Department of Chemistry
University of Texas at Austin

Name:_______________

Radioactive Decay – Supplemental Worksheet KEY

Problem #1: A sample of phosphorus-32 has an initial activity of 58 counts per second. After 12.3 days, the activity was 32 counts per second. (1) What is the half-life of phosphorus-32? (2) If phosphorus-32 is used in an experiment to monitor the consumption of phosphorus by plants, what fraction of the nuclide will remain after 30 days?

(1) First solve for k using the equation

$$[A](t) = [A]_0 e^{-kt}$$

We have [A](t), $[A]_0$, and t.

[A](t) = 32 counts per second

$[A]_0$ = 58 counts per second

t = 12.3 days

So, $k = \frac{\ln(\frac{[A]}{[A]_0})}{-t} = \frac{\ln(\frac{32}{58})}{-12.3\text{ days}} = 0.04835\text{ days}^{-1}$

Once we have k, we can solve for $t_{1/2}$ with the equation

$$t_{1/2} = \frac{\ln 2}{k} = \frac{\ln 2}{0.04835\text{ days}-1} = 14.34\text{ days}$$

(2) Now that we know k, we can use the equation $[A](t) = [A]_0 e^{-kt}$ to solve for the fraction of the nuclide that will remain after a time, t

(This fraction can be written in mathematical terms as $\frac{[A](t)}{[A]0}$).

$$[A](t) = [A]_0 e^{-kt} \Rightarrow \frac{[A](t)}{[A]0} = e^{-kt}$$

So, $\frac{[A](t)}{[A]0} = e^{-(0.04835\text{ days-1})(30\text{ days})} = 0.23$

Problem #2: Determine the percentage of a tritium sample that remains after 11.0 years knowing that the half-life of tritium is 12.3 years.

53.8%

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Problem #3: A 250.0 mg sample of carbon from a piece of cloth excavated from an ancient tomb in Nubia undergoes 1.50 * 10^3 carbon-14 disintegrations in 10.0 hours. If a current 1.00 g sample of carbon shows 921 carbon-14 disintegrations per hour, how old is the piece of cloth? The half-life of carbon-14 is 5.73 *10^3 years.

We will use the equation $[A](t) = [A]_0e^{-kt}$ and solve for t to answer this question.

However, we first have to do 2 things,

1. We have to calculate k using the half-life of carbon.
   $k = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{5730 \text{ years}} = 1.21*10^{-4}\text{ years}^{-1}$
2. We have to get the two activities into the same units. We do this so we can compare them. Here we will convert the activities into number of carbon-14 disintegrations per hour for a 1.00 g sample.
   The carbon from the Nubian cloth has an activity of
   1.50 * 10^3 carbon-14 disintegrations in 10.0 hours for a 250 mg sample
   We need to multiply this number by 4, so that it is the number of disintegrations for a 1.00 g sample instead of a 0.250 g sample.
   We need to divide this number by 10, so that it is the number of disintegrations in 1 hour instead of 10 hours.
   So the activity of the carbon from the Nubian cloth is
   $1.50 * 10^3 * \frac{4}{10}$ = 600 carbon-14 disintegrations in 1.0 hour for a 1 g sample.
   The carbon from a current sample has an activity of
   921 carbon-14 disintegrations per hour for a sample of 1.00 g.

Now we can solve for t (the age of the sample) using the equation

$$[A](t) = [A]_0e^{-kt} \Rightarrow t = \frac{\ln(\frac{[A]}{[A]_0})}{-k}$$

$$\text{So, } t = \frac{\ln(\frac{[A]}{[A]_0})}{-k} = \frac{\ln(\frac{600}{921})}{-1.21*10^{-4}\text{ years}^{-1}} = 3541.57 \text{ years}$$

Problem #4: A sample of carbon of mass 250.0 mg from wood found in a tomb in Israel underwent 2480 carbon-14 disintegrations in 20.0 hours. Estimate the time since death, knowing that a 1.00 g of carbon from a modern source underwent 1.84*10^4 disintegrations in 20.0 hours. The half-life of carbon-14 is 5.73 *10^3 years.

5.107 * 10^3 years