CH 302 – Unit 3 Review 1

FUNDAMENTALS OF NUCLEAR CHEMISTRY

Nuclear Fundamentals

There are four types of nuclear reactions that we discuss in this class:

1. Fission: a large atom splits into medium nuclei
   - Fission reactions are exothermic with atoms larger than iron
   - Common with large, unstable nuclei such as uranium

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{137}_{56}Ba + ^{97}_{36}Kr + 2\,^{1}_{0}n$$

2. Fusion: small nuclei join to form larger nuclei
   - Fusion reactions are exothermic with atoms smaller than iron
   - Common with hydrogen, deuterium, helium in extreme conditions (such as in stars)

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$$

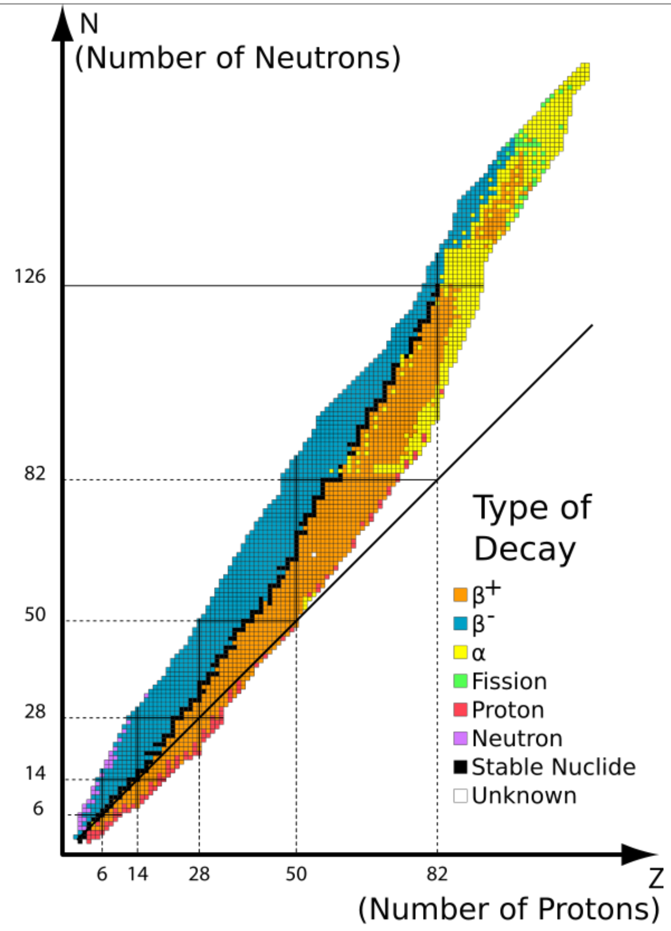
3. Nuclear Decay: an unstable nucleus reaches a lower energy state by spontaneously releasing ionizing radiation (beta decay, positron decay, alpha decay, electron capture)

$$^{210}_{84}Po \rightarrow ^{206}_{82}Pb + ^{4}_{2}He \quad , \quad ^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}\beta$$

4. Transmutation: a less stable nucleus is created by **non-spontaneously** bombarding it with ionizing radiation (opposite of nuclear decay)

$$^{102}_{46}Pd + ^{1}_{0}n \rightarrow ^{103}_{46}Pd$$

The Band of Stability



- The band of stability tells us the stable ratio of protons : neutrons for each element.
  - Additional isotopes exist outside of the band of stability
  - Where you are in relationship to the stable isotope dictates the type of decay necessary to get to the lowest energy state
- Above the line: too many neutrons (beta decay)
- Below the line: too many protons (positron decay)
- *Notice how the band of stability ends at lead – everything after lead is radioactive*

Nuclear Fundamentals

Nuclear Decay Summary:

- α decay: emission of an α-particle
  - The result is a new atomic species (z-2, m-4) and a new mass
- β decay: emission of an electron
  - The result is a new atomic species (z+1) with the same mass
  - Neutron becomes a proton
- β^+ decay: emission of a positron
  - The result is a new atomic species (z-1) with the same mass
  - Proton becomes a neutron
- Electron capture: the **addition** of an electron
  - The result is a new atomic species (z-1) with the same mass
  - Proton becomes a neutron (same effect as positron decay)

Note: z = atomic number ; m = atomic mass

Questions:

1. What is the unknown in the following equation? What type of nuclear decay is this? (Alpha particle, alpha decay)

$$^{240}_{94}Pu \rightarrow {}^{236}_{92}U + ?$$

2. Suppose you create an antimony isotope with a weight of 124 via transmutation. What type of decay will most likely restore the most stable isotope? (beta decay)

Nuclear Rate of Decay: Half-Life

- The rate at which an unstable isotope decays is measured by its half-life. **Half-life is defined as the amount of time it takes for ½ of your material to decay.**

$$\frac{\ln(2)}{k} = t_{1/2} \qquad \frac{\ln(2)}{t_{1/2}} = k$$

- Radioactive decay follows first order kinetics. This means the rate of decay is dependent on the amount of the decaying material.

$$[A] = [A]_0 e^{-kt} \qquad \ln\frac{[A]_0}{[A]} = kt$$

Exam Questions

1. Easy: How long will it take for 256 grams of Pu-241 to decay into 16 grams? The half-life of Pu-241 is 14.4 years.

2. Challenging: How long will it take for 43,453 grams of Pu-241 to decay into 6,378 grams? The half-life of Pu-241 is 14.4 years.

Exam Questions

1. How long will it take for 256 grams of Pu-241 to decay into 16 grams? The half-life of Pu-241 is 14.4 years. 4 half-lives, 57.6 years

2. How long will it take for 43,453 grams of Pu-241 to decay into 6,378 grams? The half-life of Pu-241 is 14.4 years.

40 years

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