Chapter 21
Nuclear Chemistry: The Risks and Benefits
Learning Objectives

1-6-2023

To satisfy the minimum requirements for this course, you should be able to:

1. Recognize and use the symbols for protons, neutrons, electrons, positrons, alpha particles, beta particles, and gamma rays.

2. Write nuclide symbols given the number of protons, number or neutrons, and number of electrons.

3. Write balanced equations for nuclear reactions, including common modes of radioactive decay, fission and fusion.

4. Recognize and interpret a "belt of stability" plot (Fig. 21.1). Based on the neutron-to-proton (n/p) ratio of a given nuclide and its position relative to the belt of stability be able to:
   - predict if it undergoes radioactive decay, and if so
   - predict the mode(s) of decay (*i.e.* alpha decay, beta decay, positron emission, or electron capture) that the given nuclide will undergo.

5. Qualitatively interpret a radioactive decay series (*e.g.* Fig. 21.2).

6. Use first-order kinetics to examine the rates of radioactive decay and, given appropriate data, be able to calculate:
   - the half-life of a radioisotope.
   - the age of an object (radiometric dating).
   - the amount of a radioisotope remaining in a sample after a given period of time.

7. Recognize and interpret the "curve of nuclear binding energies" plot (Fig. 21.8) in terms of nuclear stability and the magnitude of energy changes associated with fission and fusion reactions. Perform energy calculations for nuclear reactions - specifically, be able to:
   - calculate the "mass defect" (Δm) for a given nuclear reaction using isotopic atomic masses (in Table A3.3 in Appendix 3, p. APP14-16).
   - use Einstein's relation, $E = (\Delta m)c^2$, to calculate energy changes in nuclear reactions.
   - calculate nuclear binding energies.

8. Compare the relative penetrating power and biological effects of α, β, γ radiation.

9. Understand and be able to use the following units of activity and biological exposure:
   - activities: counts per minute (cpm), disintegrations per minute (dpm), curies and becquerel
   - curie (Ci): 1 Ci = 3.7×10^{10} disintegrations per second (dps); becquerel (Bq): 1 Bq = 1dps
   - roentgen equivalent for man (rem): rem = (# of rads) x (RBE)
     - radiation absorbed dose (rad): 1 rad = 0.01 J/kg of body tissue
     - relative biological effectiveness (RBE) ($\gamma \approx \beta \approx 1$; $\alpha \approx 20$)

   ***NOTE:** All constants and conversion factors shown here will be provided on an exam, but you must know how to use them.

10. NavApp: Nuclear Reactors/Weapons. Be able to:
    - explain how nuclear reactions can be used to produce energy for power generation and weapons.
    - define critical mass and describe the relationship between critical mass and chain reactions.
    - explain the functions of the major components of a pressurized water nuclear reactor: fuel elements, control rods, moderator, cooling liquid, primary loop, and secondary loop.
    - identify the primary and secondary loops in a boiler that is heated by a nuclear reactor.

Note - Sections 21.4 and 21.9 are not assigned.