CHEM 110 Chapter 7: Periodic Properties of the Elements

The Periodic Table represents a display of not only all the known elements in our universe, but also gives a large quantity of information about them to those who know how to decipher it.

Effective Nuclear Charge

Due to the fact that electrons are negatively charged and protons positively, many of the properties of the elements depend upon how strongly the outermost (valence) electrons are attracted to the nucleus.

As electrons move further from the nucleus, it follows that their attraction decreases. Hence, the average force the atom experiences between its protons and electrons can be represented by what is termed the *effective nuclear charge (Z_{eff}).*

This value can be determined by the below subtraction problem:

$$Z_{eff} = Z - S$$

Where Z is the atomic number (protons in nucleus of atom) and S represents the "screening constant." S indicates the portion of the positive nuclear charge that is not felt by the negative valence electrons due to electrons beneath them partially shielding (blocking) the attraction of the nucleus.

For example, suppose an approximation of the Z_{eff} value for an atom of sulfur is desired. Knowing that sulfur's electron configuration is [Ne]$3s^2 3p^4$, the Z value (atomic number) = 16. Hence, sulfur has a total of 16 electrons. To approximate the value of S, subtract the number of non-valence electrons sulfur contains from 16. Since sulfur has 6 valence electrons (2 in the s and 4 in the p), it follows that is has 10 non-valence electrons. The effective nuclear charge would be: 16-10 = 6. Please note that this is only an approximation. The value can be quite different due to actual shielding effects.

This helps explain a number of important properties of the different atoms of each element such as the difference in energy between the s, p, d, and f orbitals. As one goes from the s to p orbital for instance, the potential energy increases due to more effective screening (shielding) which results in lesser attraction.

Periodic Trends: See Figures in Text.

Here, a trend represents a particular pattern one notices by going either left to right across a row (period) of the Table or going from top to bottom of a column (group or family of elements).

These include: sizes of atoms and ions, ionizations energies, and electron affinities.

Atomic and ionic radii refer to the size of the atom or ion, respectively.

Ionization energy refers to the amount of energy (kJ) required to remove an electron from a particular atom. It represents how easily an atom loses an electron. ***There is more than one ionization energy for most atoms since they contain more than one electron.*** **These are represented as I_1, I_2, I_3, etc. As one goes from the first ionization energy (I_1) to the second and onward, the quantity of energy needed to remove an electron increases since the atom becomes increasingly positive as each electron is removed.**

Electron affinity **refers to the amount of energy released when a gaseous atom of that element gains an electron. It represents how easily an atom gains an electron. This relates the amount of attraction an atom has for its electrons. Metals typically have low electron affinities while non-metals have high.**

Metals, Non-metals, and Metalloids

Metals, non-metals, and metalloids or semi-metals each have unique chemical and physical properties.

METALS

Metals are the most abundant form of element in the periodic table. They have the following properties:

a. Most are solids (cesium, mercury, and gallium are exceptions)

b. Malleable: can be rolled or hammered into thin sheets

c. Ductile: formed into wires

d. Usually have a high melting point and boiling point. Exceptions: the alkali metals; mercury, and gallium

e. Do not react readily with each other to form compounds

f. Some exist in nature as the element (gold, silver, mercury, bismuth, copper) while others combine readily with other elements to form rocks and minerals.

NON-METALS

Physical Properties: can be solids, liquids (Br), or gases at room T and P; brittle, low-reflectivity (not shiny); poor conductors of heat and electricity

Chemical Properties: Combine readily with each other to form compounds (smallest particle or called a molecule). **Exs.:** C and O combine to form CO (carbon monoxide) or CO_2 (carbon dioxide), H and Cl combine to form HCl (hydrogen monochloride)

Some non-metals are **diatomic** (consist of 2 atoms bonded to each other): **H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2** (7 total).

METALLOIDS (SEMI-METALS): Have properties of both; located along stair-step line on periodic table; used in semi-conductors

Exs.: B, Si, Ge

Allotropes: Differing forms of the same element that exist due to differences in chemical bonding. Exs.: white and red phosphorus; graphite, diamond, and buckminsterfullerenes (bucky balls) all forms of C; oxygen (O_2) and ozone (O_3)

Chemical Properties of Elemental Families

The Alkali Metals (Group 1A): Let M = Alkali Metal

a) $2\ M + 2H_2O \rightarrow H_2 + 2\ MOH$ (Metal Hydroxide)
b) $2\ M + H_2 \rightarrow 2\ MH$ (Metal Hydride)
c) $2\ M + S \rightarrow M_2S$ (Metal Sulfide)
d) $4\ M + O_2 \rightarrow 2\ M_2O$ (Metal Oxide)

Note: Some produce metal peroxides (O_2^{-2}) or metal superoxides (O_2^{-}).

Peroxide: $\mathbf{2\ Na_{(s)} + O_{2(g)} \rightarrow Na_2O_{2(s)}}$

Superoxide: $\mathbf{K_{(s)} + O_{2(g)} \rightarrow KO_{2(s)}}$

e) The alkali metals produce characteristic colors when heated: Li- crimson; Na- yellow; K- lilac (violet).

The Alkaline-Earth Metals (Group 2A)

a) $M + 2 H_2O \rightarrow M(OH)_2 + H_2$
b) $2 M + O_2 \rightarrow 2 MO$

The Oxygen Family (a.k.a. Chalcogens): Group 6

a) $3 O_2 \rightarrow 2 O_3$ (ozone, using electricity)
b) NM (non-metal) + $O_2 \rightarrow NMO_2$ (Non-metal oxide)

Example: $S + O_2 \rightarrow SO_2$

The Halogens: Group 7

a) $X_2 + H_2O \rightarrow HX + HOX$ (hydrohalic + hydrohalous acids, with the exception of F_2)
b) $3 F_2 + 3 H_2O \rightarrow 6 HF + O_3$

Note: HF is a weak acid while the other hydrohalic acids (HCl, HBr, HI) are strong.

c) $H_2 + X_2 \rightarrow 2 HX$ (hydrogen halide gases)

Noble (Inert) Gases: Group 8

a) Xe or Kr + F_2 → XeF_2 or KrF_2

b) Xe + 2 or 3 F_2 → XeF_4 or XeF_6

Note: Xe will also react with oxygen to form compounds.

c) H_2 + 2 Ar + F_2 → 2HArF