



### Lesson Objectives

By the end of this lesson, you should be able to:

- Describe what a half-life is.
- Calculate the amount of a **radioactive** substance remaining after an integral number of half-lives have passed.
- Calculate the number of half-lives that have passed given mass data for the radioactive substance.

**Science Practice:** Solve scientific problems by substituting quantitative values.



### Words to Know

Fill in this table as you work through the lesson. You may also use the glossary to help you.

daughter isotope	an isotope formed from the radioactive decay of another isotope known as the <b>parent</b> isotope
half-life	the <b>time</b> required for half the radioactive nuclei in a sample to decay
parent isotope	an isotope that undergoes radioactive <b>decay</b>

## Instruction

## Half-Life

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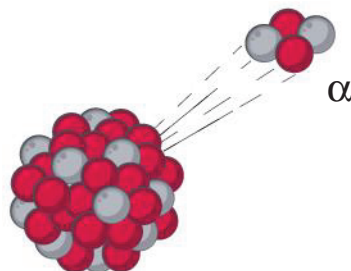
## Lesson Question

Why is it important to know the amount of time that it takes for half a radioisotope's nuclei to decay?

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## Radioisotopes

- A radioisotope is an **atom** with an unstable nucleus that will go through radioactive decay.
- Each time a radioisotope goes through radioactive decay, it captures or releases particles to become an isotope of a different element.
- The process continues until a stable isotope is formed.



## Parent and Daughter Isotopes

A **parent isotope** is an isotope that undergoes **radioactive** decay.

A **daughter isotope** is an isotope formed from the radioactive **decay** of another isotope known as the parent isotope.

Example:



Parent	Daughter
Isotope	Isotope

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### Half-Life and Radioactive Decay Rates

**Half-life** is the time required for half the radioactive **nuclei** in a sample to decay.

- All radioisotopes have a half-life.
- Half-lives are constant for each **isotope**.
- Half-lives vary dramatically from isotope to isotope.
- Half-lives are not affected by temperature, pressure, density, or concentration.

### Half-Life

- The half-life is not an exact measure of the decay of an individual **atom**.
- Half-lives range in length from tiny fractions of a second to billions of **years**.
- No known relationship exists between isotopes and half-lives.

Radioisotope	Half-life
Lithium-5	$3 \times 10^{-22}$ s
Polonium-211	0.516 s
Barium-139	82.7 min
Uranium-240	14.1 h
Bismuth-210	5.012 days
Uranium-232	68.9 years
Carbon-14	5,730 years
Plutonium-239	24,065 years
Beryllium-10	$1.6 \times 10^6$ years
Uranium-238	$4.5 \times 10^9$ years

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### The Importance of Half-Lives

- **Radioisotopes** are used as “tracers” in nuclear scanning.
  - Short half-lives avoid damaging living **tissue**.
  - Technetium-99m has a half-life of **six** hours.
- Nuclear **waste** has a long half-life.
  - Iodine-129 has a half-life of 15.7 million years.

### Radiocarbon Dating

- Radiocarbon dating is used to estimate the age of **organic** (living or once living) remains.
- It uses the radioisotope **C-14**.
- After death, **organisms** stop their intake of C-14.
- C-14's **half-life** is 5,730 years.
- It is useful for dating objects up to about 70,000 years old.

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**Half-Lives**

- After **one** half-life: Amount Remaining =  $\left(\frac{1}{2}\right)^1 = \frac{1}{\boxed{2}}$
- After **two** half-lives: Amount Remaining =  $\left(\frac{1}{2}\right)^2 = \frac{1}{4}$
- After **three** half-lives: Amount Remaining =  $\left(\frac{1}{2}\right)^3 = \frac{1}{8}$
- After ***n*** half-lives: Amount Remaining =  $\left(\frac{1}{2}\right)^n$

**Calculations with Half-Life**

Plutonium-244 has a half-life of 80 million years. After 320 million years, how much plutonium-244 will remain from a 100 g sample?

- Determine the number of half-lives.

$$\# \text{ half-lives} = \frac{\text{time elapsed}}{\text{half life}} = \frac{320 \text{ million years}}{80 \text{ million years}} = \boxed{4}$$

- Use the number of half-lives to find the amount of **parent** isotope remaining in the 100 g sample.

$$\text{mass} \times \left(\frac{1}{2}\right)^n = (100 \text{ g}) \times \left(\frac{1}{2}\right)^4 = (100 \text{ g}) \times \left(\frac{1}{\boxed{16}}\right) \approx 6 \boxed{9}$$

## Instruction

## Half-Life

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**Calculating Half-Life from Mass**

- Given initial and final masses, find the proportion of the **sample** remaining.
- Half the mass will be lost with each half-life.
- Calculate the half-life by figuring out how many halves were lost.

**Calculating Half-Lives from Mass**

A meteorite contains 0.3 g of nickel-59, a radioisotope that decays to form cobalt-59. It also contains 76.5 g of cobalt-59. How many half-lives have passed since the meteorite formed?

- Calculate the fraction of parent **isotope** in the sample.

$$0.3 \text{ g} + 76.5 \text{ g} = 76.8 \text{ g}$$

$$\frac{0.3}{76.8} = \frac{1}{\boxed{256}}$$

- Determine the **number** of half-lives.

$$\left(\frac{1}{2}\right)^n = .3 = \frac{1}{256}$$

$$2^n = 256$$

$$n = \boxed{8} \text{ half lives}$$

How old is the meteorite? The half-life of **nickel-59** is 75,000 years.

$$\boxed{8} \times (75,000 \text{ **years**}) = 600,000 \text{ years}$$

## Summary

## Half-Life

**Lesson Question**

Why is it important to know the amount of time that it takes for half a radioisotope's nuclei to decay?

**Answer**

(Sample answer) Half-life is the time required for half the radioactive nuclei in a sample to decay. Half-lives are always constant for a particular isotope, so it can be possible to identify the unknown isotopes. Half-lives are important in nuclear scanning, nuclear waste, and radiocarbon dating.

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**Radioisotopes and Nuclear Decay**

- Radioisotopes are atoms with unstable nuclei that go through **radioactive** decay until a stable isotope is formed.
- The radioisotope that decays is the **parent** isotope. It decays to become the daughter isotope.
- Half-life is the time required for half the radioactive nuclei in a sample to decay.
- Half-lives vary from fractions of seconds to billions of years but are always constant for a particular isotope.
- Half-lives are important in nuclear **scanning**, nuclear waste, and radiocarbon dating.

# Summary | Half-Life

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## Half-Life Calculations

- Relative proportions of parent and daughter isotopes can be used to determine the number of half-lives that have occurred.
- Half-life data can be used to calculate the amount of mass remaining.
- Mass data can be used to determine the number of half-lives.

*Use this space to write any questions or thoughts about this lesson.*