Name _____ Date _____ Class _____

MATH SKILLS

Half-Life

If 100.0 g of carbon-14 decays until only 25.0 g of carbon is left after 11 460 y, what is the half-life of carbon-14?

1. List the given and unknown values.

Given: *initial mass of sample* = 100.0 g
final mass of sample = 25.0 g
total time of decay = 11 460 y
Unknown: *number of half-lives* = ? half-lives
half-life = ? y

2. Write down the equation relating half-life, the number of half-lives, and the decay time, and rearrange it to solve for half-life.

$$\textit{total time of decay} = \textit{number of half-lives} \times \frac{\textit{number of years}}{\textit{half - life}}$$

$$\frac{\textit{number of years}}{\textit{half - life}} = \frac{\textit{total time of decay}}{\textit{number of half - lives}}$$

3. Calculate how many half-lives have passed during the decay of the 100.0 g sample.

$$\textit{fraction of sample remaining} = \frac{\textit{final mass of sample}}{\textit{initial mass of sample}} = \frac{25.0\text{ g}}{100.0\text{ g}} = \frac{1}{4}$$

$$\textit{after one half-life} = \frac{1}{2};\ \textit{after two half-lives} = \frac{1}{2} \times \frac{1}{2} = \frac{1}{4} \text{ of sample}$$

Two half-lives have passed.

4. Solve for the half-life.

$$\frac{\textit{number of years}}{\textit{half - life}} = \frac{11\,460\text{ y}}{2\text{ half - lives}} = \frac{5730\text{ y}}{\text{half - life}}$$

half-life of carbon-14 = 5730 y

Your Turn to Think

1. What is the half-life of a 100.0 g sample of nitrogen-16 that decays to 12.5 g of nitrogen-16 in 21.6 s?
2. All isotopes of technetium are radioactive, but they have widely varying half-lives. If an 800.0 g sample of technetium-99 decays to 100.0 g of technetium-99 in 639 000 y, what is its half-life?
3. A 208 g sample of sodium-24 decays to 13.0 g of sodium-24 within 60.0 h. What is the half-life of this radioactive isotope?

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MATH SKILLS

Half-Life *continued*

Sample Problem

Thallium-208 has a half-life of 3.053 min. How long will it take for 120.0 g to decay to 7.50 g?

1. List the given and unknown values.

Given: *half-life* = 3.053 min
initial mass of sample = 120.0 g
final mass of sample = 7.50 g
Unknown: *number of half-lives* = ? half lives
total time of decay = ?

2. Write down the equation relating half-life, the number of half-lives, and the decay time, and rearrange it to solve for the total time of decay.

$$\textit{total time of decay} = \textit{number of half-lives} \times \frac{\textit{number of } \text{min}}{\textit{half - life}}$$

3. Calculate how many half-lives have passed during the decay of the 120.0 g sample.

$$\textit{fraction of sample remaining} = \frac{7.50\ \text{g}}{120.0\ \text{g}} = 0.0625 = \frac{1}{16}$$

after one half-life = $\frac{1}{2}$; *after two half-lives* = $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$;

after three half-lives = $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8}$; *after four half-lives* = $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{16}$ of sample. Four half-lives have passed.

4. Solve for the half-life.

$$\textit{total time of decay} = 4\ \text{half-lives} \times \frac{3.053\ \text{min}}{\text{half - life}}$$

$$\textit{total time of decay} = 12.21\ \text{min}$$

Your Turn to Think

4. If the half-life of iodine-131 is 8.10 days, how long will it take a 50.00 g sample to decay to 6.25 g?
5. The half-life of hafnium-156 is 0.025 s. How long will it take a 560 g sample to decay to one-fourth its original mass?

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MATH SKILLS

Half-Life *continued*

6. Chromium-48 has a short half-life of 21.6 h. How long will it take 360.00 g of chromium-48 to decay to 11.25 g

Sample Problem

Gold-198 has a half-life of 2.7 days. How much of a 96 g sample of gold-198 will be left after 8.1 days?

1. List the given and unknown values.

Given: *half-life* = 2.7 days
total time of decay = 8.1 days
initial mass of sample = 96 g

Unknown: *number of half-lives* = ? half-lives
final mass of sample = ? g

2. Write down the equation relating half-life, the number of half-lives, and the decay time, and rearrange it to solve for the number of half-lives.

$$\textit{total time of decay} = \textit{number of half-lives} \times \frac{\textit{number of days}}{\textit{half - life}}$$

$$\textit{number of half-lives} = \frac{\textit{total time of decay}}{\dfrac{\textit{number of days}}{\textit{half - life}}}$$

3. Calculate how many half-lives have passed during the decay of the 96 g sample.

$$\textit{number of half-lives} = \frac{8.1 \text{ days}}{\dfrac{2.7 \text{ days}}{\text{half - life}}} = 3.0 \text{ half-lives}$$

4. Calculate how much of the sample will remain after 3.0 half-lives.

$$\textit{final mass of sample} = \textit{initial mass of sample} \times \textit{fraction of sample remaining}$$

$$\textit{fraction of sample remaining after three half-lives} = \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8}$$

$$\textit{final mass of sample} = 96 \text{ g} \times \frac{1}{8} = 12 \text{ g}$$

Your Turn to Think

7. Potassium-42 has a half-life of 12.4 hours. How much of an 848 g sample of potassium-42 will be left after 62.0 hours?

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MATH SKILLS

Half-Life *continued*

8. Carbon-14 has a half-life of 5730 y. How much of a 144 g sample of carbon-14 will remain after 1.719×10^4y?
9. If the half-life of uranium-235 is 7.04×10^8 y and 12.5 g of uranium-235 remain after 2.82×10^9 y, how much of the radioactive isotope was in the original sample?

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