Chapter 2:
Atoms, Elements, Isotopes, and Ions

A Review of Chemistry
Atoms

- Atoms are composed of *Protons, Neutrons* and *Electrons*
  - A *proton* has an electric charge of +1 and a rest mass of $1.67 \times 10^{-24}$ gm.
  - A *neutron* has a charge of 0 and a rest mass of $1.67 \times 10^{-24}$ gm. (about the same as a proton).
  - An *electron* has a charge of -1 and a rest mass of $9.11 \times 10^{-28}$ gm. (much, much less than a proton).
- The electron mass is negligible relative to protons and neutrons.
Atoms and Elements

• The chemical properties of an element depend on the number of protons (i.e. the net electric charge) of the nucleus.

• The number of protons in the nucleus is known as the *atomic number* of the element.

• Atomic numbers for natural element range from 1 (hydrogen) to 92 for uranium.
Chemistry

- The chemical reactions an element is capable of is determined by the electron configuration.
- Atoms with complete outer shells don’t enter chemical reactions (Inert).
- The number of lost electrons (net electric charge) is the valence.
Ions and Valence

• Atoms with 1, 2, 3, or 4 outer electrons may lose them and form positive ions (cations).
• Atoms with 7 or 8 outer electrons may gain electrons to form negative ions (anions).
• The number of lost electrons is the valence.
• The elements are arranged by chemistry into the Periodic Table.
Ions and Valence
Charge Denoted by Superscript

- Cations
  - H$^{+1}$
  - Na$^{+1}$
  - Mg$^{+2}$
  - Al$^{+3}$
  - Si$^{+4}$

- Anions
  - F$^{-1}$
  - O$^{-2}$
  - S$^{-2}$
Chemical Compounds

- Elements occur in integer ratios to maintain charge balance
- H$_2$
- H$_2$O
- SiO$_2$
- CaCO$_3$
Isotopes

• The number of *protons plus neutrons* in the nucleus is known as the *mass number* of the atom.

• Atoms of a given element (atomic number) may have differing numbers of neutrons.

• Atoms of the same element with different mass numbers are known as *isotopes*. 
Mass Number

• The mass numbers or isotopes of an element are denoted as preceding superscripts.
• For example the stable isotopes of the element oxygen are denoted $^{18}\text{O}$, $^{17}\text{O}$ and $^{16}\text{O}$.
• Oxygen has an atomic number of 8 (eight protons).
• The nucleus of $^{16}\text{O}$ thus contains eight protons and eight neutrons.
• How many neutrons are in the nucleus of $^{18}\text{O}$? (ans.: 10).
Atomic Weight

• A given element may have several stable isotopes.
• The average mass number of an element is the **atomic weight**.
• This is not an integer.
Nucleosynthesis

• The elements H, He, and minor amounts of Li were formed in the original Big Bang.
• All heavier elements were formed from the primordial H and He by nuclear fusion reactions in stars.
• The fusion reaction proceeds in steps in stars massive enough to undergo the full sequence.
Nucleosynthesis

- Large stars undergo successive fusion reactions until Fe is formed by direct fusion.
- Heavier elements are formed by neutron capture.
- The final fusion stage results in a supernova explosion.
- Our solar system formed from the remnants of a supernova.
Condensation and Accretion

- Each supernova will have a unique distribution of stable isotopes.
- The solar gas collapsed into a disk that heated and then cooled to condense solid particles of minerals called chondrules.
- The chondrules accreted to form planetesimals and the planetesimals accreted to form planets.
Accretion and Differentiation

- The accretion process was rapid and the early Earth melted.
- The elements partitioned according to their fluid-phase chemical affinities.
  - Siderophile - Metallic
  - Chalcophile - Covalent
  - Lithophile - Ionic
  - Atmophile - VanderWaals (Inert)