A *nuclear reactor* is a system designed to maintain a controlled, self-sustained chain reaction. Such a system was first achieved with uranium as the fuel in 1942 by Enrico Fermi, at the University of Chicago. Primarily, it is the uranium-235 isotope that releases energy through nuclear fission. Uranium from ore typically contains only about 0.7 percent of ^{235}U, with the remaining 99.3 percent being the ^{238}U isotope. Because uranium-238 tends to absorb neutrons without fissioning, reactor fuels must be processed to increase the proportion of ^{235}U so that the reaction can sustain itself. This process is called *enrichment.*

At this time, all nuclear reactors operate through fission. One difficulty associated with fission reactors is the safe disposal of radioactive materials when the core is replaced. Transportation of reactor fuel and reactor wastes poses safety risks. As with all energy sources, the risks must be weighed against the benefits and the availability of the energy source.

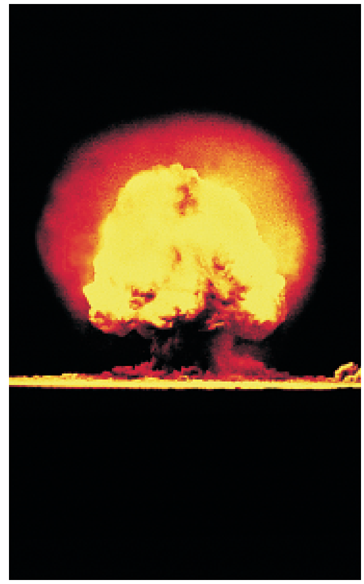

Figure 10
The first nuclear fission bomb, often called the *atomic bomb,* was tested in New Mexico in 1945.

Light nuclei can undergo nuclear fusion

Nuclear fusion occurs when two light nuclei combine to form a heavier nucleus. As with fission, the product of a fusion event must have a greater binding energy than the original nuclei for energy to be released in the reaction. Because fusion reactions produce heavier nuclei, the binding energy per nucleon must increase as atomic number increases. As shown in **Figure 8** (on the first page of this section), this is possible only for atoms with $A < 58$. Hence, *fusion occurs naturally only for light atoms.*

One example of this process is the fusion reactions that occur in stars. All stars generate energy through fusion. About 90 percent of the stars, including our sun, fuse hydrogen and possibly helium. Some other stars fuse helium or other heavier elements. The *proton-proton cycle* is a series of three nuclear-fusion reactions that are believed to be stages in the liberation of energy in our sun and other stars rich in hydrogen. In the proton-proton cycle, four protons combine to form an alpha particle and two positrons, releasing 25 MeV of energy in the process. The first two steps in this cycle are as follows:

$$^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + {}^{0}_{1}e + \nu$$

$$^{1}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + \gamma$$

This is followed by either of the following processes:

$$^{1}_{1}\mathrm{H} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{0}_{1}e + \nu$$

$$^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H}$$

The released energy is carried primarily by gamma rays, positrons, and neutrinos. These energy-liberating fusion reactions are called *thermonuclear fusion reactions.* The hydrogen (fusion) bomb, first detonated in 1952, is an example of an uncontrolled thermonuclear fusion reaction.

Did you know?

What has been called the *atomic bomb* since 1945 is actually a tremendous *nuclear fission* reaction. Likewise, the so-called *hydrogen bomb* is an uncontrolled *nuclear fusion* reaction in which hydrogen nuclei merge to form helium nuclei.