

Read the passage on the back of this worksheet taken from pages 778-781 of *Prentice Hall Chemistry: Connections to Our Changing World* (1996) and answer the following questions:

1. Describe how Henri Becquerel discovered radioactivity: _____

2. Use the data from the reading to calculate the average atomic mass of rubidium:
3. What kind of radiation does ^{87}Rb give off? _____
4. What does tin-124 become once it gives off radiation? _____
5. What is a half-life? _____

6. What is the half-life of rubidium-87? _____
7. What is the half-life of tin-124? _____
8. Are tin-124 and rubidium-87 dangerous to humans? Explain your answer. _____

9. What does carbon-14 become after it decays? _____
10. What is the half-life of carbon-14? _____
11. How is carbon-14 produced? _____

12. What chemical is essential to photosynthesis? _____
13. Why is the amount of carbon-14 constant in living things? _____

14. How can scientists estimate the age of wooden objects, textiles, and leather? _____

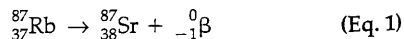
Radioisotopes

What kinds of changes take place in the nucleus of an unstable atom when it decays? All nuclear decay is accompanied by the emission of radiation, which is called radioactivity. As you should recall from Chapter 3, radioactivity was first observed in 1896 by Henri Becquerel. Becquerel had stored some photographic film in the same drawer as a sample of uranium ore with only a piece of black paper separating them. When the film was developed, it showed signs of exposure even though it had been kept in the dark. Radiation from the uranium had passed through the black paper and produced an image on the film.

The decay of unstable isotopes is a spontaneous process that takes place all the time. All elements have one or more isotopes that are unstable and that decay to produce other elements. These isotopes may be natural or they may be artificial. Many elements have at least one radioactive isotope, or **radioisotope**, that occurs naturally. Several elements, such as fluorine, do not. The only natural isotope of fluorine is fluorine-19, which is stable. However, unstable isotopes of fluorine can be produced artificially in a nuclear bombardment reaction. You will learn more about nuclear bombardment reactions later in this section.

Half-life

The element rubidium (Rb) has two naturally occurring isotopes. As it is found naturally, rubidium consists of 72.15 percent rubidium-85 and 27.85 percent rubidium-87. The ^{85}Rb isotope is perfectly stable, but ^{87}Rb is radioactive, giving off a beta particle and decaying to strontium-87:



Tin (Sn) also has a naturally occurring radioactive isotope, tin-124. This isotope accounts for 6.01 percent of naturally occurring tin and decays to produce beta particles and antimony-124.

Rubidium-87 and tin-124 are examples of natural radioactive isotopes. The radioactive fraction of any natural sample of either of these two metals is continuously decaying into another element and beta particles. Are either of these metals dangerous to your health? (You probably will not encounter much rubidium, but tin is a commonly used metal.) The answer is that these metals are not dangerous and the reason involves the **half-life** of each element. **The half-life of a radioactive isotope is the time it takes for one half of a sample of that isotope to decay.**

The half-life of rubidium-87 is 6×10^{10} (60 billion) years. This means that in 60 billion years, one half of the ^{87}Rb in a particular sample would be gone. Suppose you started with a sample containing 1.000 gram of ^{87}Rb . In 60 billion years, 0.500 gram would be left. After another 60 billion years, half of that amount, or 0.25 gram, would be left, and in yet another 60 billion years only 0.125 gram would be left. This process would continue as the amount of ^{87}Rb remaining slowly got smaller and smaller. Of course, 60 billion years is older than the current age of the universe, which is estimated to be about 15 billion years old!

Of course, the more slowly an isotope decays, the more slowly the alpha, beta, or gamma radiation that accompanies radioactive decay is produced. Normally, one particle is emitted every time the nucleus of an atom decays. If ^{87}Rb is decaying so slowly that it takes 6×10^{10} years for just half of it to change, the emission of beta particles must be very slow. And ^{124}Sn with a half-life of 1.7×10^{17} years is decaying and producing beta particles even more slowly. As a result, these isotopes are not dangerous to living things. The half-lives of some common radioisotopes are listed in Figure 24-4.

Radiocarbon Dating

One of the best known radioactive isotopes is carbon-14, which decays to produce nitrogen-14 and beta particles. The half-life of carbon-14 is 5730 years. Carbon-14 is produced in the Earth's atmosphere by the action of cosmic rays on ordinary atmospheric nitrogen (nitrogen-14). (Cosmic rays are streams of high-energy charged particles from outer space that collide with atoms in the Earth's upper atmosphere.)

New atoms of carbon-14 are produced at the same rate that the isotope decays. Scientists assume that the production of carbon-14 has been essentially constant for a long time. After being produced by the cosmic rays, the carbon-14 is then oxidized in the atmosphere to form $^{14}\text{CO}_2$, which mixes with the $^{12}\text{CO}_2$ already present in the atmosphere. As a result, the atmosphere always contains a fixed ratio of $^{14}\text{CO}_2$ to $^{12}\text{CO}_2$.

What makes carbon-14 such an important isotope? The answer is in the way in which carbon dioxide is used by plants and animals. Carbon dioxide is an essential part of the process of photosynthesis in plants. Photosynthesis is the process by which green plants use the sun's energy to convert carbon dioxide and water into sugars and starches. The sugars and starches, in turn, are food for animals that eat the plants and exhale carbon dioxide. Because this cycle exposes plants and animals to a constant source of carbon-14, the amount of this isotope in living plants and animals is constant. The emission of beta particles is likewise constant as the isotope decays.

The incorporation of carbon-14 into plant or animal tissue stops once the organism dies. The emission of beta particles will then drop as the carbon-14 decays. After 5730 years the rate of beta emission will have dropped to one half the rate in living organisms; after 11,460 years the rate will have dropped to one quarter, and so forth. By determining the rate of beta emission from plant and animal remains or products—such as wooden objects, textiles, and leather—scientists can estimate the age of these objects. Such estimates are accurate up to about 7000 years and give a reasonable approximation up to 30,000 years. (After this length of time, the rate of beta emission is too slow to be measured reliably.)