Key

Half-life

Half-life of a reaction, $t_{1/2}$: the time required for a reactant's [ ] to drop to ½ of its original value.

Radioactive decay is a first order reaction.

$$[A]_{t_{1/2}} = \frac{1}{2}[A]_o$$

From the basic equation $\ln [A]_t = \ln [A]_o - kt$

Put ½ $[A]_o$ here ↑ ↑ and $t_{1/2}$ here, and we get **t = .693/k**

For 1st order reactions...

-- $t_{1/2}$ is independent of initial concentration

-- the concentration of reactants is cut in half... every half-life

$N = N_o(1/2)^n$

N = amount remaining

N_o = original amount

n = # of half-life(s)

1. The half-life of cesium-137 is 3.2 years. If the initial mass of a sample of cesium-137 is 1.0 kg, how much will remain after 151 years?

$k = .693/3.2 = 0.2166$

$\ln \frac{[A]_o}{[A]} = kt = 32.701$ $\frac{[A]_o}{[A]} = 1.59\times10^{14}$ $\frac{1}{1.59\times10^{14}} = 6.29\times10^{-15}$ kg

2. Given that the half-life of carbon-14 is 5730 years, consider a sample of fossilized wood that, when alive, would have contained 24 g of carbon-14. It now contains 1.5 g of carbon-14. How old is the sample?

$k = \frac{.693}{5730} = 1.21\times10^{-4} \times t = \ln\left(\frac{24}{1.5}\right) = 2.773$

$t = \frac{2.773}{1.21\times10^{-4}} = 22914$ years

3. A 64-g sample of germanium-66 is left undisturbed for 1.5 hours. At the end of that period, only 2.0 g remain. What is the half-life of this material?

$\ln\left(\frac{64}{2}\right) = kt = 3.466 = k(1.5)$ $k = 2.310$ $t_{\frac{1}{2}} = \frac{.693}{2.310} = 0.30$ hrs $= 18$ min

4. With a half-life of 28.2 years, how long will it take for 1 g of strontium-90 to decay to 125 mg?

$\ln\left(\frac{1}{.125}\right) = (.025)(t)$ $t = 83.18$ yrs $k = \frac{.693}{28.2} = 0.025$

5. Cobalt-60 has a half-life of 5.3 years. If a pellet that has been in storage for 26.5 years contains 14.5 g of cobalt-60, how much of this radioisotope was present when the pellet was put into storage?

$k = \frac{.693}{5.3} = 0.131$

$\ln \frac{[A]_o}{14.5} = kt$ $\ln [A]_o = \ln [A]_t + kt = 6.146$ $[A]_o = 466.85$ g

6. A 1000 kg block of phosphorous-32, which has a half-life of 14.3 days, is stored for 100.1 days. At the end of this period, how much phosphorous-32 remains?

$k = \frac{.693}{14.3} = 0.048$

$\ln [A]_t = -kt + \ln [A]_o$

$= -(.048)(100.1) + \ln(1000)$

$= 2.103$

$[A]_t = 8.19$ kg

7. A sample of air from a basement is collected to test for the presence of radon-222, which has a half-life of 3.8 days. However, delays prevent the sample from being tested until 7.6 days have passed. Measurements indicate the presence of 6.5 μg of radon-222. How much radon-222 was present in the sample when it was initially collected?

$\ln[A]_0 = \ln[A]_t + kt$ $\quad k = \frac{.693}{3.8} = 0.182$

$= \ln(6.5) + (.182)(7.6) = 3.255$ $\quad [A]_0 = 25.92\ \mu g$

8. A 0.500 M solution of iodine-131, which has a half-life of 8.0 days, is prepared. After 40.0 days, how much iodine will remain in 1.0 L of solution? Express the results in moles.

$\ln[A]_t = -kt + \ln[A]_0 = -(.087)(40) + \ln(.5)$ $\quad k = \frac{.693}{8} = 0.087$

$= -4.173$

$[A]_t = 0.015\,M = 0.016$ moles in 1L

9. The half-life of sodium-25 is 1.0 minute. Starting with 1 kg of this isotope, how much will remain after an hour?

$\ln[A]_t = -(.693)(60) + \ln(1)$ $\quad k = \frac{.693}{1} = .693$

$= -41.58$ $\quad [A]_t = 8.75 \times 10^{-19}\,kg = 8.75 \times 10^{-16}\,g$

10. What is the half-life of polonium-214 if, after 820 seconds, a 1.0 g sample decays to 31.25 mg?

$\ln\left(\frac{1}{.03125}\right) = kt = (k)(820)$ $\quad k = 0.00423$ $\quad t_{\frac{1}{2}} = \frac{.693}{.00423}$

$= 3.466$

$= 163.83\ s$

11. $2N_2O_5(g) \longrightarrow 4NO_2(g) + O_2(g)$

Dinitrogen pentoxide decomposes to nitrogen dioxide and oxygen gas via a first-order reaction with a rate constant of $5.1 \times 10^{-4}\ s^{-1}$ at 45°C. If the concentration of N_2O_5 is 0.30M, what is the concentration after 180 sec?

$\ln[A]_t = -kt + \ln[A]_0 = -(5.1 \times 10^{-4})(180) + \ln(0.30) = -1.30$

$[A]_t = 0.27M$

How long will it take (in sec) for the concentration of N_2O_5 to decrease in half (from 0.30M to 0.15M)?

$t = \frac{.693}{5.1 \times 10^{-4}} = 1359\ s$

How long will it take to covert 75% of the starting material?

$t = \frac{\ln(4)}{5.1 \times 10^{-4}} = 2718\ s$

1. 0.0313 kg 2. 23,000 years 3. 18 minutes 4. 90 years 5. 460 g
6. 7.81 g 7. 26 μg 8. 0.016 mol 9. 9×10^{-7} g 10. 160 s 11. 0.27 M, 1359 s, 2718 s