Nuclear Power

Syll. Statements 8.4.1 – 8.4.11

Nuclear Fuel

- Primarily involve **nuclear fission**
- **Fuel:** typically is **uranium-235**
  - Must be enriched, as the most abundant isotope of uranium found naturally is U-238
  - Enriching Process
- Before enriching
  - Natural Uranium is < 1% U-235
- After enriching:
  - Uranium is at least 3% U-235

Fission Reactions:

- Nuclear power plants rely on **induced fission reactions** to begin a **chain reaction** within the reactor core
- Two examples of possible reactions:

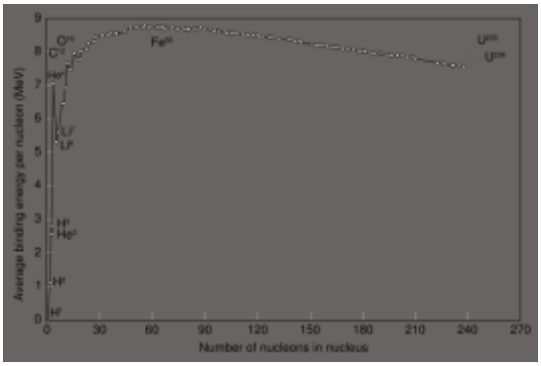
$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{236}_{92}U \rightarrow {}^{90}_{38}Sr + {}^{144}_{54}Xe + 2\left[{}^{1}_{0}n\right]$$

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{236}_{92}U \rightarrow {}^{94}_{38}Sr + {}^{140}_{54}Xe + 2\left[{}^{1}_{0}n\right]$$

Energy released?

- How much energy is released in one of the fission reactions that occur during chain reactions?

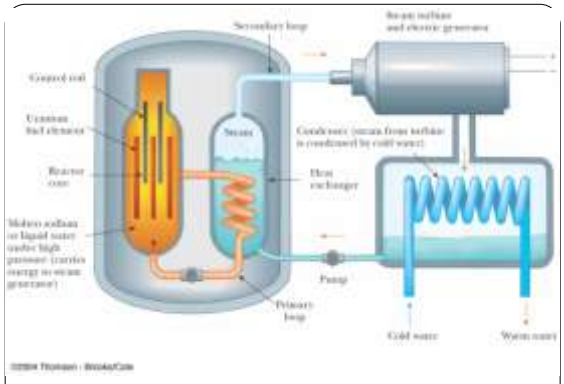
$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{236}_{92}U \rightarrow {}^{94}_{38}Sr + {}^{140}_{54}Xe + 2\left[{}^{1}_{0}n\right]$$



$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{236}_{92}U \rightarrow {}^{94}_{38}Sr + {}^{140}_{54}Xe + 2\left[{}^{1}_{0}n\right]$$

Nuclear Reactors

- **Moderator:** The material that surrounds the fuel rods and is used to slow down the incoming neutrons
  - **Neutrons** must have a kinetic energy of <1 eV, but are released with a KE of ~1 Mev during a fission reaction
- **Often**, the moderator is WATER that surrounds the fuel rods



Nuclear Reactors

- **Control Rods**
  - A material that is able to absorb excess neutrons without becoming unstable
  - Control rods are placed in the moderator between the fuel rods whenever it is necessary to limit the number of neutrons available to impact the fuel.
  - Materials used include boron carbide, silver, indium, cadmium, and hafnium. (*according to the virtual nuclear tourist*)
- **Purpose:**
  - To ensure that the energy released in the nuclear reaction is slow and controlled

Nuclear Reactors

- **Energy released in reactions:**
  - Kinetic energy of neutrons released
  - Turns to Thermal energy as neutrons are slowed down in moderator
  - Coolant pulls thermal energy out of moderator, brings to heat exchanger to turn water to steam
  - Steam turns turbines, generates electricity

Plutonium

- Produced during a possible fission reaction caused by high energy (fast-moving) neutrons and Uranium-238:

Plutonium Production:

- What's the big deal?
  - Plutonium does not occur naturally
  - Uranium-238 normally not fissionable
  - High energy neutrons are able to make it fissionable
  - Plutonium IS fissionable, and can now be used as fuel in another reactor
- **DISadvantage:**
  - Plutonium is also used for nuclear weapons…

Nuclear Reactors–Problems

- Spent fuel and all reaction by-products are highly radioactive
- VERY long half-lives for all materials
- Possible meltdowns (significant thermal energy created during reactions…)
  - If graphite is the moderator, fires can also occur…i.e. Chernobyl, 1986
  - Increased temp. = increased pressure → steam explosions

Nuclear Meltdown

- Occurs when the temperature of the reactor core increases so significantly that the radioactive material melts and leaks from sealed containment systems into the environment
- Partial Meltdown—some of the core does not melt; the molten radioactive material does not completely enter the environment except through explosions and minor leaks
- Complete Meltdown—the entire core melts; burns through containment system; thoroughly leaks into ground below reactor

Other Nuclear Reactor Disadvantages…

- Fissionable material produced could possibly be recovered and used for weapons…
- Nuclear material (Uranium) creates Radon gas—when mining, miners are exposed to large amounts
- Mines must be closed off from direct contact with atmosphere, yet well ventilated
- Waste material from mines (excess rock that's not worth keeping because of lack of U) is still radioactive…disposal a problem

Advantages of Nuclear Energy

- High power output (enormous energy density!)
- Large reserves of nuclear fuel (i.e. Uranium ores, and already-processed enriched Uranium…)
- No greenhouse gases produced by nuclear power stations

Summary of **Disadvantages**

- Disposal of radioactive waste…
- "should something go wrong…"—major public health issue
- Uranium mining issues
- Nuclear weapons possibilities

Some disasters in history

- Three Mile Island: March 28, 1979
  - Partial meltdown in one of two reactors
- Chernobyl: April 26, 1986

- http://library.thinkquest.org/17940/texts/nuclear_disasters/nuclear_disasters.html