AP CHEMISTRY

$$\text{Rate} = k\,N_t$$

TOPIC 10: NUCLEAR CHEMISTRY, EXTRA PRACTICE

Day 119

CLEARLY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS

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1. A certain radioactive isotope of uranium-299, *U*, has a half-life of 4500 days. A lab worker discovers that a sample of this substance has been sitting on a shelf for 722 days (exactly). What percent of the original nuclei is still present after 722 days? Also, write the nuclear equation if this substance was for a nuclei uranium-299, that undergoes alpha decay during this period of time.

$$^{299}_{92}U \rightarrow {}^{4}_{2}He + {}^{295}_{90}Th$$

$$(mass)_t = (mass)_0 \times 0.5^n$$

$$n = \frac{722\ days}{4500\ days} = 0.160\overline{4}$$

$$(mass)_t = 100\ g \times 0.5^{0.160\overline{4}} = 89.47\ g$$

$$\frac{89.47\ g}{100\ g} \times 100\% = 89.5\%$$

OR

$$\ln\left(\frac{[A]_t}{[A]_0}\right) = -kt \quad ; \quad \ln\left(\frac{50\ g}{100\ g}\right) = -k(4500\ days)$$

$$\frac{\ln(0.5)}{-4500\ days} = k = 0.000154\ \frac{1}{days} \quad ; \quad \left(\ln\frac{?}{100\ g}\right) = (-0.000154)(722\ days)$$

$$e^{\left(\ln\frac{?}{100\ g}\right)} = e^{((-0.000154)(722\ days))} = e^{(-0.1112116)}$$

$$\frac{?}{100\ g} = 0.895 \quad ; \quad \frac{?}{100\ g} = 0.895$$

$$? = (0.895)(100\ g) = 89.5\ g$$

$$\frac{89.47\ g}{100\ g} \times 100\% = 89.5\%$$

2. A 0.365 gram sample of bismuth-212, *Bi*, is decaying at a rate of 3.18 x 10^{15} disintegrations of nuclei per second (dis sec^{-1} OR nuclei sec^{-1}). First, write the nuclear equation for bismuth-212 when the nuclei undergo alpha capture. Then calculate the decay rate constant, *k*, of bismuth-212 (in sec^{-1}). Also, calculate the half-life period of time for this nuclear reaction.

$$^{212}_{83}Bi + {}^{4}_{2}He \rightarrow {}^{216}_{85}At \quad \text{(astatine - 216)}$$

$$Rate = k\,N_t$$

$$\frac{0.365\ gram}{} \times \frac{1\ mol}{212\ grams} \times \frac{6.02\times10^{23}\,nuc}{1\ mol} = 1.0365\times10^{21}\ nuc$$

$$k = \frac{Rate}{N_t} = \frac{3.18\times10^{15}\ nuc\ \sec^{-1}}{1.0365\times10^{21}\ nuc} = 3.068\times10^{-6}\ \frac{1}{\sec}$$

$$t_{1/2} = \frac{\ln(0.5)}{-k} = \frac{\ln(0.5)(\sec)}{-3.068\times10^{-6}} = 2.26\times10^{5}\ \sec$$

IF curious… $\dfrac{2.26\times10^{5}\ \sec}{} \times \dfrac{1\ hour}{3600\ \sec} = 62.8\ hours$

3. Radon-223 undergoes positron decay with an initial mass of 469 grams. Currently the sample has a mass of 62.4 grams after 35.3 days. First, write the nuclear equation for this reaction, and then calculate the number of half-lives that have elapsed.

$$^{223}_{86}Rn \rightarrow \ ^{0}_{+1}e + \ ^{223}_{85}At$$

$$\ln\left(\frac{[A]_t}{[A]_0}\right) = -kt \quad ; \quad \ln\left(\frac{62.4\ g}{469\ g}\right) = -k(35.6\ days)$$

$$\frac{\ln\left(\frac{62.4\ g}{469\ g}\right)}{-35.6\ days} = k = 0.0566584\ \frac{1}{days}$$

$$t_{1/2} = \frac{\ln(0.5)(days)}{-0.0566584} = 12.2\ days$$

$$number\ of\ half-lives = \frac{35.6\ days}{12.2\ days} = 2.91$$

<u>OR</u>

$$(mass)_t = (mass)_0 \times 0.5^n$$

$$62.4\ g = 469\ g \times 0.5^n$$

$$\frac{62.4\ g}{469\ g} = 0.5^n = 0.133049$$

$$\log_{0.5}\left(0.5^n\right) = \log_{0.5}(0.133049)$$ … Yep, that is logarithm base 0.5 ☺

$$n = 2.90997$$

n = number of half-lives

4. A lab worker discovered that 39.5% of the original amount of americium-247, *Am*, remained (changed due to beta decay) in the original package that the material was shipped within. The original amount (on the shipping date) of americium-247 HAD a mass of 2250 grams. The shipping date (and time) on the container (the moment it was packaged contained 100% of the sample which was americium-247) was EXACTLY 9.00 days ago (to the second – isn't that amazing?). First, write the nuclear equation for this reaction, and then calculate the decay rate constant, *k*, for americium-247. Finally, calculate the half-life period of time for this nuclear reaction.

$$^{247}_{95}Am \rightarrow \, ^{0}_{-1}e + \, ^{247}_{96}Cm \quad \text{(Curium – 247)}$$

$$39.5\% \; of \;\; 2250 \; g \;=\; (0.395)(2250 \; g) \;=\; 888.75 \; g$$

$$\ln\left(\frac{[A]_t}{[A]_0}\right) = -kt \;\; ; \;\; \ln\left(\frac{888.75 \; g}{2250 \; g}\right) = -k(9.00 \; days) \;\; ;$$

$$\frac{\ln\left(\frac{888.75 \; g}{2250 \; g}\right)}{-9.00 \; days} \;=\; k \;=\; 0.103208 \; \frac{1}{days}$$

$$t_{1/2} \;=\; \frac{\ln(0.5)}{-k} \;=\; \frac{\ln(0.5)(days)}{-0.103208} \;=\; 6.72 \; days$$