Chapter: Nuclear Chemistry
Section 4: Nuclear Fission and Nuclear Fusion

Nuclear fission: very heavy nucleus splits into more-stable nuclei of intermediate mass

- Releases enormous amounts of energy
- Power nuclear reactors, nuclear missiles, and nuclear-powered submarines and aircraft carriers
    - First atomic bomb used in warfare was a bomb that was dropped on Hiroshima, Japan on August 6, 1945
- Can occur spontaneously or when nuclei are bombarded by particles
- Nucleus splits into medium-mass parts with the emission of more neutrons
- The mass of the products is less than the mass of the reactants
    - The missing mass is converted to energy
- 1938 Germany: Otto Hahn and Fritz Stassmann bombarded uranium with neurons
    - Uranium-235 + neutron → Strontium-90 + Xenon-143 + neutron

Chain reaction: a reaction in which the material that starts the reaction is also one of the products and can start another reaction

- Continues until all of the nuclide has split or until the neutrons fail to strike the nuclide

Critical mass: the minimum amount of nuclide that provides the number of neutrons needed to sustain a chain reaction

Nuclear reactors: controlled-fission chain reactions to produce energy

- Controlled energy → electricity
- Uncontrolled energy → BOMB

Nuclear Power Plants: use heat from nuclear reactors to produce electrical energy

- 5 main components:
    1. **Shielding:** radiation-absorbing material that is used to decrease exposure to radiation, especially gamma rays, from nuclear reactors
    2. *Fuel:* uranium-235 is typically used as the fissionable fuel to produce heat, which is absorbed by the coolant
    3. **Control Rods:** neutron-absorbing rods that help control the reaction by limiting the number of free neutrons

4. **Moderator:** used to slow down the fast neutrons produced by fission
    a. Usually liquid water under high pressure
5. Coolant

Current problems with nuclear power plant development include:

- environmental requirements
- safety of operation
- plant construction costs
- storage and disposal of spent fuel and radioactive wastes

Nuclear waste: radioactive products of fission and fusion reactions

- fission produces more waste than fusion
- Containment:
    - Radioactive waste from medical research has a half-life of a few months
    - Waste from a nuclear reactor will take hundreds of thousands of years to decay, therefore it needs to be contained from living organisms
- Storage:
    - Most common form of nuclear waste is spent fuel rods from nuclear power plants
        - Above ground in water pools
        - Dry casks which are made out of concrete and steel
    - Both methods are temporary storage until it is moved to permanent underground storage
- Disposal:
    - 77 disposal sites in the U.S.
    - New site near Las Vegas called Yucca Mountain for permanent disposal
    - Transported beginning in 2010

Did You Know?

- 20% of the electrical power in the U.S. is nuclear power
- In Russia in 1986, The Chernobyl accident occurred shortly after technicians briefly removed most of the control rods – which act as neutron absorbers – during a test causing a melt down
- Canada has an abundant supply of natural uranium but no facilities for enriching it
- Canada has also specialized in heavy water (or D_2O) reactors. The heavy water is used as a coolant and a moderator

Nuclear Fusion: light-mass nuclei combine to form a heavier, more stable nucleus

- Releases more energy than fission
- Occurs naturally in the sun and other stars
- Uncontrolled fusion reactions of hydrogen are the source of energy for the hydrogen bomb
- A fission reaction is used to provide the heat and pressure necessary to trigger the fusion of nuclei
- One of the major problems is that no known material can withstand the initial temperatures (about 10^8 K or 99999726.85 ^oC) required to induce fusion at high temperatures