Atomic Theory

I. Dalton's Atomic Theory (1803)
- A. Atomic Theory of Matter
  1. All elements are composed of atoms, which are indivisible and indestructible particles (**spheres**)
     - a. atoms - smallest particle of an element with all the properties of the element
  2. All atoms of the same element are exactly alike; they all have the same mass.
  3. Atoms of different elements are different, having different masses.
  4. Compounds are formed by the joining of atoms of two or more elements.
     - a. Atoms of a compound are joined in a definite whole - number ratio (2:1 etc.)
- B. Law of Conservation of Mass (Antoine Lavoiser - 1770's)
  1. Since atoms cannot be divided or destroyed, then a chemical change is a rearrangement of atoms.
     - a. The total mass of substances in a reaction does not change.
- C. ***Law of Definite Proportions (Joseph Proust - 1799)***
  1. ***Atoms of different elements combine in a definite ratio in a compound, therefore the ratio of the masses in the compound are fixed***
- D. ***Law of Multiple Proportions (Dalton - 1803)***
  1. ***Atoms of different elements which form two or more compounds, always combine in whole number ratios***

II. Modern Atomic Theory
- A. Atoms have detailed structure
  1. This structure can be altered temporarily during chemical change (ions)
  2. Atoms can be changed from one element to another (radioactive decay)
  3. Atom is mostly empty space
- B. Structure of an Atom
  1. Electrons - ***discovered by J.J. Thompson in 1897 using a cathode ray tube***
     - a. ***mass = 1/1836 of a proton (negligible mass in determining atomic mass)***
       1. ***Proven by Robert Milliken in 1909 using oil droplets in an electric field***
     - b. charge = -1
  2. **Rutherford's gold foil experiment**
     - a. Most of the atom **consists of empty space** (electrons are outside the nucleus)
       1. accounts for the **volume** of the atom (moves around the nucleus in space)
     - b. The mass of the atom is concentrated almost entirely in the nucleus (protons & neutrons)
       1. **Nucleus is positively charged (proton) and dense**
  3. Nucleons - the particles that make up the nucleus (protons & neutrons)
     - a. Protons - determines the **atomic number**
       1. mass = 1 atomic mass unit
       2. charge = +1
       3. takes up very little of the atoms total volume
       4. accounts for the mass of the atom (along with the neutron)
     - b. Neutrons
       1. mass = 1 atomic mass unit
       2. no charge

3. part of the nucleus
4. accounts for the mass of the atom
5. The number may vary, producing **isotopes** of a particular atom.
    a. isotope – has the same atomic number but different atomic mass because of a different number of neutrons (ex. H-1 Hydrogen (protium), H-2 deuterium, H-3 tritium)
    b. Nuclide is a general term for any isotope of an element
6. **Calculating the Average Atomic Mass of an element**
    a. Atoms are alike in those characteristics that determine the chemical properties of an element
    b. Atomic mass is determined by calculating the average mass of all the isotopes of that element.
        1. **Isotope A mass x % + Isotope B mass x % … = average atomic mass**

III. Atomic Mass

A. Atomic mass is based on 1/12 of a carbon -12 atom. (standard)

B. The weighted average mass of the naturally occurring isotopes of that element.

1. weighted according to the proportions in which the isotopes occur
    a. accounts for fractional atomic masses found in the periodic table
2. isotope – atom with the same number of protons, but a different number of neutrons. The element is the same, but has a different mass

C. Gram Atomic Mass - the mass of one mole of atoms (molar mass)

1. 1 mole of C = 12g and contains 6.02 $X10^{23}$ atoms of carbon
2. 1 mole of Na = 23g and contains 6.02 $X10^{23}$ atoms of carbon
3. Any portion of mass will have a proportional number of moles or atoms

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Chapter 4 – Modern Theory - Arrangement of Electrons in Atoms

VI. **Modern Theory – Wave Mechanical Model (Electron Cloud theory)**

A. Bohr Model - Neils Bohr (1913)

1. electrons were considered to revolve around the nucleus in concentric circular **orbits** (energy levels)
    a. solar system model
        1. Rings are labeled K,L,M,N,O,P,Q
        2. New system uses quantum numbers - 1,2,3,4,5,6,7
2. **Ground State** - electrons are in the lowest available energy levels.
3. **Excited State** - atoms absorb energy and electrons shift to a higher energy level
    a. This state is unstable - electrons fall back to lower energy levels
        1. **energy is released** when electrons return to the ground state
        2. **Light emitted** by excited electrons produces a distinct emission spectra for each element
4. Valence Electrons - electrons in the outermost principal energy level
    a. The number of valence electrons directly relates to the chemical properties of an element

1. valence electrons match the group number in the upper sections of the periodic table

b. Kernel - the electrons of the atom excluding the valence electrons (inner or core electrons)

c. Period # (# on side of periodic table) = Principle Energy Level (first number)

1. valence electrons are only from that level

5. Ionization Energy - amount of energy required to remove the most loosely bound electron from an atom in the gaseous phase.

a. Second ionization energy refers to the removal of the second electron and so on

b. Measured in kcal/mole of atom

VII.

A. ***Quantum Energy - A distinct, discrete amount of energy and fractions of that quantum are not allowed.***

1. ***Energy is not given off nor absorbed in a continuous flow, but in small packets of "quanta"***

B. Spectral Lines - wavelengths of radiant energy (light) produced by atoms in the excited state whose electrons return to the ground state.

1. Release of quanta (also called photons) produces a specific frequency of light for specific elements

a. produces a bright line spectrum

2. ***detected by using a spectroscope - only detects the light portion of the electromagnetic spectrum***

a. ***Wavelength (l) is measured in nanometers in the visible light spectrum (Spectroscopy)***

1. ***First Quantum Level - produces Lyman series (ultraviolet)***
2. ***Second Quantum Level - produces Balmer series (visible)***
3. ***Third Quantum Level - produces Paschen series (infrared)***

3. ***Calculation of wavelength and energy***

a. ***C= lv where c = speed of light 3.00x10^{8}m/s, l = wavelength in nm, v = frequency in /sec***

b. ***E=hc where E = energy in joules and h= Planck's constant (6.63x10^{-34}j***

VIII. ***Atomic Orbital Model (Wave Mechanical Model -deBroglie, Heisenberg and Schrodinger)***

A. ***Electrons***

1. ***occupy orbitals that differ in size, shape and orientation in space. (Shrodinger)***
2. ***have wave properties (deBroglie)as well as mass***
3. ***Orbital - the average region of the most probable electron location (electron location is impossible to determine (Heisenberg Uncertainty Principle)***

B. ***Energy Levels - represented by four quantum numbers***

1. ***Principal Quantum Number = the shell number in Bohr's model***

a. ***also called Principle energy level, or shell***

b. ***equals the period number in the periodic table (numbers on the left side)***

2. ***Second Quantum Number = sublevels – relative distance from the nucleus and geometric orientation (shape)***

a. ***Total # of sublevels in each principle energy level = the # of principle energy level***

b. ***sublevels are designated s,p,d,f***

1. ***in any principle energy level the s sublevel is lowest in energy, and f is the***

highest in energy

c. ***more spectral lines indicate more sublevels in heavier elements***

3. ***Third Quantum Number = orbitals – determined by geometric orientation around the nucleus***
    a. ***each orbital is capable of holding a total of 2 electrons (spin in opposite directions)***
        1. ***s sublevel = 1 orbital (2 electrons) -***
        2. ***p sublevel = 3 orbitals (6 electrons)***
        3. ***d sublevel = 5 orbitals (10 electrons)***
        4. ***f sublevel = 7 orbitals (14 electrons)***
            a. ***overlapping of s and d levels allows transition elements (B series) to have multiple oxidation states***
4. ***Fourth Quantum Number = spin of the electron (shown by arrows)***
    a. ***Short hand form shows the first three quantum numbers***
    b. ***box or circle diagrams also show electron spin***

C. ***Using Quantum numbers***
1. ***Principle Energy Level (PEL) n=1…..***
2. ***Sublevel (Subshell)=l***
    a. ***S=0, p=1, d=2, f=3***
3. ***Orbitals m_l***
    a. ***S=0, p= -1,0,+1, d=-2,-1,0,+1,+2…***
4. ***Electron spin +1/2, -1/2***
5. ***Example… Aluminum's last electron would be 3,1,-1,+1/2***

D. ***Electron Configuration Rules for atoms***
1. ***No more than two electrons can be placed in any orbital***
2. ***The added electron is placed in the unfilled orbital of lowest energy***

E. ***Orbital diagrams***
1. ***The two electrons in an orbital have opposite spins (Pauli exclusion principle)***

2. ***Hund's Rule - a 2nd electron is not added to an orbital until each orbital in the sublevel contains one electron.***

F. No more than 4 orbitals are occupied in the outermost principal energy level of any atom except for palladium