Success 24/7 Chemistry Notes: Half-Life and Carbon Dating

Half-life ($t_{1/2}$)

The time required for one half of a radioisotope to emit radiation and decay to products is called its half-life.

- The longer the half-life, the more stable the isotope.
- Half-life values range from 2.1×10^{-25} seconds (hydrogen-7) to 2.2×10^{24} years (tellurium-128).
- Decay series - series of nuclear decays that eventually lead to a stable product.
    - The heaviest nuclide of each decay series is called the parent nuclide.
    - The nuclides produced by its decay series are called daughter nuclides.

How to calculate half-life:

$$A = A_0 \cdot \left(\frac{1}{2}\right)^n$$

Where: A = the amount remaining, A_0 = the initial amount, n = the number of half-lives

OR

If there is a whole number of half-lives, you may use the "arrow method".

Each arrow represents a half-life (an amount of **TIME**).

Mass (or amount) $\xrightarrow{half\ life\ time}$ ½ of the previous mass remains $\xrightarrow{half\ life\ time}$ ½ of the previous mass remains…

Half-life examples:

1. The half-life of Zn-71 is 2.4 minutes. If one had 100.0 g at the beginning, how many grams would be left after 7.2 minutes has elapsed?

2. After 24.0 days, 2.00 milligrams of an original 128.0 milligram sample remain. What is the half-life of the sample?

3. Pd-100 has a half-life of 5.0 days. If one had 6.02×10^{23} atoms at the start, how many atoms would be present after 20.0 days?

Carbon-14 dating

- C-14 is continually produced in the atmosphere when high energy neutrons from the sun collide with N-14 in the air.

$$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}p$$

- C-14 combines with O_2 to form CO_2 which is incorporated into plant materials. In living plants and animals, C-14 is continuously replaced.

- After a plant or animal dies, the C-14 decays through beta emission into N-14

$$^{14}_{6}C \rightarrow \ ^{0}_{-1}e + ^{14}_{7}N$$

- The proportion of carbon-14 in the atmosphere is relatively constant. The ratio of carbon-14 to carbon-12 is used to identify the age of wood, cloth and other organic artifacts.

- Note: C-14 dating only works for organic materials!

- The half-life of carbon-14 is 5,730 years.

Example:

If an organic substance has 70.0 mg of C-14 when it dies, how much will be left after 17,190 years?

How to handle fractions and percentages:

How long does it take a 180 g sample of Au-198 to decay to 1/8 its original mass? (The half life of Au-198 is 2.69 days.)

An artifact has only 3.125% of the Carbon-14 amount that is present in living organisms. How old is the object?

Practice:

1. An isotope of cesium-137 has a half-life of 30 years. If 1.0 g of cesium-137 disintegrates over a period of 90 years, how many g of cesium-137 would remain?

2. Selenium-83 has a half-life of 25.0 minutes. How many minutes would it take for a 10.0 mg sample to decay and have only 1.25 mg of it remain?

3. It takes 84.3 minutes for 93.75% of a radioisotope to decay into another isotope. What is its half-life?

4. Based on the following half-lives, which isotope the most stable?
    a. B-15: 2.92×10^{-3} seconds
    b. C-15: 2.449 seconds
    c. Cf-249: 1.11×10^{10} seconds
    d. He-10: 1.52×10^{-21} seconds