AP CHEMISTRY

TOPIC 10: NUCLEAR CHEMISTRY, PART B, EXAMPLES, PART II Day 118:

- Half-life (Nuclear)

HALF-LIFE: (con't)

Radioactive decay can be described as a first-order process, which means it can be described with the following equation (not on the AP equation sheet – but should know equation)

$$Rate = k\,N_t$$

Where k is a constant, N_t is the number of radioactive nuclei of the sample at time t.

Also, we can use the equation from the Kinetics section (when we did half-life for a first-order reaction).

$$\ln[A]_t - \ln[A]_0 = -kt$$

which is rearranged as:

$$\ln\left(\frac{[A]_t}{[A]_0}\right) = -kt$$

Recall, $\ln\left(\frac{[A]_t}{[A]_0}\right)$ can represent a percent remaining

Recall for first-order reactions:

$$t_{1/2} = \frac{\ln(0.5)}{-k}$$

Example #3:

Iodine-131, a radioactive isotope of iodine, has a half-life of 8.07 days. A lab worker discovers that a sample of iodine-131 has been sitting on a shelf for exactly 7 days? What percent of the original nuclei is still present after the 7.00 days. (54.8%)

$$\ln\left(\frac{[A]_t}{[A]_0}\right) = -kt \qquad k = \frac{\ln(0.5)}{-t_{1/2}} = \frac{\ln(0.5)}{-8.07\ days} = 0.085892\ \frac{1}{days}$$

Pick any mass (I like 100 grams)

$$\ln\left(\frac{[A]_t}{100\ g}\right) = -\left(0.085892\ \frac{1}{days}\right)(7\ days)$$

$$\ln\left(\frac{[A]_t}{100\ g}\right) = -0.601244 \qquad e^{\ln\left(\frac{[A]_t}{100\ g}\right)} = e^{-0.601244}$$

$$\frac{[A]_t}{100\ g} = 0.5481 \qquad \textit{Therefore, } [A]_t = 0.5481(100\ g) = 54.8g$$

$$\frac{54.8g}{100\ g} \times 100\% = 54.8\%$$

<u>OR</u> ***(see next page)***

$$n = \frac{total\ \ time}{half-life\ \ time} \quad ; \quad n = \frac{7\ \ days}{8.07\ \ days} = 0.86741$$

$$(100\ \ g)\left(0.5^{0.86741}\right) = 54.8\ \ g$$

$$\frac{54.8g}{100\ \ g} \times 100\% = 54.8\%$$

Example #4:

A 2.8 x 10^{-6} gram collection of plutonium-238 is decaying at a rate of 1.8 x 10^{6} nuclei disintegrations per second (nuc sec^{-1}). What is the decay rate constant, *k*, for plutonium-238?

$$Rate = k\, N_t$$

$$\frac{2.8\times10^{-6}\ \ gram\ Pu}{} \times \frac{1\ mol\ Pu}{238\ \ grams} \times \frac{6.022\times10^{23} nuc}{1\ mol\ Pu} = 7.08\times10^{15}\ \ {}^{238}_{94}Pu\ nuc$$

$$k = \frac{Rate}{N_t} = \frac{1.8\times10^{6}\ \ nuc\ \ \sec^{-1}}{7.08\times10^{15}\ \ nuc} = 2.54\times10^{-10}\ \ \sec^{-1}$$

Example #5:

a. A 0.155 gram sample of berkelium-250 has a decay rate 1.21 x 10^{9} nuclei disintegrations sec^{-1}. What is the decay constant for ${}^{250}_{97}Bk$?

$$Rate = k\, N_t$$

$$\frac{0.155\ \ gram\ Bk}{} \times \frac{1\ mol\ Bk}{250\ \ grams} \times \frac{6.022\times10^{23} nuclei}{1\ mol\ Bk} = 3.73\times10^{20}\ \ {}^{250}_{97}Bk\ nuclei$$

$$k = \frac{Rate}{N_t} = \frac{1.21\times10^{9}\ \ nuclei\ \ \sec^{-1}}{3.73\times10^{20}\ \ nuclei} = 3.241\times10^{-12}\ \ \sec^{-1}$$

b. What is the half-life of the substance in part (a)?

$$k = 3.241\times10^{-12}\ \ \sec^{-1}$$

$$t_{1/2} = \frac{\ln(0.5)}{-k} = \frac{\ln(0.5)}{-3.241\times10^{-12}\ \ \sec^{-1}} = 2.14\times10^{11}\ \ \sec$$

Or 6775 Years