

WS 28.1 Radioactive Dating!

	# of protons	# of neutrons	Mode of radioactive decay	Half-Life, $t_{1/2}$
C-11	6	5	β^+ decay (positron emission)	20.3 minutes
C-12	6	6	none (stable isotope)	N/A
C-13	6	7	none (stable isotope)	N/A
C-14	6	8	β^- decay (beta emission)	5730 years
Pb-210	82	128	β^- decay (beta emission)	22.3 years
U-238	92	146	α decay (alpha emission)	4.47×10^9 years
Rf-261	104	157	α decay (alpha emission)	62 seconds

1. Complete the chart, above.

2. Carbon-14 forms in the upper atmosphere when nitrogen nuclei are struck from neutrons (from cosmic radiation).

a. Complete the equation that shows the formation of C-14:



b. Write an equation for the beta-decay of Carbon-14.



c. After we die, how long will it take for half of our carbon-14 atoms to undergo radioactive decay? 5730 yrs
(the half-life of carbon)

3. $X_f = X_i(0.5)^N$

a. Define: X_f final amount of radioactive substance, X_i initial amount of radioactive substance, N number of half-lives that have passed.

b. If a sample contained 12.00 grams of C-14 17,190 years ago, how many grams of Carbon-14 would it contain now?

$$N = \frac{17190 \text{ yr}}{5730 \text{ yr}} = 3.000$$

$$X_f = X_i(0.5)^N = (12.00\text{g})(0.5)^3 = 12.00\text{g}(.125) = 1.50 \text{ grams}$$

$$12.00\text{g} \xrightarrow{1} 6.00\text{g} \xrightarrow{2} 3.00\text{g} \xrightarrow{3} 1.50\text{g}$$

c. How many grams of a 100.0 gram sample of C-14 would remain after 20,000 years?

$$X_f = (100.0\text{g})(0.5)^{3.4904} = 100.0\text{g}(0.088978) = 8.9 \text{ grams}$$

$$N = \frac{20000 \text{ yr}}{5730 \text{ yr}} = 3.4904$$

d. If an organic sample only contains 12.5% of its original C-14, how old is it?

$$X_f = X_i(0.5)^N \quad \ln(.125) = N \ln(.5) \quad 3.00(5730 \text{ yr})$$

$$12.5 = 100(0.5)^N \quad N = \ln(.125) / \ln(.5) \quad = 17190 \text{ yr}$$

$$0.125 = (0.5)^N \quad N = 3.00 \text{ half-lives} \quad \text{or } 17200 \text{ yr}$$

e. How old is an organic sample if it only contains 10.0% of its original C-14?

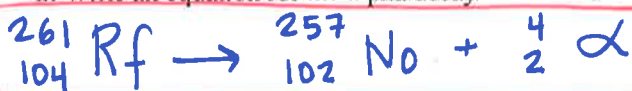
$$X_f = X_i(0.5)^N \quad \ln(.100) = N \ln(.5)$$

$$10.0 = 100(.5)^N \quad N = \frac{\ln(.100)}{\ln(.5)} = \frac{-2.3026}{-.69315} = 3.3219 \text{ half-lives}$$

$$0.100 = (0.5)^N \quad (3.3219)(5730 \text{ yr}) = 19035 \rightarrow 1.90 \times 10^4 \text{ yr}$$

4. Rutherfordium-261 undergoes alpha decay with a half-life of 62 seconds (look it up in the chart!)

a. Write an equation for the alpha decay of Rf-261.



b. If you start with a 1.0 mg sample of Rf, how many milligrams of Rf would remain after 160 seconds?

$$X_f = X_i(0.5)^N = (1.0\text{mg})(0.5)^{2.5806} = 0.16717\text{mg} \rightarrow \boxed{0.17\text{mg}}$$

$$N = \frac{160\text{s}}{62\text{s}} = 2.5806$$

c. How long would it take for a sample of Rf to decay so that only 20.0% of the Rf atoms remained?

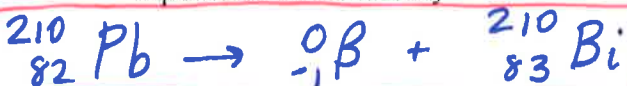
$$20.0 = 100(0.5)^N \quad \ln(.200) = N \ln(.5)$$

$$0.200 = (0.5)^N \quad N = \frac{\ln(.200)}{\ln(.5)} = \frac{-1.60944}{-.693147} = 2.3219 \text{ half lives}$$

$$(2.3219)(62\text{s}) = 143.95\text{s}$$

5. Lead-210 beta decays with a half-life of 22.3 years.

a. Write an equation for the Beta-decay of lead-210.



b. If a sample contains 50.0 mg of lead-210, how many milligrams will remain, as lead-210, after 100. years?

$$N = \frac{100.\text{yr}}{22.3\text{yr}} = 4.4843 \text{ half lives} \quad X_f = (50.0\text{mg})(0.5)^{4.4843} = (50.0\text{mg})(.04468) = \boxed{2.23\text{mg}}$$

6. Uranium-238 is one of many radioactive isotopes found in the "spent fuel" of a nuclear reactor.

U-238 alpha decays with a half-life of 4.47×10^9 years.

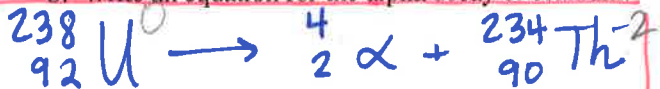
a. How long would it take for a 20.0 kg sample of U-238 to decay so that only 18.0 kg remained as U-238?

$$X_f = X_i(0.5)^N \quad \ln(.900) = N \ln(.5)$$

$$18.0\text{kg} = 20.0\text{kg}(0.5)^N \quad N = \frac{\ln(.900)}{\ln(.5)} = \frac{-.10536}{-.693147} = 0.15200 \text{ half lives}$$

$$0.900 = (0.5)^N \quad (0.15200)(4.47 \times 10^9 \text{yr}) = \boxed{6.79 \times 10^8 \text{yr}}$$

b. Write an equation for the alpha decay of uranium.



c. Explain why samples of uranium ore often contain trapped helium gas. Refer to your equation, above.

an alpha particle has 2 protons and 2 neutrons, the same as a He nucleus. If alphas are trapped in the U, they gain 2e- to form He (gas).

d. Based on the half lives given in #4 and #6 for Uranium and Rutherfordium, which would you rather stand next to: a 1.00 gram sample of Rf-261, or a 1.00 g sample of U-238? _____

Explain:

$$t_{1/2} = 62\text{s}$$

$$t_{1/2} = 4.47 \times 10^9 \text{yr}$$

Ummm... I'll choose the uranium. It has a longer half-life, so undergoes alpha decay at a lower rate. Uranium will eject much fewer alpha particles per unit time than the Rf.