April 26: Nuclear Fission and Fusion

Objectives

- Identify reactions and products in the nuclear power cycle and nuclear weapons.

What's the point?

- How do nuclear weapons and power plants work?

Energy from nuclear fission

Nuclear power plants and atomic bombs use a **fission chain reaction**, in which neutrons released by fissioning nuclei cause other nuclei to fission. A chain reaction can only occur when enough nuclei—a **critical mass**— are present and closely-packed enough to capture the released neutrons.

Fission fuel

Only **fissile** nuclei, which fission after absorbing a room-temperature neutron, can be used to make fuel for nuclear reactors and bombs. The three fissile nuclei are uranium-233, uranium-235, and plutonium-239.

Uranium-235 occurs as less than 1% of natural uranium on Earth; the rest of natural uranium is uranium-238. The U-233 in natural uranium must be painstakingly concentrated to become suitable as a nuclear fuel.

Uranium-233 is created in reactors by neutron capture by thorium-232 followed by two β-decays, and plutonium-239 is created by neutron capture of uranium-238 followed by two β-decays. Since these are different chemical elements from their parents, they can be purified by chemical means.

Energy from nuclear fusion

Hydrogen bombs use the **thermonuclear fusion** reaction of deuterium (hydrogen-2) and tritium (hydrogen-3). Very high temperatures are needed to give the nuclei enough kinetic energy to overcome their electric repulsion. This high temperature is provided by a fission explosion.

Concerted effort has so far failed to achieve human-controlled nuclear fusion.

Fusion in stars

Stars such as the sun get most of their energy by fusing protons in their hot, dense interiors. Energy is released only when the nuclei produced are no heavier than iron.

Elements heavier than iron are produced in the catastrophic collapse of massive stars that have exhausted the light elements in their cores. The kinetic energy of the collapse produces extremely high temperatures and pressures that creates heavier elements and produces a supernova explosion. Every atom of these heavier elements that now exists was created in a supernova explosion.