

# Absolute Dating

**Key Concept** Because radioactive decay occurs at a constant rate, the age of a rock can be estimated by analyzing the amounts of different isotopes in a rock.

## What You Will Learn

- Radioactive decay is the process by which a radioactive isotope changes into a stable isotope.
- Radiometric dating is the process in which parent and daughter isotopes are analyzed to determine the age of rocks and fossils.

## Why It Matters

Estimating the age of rocks and fossils helps tell the story of Earth's past.

## Vocabulary

- absolute dating
- radioactive decay
- radiometric dating
- half-life

## READING STRATEGY

**Clarifying Concepts** Take turns reading this section out loud with a partner. Stop to discuss ideas that seem confusing.

**absolute dating** (AB suh LOOT DAYT ing) any method of measuring the age of an event or object in years

**radioactive decay** (RAY dee oh AK tiv dee KAY) the process in which a radioactive isotope tends to break down into a stable isotope of the same element or another element



**7.3.c** Students know how independent lines of evidence from geology, fossils, and comparative anatomy provide the bases for the theory of evolution.

**7.4.d** Students know that evidence from geologic layers and radioactive dating indicates Earth is approximately 4.6 billion years old and that life on this planet has existed for more than 3 billion years.

▶ If you want to know exactly how old a person is, you can ask the person. But how can you find out the age of a rock? Finding the age of an object by determining the number of years the object has existed is called **absolute dating**. Read on to see how unstable atoms are used in one method of absolute dating.

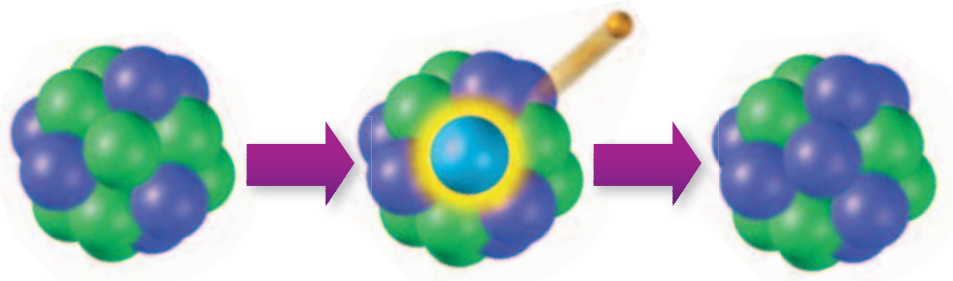
## Radioactive Decay

Atoms of the same element that have the same number of protons but have different numbers of neutrons are called *isotopes*. Most isotopes are stable, meaning that they stay in their original form. But some isotopes are unstable. Scientists call unstable isotopes *radioactive*. The breakdown of a radioactive isotope into a stable isotope of the same element or another element is called **radioactive decay**. **Figure 1** shows one example of how radioactive decay can happen.

Each kind of unstable isotope decays at a different rate. The rate of radioactive decay for a given isotope can be determined experimentally. For each kind of isotope, the rate of decay is constant. So, certain naturally occurring radioactive isotopes can be used as a kind of “clock” to find the ages of rocks that contain these isotopes.

**Standards Check** What is radioactive decay? **7.4.d**

**Figure 1** Radioactive Decay



**Unstable Isotope**  
6 protons,  
8 neutrons

**Radioactive Decay**  
When some unstable isotopes decay, a neutron is converted into a proton. In the process, an electron is released.

**Product of Decay: Stable Isotope**  
7 protons,  
7 neutrons

## Dating Rocks—Parent and Daughter Isotopes

An unstable radioactive isotope is called a *parent isotope*. The stable isotope produced by radioactive decay is called the *daughter isotope*. Radioactive decay can occur as a single step or a series of steps. In either case, the rate of decay is constant.

To date rock, scientists compare the amount of parent isotope with the amount of daughter isotope. The more daughter isotope there is, the older the rock is. For this reason, radiometric dating works only on rocks that contained either no daughter isotope or a known amount of daughter isotope at the time the rock formed.

### Radiometric Dating

If you know the rate of decay for a radioactive element in a rock, you can figure out the absolute age of the rock. Determining the absolute age of a sample based on the ratio of parent material to daughter material is called **radiometric dating**. For example, let's say that a rock sample contains an isotope with a half-life of 10,000 years. A **half-life** is the time needed for one-half of a radioactive sample to decay. In this rock sample, after 10,000 years, half of the parent material will have decayed and become daughter material. You analyze the sample and find equal amounts of parent material and daughter material. Half of the original radioactive isotope has decayed, so the sample must be about 10,000 years old. **Figure 2** shows how this steady decay happens.

### The Most Useful Rock Samples

Igneous rocks are the best types of rock samples to use for radiometric dating. When igneous rock forms, elements are separated into different minerals in the rock. Thus, when they form, minerals in igneous rocks often contain only a parent isotope and none of the daughter isotope.

## INTERNET ACTIVITY

### Radioactive Benefits

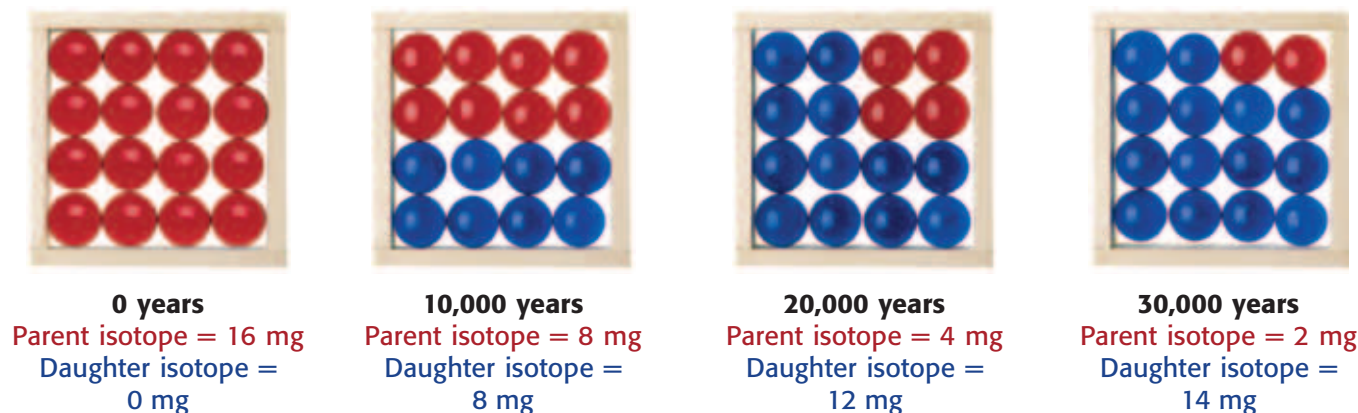
Can radioactivity be a good thing? Write an essay that describes how radioactivity can be beneficial. Go to **go.hrw.com**, and type in the keyword HY7RADW.

### radiometric dating

(RAY dee oh MET rik DAYT ing) a method of determining the age of an object by estimating the relative percentages of a radioactive (parent) isotope and a stable (daughter) isotope

**half-life** (HAF lief) the time required for half of a sample of a radioactive isotope to break down by radioactive decay to form a daughter isotope

**Figure 2** After every half-life, the amount of parent material decreases by one-half. **What fraction of parent material remains after two half-lives?**





**Figure 3** Half Dome in California's Yosemite National Park formed when a large mass of magma cooled very slowly below Earth's surface.

## Using Radiometric Dating

Scientists use different radiometric-dating techniques based on the estimated age of a sample. The half-life of an isotope determines how the isotope can be used for dating. The older the rock is, the more daughter material there will be in the rock. Isotopes with long half-lives can be used to date old rocks but not young rocks. For isotopes with long half-lives, younger rocks do not contain enough daughter material to allow accurate measurements.

### Methods of Radiometric Dating

One isotope used for radiometric dating is potassium-40. Potassium-40 has a half-life of 1.3 billion years. It decays to argon and calcium. Geologists measure argon as the daughter material. This method can be used to date rocks older than 100,000 years.

Uranium-238 is a radioactive isotope that decays to lead-206. The half-life of uranium-238 is 4.5 billion years. Uranium-lead dating can be used to date rocks older than 10 million years.

Half Dome, in Yosemite National Park, is shown in **Figure 3**. This dome is composed of igneous rock. After the rock formed, it was uplifted and shaped by glaciers. Uranium-lead dating shows that the rock in Half Dome formed about 85 million years ago. So, geologists can use relative dating to determine that the uplift and glacial erosion happened sometime in the last 85 million years.

## Quick Lab



### Radioactive Decay

1. Use a **clock** or **watch with a second hand** to record the time. Wait 20 s, and then use **scissors** to carefully cut a **sheet of paper** in half. Select one piece, and set the other piece aside.
2. Repeat step 1 until nine 20 s intervals have elapsed.
3. What does the whole piece of paper used in this lab represent?
4. What do the pieces of paper you set aside in each step represent?
5. How much of your paper isotope was left after the first interval? after three intervals? after nine intervals? Express your answers as percentages.




6. What is the half-life of your paper isotope?



## The Age of Our Solar System

Can radiometric dating be used to find the age of Earth? Yes, but not by dating rocks from Earth. The first rocks that formed on Earth have been recycled by plate tectonics and erosion. Therefore, there are no Earth rocks left that are as old as our planet. But other bodies in space contain rock that is as old as our solar system.

For example, the moon and some meteorites contain rock that formed as our solar system, including Earth, was forming. *Meteorites* are small, rocky bodies that have traveled through space and fallen to Earth's surface. Geologists have found meteorites on Earth. Rocks from the moon have also been collected, as shown in **Figure 4**. Radiometric dating has been done on these rocks from other parts of our solar system. The absolute ages of these samples show that our solar system, including Earth, is about 4.6 billion years old.

**Standards Check** Approximately how old are Earth and the solar system? What is the evidence for this age?  7.4.d



**Figure 4** Scientist-astronaut Harrison Schmitt collects samples of rock on the moon with the lunar rake during the Apollo 17 mission.

### SECTION Review



7.3.c, 7.4.d

### Summary

- During radioactive decay, an unstable isotope decays and becomes a stable isotope of the same element or a different element.
- Radiometric dating, based on the ratio of parent to daughter material, is used to determine the absolute age of a sample.
- The method of radiometric dating is chosen based on the estimated age of the sample.
- Earth and the solar system are about 4.6 billion years old.

### Using Vocabulary

- 1 Use *absolute dating*, *radioactive decay*, *radiometric dating*, and *half-life* in separate sentences.

### Understanding Concepts

- 2 **Describing** Explain how radioactive decay occurs.
- 3 **Summarizing** How does radioactive decay relate to radiometric dating?
- 4 **Analyzing** In order for radiometric dating to be accurate, what must be true about the daughter material at the time a rock formed?
- 5 **Evaluating** How do geologists know that Earth and the solar system are approximately 4.6 billion years old?

### Critical Thinking

- 6 **Analyzing Methods** Explain why radioactive decay must be constant in order for radiometric dating to be accurate.
- 7 **Making Inferences** Why are there rocks on the moon that are older than any rocks on Earth?

### Challenge

- 8 **Applying Concepts** Could the potassium-argon method of radiometric dating be used to date rock that is estimated to have formed 1,000 years ago? Explain why or why not.

### Internet Resources

For a variety of links related to this chapter, go to [www.scilinks.org](http://www.scilinks.org)  
Topic: **Absolute Dating**  
SciLinks code: **HY70003**