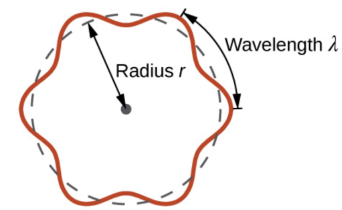
Introduction to Physical Science

Quantum Theory

Presented by Robert Wagner

Wave Nature of Particles

- Macroscopic particle has a well-defined momentum (p = mv)
- Microscopic world - follow different rules than those for macroscopic objects
  - Light behaves like a particle ; Can an electron behave like a wave
- de Broglie wavelength - electron behaves like a wave



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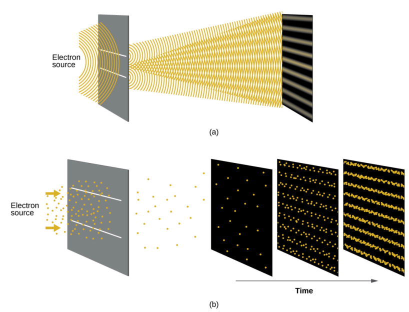
Electrons as Waves

- Electrons sent through slits create an interference pattern
  - Electrons have a dual nature



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Example

- If an electron travels at a velocity of and has a mass of , what is its wavelength?

$$v = 1.000x10^{7}\ m/s\ ;\ m = 9.109x10^{-28}\ g$$

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

$$\lambda = \frac{6.626x10^{-34}\ kg \cdot m^{2}/s}{(9.109x10^{-31}\ kg)(1.00x10^{7}\ m/s)}$$

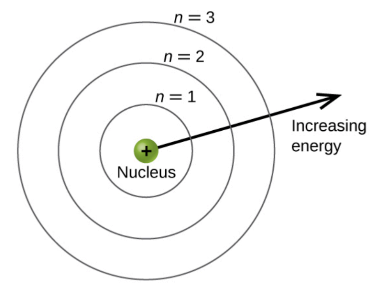
$$\lambda = 7.274x10^{-11}\ m$$

Heisenberg Uncertainty Principle

- How accurately can we measure the properties of an electron (or other particle)?
- A limit to how accurately we can measure the position and momentum of an electron simultaneously.
-
- Not significant for macroscopic objects
- Gives and ultimate limit on what can be known in science

Principal Quantum Number

- Principal quantum number (shell number)
  - Location of energy level
  - Energy levels n = 1,2,3,…
- Secondary quantum number (angular momentum)
  - Levels: l = 0,1,2,…,n-1
  - Orbitals: l = 0 are s orbitals ; l = 1 are p orbitals ; l = 2 are d orbitals ; f, g, & h for l = 3,4,&5



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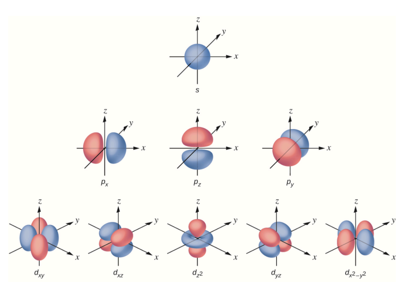

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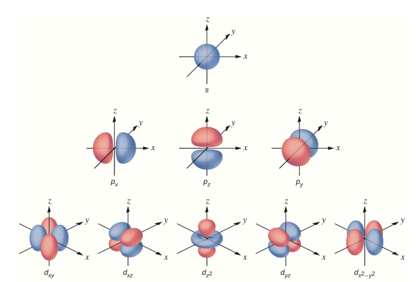
Quantum Numbers (2)

- Magnetic quantum number
  - Spatial orientation of the orbital
  - Number of orbitals: 2l+1
- Principal quantum number: General value of electron energy
- Secondary quantum number: Shape of the orbital
- Magnetic quantum number: Orientation of orbital in space



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Orbital Energies

- Orbital is labeled by its principal quantum number and secondary quantum number
- Spin quantum number
  - Electron can have spin “up” or spin “down”

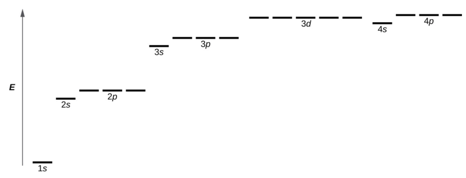

Figure 6.22 The chart shows the energies of electron orbitals in a multi-electron atom.

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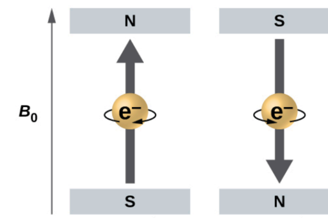

Pauli Exclusion Principle

- The electron is described by the four quantum numbers.
- Exclusion principle
  - No two electrons in an atom can have the same set of quantum numbers
  - At most two electrons can occupy each orbital

Quantum Numbers, Their Properties, and Significance

Name	Symbol	Allowed values	Physical meaning
principal quantum number	n	1, 2, 3, 4, ….	shell, the general region for the value of energy for an electron on the orbital
angular momentum or azimuthal quantum number	l	$0 \leq l \leq n - 1$	subshell, the shape of the orbital
magnetic quantum number	m_l	$-l \leq m_l \leq l$	orientation of the orbital
spin quantum number	m_s	$\frac{1}{2}, -\frac{1}{2}$	direction of the intrinsic quantum “spinning” of the electron

Example

- How many electrons can occupy a shell with n=2? n=5?

$n = 2$; $n = 5$

n = 2 has four orbitals: one 2s orbital and 3 2p orbitals. Two electrons per orbital means 8 electrons.

n = 5 has 25 orbitals: one 5s orbits, three 5p orbitals, five 5d orbitals, seven 5f orbitals, nine 5g orbitals. Two electrons per orbital means 50 electrons in the shell.

Example

- Complete the table for atomic orbitals.
  - n = primary quantum number
  - l = secondary quantum number (s,p,d,f,…)
  - m_l=2l+1

Orbital	*n*	*l*	m_l degeneracy
4*f*			
	4	1	
	7		7
5*d*			

Summary

- Electrons (and other particles) have been found to behave like waves much as light can behave like a particle
- The uncertainty principle limits how accurately we can know the position and momentum of a particle simultaneously
- Four quantum numbers specify the state of an electron within an atom