extension

Integrating Astronomy
Visit go.hrw.com for the activity "The Life Cycle of a Star."

Keyword HF6SUBX

One example of this process is the fission of uranium-235. First, the nucleus is bombarded with neutrons. When the nucleus absorbs a neutron, it becomes unstable and decays. The fission of ^{235}U can be represented as follows:

$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U^{*} \rightarrow X + Y + \text{neutrons}$$

The isotope $^{236}_{92}U^{*}$ is an intermediate state that lasts only for about 10^{-12} s before splitting into X and Y. Many combinations of X and Y are possible. In the fission of uranium, about 90 different daughter nuclei can be formed. The process also results in the production of about two or three neutrons per fission event.

A typical reaction of this type is as follows:

$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{140}_{56}Ba + {}^{93}_{36}Kr + 3\,{}^{1}_{0}n$$

To estimate the energy released in a typical fission process, note that the binding energy per nucleon is about 7.6 MeV for heavy nuclei (those having a mass number of approximately 240) and about 8.5 MeV for nuclei of intermediate mass (see **Figure 8** on the previous page). The amount of energy released in a fission event is the difference in these binding energies (8.5 MeV − 7.6 MeV, or about 0.9 MeV per nucleon). Assuming a total of 240 nucleons, this is about 220 MeV. This is a very large amount of energy relative to the energy released in typical chemical reactions. For example, the energy released in burning one molecule of the octane used in gasoline engines is about one hundred-millionth the energy released in a single fission event.

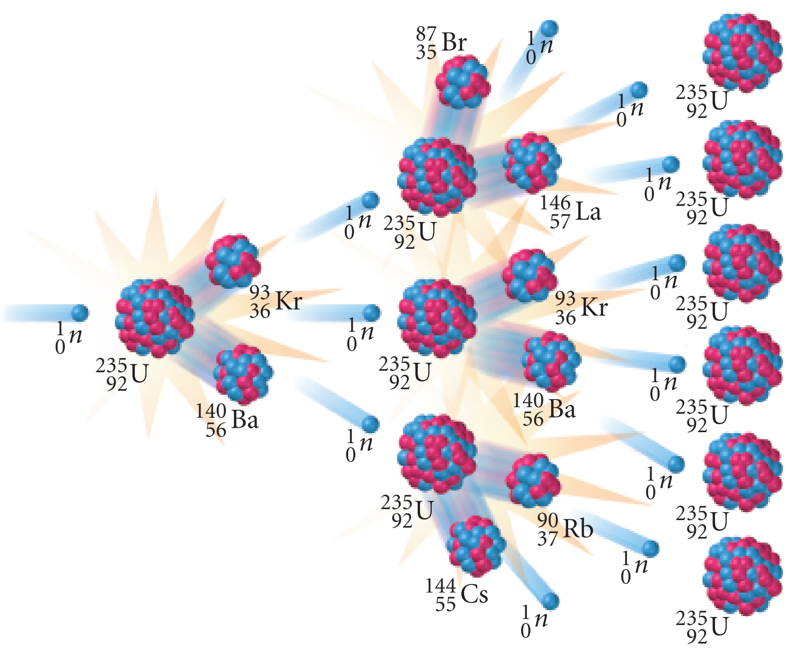

Figure 9
A nuclear chain reaction can be initiated by the capture of a neutron.

Neutrons released in fission can trigger a chain reaction

When ^{235}U undergoes fission, an average of about 2.5 neutrons are emitted per event. The released neutrons can be captured by other nuclei, making these nuclei unstable. This triggers additional fission events, which lead to the possibility of a *chain reaction,* as shown in **Figure 9.** Calculations show that if the chain reaction is not controlled—that is, if it does not proceed slowly—it could result in the release of an enormous amount of energy and a violent explosion. If the energy in 1 kg of ^{235}U were released, it would equal the energy released by the detonation of about 20 000 tons of TNT. This is the principle behind the first nuclear bomb, shown in **Figure 10,** which was essentially an uncontrolled fission reaction.