14.4.2: Radiocarbon Dating- Using Radioactivity to Measure the Age of Fossils and Other Artifacts

Learning Objectives

- Identify the age of materials that can be approximately determined using Radiocarbon dating.

Radiometric Dating

Several radioisotopes have half-lives and other properties that make them useful for purposes of "dating" the origin of objects such as archaeological artifacts, formerly living organisms, or geological formations. The radioactivity of carbon-14 provides a method for dating objects that were a part of a living organism. This method of radiometric dating, which is also called **radiocarbon dating** or **carbon-14 dating**, is accurate for dating carbon-containing substances that are up to about 30,000 years old, and can provide reasonably accurate dates up to a maximum of about 50,000 years old.

Naturally occurring carbon consists of three isotopes:

, which constitutes about 99% of the carbon on earth; , about 1% of the total; and trace amounts of

. Carbon-14 forms in the upper atmosphere by the reaction of nitrogen atoms with neutrons from cosmic rays in space:

All isotopes of carbon react with oxygen to produce CO_2 molecules. The ratio of

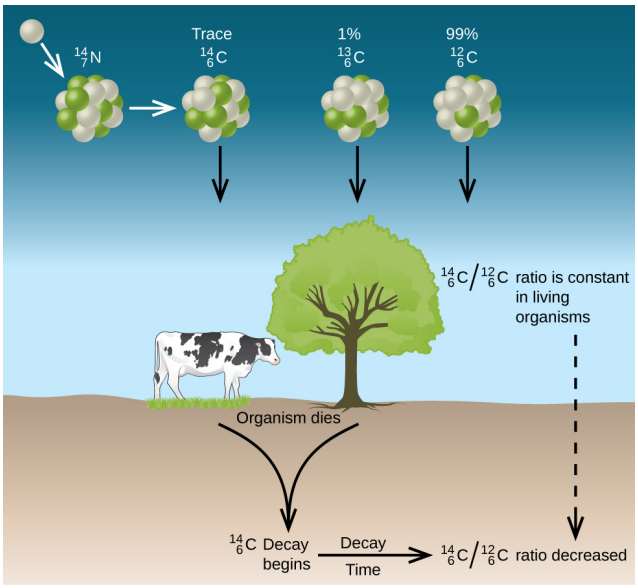
to depends on the ratio of to in the atmosphere. The natural abundance of in the atmosphere is approximately 1 part per trillion; until recently, this has generally been constant over time, as seen is gas samples found trapped in ice. The incorporation of and into plants is a regular part of the photosynthesis process, which means that the ratio found in a living plant is the same as the ratio in the atmosphere. But when the plant dies, it no longer traps carbon through photosynthesis. Because

is a stable isotope and does not undergo radioactive decay, its concentration in the plant does not change. However, carbon-14 decays by β emission with a half-life of 5730 years:

Thus, the

ratio gradually decreases after the plant dies. The decrease in the ratio with time provides a measure of the time that has elapsed since the death of the plant (or other organism that ate the plant). Figure

visually depicts this process.



Figure

: Along with stable carbon-12, radioactive carbon-14 is taken in by plants and animals, and remains at a constant level within them while they are alive. After death, the C-14 decays and the C-14:C-12 ratio in the remains decreases. Comparing this ratio to the C-14:C-12 ratio in living organisms allows us to determine how long ago the organism lived (and died). (CC BY 4.0; OpenStax)

For example, with the half-life of

being 5730 years, if the ratio in a wooden object found in an archaeological dig is half what it is in a living tree, this indicates that the wooden object is 5730 years old. Highly accurate determinations of ratios can be obtained from very small samples (as little as a milligram) by the use of a mass spectrometer.

When we speak of the element Carbon, we most often refer to the most naturally abundant stable isotope ^{12}C. Although ^{12}C is definitely essential to life, its unstable sister isotope ^{14}C has become of extreme importance to the science world. Radiocarbon dating is the process of determining the age of a sample by examining the amount of ^{14}C remaining against its known half-life, 5,730 years. The reason this process works is because when organisms are alive, they are constantly replenishing their ^{14}C supply through respiration, providing them with a constant amount of the isotope. However, when an organism ceases to exist, it no longer takes in carbon from its environment and the unstable ^{14}C isotope begins to decay. From this science, we are able to approximate the date at which the organism lived on Earth. Radiocarbon dating is used in many fields to learn information about the past conditions of organisms and the environments present on Earth.

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