Lesson 3

Absolute Dating

ESSENTIAL QUESTION

How is the absolute age of rock measured?

By the end of this lesson, you should be able to summarize how scientists measure the absolute age of rock layers, including by radiometric dating.

A clock is one way of measuring absolute time.

Lesson Labs

Quick Labs
- Index Fossils
- Radioactive Decay

Engage Your Brain

1 Predict Check T or F to show whether you think each statement is true or false.

T	F	
☐	☐	All rocks are made of matter and all matter is made of atoms.
☐	☐	We use calendars to measure the absolute age of people.
☐	☐	Someone tells you that he is older than you are. This tells you his absolute age.
☐	☐	If you cut a clay ball in two and then cut one of the halves in two, you will end up with four pieces of clay.

2 Explain What is the age of this person? How do you know?

Active Reading

3 Synthesize You can often define an unknown word if you know the meaning of its word parts. Use the word parts and sentence below to make an educated guess about the meaning of the phrase *radiometric dating*.

Word part	Meaning
radio-	relating to radiation
-metric	relating to measurement

Example sentence
By using radiometric dating, the scientist found that the rock was 25 million years old.

radiometric dating:

Vocabulary Terms

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

4 Apply As you learn the definition of each vocabulary term in this lesson, create your own definition or sketch to help you remember the meaning of the term.

It's About Time!

How can the absolute age of rock be determined?

Determining the actual age of an event or object in years is called **absolute dating**. Scientists use many different ways to find the absolute age of rock and other materials. One way is by using radioactive isotopes (ray•dee•oh•AK•tiv EYE•suh•tohpz).

Using Radioactive Isotopes

Atoms of the same element that have a different number of neutrons are called isotopes. Many isotopes are stable, meaning that they stay in their original form. But some isotopes are unstable, and break down to form different isotopes. The unstable isotopes are called *radioactive*. The breakdown of a radioactive isotope into a stable isotope of the same element or of another element is called **radioactive decay**. As shown on the right, radioactive decay for many isotopes happens when a neutron is converted to a proton, with the release of an electron. A radioactive isotope is called a *parent isotope*. The stable isotope formed by its breakdown is called the *daughter isotope*.

Each radioactive isotope decays at a specific, constant rate. **Half-life** is the time needed for half of a sample of a radioactive substance to undergo radioactive decay to form daughter isotopes. Half-life is always given in units of time.

Active Reading **5 Describe** How much of a radioactive parent isotope remains after one half-life has passed? Explain your answer.

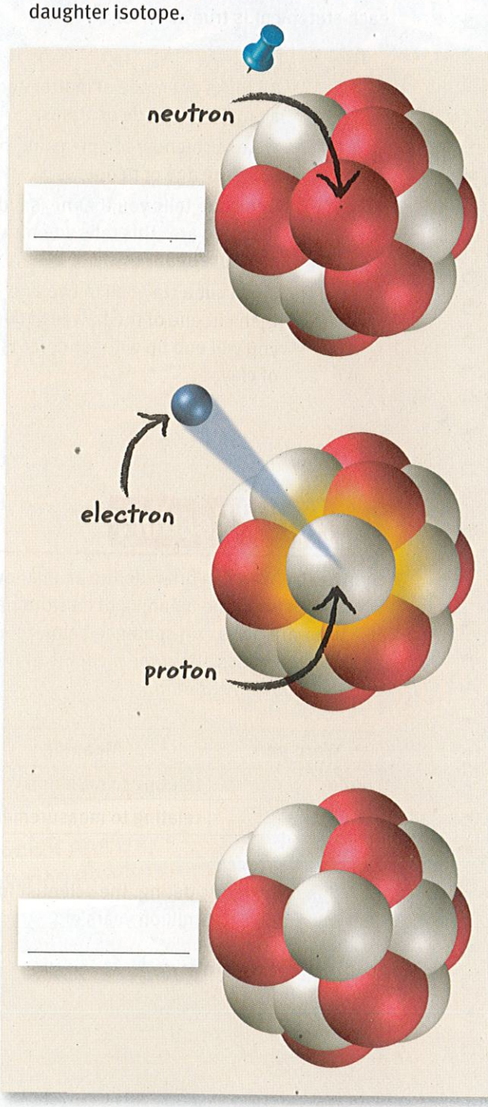
_____

_____

_____

Visualize It!

6 Identify Label the parent isotope and the daughter isotope.



_____

_____

By Radiometric Dating

Some radioactive isotopes in mineral crystals can act as clocks. These mineral crystals record the ages of the rocks in which the minerals formed. Scientists study the amounts of parent and daughter isotopes to date samples. If you know how fast a radioactive isotope decays, you can figure out the sample's absolute age. Finding the absolute age of a sample by determining the relative percentages of a radioactive parent isotope and a stable daughter isotope is called **radiometric dating** (ray•dee•oh•MET•rik DAYT•ing). The figure on the right shows how the relative percentages of a parent isotope and a daughter isotope change with the passing of each half-life.The following is an example of how radiometric dating can be used:

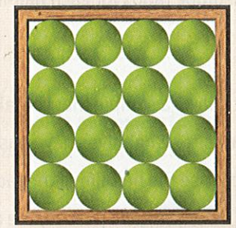
- You want to determine the age of a sample that contains a radioactive isotope that has a half-life of 10 million years.
- You analyze the sample and find equal amounts of parent and daughter isotopes.
- Because 50%, or ½, of the parent isotope has decayed, you know that 1 half-life has passed.
- So, the sample is 10 million years old.

What is the best rock for radiometric dating?

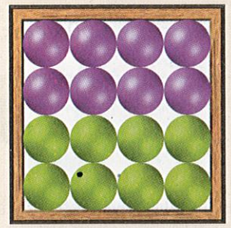
Igneous rock is often the best type of rock sample to use for radiometric dating. When igneous rock forms, elements are separated into different minerals in the rock. When they form, minerals in igneous rocks often contain only a parent isotope and none of the daughter isotope. This makes the isotope percentages easier to interpret and helps dating to be more accurate.

Visualize It!

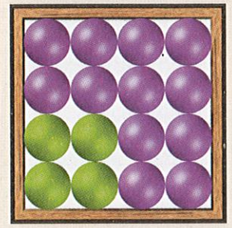
7 Calculate Fill in the number of parent isotopes and daughter isotopes in the spaces beside the images below.



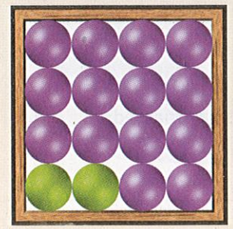
0 years
Parent isotope = 16
Daughter isotope = 0
100% of the sample is parent isotope.



After 1 half-life
Parent isotope = 8
Daughter isotope = 8
50%, or $\frac{1}{2}$, of the sample is parent isotope.



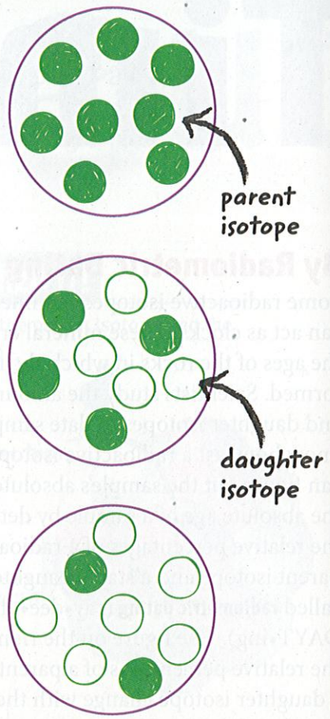
After 2 half-lives
Parent isotope = 4
Daughter isotope = ___
25%, or $\frac{1}{4}$, of the sample is parent isotope.



After 3 half-lives
Parent isotope = ___
Daughter isotope = ___
12.5%, or $\frac{1}{8}$, of the sample is parent isotope.

Do the Math Sample Problem

A crystal contains a radioactive isotope that has a half-life of 10,000 years. One-fourth (25%) of the parent isotope remains in a sample. How old is the sample?



Identify

A. What do you know? Half-life = 10,000 years, parent isotope = 25%

B. What do you want to find out? How old the sample is. So, you need to know how many half-lives have gone by since the crystal formed.

Plan

C. Draw the parent-to-daughter isotope ratios for each half-life.

Solve

D. The third drawing on the right shows a sample that contains 25% parent isotope. This amount is present after 2 half-lives have passed.

E. Find the age of the sample. Because the half-life of the radioactive isotope is 10,000 years and 2 half-lives have passed, the age of the sample is:

$2 \times 10{,}000 \text{ years} = 20{,}000 \text{ years}$

Do the Math You Try It

8 Calculate A crystal contains a radioactive isotope that has a half-life of 20,000 years. You analyze a sample and find that one-eighth (12.5%) of the parent isotope remains. How old is the sample?

Identify

A. What do you know? _____

B. What do you want to find out? _____

Plan

C. Draw the parent-to-daughter isotope ratios on the right.

Solve

D. Figure out how many half-lives have passed: _____

E. Find the age of the sample:

_____

Answer: _____

Time for a Change

What are some radiometric dating methods?

Scientists use many different isotopes for radiometric dating. The half-life of an isotope is very important in determining the time range that it is useful for dating. If the half-life is too short compared with the age of the sample, there will be too little parent isotope left to measure. If the half-life is too long, there will not be enough daughter isotope to measure. Also, different methods may only be useful for certain types of materials.

Active Reading

9 Identify As you read, underline the time frame for which radiocarbon dating is useful.

Radiocarbon Dating

The ages of wood, bones, shells, and other organic remains can be found by radiocarbon dating. The radioactive isotope carbon-14 combines with oxygen to form radioactive carbon dioxide, CO_2. Most CO_2 in the atmosphere contains nonradioactive carbon-12, but radioactive carbon-14 is also present.

Plants absorb CO_2 from the atmosphere, which they use to build their bodies through photosynthesis. As long as a plant is alive, the plant takes in carbon dioxide with the same carbon-14 to carbon-12 ratio. Similarly, animals convert the carbon from the food they eat into bone and other tissues. So, animals inherit the carbon isotope ratio of their food sources.

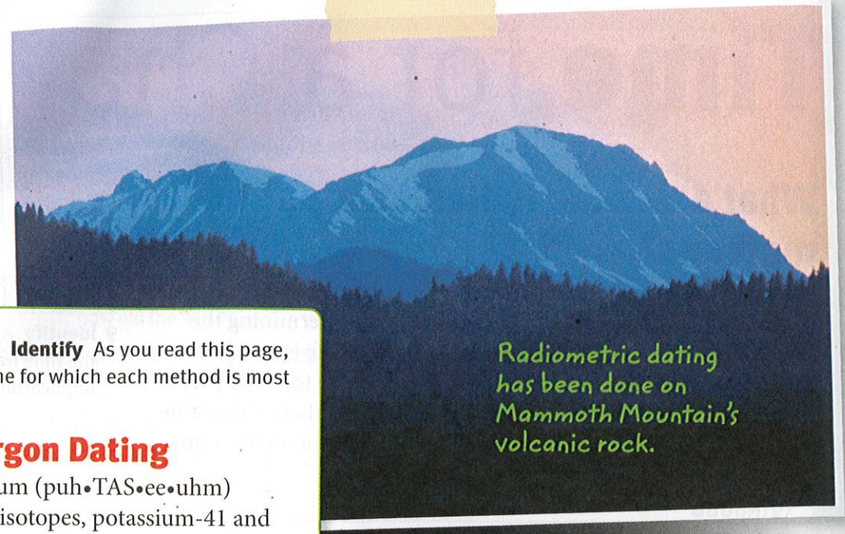
Once a plant or animal dies, carbon is no longer taken in. The ratio of carbon-14 to carbon-12 decreases in the dead organism because carbon-14 undergoes radioactive decay to nitrogen-14. The half-life of carbon-14 is only 5,730 years. Also, radiocarbon dating can only be used to date organic matter. So this method is used to date things that lived in the last 45,000 years.

Active Reading **10 Explain** You have found a bone in a layer of rock that you think is about 500,000 years old. Would you use radiocarbon dating to find the age of this bone? Why or why not?

_____

_____

Materials such as these woolly mammoth teeth can be radiocarbon dated.



Radiometric dating has been done on Mammoth Mountain's volcanic rock.

Active Reading **11 Identify** As you read this page, underline the time frame for which each method is most useful.

Potassium-Argon Dating

The element potassium (puh•TAS•ee•uhm) occurs in two stable isotopes, potassium-41 and potassium-39, and one radioactive isotope that occurs naturally, potassium-40. Potassium-40 decays to argon and calcium. It has a half-life of 1.25 billion years. Scientists measure argon as the daughter isotope. Potassium-argon dating is often used to date igneous volcanic rocks. This method is used to date rocks that are between about 100,000 years and a few billion years old.

Scientist and astronaut Harrison Schmitt collected samples of rock on the moon during the **Apollo 17** mission in 1972.

Uranium-Lead Dating

An isotope of uranium (yoo•RAY•nee•uhm), called uranium-238, is a radioactive isotope that decays to lead-206. Uranium-lead dating is based on measuring the amount of the lead-206 daughter isotope in a sample. Uranium-238 has a half-life of 4.5 billion years.

Uranium-lead dating can be used to determine the age of igneous rocks that are between 100 million years and billions of years old. Younger rocks do not have enough daughter isotope to be accurately measured by this method. Uranium-lead dating was used to find the earliest accurate age of Earth.

Time Will Tell

How is radiometric dating used to determine the age of Earth?

Radiometric dating can be used to find the age of Earth, though not by dating Earth rocks. The first rocks that formed on Earth have long ago been eroded or melted, or buried under younger rocks. So, there are no Earth rocks which can be directly studied that are as old as our planet. But other bodies in space do have rock that is as old as our solar system.

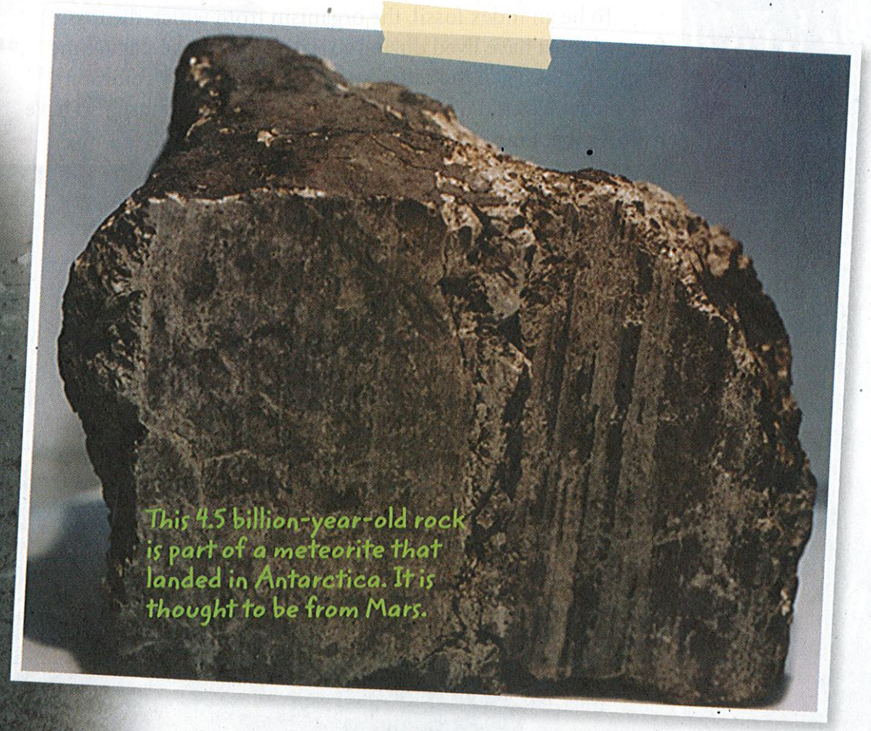
Meteorites (MEE•tee•uh•rytz) are small, rocky bodies that have traveled through space and fallen to Earth's surface. Scientists have found meteorites on Earth, such as the one shown below. Rocks from the moon have also been collected. Radiometric dating has been done on these rocks from other parts of our solar system. The absolute ages of these samples show that our solar system, including Earth, is about 4.6 billion years old.

Active Reading

12 Identify As you read, underline the reason why scientists cannot use rocks from Earth to measure the age of Earth.

Think Outside the Book Inquiry

13 Model Develop a way to help people understand how large the number 4.6 billion is.



This 4.5 billion-year-old rock is part of a meteorite that landed in Antarctica. It is thought to be from Mars.

Showing Your **Age**

How can fossils help to determine the age of sedimentary rock?

Sedimentary rock layers and the fossils within these layers cannot be dated directly. But igneous rock layers on either side of a fossil layer can be dated radiometrically. Once the older and younger rock layers are dated, scientists can assign an absolute age range to the sedimentary rock layer that the fossils are found in.

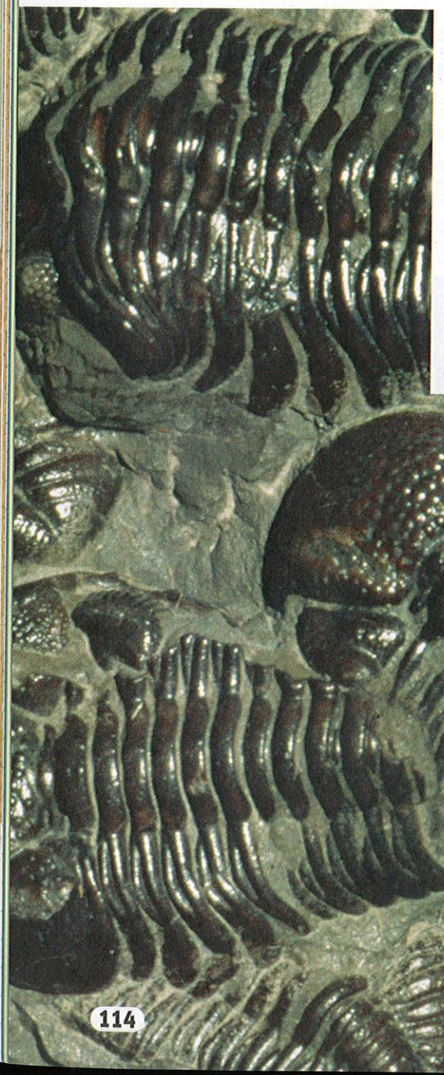
Active Reading

14 Identify As you read, underline the requirements for a fossil to be an index fossil.

Using Index Fossils

Scientists have found that particular types of fossils appear only in certain layers of rock. By dating igneous rock layers above and below these fossil layers, scientists can determine the time span in which the organisms lived. *Index fossils,* such as the ones shown below, are fossils that are used to estimate the absolute age of the rock layers in which they are found. Once the absolute age of an index fossil is known, it can be used to determine the age of rock layers that contain the same index fossil anywhere on Earth.

To be an index fossil, the organism from which the fossil formed must have lived during a relatively short geologic time span. The fossils of the organism must be relatively common and must be found over a large area. Index fossils must also have features that make them different from other fossils.



Phacops rana fossils are used as index fossils. This trilobite lived between 405 million and 360 million years ago.

How are index fossils used?

Index fossils act as markers for the time that the organisms lived on Earth. Organisms that formed index fossils lived during short periods of geologic time. So, the rock layer that an index fossil is found in can be dated accurately. For example, ammonites were marine mollusks, similar to a modern squid. They lived in coiled shells in ancient seas. The ammonite *Tropites* (troh•PY•teez) lived between 230 million and 208 million years ago. So, whenever scientists find a fossil of *Tropites*, they know that the rock layer the fossil was found in formed between 230 million and 208 million years ago. As shown below, this can also tell scientists something about the ages of surrounding rock layers.

Trilobite (TRY•luh•byt) fossils are another example of a good index fossil. The closest living relatives of trilobites are the horseshoe crab, spiders, and scorpions. *Phacops rana* is a trilobite that lived between 405 million and 360 million years ago. The *Phacops rana* fossil, shown on the previous page, is the state fossil of Pennsylvania.

Index fossils can also be used to date rock layers in separate areas. The appearance of the same index fossil in rock of different areas shows that the rock layers formed at about the same time.

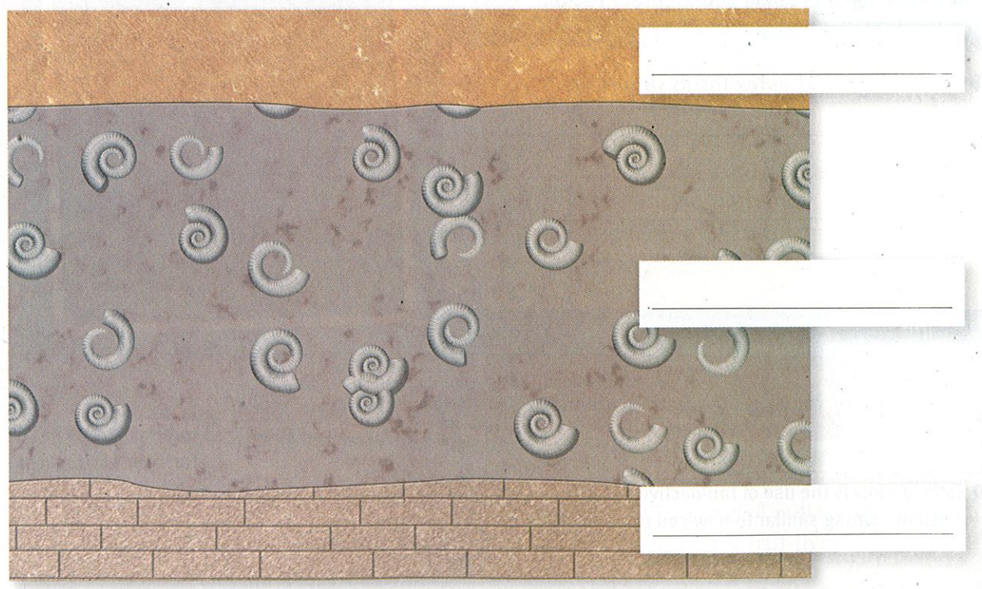
Active Reading

15 Identify As you read, underline examples of organisms whose fossils are index fossils. Include the time frame for which they are used to date rock.

Visualize It!

16 Infer *Tropites* fossils are found in the middle rock layer shown below. Place each of the following ages beside the correct rock layer: 215 million/500 million/100 million.

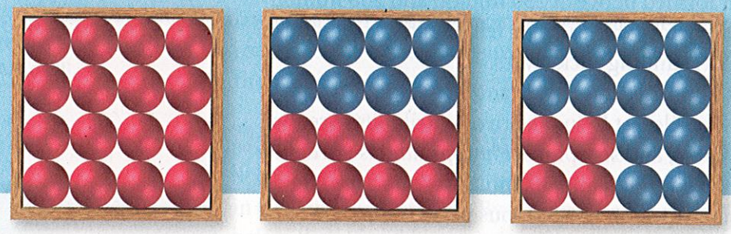
Fossils of a genus of ammonites called ***Tropites*** *are good index fossils.*



Visual Summary

To complete this summary, fill in the blanks with the correct word or phrase. Then, use the key below to check your answers. You can use this page to review the main concepts of the lesson.

Radiometric dating can be used to find the absolute ages of materials such as igneous rocks. This method uses the radioactive decay of an isotope.



17 During radioactive decay, the amount of _____ isotope decreases by one-half after every _____

Absolute Dating

Index fossils can be used to estimate the absolute ages of some sedimentary rocks.

18 Four things that index fossils should be:

A _____

B _____

C _____

D _____

Answers: 17 parent, half-life; 18 In large numbers, in a large area, have special features, lived during a short time period

19 Relate How is the use of radioactive decay in absolute dating similar to how you use a clock?

Lesson Review

Vocabulary

Fill in each blank with the term that best completes the following sentences.

1 The breakdown of a radioactive isotope into a stable isotope is called _____

2 The _____ is the time needed for half of a sample of a radioactive isotope to break down to form daughter isotopes.

3 _____ is a method used to determine the absolute age of a sample by measuring the relative amounts of parent isotope and daughter isotope.

Key Concepts

4 Summarize How are radioactive isotopes used to determine the absolute age of igneous rock? Name two radiometric methods that are used.

5 Describe What happens to an isotope during radioactive decay?

6 Explain Why are igneous rocks the best type of rock sample for radiometric dating?

7 Describe How old is Earth and how did scientists find this out?

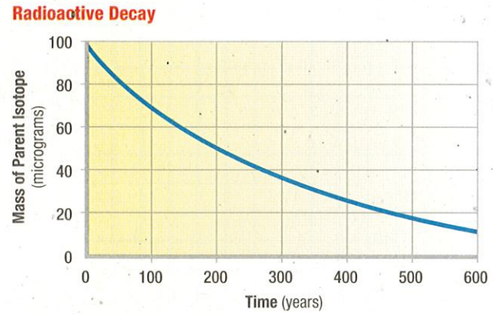
8 Explain What are index fossils and how are they used to determine the absolute age of sedimentary rock?

Critical Thinking

9 Justify An igneous rock sample is about 250,000 years old. Would you use uranium-lead radiometric dating to find its age? Explain.

10 Calculate A sample of wood contains 12.5% of its original carbon-14. What is the estimated age of this sample? Show your work.

Use this graph to answer the following questions.



11 Analyze What is the half-life of the radioactive isotope?

12 Analyze What mass of radioactive isotope will be left after three half-lives?