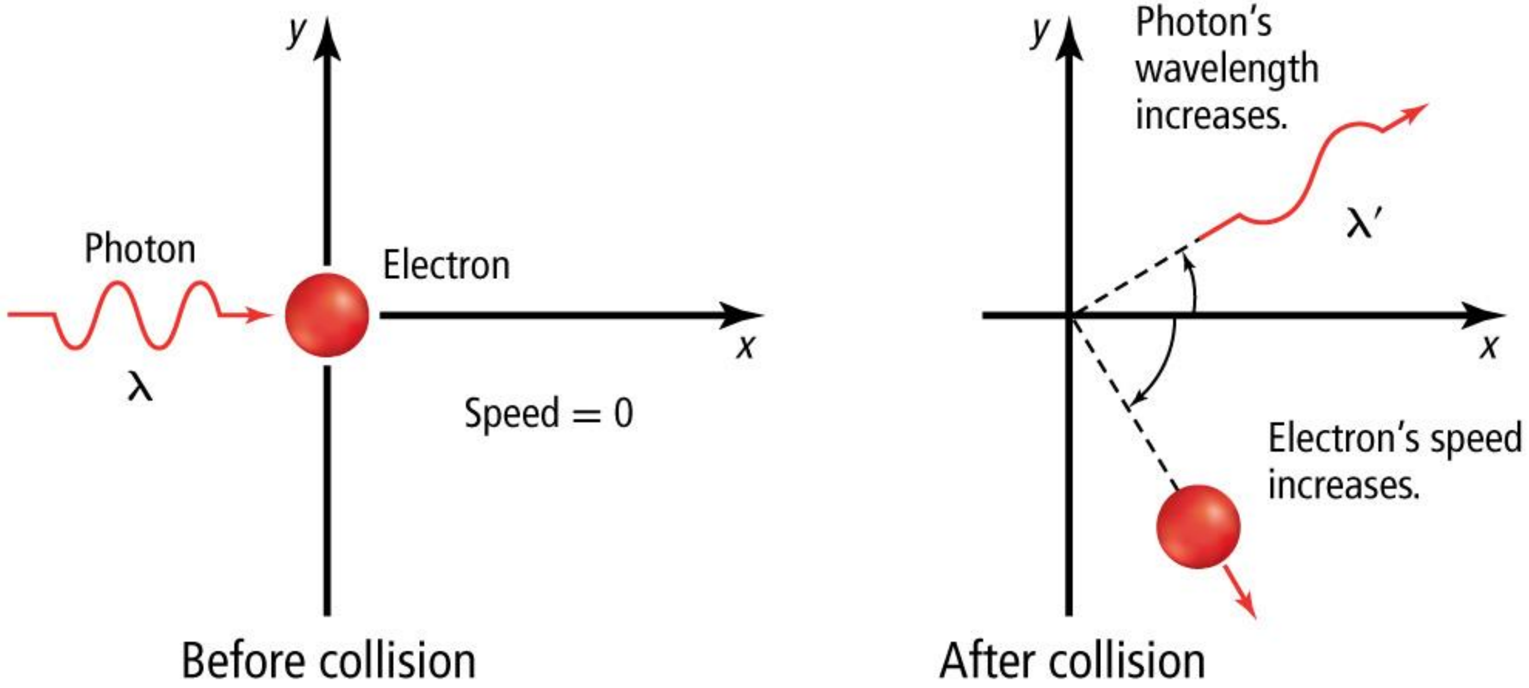
Quantum Mechanics

The hidden world of the electron

Heisenberg Uncertainty Principle:

- →It is impossible to know both the location and path of motion of an electron at the same time
- →the more we know about one, the less we know about the other

Heisenberg Uncertainty Principle



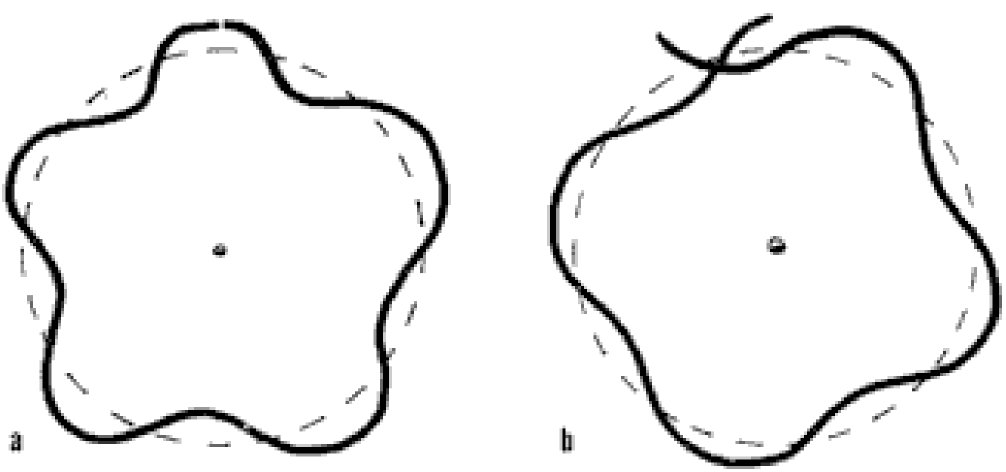
DeBroglie

- DeBroglie proposed that **all** matter has a *dual* nature.
  - ***Not just light***
- An electron has a particle nature and a wave nature
- Electrons can be thought of as "standing waves" around the nucleus

DeBroglie

Only certain size "standing waves" can "fit"

- Only certain λ, so only certain ν, so only certain Energies



The Bohr model failed because:

1. It failed to recognize the wave nature of the electron *(DeBroglie)*

2. It proposed exact orbits, and failed to recognize the uncertainty principle *(Heisenberg)*

Quantum Mechanics

- Uses wave equations to predict the **most probable location** of the electrons
  - *NOT the path of their motion*
- Energy calculations predict some locations as more probable, some less so, and some impossible

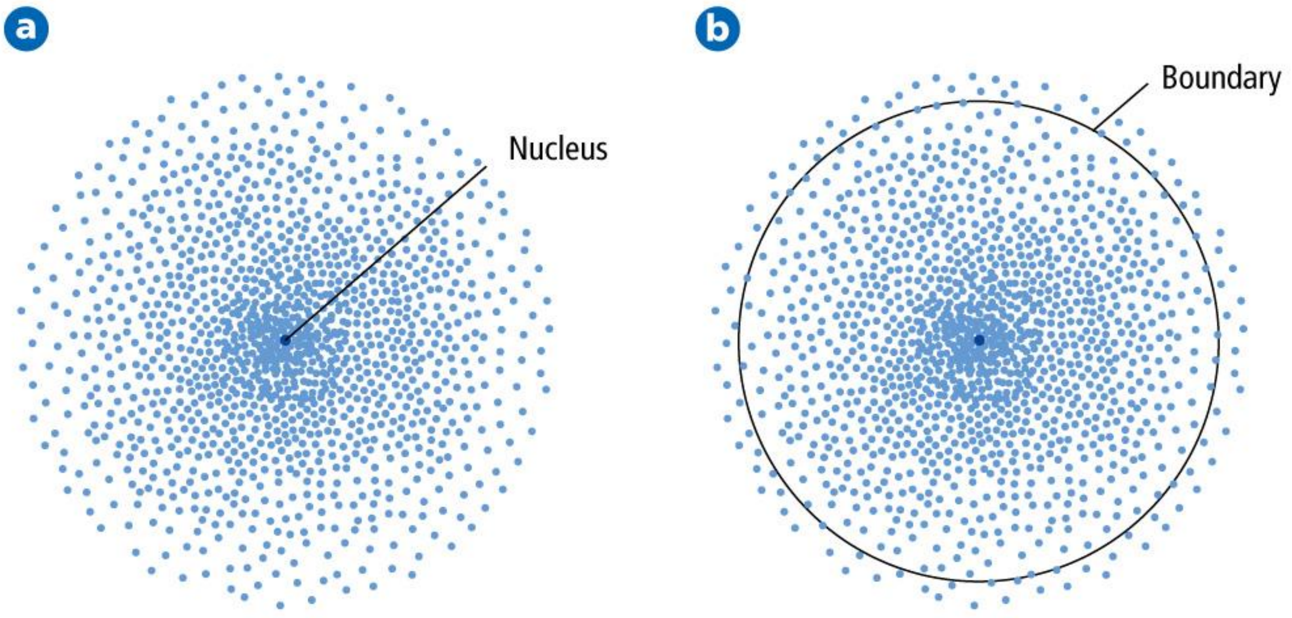
Back to waves…

- Schrödinger treated electrons as waves in a model called the *quantum mechanical* model of the atom.

- Schrödinger's wave equations applied equally well to elements other than hydrogen.

The Quantum Mechanical Model of the Atom

- The wave equation predicts a three-dimensional region around the nucleus called the **atomic orbital**.



Density Maps

Energy Levels

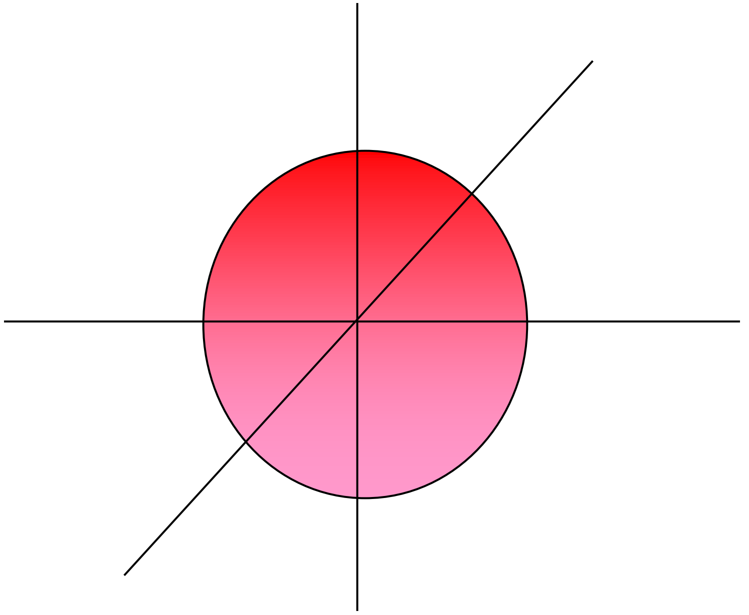
- Distances from the nucleus where electrons are most likely to exist
- Farther out from nucleus means higher energy
- analogy: floors in a multistory building

Orbitals

- Regions within the energy level where the electrons are most likely found
- different types of orbitals have different shapes and different letter designations
- analogy: rooms on a floor in a building

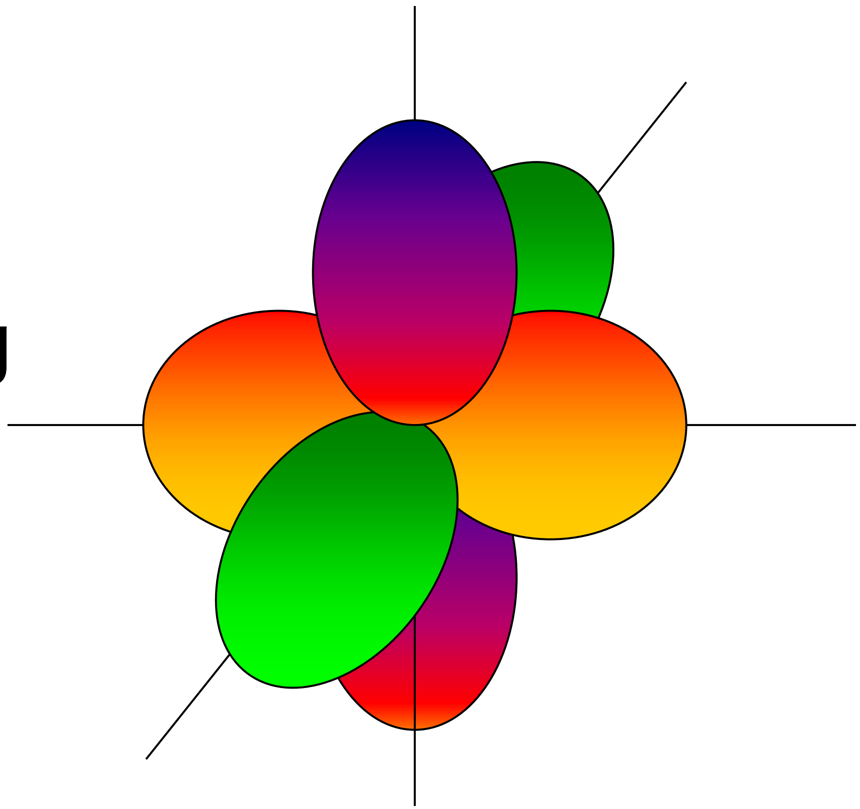
s orbital

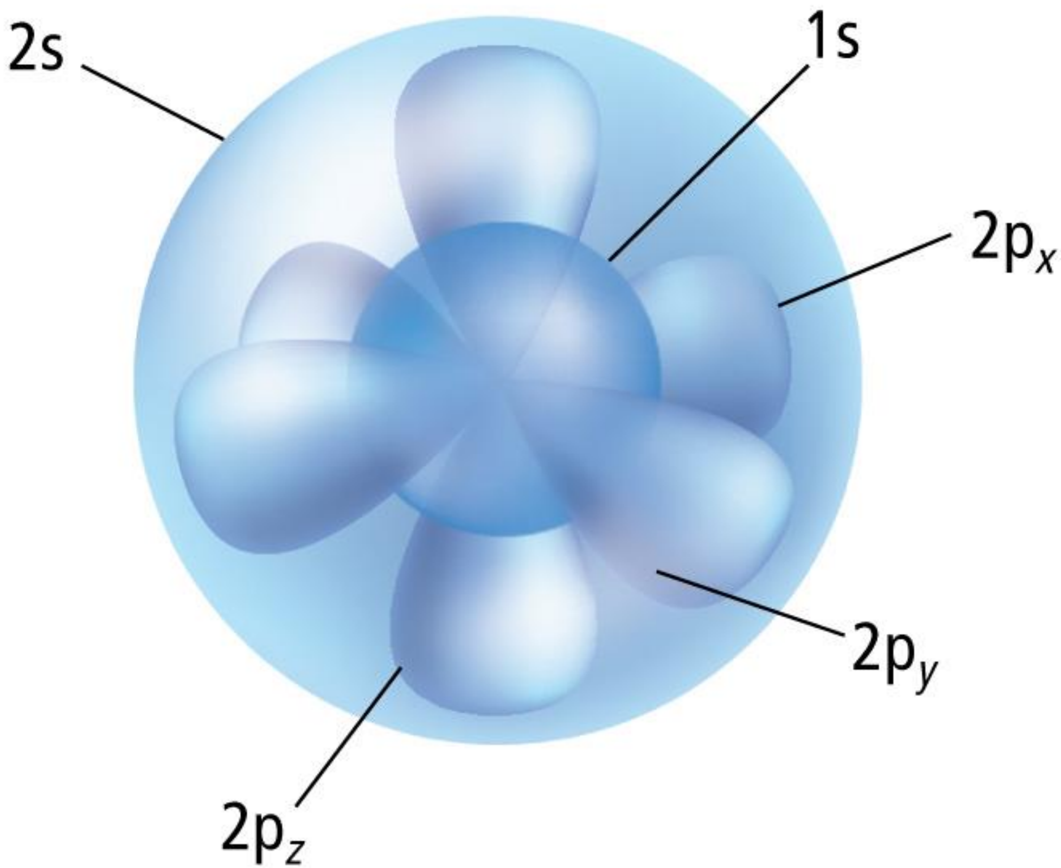
- Spherical in shape
- exists at every energy level
- the lowest energy orbital at any energy level



p orbital

- “figure 8” or “dumb-bell” shaped
- exist as a set of three orbitals, aligned along the x, y, and z axes
- exist at every energy level starting at the second

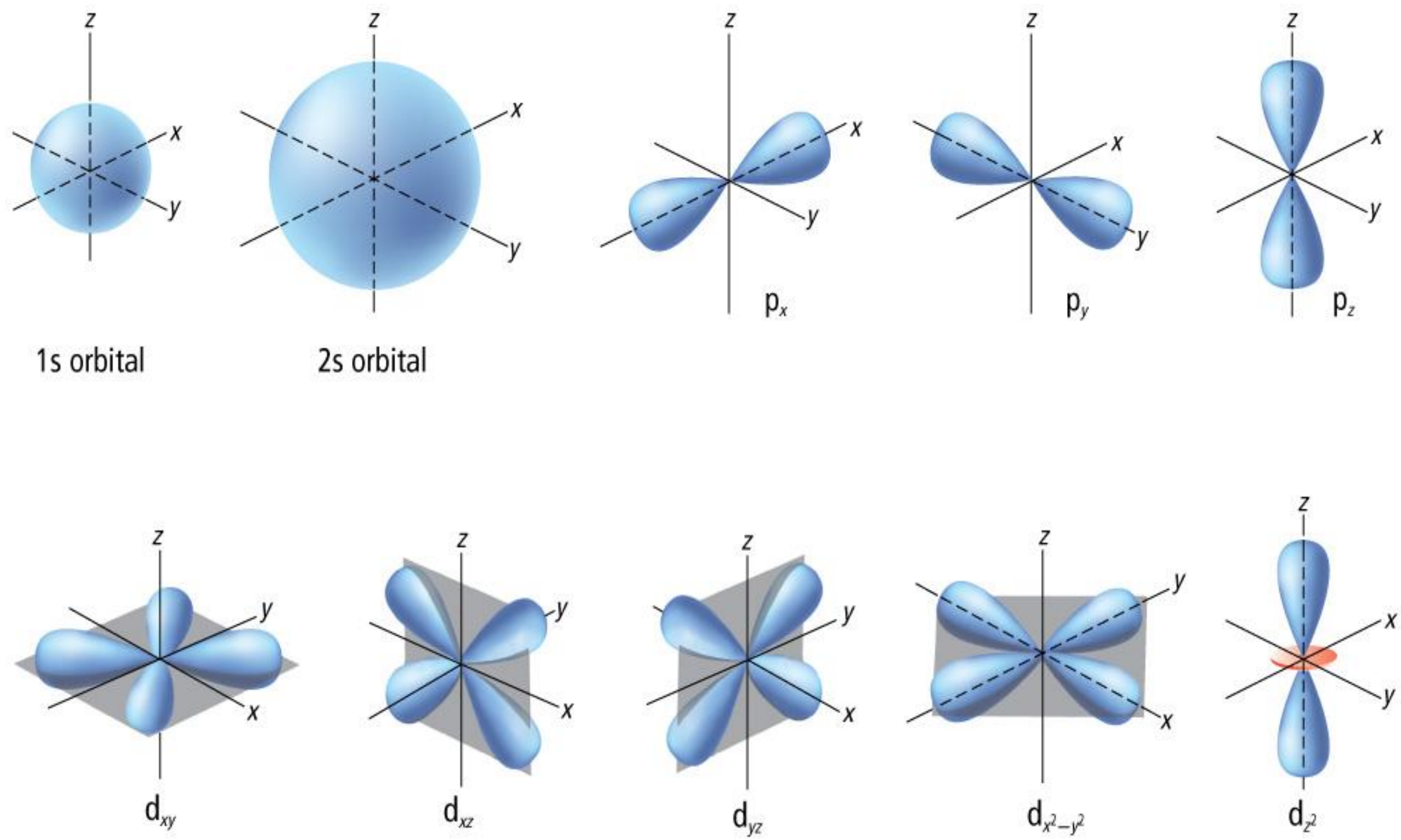




2s
1s
2p$_x$
2p$_y$
2p$_z$

Beyond the p's

- d orbitals
  - exist as a set of 5
  - begin at the third energy level
- f orbitals
  - exist as a set of 7
  - begin at the fourth energy level



1s orbital
2s orbital
p$_x$
p$_y$
p$_z$
d$_{xy}$
d$_{xz}$
d$_{yz}$
d$_{x^2-y^2}$
d$_{z^2}$

Pauli exclusion principle

- No two electrons within the atom can have exactly the same energy
- Each individual orbital can contain at most two electrons
  - –they must have “opposite spin”

Symmetry in nature

- Number of orbitals at energy level:
  - n^2
  - ex: 3rd level, $3^2 = 9$ orbitals
- Number of e^-'s at energy level:
  - $2n^2$
  - ex: 3rd level, $2 \times 3^2 = 18$ e^-'s

Summary of energy levels

- First energy level

→lowest energy

→closest to the nucleus

→one s orbital

→2 electrons max

Summary of energy levels

- Second energy level

→one “s” orbital, 3 “p” orbitals

→s orbital lower energy

→4 orbitals total

→8 electrons max

Summary of energy levels

- Third energy level

→one s orbital, 3 p’s, 5 d’s

→p orbital lower energy than d

→9 orbitals total

→18 electrons max

Summary of energy levels

- Fourth energy level

→one s, 3 p’s, 5 d’s, 7 f’s

→d orbital lower energy than f

→16 orbitals total

→32 electrons max