Quick Quiz
If I detect one electron which passed through a double slit apparatus what will I see?
  a) a small “lump”
  b) a wiggly shape with peaks and valleys
  c) a broad smear
  d) two broad smears, one for each slit

Quick Quiz
White light (containing all visible colors) passes through a gas and the spectrum is analyzed. The spectrum is an absorption spectrum and could best be described in terms of
  a) electrons jumping up to higher energy levels.
  b) electrons falling down to lower energy levels.
  c) photons jumping up to higher energy levels.
  d) photons falling down to lower energy levels.

The Wave Model of the Atom
• Standing Waves
• Orbitals
• Resolution of Problems with Bohr Model
• Orbital Energies
• Exclusion Principle
Standing Waves

- interference waves that arise when waves moving in different directions interfere with each other giving rise to stationary nodes and anti-nodes
- these can occur in atoms giving rise to orbitals (not orbits)

Orbitals

- Standing waves of probability giving the likelihood of an electron being in a particular atomic location
- Like a cloud of probability
- Labeled “s”, “p”, “d”, “f”, “g”, ...
- Schroedinger’s equation
  $$\frac{\hbar^2}{8\pi^2m} \frac{d^2\Psi(x)}{dx^2} + V(x) \Psi(x) = E\Psi(x)$$

Bohr Model Problems Solved!

- Only certain patterns and energies will form standing waves.
  - This solves the problem with Bohr’s special orbits.
- Electrons are not moving (and hence not accelerating).
  - This solves the problem with Bohr’s electrons not radiating in his “magical” orbits
Orbital Shapes – 90% probability of finding the electron inside this shape.

s Orbital

• highest probability where darkest

p and d orbitals

p - always come in sets of 3

d - always come in sets of 5
Orbital Energies

- A different discrete energy is associated with each orbital.
- When an electron jumps between orbitals with different energies, discrete colors of light are emitted, just as in the Bohr atom.
- Orbitals with closely spaced energies are called shells (numbered 1, 2, 3, ...).
  - Within a shell, energy increases as "s", "p", "d", ...
- Higher energy shells are further from the nucleus.

Orbital and Shell Occupancy

- Orbitals
  - 1 kind of "s" orbital
  - 3 kinds of "p" orbitals
  - 5 kinds of "d" orbitals
  - 7 kinds of "f" orbitals
- Shells
  - Level 1: "s" orbital
  - Level 2: "s" and "p" orbitals
  - Level 3: "s", "p", and "d" orbitals
  - Level 4: "s", "p", "d", and "f" orbitals

Spin

- Spin is the direction of the electron’s magnetic field.
- Spin up and spin down.
- A spin up electron has less energy than a spin down electron.
Exclusion Principle

- No more than two electrons can exist in an orbital at the same time.
- If there are two electrons in an orbital, they must have different spin.
  - "spin up"
  - "spin down"
- An electron must have 3 distinct labels: shell, orbital shape, spin.

Energy Well Diagram

Hydrogen

free electron

Level 3

Level 2

Level 1

free electron

Level 3

Level 2

Level 1
Helium

Lithium

Beryllium
Quick Check

• How many p electrons can there be in a shell?
• Which orbitals are in third shell?
• How many electrons are in an atom that has both the first and second shells filled?

Summary of Wave Model

• Positive, tiny, dense nucleus surrounded by electrons
• Only certain orbitals produce standing probability waves
• Each orbital has a discrete energy
• Exclusion principle – no more than 2 electrons per orbital and if 2 electrons are in same orbital, must differ by spin
• Groups of closely spaced orbitals are called shells.