Periodic Properties of the Elements

Chapter 7

1

Periodic Classifications

- **Remember:**
  - Vertical Columns are called **groups** or **families**
  - Have similar properties and number of valence electrons
  - Some have special names
    - Alkali Metals — Group 1
    - Alkaline Earth Metals — Group A
    - Chalcogens — Group 16
    - Halogens — Group 17
    - Noble Gases — Group 18

2

Periodic Classifications

- **Remember:**
  - Horizontal rows are called **periods**
  - They vary in properties
  - From left to right
    - Metallic properties
    - Atomic radius
    - Electronegativity

3

Free Elements

- There are special elements that exist in different forms when they are free elements
  - Diatomic molecules
    - Br_2, I_2, N_2, Cl_2, H_2, O_2, F_2
  - Other molecular compounds
    - S_8 and P_4

4

Ion Formation

- Metals typically form cations where as nonmetals typically form anions
- Ion Formation is based on stability
  - Group 1 — 1+ cation
  - Group 2 — 2+ cation
  - Group 3-12 — Varies
  - Group 13 — 3+ cation
  - Group 15 — 3- anion
  - Group 16 — 2- anion
  - Group17 — 1- anion

5

Periodic Trends in Physical Properties

- There are five properties which we are going to focus on
  1. Effective nuclear charge
  2. Atomic radius
  3. Ionic radius
  4. Ionization Energy
  5. Electron Affinity

6

Effective Nuclear Charge

- **Effective Nuclear Charge (Z_{eff}):**
  - The charge/attraction felt by an electron from the nucleus
  - Relates to atomic number (# of protons) and shielding/screening electrons

7

Effective Nuclear Charge

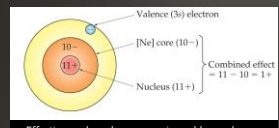
- **Shielding Electrons:**
  - Electrons in the energy levels between the nucleus and the valence shell electrons
  - They "shield" the valence electrons from the attractive force exerted by the protons in the nucleus
  - Z_{eff} decreases with increasing # of shielding electrons

8

Effective Nuclear Charge

- $Z_{eff} = Z - S$
  - Z = nuclear charge (atomic number)
  - S = the screening constant (approximately equal to the # of core electrons)

9

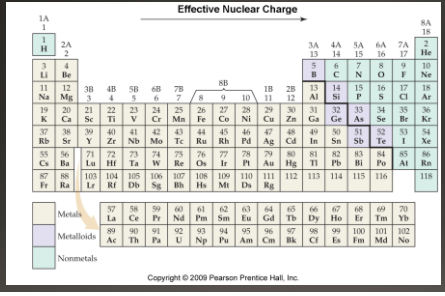


Effective nuclear charge experienced by a valence electron

The shielding electrons (10-) and the nucleus (11+) combine to have a 1+ effect.

10

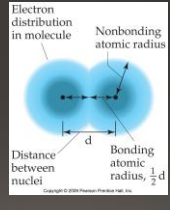
Z_{eff} Trend



11

Atomic Radius

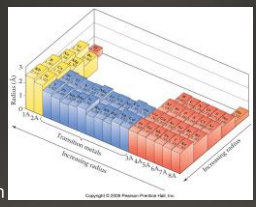
- **Atomic Radius:**
  - ½ the distance between the nuclei of 2 adjacent atoms
  - Atomic radius is directly related to Z_{eff}



12

Radius and Bond Length

- Measured in Angstrom (A)
- Distance between two nuclei in a bond (bonding atomic radius)
- Distance between two nuclei in collision (nonbonding atomic radius)



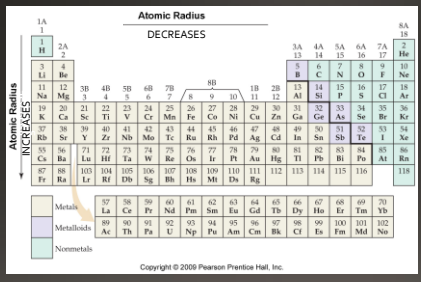
13

Trend for Atomic Radius

- Down a column, atomic radius increases
  - Increase in energy shells
  - Outer electrons more likely to be farther from nucleus
- Across a period, atomic radius decreases
  - Increase in effective nuclear charge (Z_{eff})

14

Trend for Atomic Radius



15

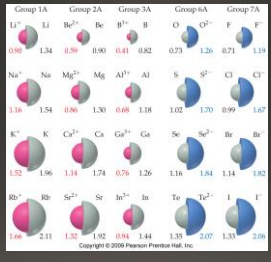
Ionic Radius

- **Anions** are larger than their atoms (e^- added to outermost orbital; more e^--e^- repulsion)
- **Cations** are smaller than their atoms (e^- removed from outermost orbital; less e^--e^- repulsion)
- Ionic radius is directly related to Z_{eff} too

16

Trend for Ionic Radius

- Follows same trend as atomic radius for same reasons
- Exception occurs when switching from cations to anions at Group 4A/14



17

Isoelectronic Series

- Groups of ions all containing the same number of electrons
- What is the relationship between atomic number and radius in an isoelectric series?

	O^{2-}	F^{-1}	Na^{+1}	Mg^{2+}	Al^{3+}
Electrons	10	10	10	10	10
Protons	8	9	11	12	13
Radius	1.26	1.19 Å	1.16 Å	0.86 Å	0.68 Å

18

Ionization Energy

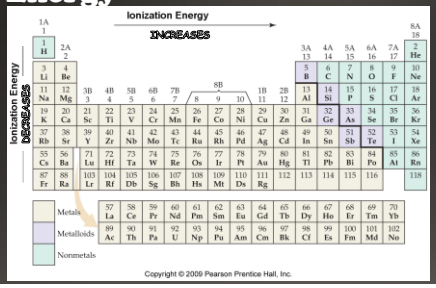
- The minimum energy (in kJ/mol) required to remove a ground state electron from a gaseous atom

$$\text{Energy} + X_{(g)} \rightarrow X^{+} + e^{-}$$

- Always a positive value where the magnitude is a measure of how "tightly" the electron is held in the atom

19

Trend for Ionization Energy



20

Ionization Energy

- What do you notice about the successive removal of electrons?

TABLE 7.2 ● Successive Values of Ionization Energies, I, for the Elements Sodium through Argon (kJ/mol)

Element	I_1	I_2	I_3	I_4	I_5	I_6	I_7
Na	495	4562	(inner-shell electrons)				
Mg	738	1451	7733				
Al	578	1817	2745	11,577			
Si	786	1577	3232	4356	16,091		
P	1012	1907	2914	4964	6274	21,267	
S	1000	2252	3357	4556	7004	8496	27,107
Cl	1251	2298	3822	5159	6542	9362	11,018
Ar	1521	2666	3931	5771	7238	8781	11,995

Copyright © 2009 Pearson Prentice Hall, Inc.

21

Electron Affinity (E_{ea})

- A measure of energy gained or released when an atom accepts an electron to form an anion

$$X_{(g)} + e^{-} \rightarrow X^{-}_{(g)}$$

- Elements with high electron affinity release a lot of energy when accepting an electron (and become more stable)
- A positive electron affinity means that the resulting anion is unstable so atom must gain energy to form it

22

Trend of Electron Affinity

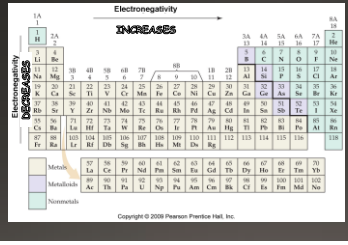
1A							8A
H −73							He > 0
Li −60	Be > 0	B −27	C −122	N > 0	O −141	F −328	Ne > 0
Na −53	Mg > 0	Al −43	Si −134	P −72	S −200	Cl −349	Ar > 0
K −48	Ca −2	Ga −30	Ge −119	As −78	Se −195	Br −325	Kr > 0
Rb −47	Sr −5	In −30	Sn −107	Sb −103	Te −190	I −295	Xe > 0
1A	2A	3A	4A	5A	6A	7A	8A

Copyright © 2009 Pearson Prentice Hall, Inc.

23

Electronegativity

- The ability of an atom to attract electrons towards itself in a **chemical bond**



24

Reactivity

- **Group Trends:**
  - **Metals:**
    - Increases top to bottom
    - Most reactive
  - **Non-Metals:**
    - Decreases down group
    - Most reactive
- **Period Trends:**
  - **Metals:**
    - Decreases left to right
  - **Non-Metals:**
    - Increases left to right

25