3-1 The Atom: From Philosophical Idea to Scientific Theory
I.   Atomic Theory
    A. Modern Atomic Theory
        1. All matter is made up of very tiny particles called atoms
        2. Atoms of the same element are chemically alike
        3. Individual atoms of an element may not all have the same mass.   However, the atoms of an element
            have a definite average mass that is characteristic of the element
        4. Atoms of different elements have different average masses
        5. Atoms are not subdivided, created, or destroyed in chemical rxns

3-2 The Structure of the Atom
I.   The Electron
    A. Discovery
        1. Joseph John Thomson (1897)
            a. Cathode ray tube produces a ray with a constant charge to mass ratio
            b. All cathode rays are composed of identical negatively charged particles (electrons)
   B. Inferences from the properties of electrons
        1. Atoms are neutral, so there must be positive charges to balance the negatives
        2. Electrons have little mass, so atoms must contain other particles that account
          for most of the mass

II.   The Nucleus
    A. The Rutherford Experiment (1911)
        1. Alpha particles (helium nuclei) fired at a thin sheet of gold
            a. Assumed that the positively charged particles were bounced back if they approached a
               positively charged atomic nucleus head-on (Like charges repel one another)
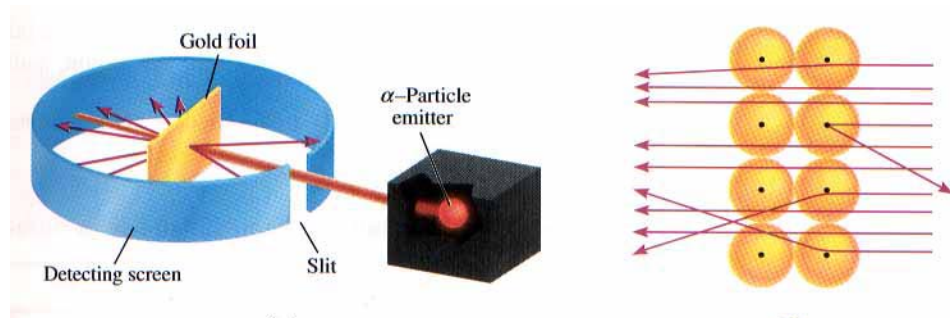
        2. Very few particles were greatly deflected back from the gold sheet
            a. nucleus is very small, dense and positively charged
            b. most of the atom is empty space
    B. Structure of the Nucleus
        1. Protons
            a. Positive charge, mass of 1.673×10^{-27} kg
            b. The number of protons in the nucleus determines the atom's identity and is called the atomic
               number
        2. Neutrons
            a. No charge, mass of 1.675×10^{-27} kg
        3. Nuclear Forces
            a. Short range attractive forces:
                    neutron-to-neutron, proton-to-proton, proton-to-neutron

Particle	Symbols	Relative charge	Mass Number
Electron	e^- $_{-1}^{0}e$	-1	0
Proton	p^+ $_{1}^{1}H$	+1	1
Neutron	n° $_{0}^{1}n$	0	1

C. Sizes of Atoms
    1. Atomic radius
        a. 40 to 270 picometers (pm)
            (1) 1 pm $= 10^{-12}$m
        b. Most of the atomic radius is due to the electron cloud
    2. Nuclear radius
        a. 0.001 pm
        b. density is 2×10^{8} metric tons/cm^3
            (1) 1 metric ton = 1000kg

3-3 Counting Atoms
I.   Atomic Number, Isotopes and Mass Number
    A. Atomic Number (Z)
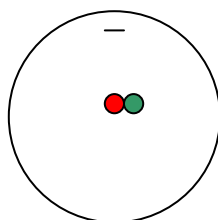   1. The number of protons in the nucleus of each atom of that element
        2. Atoms are identified by their atomic number
        3. Because atoms are neutral,
                # protons = # electrons
        4. Periodic Table is in order of increasing atomic number
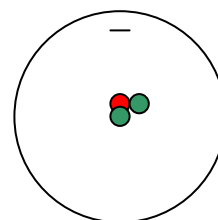   B. Isotopes
        1. Atoms of the same element that have different masses
        2. All elements of the same element have the same # of protons, but may vary in the number of neutrons
        3. Although isotopes have different masses, they do not differ significantly in their chemical behavior
        4. Hydrogen as an example:
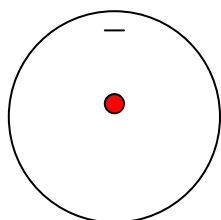
Protium (hydrogen-1)   Deuterium (hydrogen-2)   Tritium (hydrogen-3)

    C. Mass Number
        1. The total number of protons and neutrons in the nucleus of an isotope
    D. Designating Isotopes
        1. Hyphen notation
            a. Mass number is written after the name of the element
                (1) hydrogen-2, helium-4
        2. Nuclear Symbol
            a. Composition of the nucleus using the element's symbol
                (1) $_{1}^{2}H$ Mass number = 2   Atomic number = 1
                (2) $_{2}^{4}He$ Mass number = 4   Atomic number = 2

II.   <u>Using Atomic Mass</u>
      A. Average Atomic Masses
            1.   The weighted average of the atomic masses of the naturally occurring isotopes of an element
                 a.   Atomic masses on the periodic table are average masses
                 b.   In calculations using atomic mass, we will round the masses to two decimal places before doing calculations

Examples: Mg = 24.3050   we use: 24.31
                         O = 15.9994   we use: 16.00
                         N = 14.00674 we use: 14.01

III.   <u>Avogadro's Number and the Mole</u>
      A. The Mole
            1.   The amount of substance that contains as many particles are there are in exactly 12 grams of carbon-12
            2.   The amount of substance that contains the Avogadro number of particles
      B. Avogadro's Number
            1.   The number of particles in exactly one mole of a pure substance
            2.   Avogadro's number = 6.022×10^{23}
      C. Molar Mass
            1.   The mass of one mole of a pure substance
                 a.   Units are grams/mole (or g/mol)
                 b.   Molar mass of an element equals the average atomic mass in gram units
      D. Gram/Mole Conversions
            1.   Convert from grams to moles

$$grams \quad x \quad \left(\frac{1}{molar\ mass} \right) = moles$$

            2.   Convert from moles to grams

$$moles \quad x \quad molar \quad mass = grams$$

      E. Conversions with Avogadro's Number
            1.   Review sample problems on pages 84 and 85 - solutions vary depending on the given data and the desired quantity

22-1 The Nucleus
I.   <u>Introduction</u>
      A. Nucleons
            1.   Neutrons and protons
      B. Nuclides
            1.   Atoms identified by the number of protons and neutrons in the nucleus
                 a.   radium-228 or $^{228}_{88}Ra$
II.   <u>Nuclear Reactions</u>
      A. Nuclear Reaction
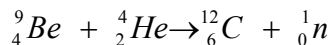   1.   A reaction that affects the nucleus of an atom
            2.   Small amounts of mass are converted to LARGE amounts of energy
                 a. $E = mc^2$
      B. Transmutations
            1.   A change in the identity of a nucleus as a result of a change in the number of its protons
      C. Balancing Nuclear Reactions
            1.   Total atomic numbers and mass numbers must be equal on both sides

$$^{9}_{4}Be \ + \ ^{4}_{2}He \rightarrow ^{12}_{6}C \ + \ ^{1}_{0}n$$

22-2 Radioactive Decay

I.   Introduction
        A. Radioactive Decay
                1. The spontaneous disintegration of a nucleus into a slightly lighter and more stable nucleus, accompanied by emission of particles, electromagnetic radiation, or both
        B. Nuclear Radiation
                1. Particles or electromagnetic radiation emitted from the nucleus during radioactive decay
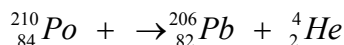   C. Unstable Nuclides
                1. All nuclides beyond atomic # 83 are unstable and radioactive
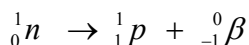
II.   Types of Radioactive Decay
        A. Alpha Emission
                1. Alpha particle (α) is a helium nucleus ($_2^4He$), so it has a 2+ charge.
                2. Alpha emission is restricted almost entirely to very heavy nuclei
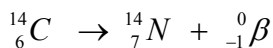
$$_{84}^{210}Po \ + \ \rightarrow _{82}^{206}Pb \ + \ _2^4He$$

        B. Beta Emission
                1. Beta particle (β) is an electron emitted from the nucleus during nuclear decay

$$_0^1n \ \rightarrow \ _1^1p \ + \ _{-1}^0\beta$$

                2. Beta particles are emitted when a neutron is converted into a proton and an electron

$$_6^{14}C \ \rightarrow \ _7^{14}N \ + \ _{-1}^0\beta$$

        C. Gamma Emission
                1. Gamma rays () are high-energy electromagnetic waves emitted from a nucleus as it changes from an excited state to a ground energy state
                2. Gamma rays are produced when nuclear particles undergo transitions in energy levels
                3. Gamma emission usually follows other types of decay that leave the nucleus in an excited state

10^{-12}	10^{-10}	10^{-8}	4 to 7×10^{-7}	10^{-4}	10^{-2}	1		10^2		10^4
gamma	xrays	UV	visible	IR	micro		Radio waves			
								FM	short	AM
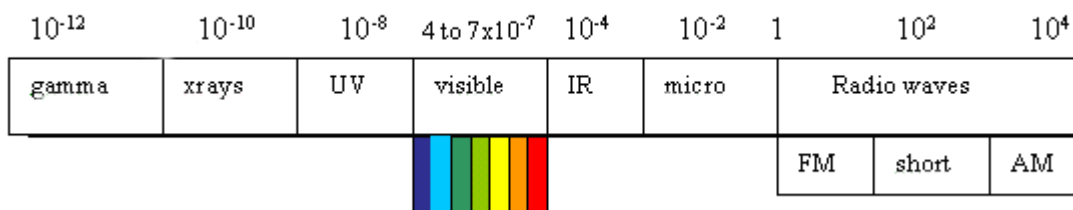
III.   Half-Life
        A. Half-Life ($t_{1/2}$)
                1. The time required for half the atoms of a radioactive nuclide to decay
                        a. More stable nuclides decay slowly
                        b. Less stable nuclides decay rapidly

Table 22-2	**Representative Radioactive Nuclides and Their Half Lives**		
Nuclide	*Half-life*	*Nuclide*	*Half-life*
$_1^3H$	12.32 years	$_{84}^{214}Po$	163.7 μseconds
$_6^{14}C$	5715 years	$_{84}^{218}Po$	3.0 minutes
$_{15}^{32}P$	14.28 days	$_{85}^{218}At$	1.6 seconds
$_{19}^{40}K$	1.3 x 109 years	$_{92}^{238}U$	4.46 x 109 years
$_{27}^{60}Co$	10.47 minutes	$_{94}^{239}Pu$	2.41 x 104 years

22-3 Nuclear Radiation
    A. Penetrating Ability
        1. Alpha Particles
            a. Least penetrating ability due to large mass and charge
            b. Travel only a few centimeters through air
            c. Cannot penetrate skin
            d. Can cause harm through ingestion or inhalation
   2. Beta Particles
            a. Travel at speeds close to the speed of light
            b.   Penetrating ability about 100 times greater than that of alpha particles.
            c. They have a range of a few meters in air.
        3. Gamma rays
            a.   Greatest penetrating ability
            b.   Protection requires shielding with thick layers of lead, cement, or both

    B. Penetrating ability of radiation

Increasing penetrating ability →

ALPHA————————————→ BETA ———————————————→ GAMMA
Least harmful   most harmful
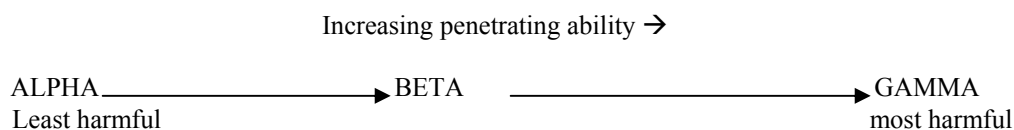
    C. Radioactive Elements
        1. All isotopes of all man-made elements are radioactive
        2. Some naturally isotopes are radioactive
            a. All isotopes of all elements beyond bismuth (atomic #83) are radioactive

22-4 Nuclear Fission and Nuclear Fusion
I.   Nuclear Fission
    A. Nuclear Fission
        1.   A very heavy nucleus splits into more stable nuclei of intermediate mass
        2.   The mass of the products is less than the mass of the reactants. Missing mass is converted to energy
            a. Small amounts of missing mass are converted to HUGE amounts of energy ($E = mc^2$)
    B. Nuclear Chain Reaction
        1. A reaction in which the material that starts the reaction is also one of the products and can start another
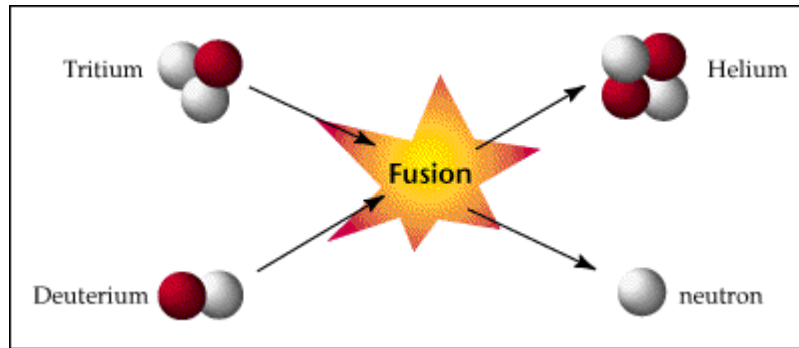   reaction
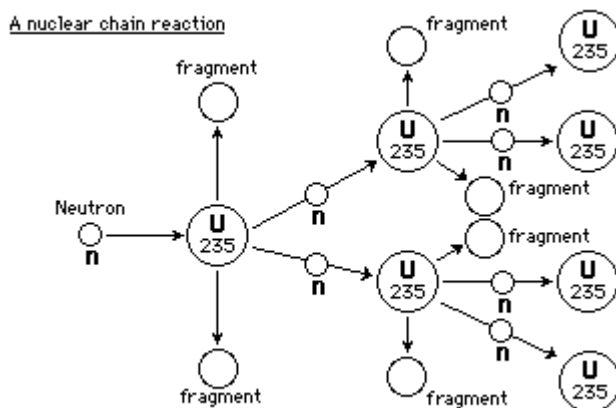
    C. Critical Mass
        1.   The minimum amount of nuclide that provides the number of neutrons needed to sustain a chain reaction

II. Nuclear Fusion
    A. Nuclear Fusion
            1. Light-mass nuclei combine to form a heavier, more stable nucleus

    B. Fusion Reactions
            1. More energetic than fission rxns
            2. Source of energy of the hydrogen bomb
            3. Could produce energy for human use if a way can be found to contain a fusion rxn (magnetic field?)