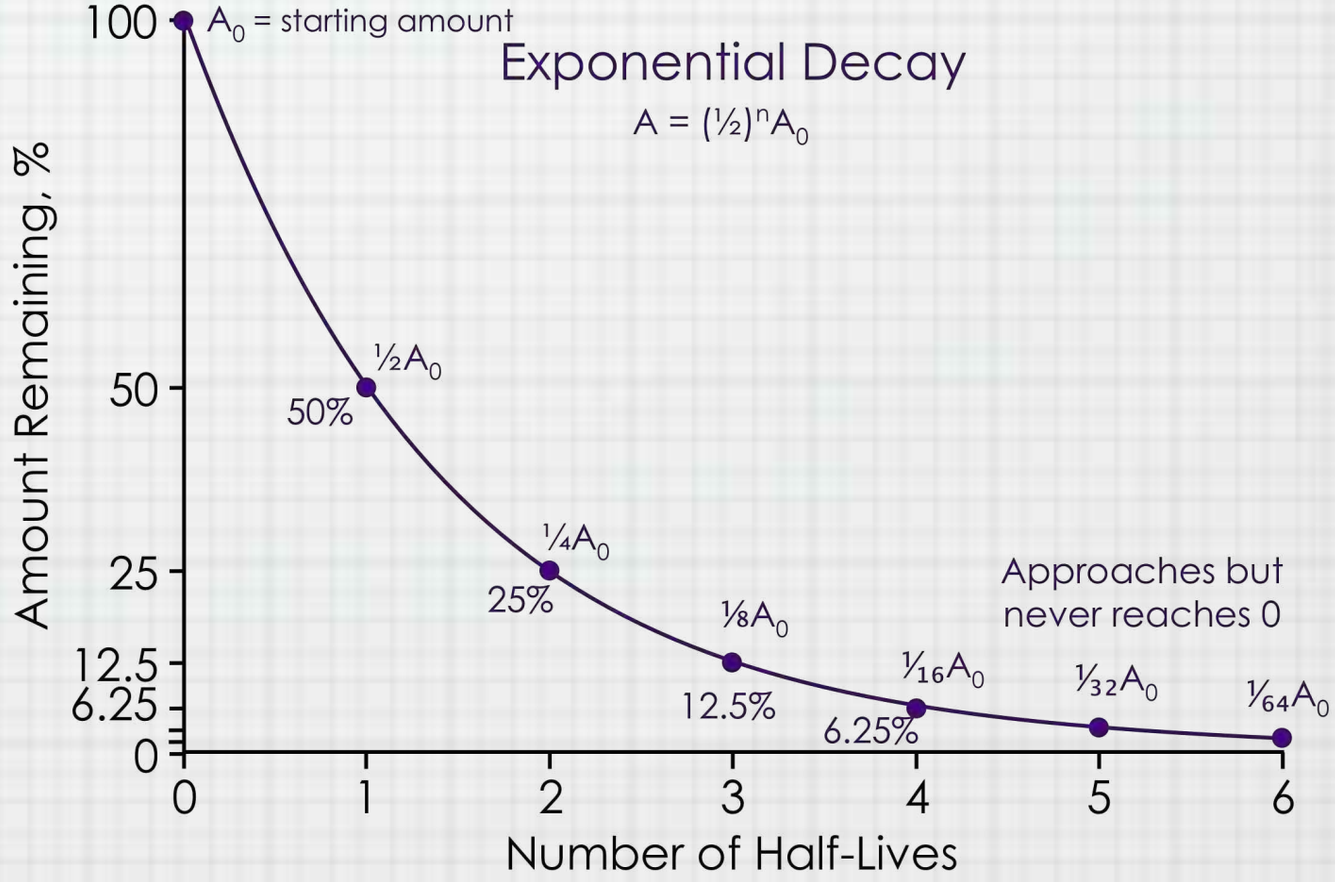
Radioactive Decay Rates, Half Life and Radiochemical Dating

Chem Honors

Half-life

- $t_{1/2}$ = time for ½ of any radioactive isotope to undergo decay.
  - Shorter half-life means more rapid decay, higher radioactivity
    - Each isotope has unique ½-life.
- After each half-life, half of the previous amount remains: ½, ¼, ⅛, $\frac{1}{16}$, $\frac{1}{32}$, etc.
- Exponential decay: Y decreases, X is an exponent in the equation:
- $A = A_0(½)^n$, where A = final amount, A_0 = initial amount, n = # of half lives = elapsed time/$t_{1/2}$



Half-Life Problems

* Type 1: given time and $t_{1/2}$, use A or A_0 to find the other
  * The half-life of radium-226 is 1600 years. How many grams of a 0.25g sample will remain after 4800 years?
    * First find n=4800 yrs/1600 yrs = 3 **Use n to solve for A**
    * A_0 = 0.25 g so A = (0.25 g)(½)^3 = 0.031 g
    * Or solve visually (each arrow = 1 ½-life):

      0.25 g → 0.125 g → 0.0625 g → 0.03125 g = 0.031 g
  * The half-life of thorium-227 is 18.72 days. How many grams were initially present if 10.0 g remain after 37.44 days?
    * $n = \frac{37.44 \text{ days}}{18.72 \text{ days}} = 2$
    * $10.0\text{ g} = A_0\left(\frac{1}{2}\right)^2$ so $A_0 = \left(10.0\text{ g}\right)\left(2\right)^2 = \boxed{40.0\text{ g}}$
    * 10.0 g → 20.0 g → 40.0 g

Half-Life Problems

- Type 2: know A and A_0, use time or $t_{½}$ to find the other
  - A bone contains 12.5% of the original amount of C-14 ($t_{½}$ = 5730 yr). How old is the bone?
    - Know A=12.5%, A_0=100%, first find n:
    - $12.5\% = (100\%)(½)^n \Rightarrow n = 3$ ½-lives
      - Or: 100% → 50% → 25% → 12.5%, or 3 ½-lives

$$\text{time} = n \times t_{½} = 3 \times 5730 \text{ yrs} = 17200 \text{ yrs} \quad \text{(elapsed time = age)}$$

Isotopic dating using C-14

- C-14 constantly formed in atmosphere: ${}^{14}_{7}N + {}^{1}_{0}n \rightarrow {}^{14}_{6}C + {}^{1}_{1}p$
  - Absorbed by living organisms (C cycle)
  - Decays at steady rate: ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$
  - Level stays constant while organism is alive (about 1 in 1×10^9 C atoms)
    - Steady state reached: equal creation & decay
  - Level decreases after death (C-14 decaying but no longer absorbed)
    - Can give age to about 50,000 years
  - Read "Carbon-14 Dating"

* Use isotopes with longer half-lives for longer times (e.g. U-238 $t_{1/2}=4.5\times10^9$ yr)