Arrangement of Electrons in Atoms
Refinements of the Atomic Model

Quantum Numbers and Atomic Orbitals

I. Quantum Model of the Atom
   A. Quantum theory -- describes mathematically the wave properties of electrons and other very small particles
   B. Oribital -- 3-D region about the nucleus in which a particular electron can be located

II. Quantum Numbers
   A. Numbers that specify the properties of atomic orbitals and of their electrons
   B. Indicate:
      1. distance from the nucleus
      2. orbital shape
      3. orbital position
   C. Principal Quantum Number
      1. Symbolized by n
      2. Indicates main energy levels surrounding a nucleus
      3. Referred as shells
      4. Ranges from 1-7
   D. Orbital Quantum Number
      1. Indicates shape of an orbital
      2. Referred as sublevels or subshells
      3. Ranges from s, p, d, f
      4. s - spherical
      5. p - two lobes
      6. d - four lobes, one with two lobes with donut
      7. f - very complex
   E. Magnetic Quantum Number
      1. Indicates the orientation of an orbital about the nucleus
      2. s-orbital -- one orientation
      3. p-orbital -- three orientations (x, y, z)
      4. d-orbital -- five orientations
      5. f-orbital -- seven orientations
   F. Spin Quantum Number
      1. Indicates two possible states of an electron in an orbital
      2. +1/2 and -1/2 (opposite spins)
   G. Magnetism
      1. Diamagnetism -- weakly repels any magnetic field, but only when another magnetic field is in its presence.
      2. Paramagnetism -- weak attraction to a magnetic field, but only when another magnetic field is in its presence.
      3. Ferromagnetism -- strong form of paramagnetism (bar magnet), but also maintains a constant magnetic field.

Electron Configurations

I. Rules Governing Electron Configurations
   A. Electron Configuration -- Arrangement of electrons in atoms
   B. Aufbau Principle
      1. Electron occupies the lowest-energy orbital that can receive it.
      2. 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p...
   C. Hund's Rule
      1. Orbitals of equal energy are each occupied by one electron before any is occupied by a second electron
      2. p_x, p_y, p_z
   D. Pauli Exclusion Principle
      1. No two electrons in the same atom can have the same four quantum numbers
      2. two electrons of opposite spin can occupy the same orbital

II. Representing Electron Configurations
   A. Orbital Notation
      1. Unoccupied orbital is represented by a line (___)
      2. Orbital containing one electron is represented by an arrow ($\underline{\ \uparrow\ \ \ }$)
      3. Orbital containing two electrons is represented by two arrows in opposite directions ($\underline{\uparrow\ \downarrow}$)
      4. Lines are labeled with principal quantum number and subshell letter ($\underset{1s}{\underline{\uparrow\ \downarrow}}$)
   B. Electron-Configuration Notation
      1. Lines and arrows are not used
      2. Number of electrons in a sublevel is shown by adding superscripts to the sublevel designations
      3. $1s^1$ = one electron in the 1s orbital
      4. $1s^2$ = two electrons in the 1s orbital

C. Electron-Dot Notation
1. Shows only electrons in the highest, or outermost, main energy level
2. Highest Occupied Energy Level -- Electron-containing main energy level with the highest principal quantum number.
3. Dots representing number of electrons in the highest occupied energy levels are placed around the symbol of the element
4. Inner-Shell Electrons -- Electrons not in the highest occupied energy level
5. Number of electrons Electron-dot notation

Number of electrons	Electron-dot notation
1	X
2	X
3	X
4	X
5	X
6	X
7	X
8	X

III. Elements of the Second and Third Periods

A. Second-period Elements
1. After 1s is filled, 2s is then filled
2. After 2s is filled, 2p is then filled
    a. Each p orbital is filled with one electron
    b. After last p orbital is filled, the p orbitals receive a second electron, but with opposite spins
3. Octet -- s and p sublevels of their highest main energy level filled eight electrons

B. Third-period Elements
   1. After the first octet is filled, the third main energy level is then filled.
   2. After an octet is filled, square brackets are placed around the symbol

      $Ne = 1s^2\ 2s^2\ 2p^6 = [Ne]$

      $Na = 1s^2\ 2s^2\ 2p^6\ 3s^1 = [Ne]\ 3s^1$
   3. Noble gas
      a. Group 18 elements (He, Ne, Ar, Kr, Xe, Rn)
      b. Contains an octet in its outer shell (except He)
   4. Noble gas configuration -- Outer main energy level fully occupied by eight electrons

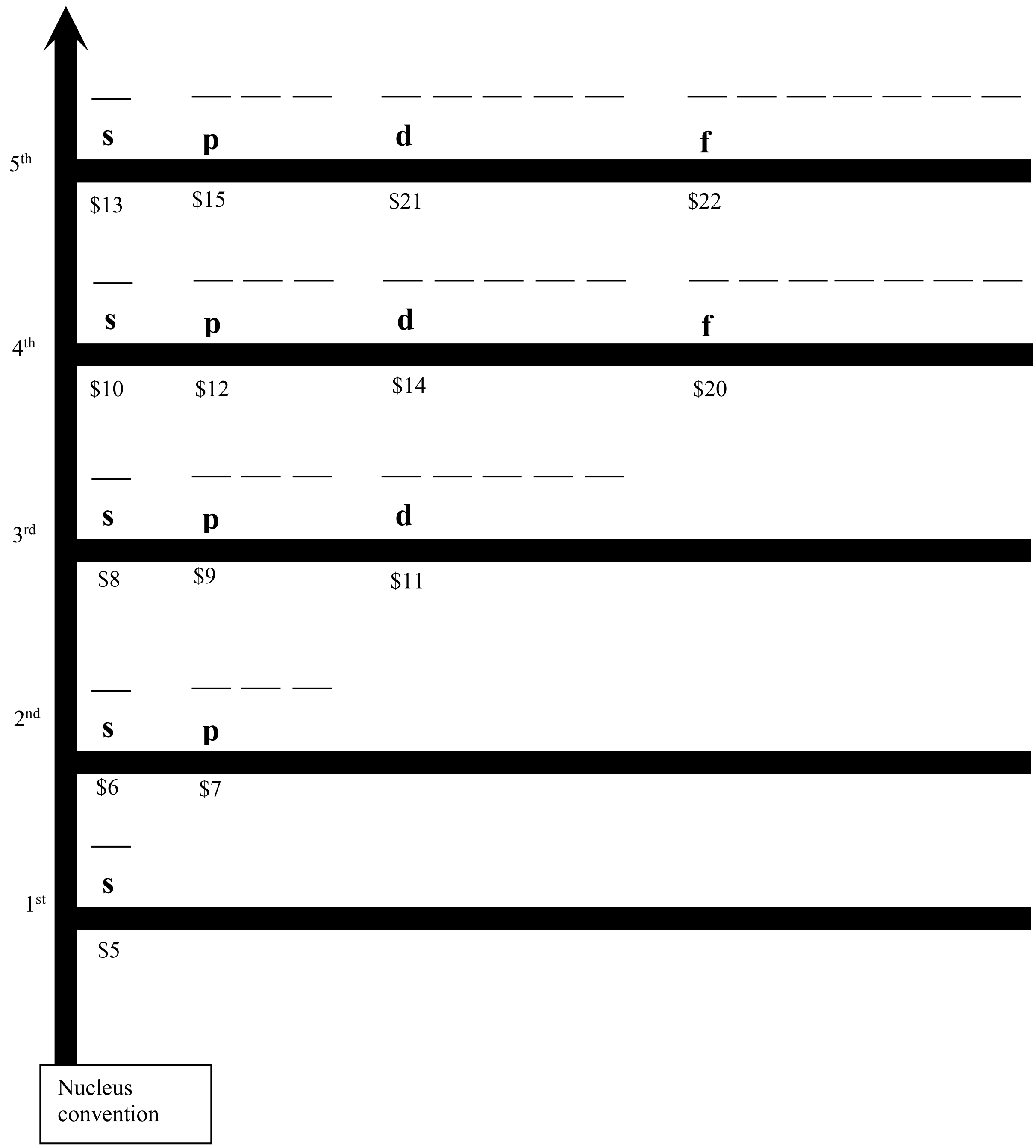
IV. Elements of the Fourth and Fifth Periods
   A. Cr and Cu seems to violate the normal electron configuration
   B. 3d orbital is filled
   C. d orbital contains 5 orbitals in its sublevel
   D. d orbital can hold 10 electrons

V. Elements of the Sixth and Seventh Periods
   A. 4f orbital is filled
   B. f orbital contains 7 orbitals in its sublevel
   C. f orbital can hold 14 electrons

VI. Diagram (“Electron Convention”):

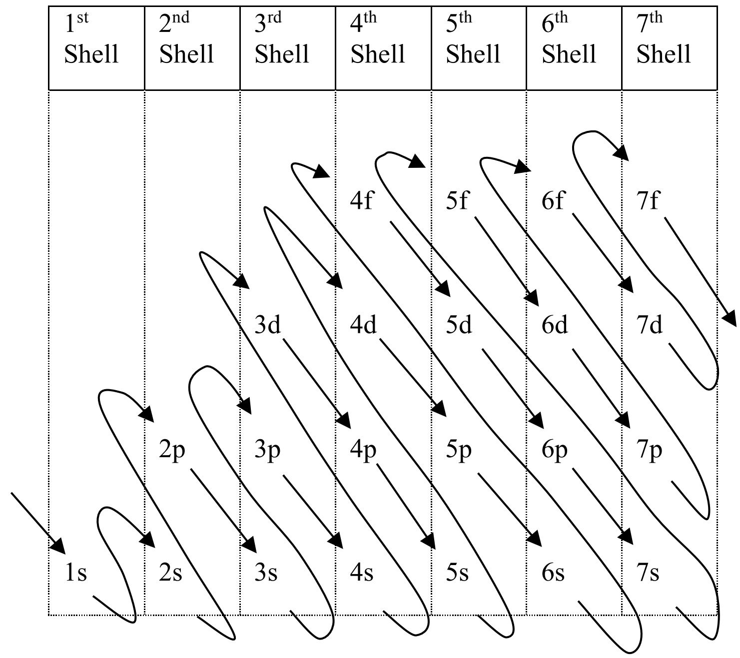
Rules that electrons follow (with a few exceptions, such as Cu and Cr)

1. Electrons are cheap.
2. They want to be as close to the convention (nucleus) as possible.
3. They prefer a room to themselves. (Each room can only occupy 2 electrons.)
4. If they must room with someone (in order to save money), they will room with one other, but they must be of an opposite gender (opposite spin).



VII. Diagram (Order of filling):

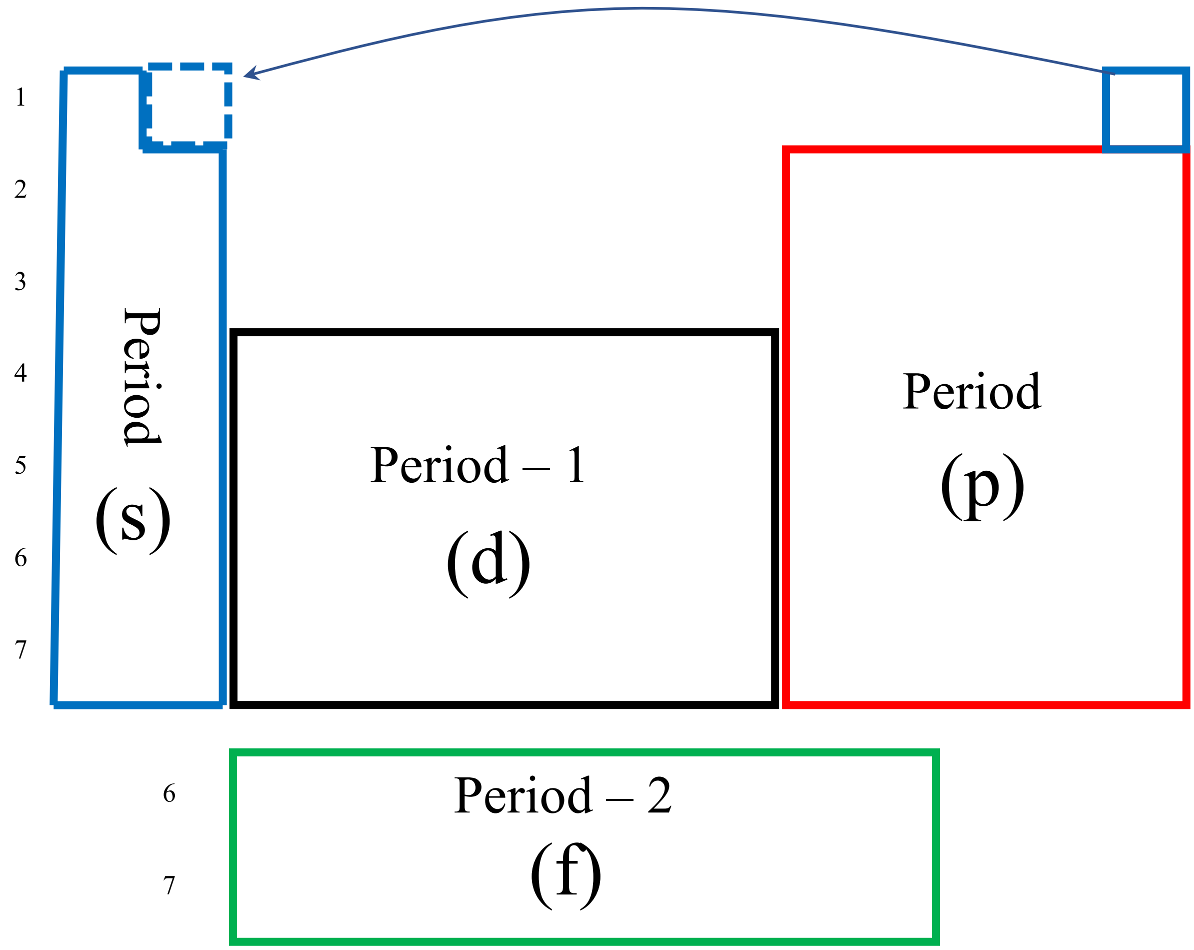
Orbital	Shape	Total # of orientations (spaces)	Total # electrons (occupants)
f	8-lobes, 2-lobes with 2-rings	7	14
d	4-lobes, 2-lobes with ring	5	10
p	2-Lobes	3	6
s	Spherical	1	2



Order in which electron configurations are written

1s	2s 2p	3s 3p 3d	4s 4p 4d 4f	5s 5p 5d 5f	6s 6p 6d 6f	7s 7p 7d 7f
1st Shell	2nd Shell	3rd Shell	4th Shell	5th Shell	6th Shell	7th Shell

VIII. Using the periodic table to find the electron configuration:



IX. Examples

1. Write both the complete and shorthand electron configurations, as well as the electron-dot symbols, for each of the following:

a. Na

b. Al

c. P

d. Ar

e. Br

f. Sr

2. Identify each atom on the basis of its electron configuration:

a. $1s^2\ 2s^2\ 2p^1$

b. $1s^2\ 2s^2\ 2p^5$

c. $[Ne]\ 3s^2$

d. $[Ne]\ 3s^2\ 3p^2$

e. $[Ne]\ 3s^2\ 3p^5$

f. $[Ar]\ 4s^1$

g. $[Ar]\ 3d^6\ 4s^2$

Periodic Law
Electron Configuration and the Periodic Table

I. Groups, Periods, and the Blocks of the Periodic Table
   A. Inner-shell electrons have little influence on properties of an element because they do not come into contact with their surroundings
   B. Outermost electrons play the largest role in determining chemical properties
   C. Each period is determined by the sublevels being filled with electrons
      1. First energy level holds two electrons in its 1s sublevel
      2. Second energy level holds eight electrons total in the 2s and 2p
   D. Period of an element can be determined from its electron configuration
   E. 4 blocks of periodic table
      1. s-block
      2. p-block
      3. d-block
      4. f-block
      5. Name of each block is based on whether and s, p, d, or f sublevel is being filled in successive elements of that block.

Electron Configuration and Periodic Properties

I. Atomic Radii
   A. One-half the distance between the nuclei of identical atoms joined in a molecule
   B. Period Trends
      1. Gradual decrease in atomic radii across the periods
      2. Caused by increasing positive charge of the nucleus
      3. Electrons are pulled closer to the nucleus
      4. Can be offset by large number of electrons in the same outer energy level
   C. Group Trends
      1. Atomic radii increases going down the column
      2. New outer shells are added going down the column