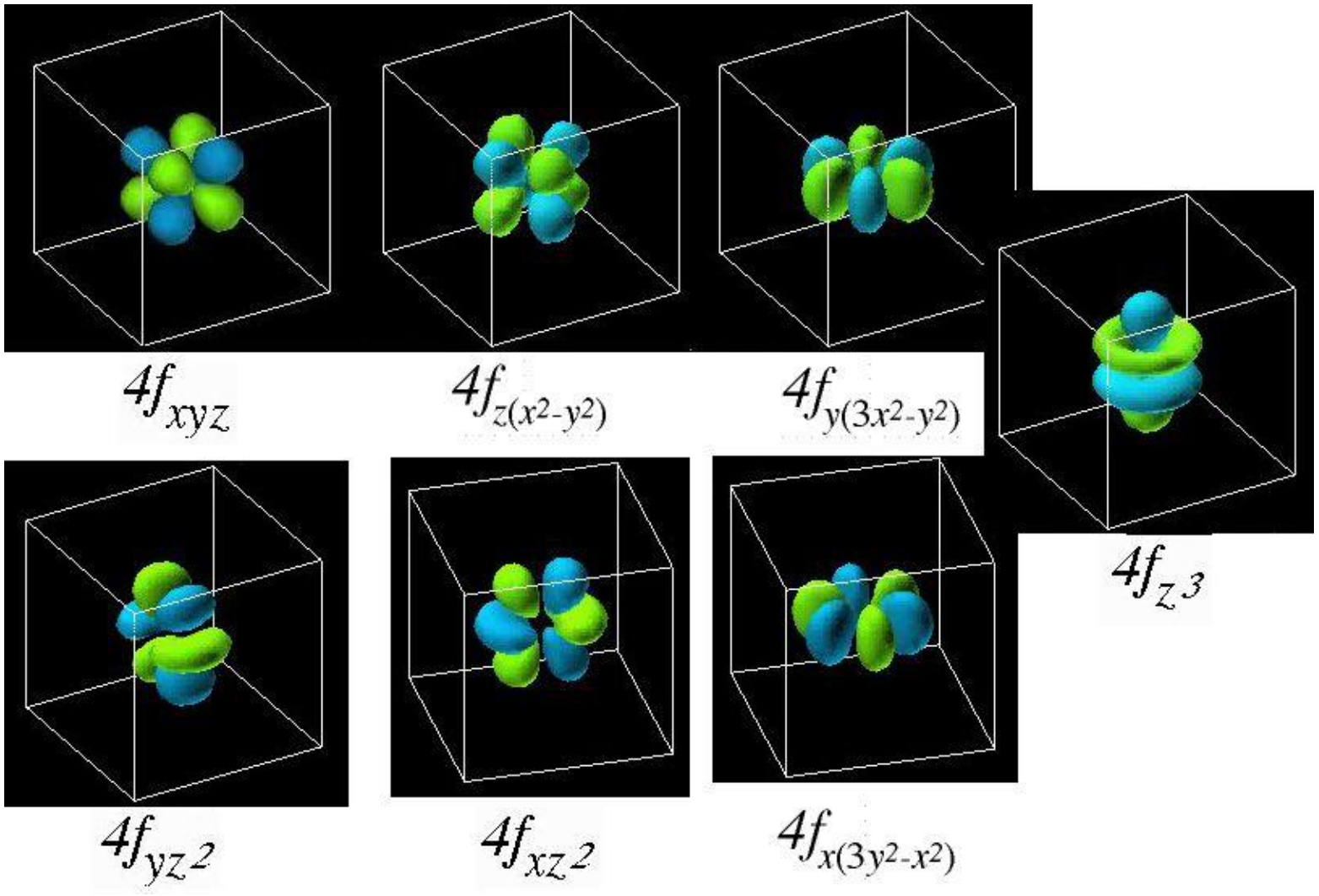
http://www.rmutphysics.com/CHARUD/scibook/crystal-structure/porbital.gif

- The d orbitals




Orbitals
S
p
d

f orbitals



Magnetic Quantum Number, m_ℓ

- Indicates the orientation of the orbital in space.
- Values of m_ℓ: integers $-\ell$ to ℓ
- The number of values represents the number of orbitals.
- Example:

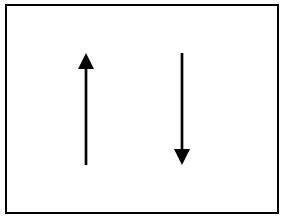
  for $\ell = 2$, m_ℓ = -2, -1, 0, +1, +2

  Which sublevel does this represent?

  Answer: d

Electron Spin Quantum Number, (m_s or s)

- Indicates the spin of the electron (clockwise or counterclockwise).
- Values of $m_{s:}$ +1/2, -1/2



Example:

- List the values of the four quantum numbers for orbitals in the 3d sublevel.
- Answer:

n=3

$\ell = 2$

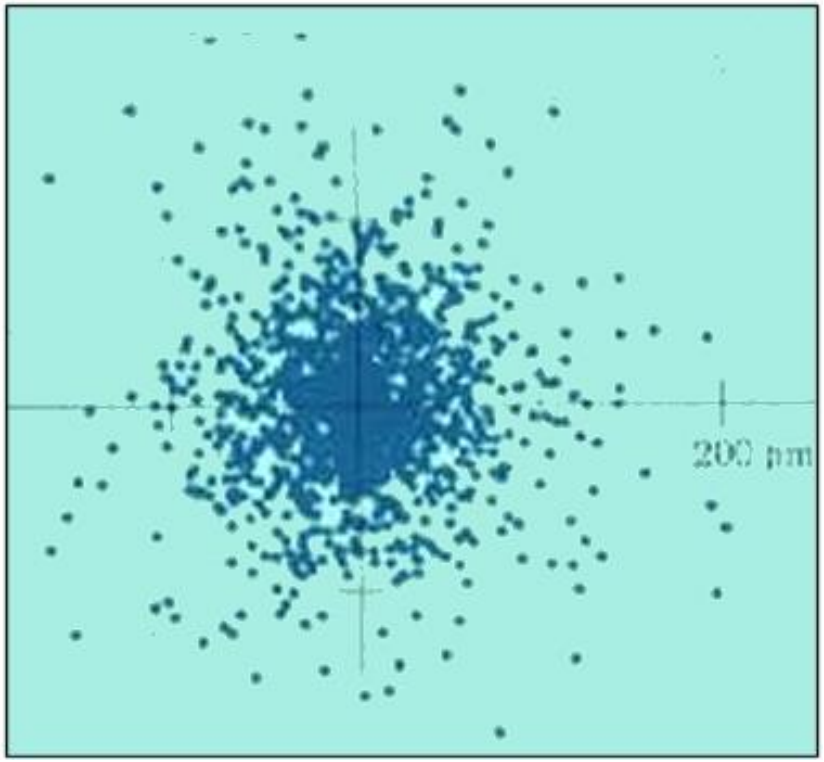
m_ℓ = -2,-1, 0, +1, +2

m_s = +1/2, -1/2 for each pair of electrons

The Electron Cloud

- The electron cloud represents positions where there is probability of finding an electron.

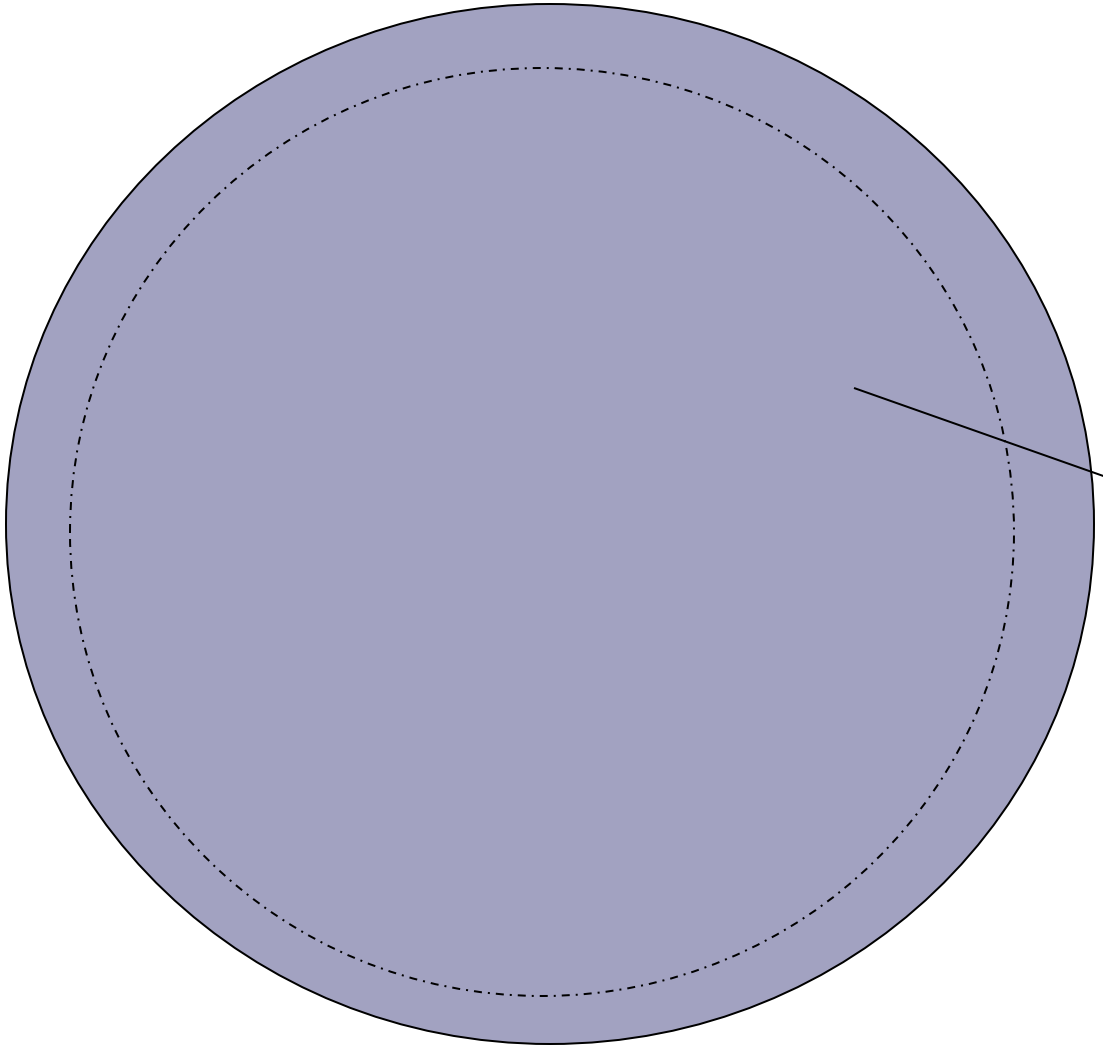
The Electron Cloud



The higher the electron density, the higher the probability that an electron may be found in that region.

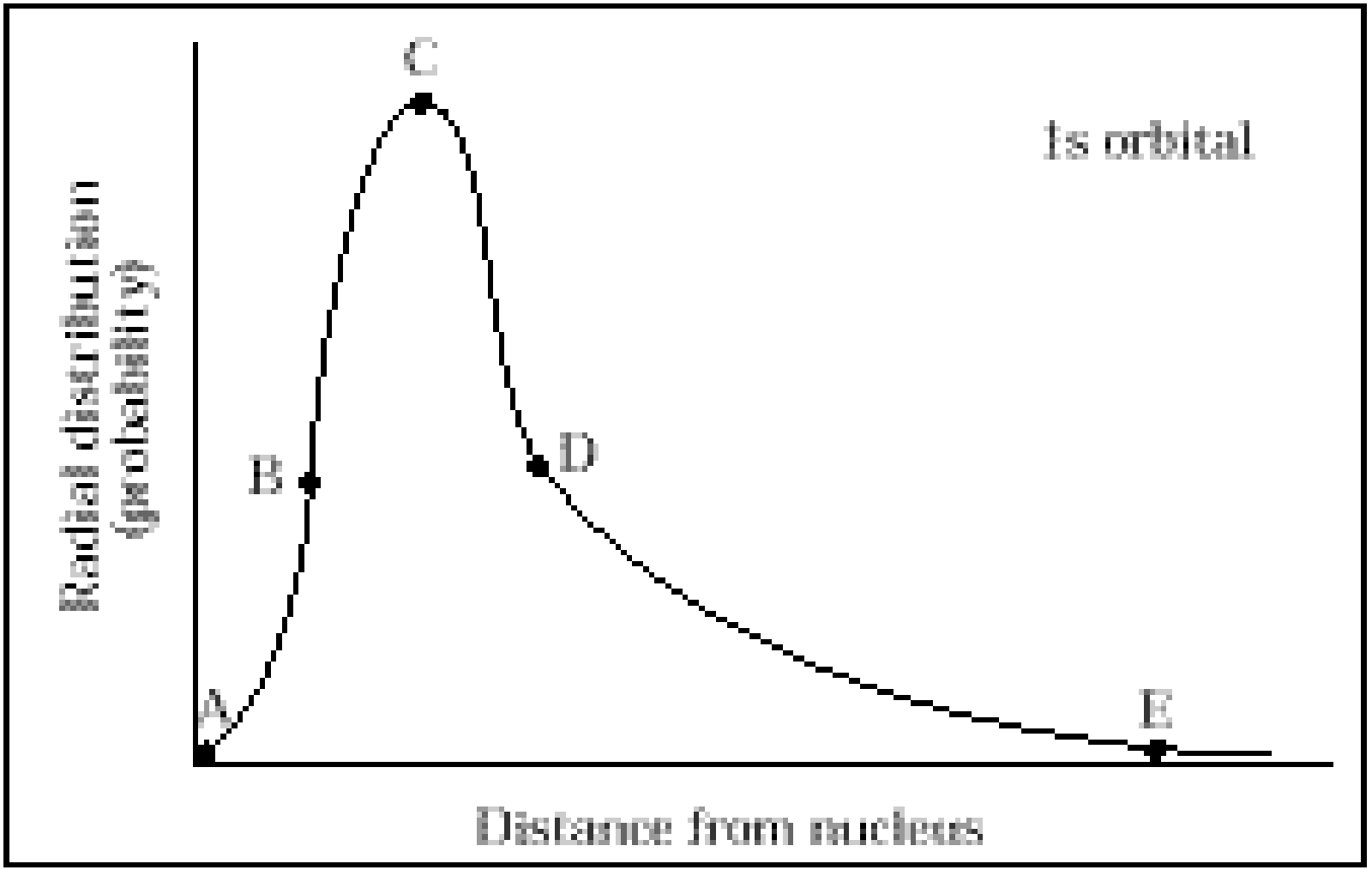
http://www.chemeng.uiuc.edu/~alkgrp/mo/gk12/quantum/H_S_orbital.jpg

The Electron Cloud for Hydrogen



90% probability of finding the electron within this space

Probability Curve for Hydrogen



FYI: Schrodinger's Equations!!!

- ψ is called the wave function and indicates the probability of where an electron may be found.

$$\frac{-\hbar^2}{2m}\frac{\partial^2\Psi(x,t)}{\partial x^2}+U(x)\Psi(x,t)=i\hbar\frac{\partial\Psi(x,t)}{\partial t}$$

Quantum Mechanical Model

- Electrons are located in specific energy levels.
- There is no exact path around the nucleus.
- The model estimates the probability of finding an electron in a certain position.