1. What Is Radioactive Material?

Radioactivity is a part of nature. Everything is made of atoms. Radioactive atoms are unstable; that is, they have too much energy. When radioactive atoms spontaneously release their extra energy, they are said to **decay**. All radioactive atoms decay eventually, though they do not all decay at the same rate. After releasing all their excess energy, the atoms become stable and are no longer radioactive. The time required for decay depends upon the type of atom. This Fact Sheet explains the process of radioactive decay.

➤ The Atom

The explanation of radioactive decay begins with a description of the atom. Atoms are made up of three subatomic particles: **protons, neutrons, and electrons**. The protons and neutrons are packed together in the **nucleus** at the center of the atom (see Figure 1). The space outside the nucleus is occupied by the electrons. The number of protons in the nucleus determines what material, or **element**, the atom is. For example, if the nucleus contains 8 protons, the atom is oxygen. If the nucleus contains 17 protons, the atom is chlorine.

➤ Isotopes and Nuclides

While all atoms of the same element contain the same number of protons, the number of neutrons may be different. For example, carbon atoms have six protons. If a carbon atom also has six neutrons, it is Carbon-12. If it has seven neutrons, it is Carbron-13. A carbon atom containing six protons and eight neutrons is Carbon-14. This form, or **isotope** of carbon is radioactive. Carbon-14 is radioactive while Carbon-12 and Carbon-13 are stable.

The term **nuclide** is used to refer to any type of atom, so that Carbon-12 and Hydrogen-2 are nuclides. They are not isotopes of each other because they differ in the number of protons that they each have in their nucleus.

The prefix “radio-” can be added to either term, making radioisotope or radionuclide, whenever the atom referred to is radioactive.

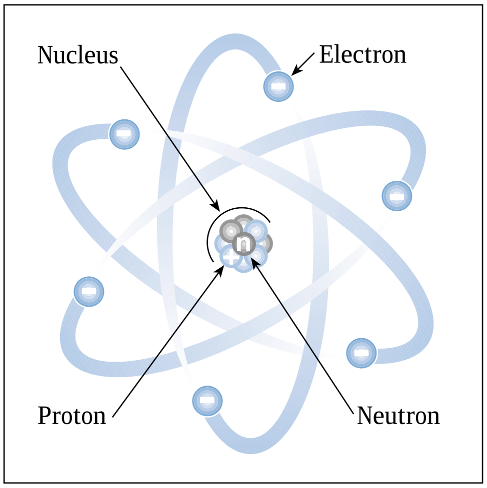

Figure 1. **The Atom**

➤ Radioactive Decay

When the nucleus of a radionuclide spontaneously gives up its extra energy, that energy is called **ionizing radiation**. Ionizing radiation may take the form of **alpha particles**, **beta particles**, or **gamma rays**. The process of emitting the radiation is called **radioactive decay.**

➤ Decay Chain

When the nucleus of a radioactive atom decays, giving up its excess energy, the nucleus is altered. It is transformed into another atom which in many cases is a different element. This new atom may be stable or unstable. If it is stable, the new atom is not radioactive. If it is unstable, it also will decay, transforming its nucleus and emitting more ionizing radiation. Several decays may be required before a stable atom is produced. This sequence is known as a **decay chain** (see Figure 2).

Decay chains of radioactive atoms have been studied extensively. Scientists know exactly how many decays are required for each radioactive atom to become stable. In addition, they know how much energy will be released with each decay.

➤ Half-Life

It is not possible to predict exactly when a particular radioactive atom will decay.

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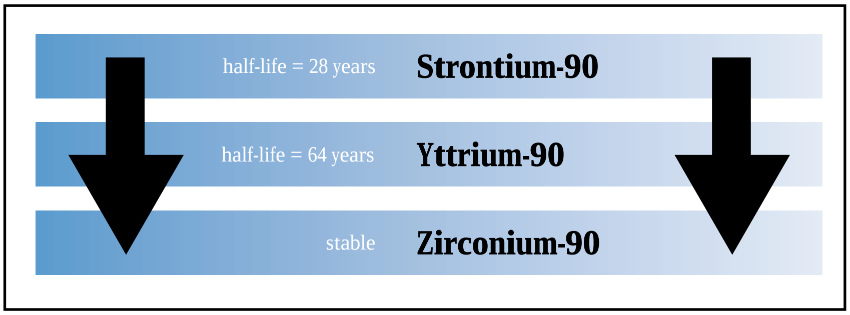

Figure 2. **Decay Chain for an Isotope of Strontium**

However, scientists have determined the time required for half of a large number of identical radioactive atoms to decay. This time is called the **half-life.**

Suppose, for example, a large number of radioactive atoms with a half-life of three hours were put in a box. After three hours, one-half of those radioactive atoms would remain. The other half would have been transformed to a different atomic form. After three more hours, one-half of the remaining radioactive atoms (one-quarter of the initial number) would still be unchanged. The concept of half-life is illustrated in Figure 3.

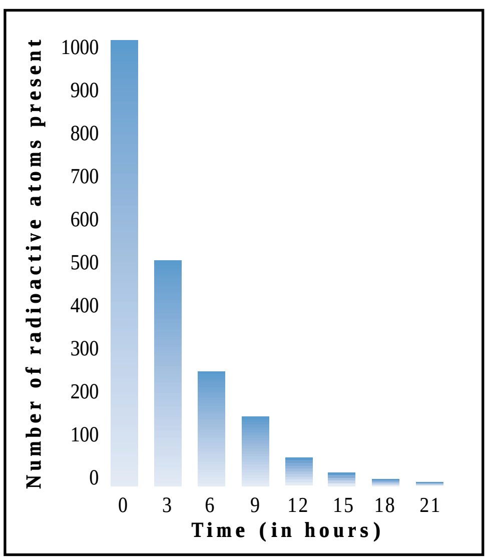

Figure 3. **Radioactive Decay of Atoms with a Half-Life of Three Hours**

After ten half-lives, less than 0.1 percent of the original radioactive atoms remain. This is true for any radioactive material.

The half-life can vary substantially from one radionuclide to another, ranging from a fraction of a second to billions of years. For example, Iodine-131, a radionuclide with important medical applications, has a half-life of 8.04 days. Hydrogen-3 (also called tritium), a radionuclide that is frequently a component of low-level radioactive waste, has a half-life of 12.25 years. Cesium-137, one radionuclide found in spent nuclear fuel, has a half-life of 30.17 years. Carbon-14, the radioisotope of carbon that is used in carbon dating as well as biomedical research, has a half-life of 5,730 years.

It should be noted that long "half-life" does not necessarily mean "more hazardous". It simply means that the energy is emitted over a longer period of time.

➤ For More Information

If you would like to read more about radioactive material and its decay, some of the references and other Fact Sheets listed below may be helpful.

- American Chemical Society, *Chemistry in the Community*, 2nd edition, Kendall/Hunt Publishing Company, 1988. Fifth section of the book, *Nuclear Chemistry in Our World*, discusses radiation.
- Raymond L. Murray, *Understanding Radioactive Waste,* 4th Edition, Battelle Press, 1994.
- James E. Turner, *Atoms, Radiation and Radiation Protection*, 2nd edition, John Wiley & Sons, Inc., 1995.
- Other Fact Sheets:

  #2. What Is Ionizing Radiation?

  #3. What are the Sources of Ionizing Radiation?

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