Half-Life

Unit: Nuclear Chemistry

MA Curriculum Frameworks (2016): N/A (HS-PS1-8 in physics frameworks)

Mastery Objective(s): (Students will be able to…)

- Determine the amount of radioactive material remaining after an integer number of half-lives.
- Determine the amount of time that has elapsed based on the fraction of radioactive material remaining (*e.g.,* carbon dating).

Success Criteria:

- Solutions use the appropriate equation for the information given.
- Solutions have the correct quantities substituted for the correct variables.
- Algebra and rounding to appropriate number of significant figures is correct.

Tier 2 Vocabulary: half-life, decay

Language Objectives:

- Explain how exponential decay works.

Notes:

The atoms of radioactive elements are unstable, and they spontaneously decay (change) into atoms of other elements.

For any given atom, there is a certain probability, *P*, that it will undergo radioactive decay in a given amount of time. The half-life, τ, is how much time it would take to have a 50 % probability of the atom decaying. If you start with *n* atoms, after one half-life, half of them (0.5*n*) will have decayed.

Amount of Material Remaining

If we start with 32 g of ^{53}Fe, which has a half-life (τ) of 8.5 minutes, we would observe the following:

# minutes	0	8.5	17	25.5	34
# half lives	0	1	2	3	4
amount left	32 g	16 g	8 g	4 g	2 g

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Finding the Time that has Passed (integer number of half-lives)

If the amount you started with divided by the amount left is an exact power of two, you have an integer number of half-lives and you can make a table.

Sample problem:

Q: If you started with 64 g of $^{131}\mathrm{I}$, how long would it take until there was only 4 g remaining? The half-life (τ) of $^{131}\mathrm{I}$ is 8.07 days.

A: $\frac{64}{4} = 16$ which is a power of 2, so we can simply make a table:

# half lives	0	1	2	3	4
amount remaining	64 g	32 g	16 g	8 g	4 g

From the table, after 4 half-lives, we have 4 g remaining.

The half-life (τ) of $^{131}\mathrm{I}$ is 8.07 days.

$$8.07 \times 4 = 32.3 \text{ days}$$

Finding the amount remaining and time that has passed for a non-integer number of half-lives requires logarithms, and is beyond the scope of this course.

Homework Problems

For these problems, you will need to use half-life information from "Table U. Selected Radioisotopes" on page 514 of your Chemistry Reference Tables.

1. If a lab had 128 g of $^{3}\mathrm{H}$ waste 49 years ago, how much of it would be left today? (*Note: you may round off to a whole number of half-lives.*)

   Answer: 8 g

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2. Suppose a student stole a 20. g sample of ^{42}K at 8:30am on Friday. When the student was called down to the vice principal's office on Monday at the convenient time of 10:54am, how much of the ^{42}K was left?

   Answer: 0.31 g

3. If a school wants to dispose of small amounts of radioactive waste, they can store the materials for ten half-lives, and then dispose of the materials as regular trash.

   a. If we had a sample of ^{32}P, how long would we need to store it before disposing of it?

      Answer: 143 days

   b. If we had started with 64 g of ^{32}P, how much ^{32}P would be left after ten half-lives? Approximately what fraction of the original amount would be left?

      Answer: 0.063 g; approximately $\frac{1}{1000}$ of the original amount.

4. If the carbon in a sample of human bone contained only one-fourth of the expected amount of ^{14}C, how old is the sample?

   (*Hint: pretend you started with* 1 g *of* ^{14}C *and you have* 0.25 g *remaining.*)

   Answer: 11 460 years

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