Preview of Period 17: Uses of Nuclear Energy

17.1 Nuclear Power Plants

How do nuclear power plants differ from conventional power plants?

What types of nuclear reactors exist? How do their safety features compare?

17.2 Nuclear Fuel

What fuels a nuclear reactor?

What controls the nuclear reaction?

17.3 Radioactive Waste

How radioactive is the waste from nuclear reactors?

How should radioactive waste be disposed of?

Nuclear Fission Reactions

- Uranium-235 nuclei can spontaneously fission (split)
- The products of the fission of a U-235 nucleus are smaller fission fragments, neutrons and energy.
- Other U-235 nuclei absorb the neutrons. These U-235 nuclei fission and emit neutrons.
- This process of neutron absorption resulting in fission produces an exothermic chain reaction.

Fuel for Conventional Nuclear Reactors

- Naturally-occurring uranium ore consists of two isotopes of uranium: ore is about 99.3% uranium-238 and only 0.7% uranium-235.
- Since conventional reactors use uranium-235 as fuel, naturally occurring ore must be enriched to decrease the percentage of uranium-238.

Components of Conventional Nuclear Reactors

a) **Fuel rods** filled with a mixture two isotopes of uranium: U-235 and U-238.

b) **Moderator** (usually water or graphite) to slow the velocity of the fast-moving neutrons. Fuel rods are placed in the moderator.

c) **Control rods** to absorb the neutrons and control the rate of the reaction. Control rods (usually cadmium or boron) can slow down or stop the reaction.

d) **Coolant** (usually water or helium gas) to transfer heat from the reactor core to the vessel that produces steam to turn the turbines.

e) **Containment systems** to prevent radiation from escaping into the environment. Double containment systems are safer.

Types of Conventional Nuclear Reactors

- Reactors that use fuel rods and are graphite moderated and water cooled. (Chernobyl type)
- Reactors that use fuel rods and are water moderated and water cooled. (type of reactor used in U.S.)
- Reactors that use small, widely separated, ceramic-coated fuel pellets. These reactors may be water moderated or graphite moderated and may be water cooled or gas cooled.

Which type of reactor is safest?

Which type is the least safe?

In which type of reactor could an uncontrolled chain reaction occur?

In which type of reactor could a meltdown occur?

Breeder Reactors

Breeder reactors use fast neutrons, so no moderator is needed to slow down the neutrons.

Conventional reactors use relatively scarce uranium-235 (Only 0.7% of natural uranium is the U-235 isotope.)

Breeder reactor fuel is plutonium-239, which has been created from uranium-238. Mixed in with the plutonium-239 is uranium-238.

Breeder reactors create additional plutonium-239 from uraniuim-238 while they are operating. In this way, breeder reactors produce more plutonium than they use.

The uranium-238 used by breeder reactors to create plutonium-239 is much more plentiful than the uranium-235 used by conventional reactors.

The plutonium produced in breeder reactors can be more easily converted into nuclear weapons than can the byproducts of conventional reactors.

Period 17 Summary

17.1: Nuclear reactors generate electricity by heating water to produce steam. Pressure from the steam turns turbines.

Water is heated with the energy emitted during the fission of U-235.

U-235 may decay spontaneously, splitting into fission fragments plus two or three free neutrons.

These free neutrons can induce fission in other uranium-235 nuclei. This may produce an exothermic chain reaction.

The percentage of U-235 in naturally occurring uranium ore must be enriched for use in reactors.

17.2: Conventional nuclear fission reactors contain:

1) Fuel rods, which usually contain ceramic-coated pellets of uranium oxide;

2) a moderator, into which the fuel rods are inserted, to slow down the neutrons

3) control rods that absorb neutrons and can decrease the rate of fission;

4) a coolant that transfers thermal energy to generate steam and prevents the core from overheating; and

5) a containment system to prevent leakage of radioactive substances into the environment

Period 17 Summary, Continued

17.3: Types of conventional nuclear reactors:

Graphite moderated, water cooled reactors (the Chernobyl type), which could result in a runaway chain reaction if the water coolant is lost;

Water moderated, water cooled reactors (the U.S. type), which could experience a meltdown if the water coolant is lost but not a runaway chain reaction; and

Graphite moderated, gas-cooled reactors (the European type), in which small fuel pellets are coated with heat-resistance ceramic material. These reactors are unlikely to have a meltdown or runaway chain reaction.

17.4: Breeder reactors use a fuel containing 15% plutonium-239 and 85% uranium-238.

Breeder reactors use fast neutrons, so no moderator is needed.

One byproduct of breeder reactors is more plutonium, which is made from the U-238.

Spent fuel rods of plutonium could be converted into crude nuclear weapons.

Period 17 Summary, Continued

17.5 Storing radioactive waste

Used fuel rods from reactors are extremely radioactive.

Plans for a radioactive waste repository in Nevada have been underway for over a decade.

Currently, spent fuel rods are stored at the reactor site.

17.6: Nuclear fusion reactors using the non-radioactive fuel deuterium are an attractive alternative to fission reactors if the challenging technical problems involved in pushing two positively-charged nuclei together to fuse could be overcome.

If matter and antimatter particles meet, they annihilate each other in a burst of energy, mainly in the form of photons, in which all of the matter is converted into energy. However, since the Universe seems to consist almost entirely of matter, this does not appear to be a reasonable energy source.

Period 17 Review Questions

R.1 **Why are the used fuel rods from a nuclear reactor so radioactive?**

R.2 **Could a Chernobyl-type accident happen in the U.S.? Why, or why not?**

R.3 **Could a meltdown accident, similar to the problem portrayed in the movie "China Syndrome," occur in the U.S.? Why or why not?**

R.4 **What are the advantages of a breeder nuclear reactor? What are the disadvantages? Do you think more breeder reactors should be built?**

R.5 **Why is it so difficult to build a working fusion reactor?**