AP CHEMISTRY

TOPIC 10: NUCLEAR CHEMISTRY, REVIEW – PART II

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 thorium-240, *Th*, has a half-life of 8.87 hours. A lab worker discovers that a sample of this substance has been sitting on a shelf for 1.50 days (exactly). What percent of the original nuclei is still present after 1.50 days? Also, write the nuclear equation if this substance was for a nuclei thorium-240 that undergoes electron capture during this period of time.

$$^{240}_{90}Th + ^{0}_{-1}e \rightarrow ^{240}_{89}Ac$$

$$\ln\left(\frac{[A]_t}{[A]_0}\right) = -kt \;\; ; \;\; \ln\left(\frac{0.5}{1.0}\right) = -kt_{1/2} \;\; ; \;\; k = \frac{\ln(0.5)}{-t_{1/2}} = \frac{\ln(0.5)}{-8.87 \; hrs} = 0.078145 \; hrs^{-1}$$

$$\frac{1.50 \; days}{} \times \frac{24 \; hrs}{1 \; day} = 36.0 \; hrs$$

$$\ln\left(\frac{[A]_t}{100 \; g}\right) = -\left(0.078145 \; hrs^{-1}\right)\left(36.0 \; hrs\right) \;\; ; \;\; \ln\left(\frac{[A]_t}{100 \; g}\right) = -2.813224 \;\; ;$$

$$e^{\left(\ln\left(\frac{[A]_t}{100 \; g}\right)\right)} = e^{-2.813224}$$

$$\frac{[A]_t}{100 \; g} = 0.0600 \;\; ; \;\; [A]_t = (0.0600)(100 \; g) = 6.00 \; g$$

$$\frac{6.00 \; g}{100 \; g} \times 100\% = 6.00\%$$

OR

$$(\text{mass})_t = (\text{mass})_0 \text{ x } 0.5^n$$

$$n = \frac{36 \; hrs}{8.87 \; hrs} = 4.0586246$$

$$(\text{mass})_t = (100.0 \text{ grams})(0.5^{4.0586246}) = 6.00 \text{ grams}$$

$$\frac{6.00 \; g}{100 \; g} \times 100\% = 6.00\%$$

2. A 1.77 x 10^{-4} gram sample of nobelium-255, *No*, is decaying at a rate of 4.0108 x 10^{15} disintegrations of nuclei per second (dis sec^{-1} OR nuclei sec^{-1}). First, write the nuclear equation for nobelium-255 when the nuclei undergo alpha emission. Then calculate the decay rate constant, *k*, of nobelium-255 (in sec^{-1}). Also, calculate the half-life period of time for this nuclear reaction (**in hours**).

$$^{255}_{102}No \rightarrow \, ^{4}_{2}He + \, ^{251}_{100}Fm$$

$$Rate = k\, N_t$$

$$\frac{1.77\times10^{-4}\ gram\ \ ^{255}_{102}No}{} \times \frac{1\ mol\ \ ^{255}_{102}No}{255\ \ grams} \times \frac{6.02\times10^{23}\, nuc}{1\ mol\ \ ^{255}_{102}No} = 4.1786\times10^{17}\ \ ^{255}_{102}No\ \ nuc$$

$$k = \frac{Rate}{N_t} = \frac{4.0108\times10^{15}\ nuc\ \sec^{-1}}{4.1786\times10^{17}\ nuc} = 9.59848\times10^{-3}\ \sec^{-1}$$

$$t_{1/2} = \frac{\ln(0.5)}{-k} = \frac{\ln(0.5)}{-9.59848\times10^{-3}\ \sec^{-1}} = 72.2\ \sec$$

$$\frac{72.2\ \sec}{} \times \frac{1\ \min}{60\ \sec} \times \frac{1\ hour}{60\ \min} = 0.0201\ hour$$

3. Lead-210 undergoes alpha decay with an initial mass of 445.3 grams. Currently the sample has a mass of 24.2 grams after 789.5 hours. First, write the nuclear equation for this reaction and then calculate the number of half-lives that have elapsed.

$$^{210}_{82}Pb \rightarrow \, ^{4}_{2}He + \, ^{206}_{80}Hg$$

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

$$\ln\left(\frac{24.2\ g}{445.3\ g}\right) = -k\left(789.5\ hrs\right)$$

$$\frac{\ln\left(\frac{24.2\ g}{445.3\ g}\right)}{-789.5\ hrs} = k = 0.003688911\ hrs^{-1}$$

$$t_{1/2} = \frac{\ln(0.5)}{-k} = \frac{\ln(0.5)}{-0.003688911\ hrs^{-1}} = 187.86\ hrs$$

$$number\ \ of\ \ half-lives = \frac{789.5\ hrs}{187.86\ hrs} = 4.20$$

4. A lab worker discovered that 7.55% of the original amount of plutonium-250, *Pu*, remained (changed due to beta decay) in the original package that the material was shipped within. The original amount (on the shipping date) of plutonium-250 HAD a mass of 973 grams. The shipping date (and time) on the container (the moment it was packaged contained 100% of the sample which was plutonium-250) was EXACTLY 24 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 plutonium-250. Finally, calculate the half-life period of time for this nuclear reaction.

$$^{250}_{94}Pu \rightarrow \, ^{0}_{-1}e + \, ^{250}_{95}Am$$

$$7.55\% \ of \ 973 \ g = (0.0755)(973 \ g) = 73.4615 \ g$$

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

$$\ln\left(\frac{73.4615 \ g}{973 \ g}\right) = -k(24 \ days)$$

$$\frac{\ln(0.0755)}{-24 \ days} = k = 0.107651 \ days^{-1}$$

$$t_{1/2} = \frac{\ln(0.5)}{-k} = \frac{\ln(0.5)}{-0.107651 \ days^{-1}} = 6.44 \ days$$