Fusion reactors are being developed

The enormous amount of energy released in fusion reactions suggests the possibility of harnessing this energy for useful purposes on Earth. Efforts are under way to create controlled thermonuclear reactions in the form of a *fusion reactor.* Because of the ready availability of its fuel source—water—controlled fusion is often called the ultimate energy source.

For example, if deuterium (^2_1H) were used as the fuel, 0.16 g of deuterium could be extracted from just 1 L of water at a cost of about one cent. Such rates would make the fuel costs of even an inefficient reactor almost insignificant. An additional advantage of fusion reactors is that few radioactive byproducts are formed. The proton-proton cycle shows that the end product of the fusion of hydrogen nuclei is safe, nonradioactive helium. Unfortunately, a thermonuclear reactor that can deliver a net power output for an extended time is not yet a reality. Many difficulties must be resolved before a successful device is constructed.

For example, the energy released in a gas undergoing nuclear fusion depends on the number of fusion reactions that can occur in a given amount of time. This varies with the density of the gas because collisions are more frequent in a denser gas. It also depends on the amount of time the gas is confined.

In addition, the Coulomb repulsion force between two charged nuclei must be overcome before they can fuse. The fundamental challenge is to give the nuclei enough kinetic energy to overcome this repulsive force. This can be accomplished by heating the fuel to extremely high temperatures (about 10^8 K, or about 10 times greater than the interior temperature of the sun). Such high temperatures are difficult and expensive to obtain in a laboratory or a power plant.

SECTION REVIEW

1. What are the similarities and differences between fission and fusion?
2. Explain how nuclear reactors utilize chain reactions.
3. What is enrichment? Why is enrichment necessary when uranium is used as a reactor fuel?
4. A fission reaction leads to the formation of ^{141}Ba and ^{92}Kr when ^{235}U absorbs a neutron.
   - **a.** How is this reaction expressed symbolically?
   - **b.** How many neutrons are released in this reaction?
5. What are some advantages to fusion reactors (as opposed to fission reactors)? What are some difficulties in the development of a fusion reactor?
6. **Critical Thinking** Why would a fusion reactor produce less radioactive waste material than a fission reactor does?