NOTES: 25.3 – Nuclear Fission & Fusion
Nuclear Fission:

- The splitting of a heavy nucleus into lighter nuclei
FISSION: a heavy nucleus splits into 2 lighter nuclei

- some elements undergo fission spontaneously
- some elements can be induced to undergo fission when bombarded with other particles (e.g. neutrons)
Nuclear Fusion:

- the combination of light nuclei to produce a heavier nucleus
**FUSION**: 2 nuclei combine to form a heavier nucleus

- the sun is a tremendous fusion reaction; the major fusion reaction in the sun is thought to be:

\[
\begin{align*}
\text{\( _1^2\text{H} + _1^3\text{H} \rightarrow _2^4\text{He} + _0^1\text{n} \)}
\end{align*}
\]

- both fission & fusion release large amounts of energy (fusion more than fission)
Uses / Applications of FISSION:
The Atomic Bomb (FISSION)

- when the nucleus of U-235 splits, 2 isotopes are formed, plus **neutrons are emitted**
- these neutrons **collide with other U-235 atoms**, causing them to undergo fission; they release neutrons, and so on…
- **The result - CHAIN REACTION!!**
FISSION:

A neutron is directed at the nucleus of an atom. The nucleus splits, releasing two or more neutrons and creating new atomic nuclei called fission products.
FISSION / CHAIN REACTION!!!
The Atomic Bomb (FISSION)
The Atomic Bomb (FISSION)

Nuclear Fission Chain Reaction

- $^{235}\text{U}$
- Neutron
- Fission Product
CRITICAL MASS:

- The minimum mass of fissionable material that must be used to sustain a chain reaction.
Two types of bombs (but both use FISSION)...

- Little Boy: U-235 (Hiroshima)
- Fat Man: Pu-239 (Nagasaki)
Nuclear Reactors (controlled FISSION)
Nuclear Reactors (controlled FISSION):

- use subcritical masses of fissionable material
- **CORE**: contains fuel pins made of U-235; interspersed among the pins are **control rods**
- control rods: absorb neutrons
  - pull rods out of core: fission increases
  - push rods back into the core: fission decreases
- **Safety feature**: if power is lost, rods will automatically fall into the core and shut the reaction down.
Nuclear Reactors (FISSION)

“The energy produced by breaking down the atom is a very poor kind of thing. Anyone who expects a source of power from the transformation of these atoms is talking moonshine.”

Ernest Rutherford
Nuclear Reactors (FISSION)

Note: There are no commercial reactors in Alaska or Hawaii. Calculated data as of 12/00.
Nuclear Power Plants
Nuclear Power Plants
Nuclear Power Plants
TO GENERATE ELECTRICITY:

1) Fission heats up water in vessel and heat is carried away.
2) This heat is used to heat up water in a second system, which turns into steam.
3) Steam turns turbine of a generator.
4) Generator makes electricity.
PROS OF NUCLEAR ENERGY:

- no air pollution
- enormous amt. of energy released
- alternative to using our rapidly decreasing fossil fuels
CONS OF NUCLEAR ENERGY:

- containers for waste products may erode or break
- thermal pollution (heated water returned to rivers, etc.)
- potential theft of fuel (Pt-239) for use in weapons
What about applications / uses of FUSION?
Controlled Nuclear FUSION

- **PROS:**
  - a very abundant supply of energy world wide.
  - environmentally clean
  - no creation of weapon materials
  - no chance of runaway reactions leading to accidents

- **CONS:**
  - it doesn’t work; at least not yet…
Nuclear Fusion:

"Every time you look up at the sky, every one of those points of light is a reminder that fusion power is extractable from hydrogen and other light elements, and it is an everyday reality throughout the Milky Way Galaxy."

Carl Sagan, Spitzer Lecture, October 1991
Nuclear Fusion:

- **Obstacles…**
  - HOT! – plasma at least 100 million °C
  - high density plasma
  - containment of plasma
  - confinement time
NOTES: 25.4 – Radiation in the “real” world:
Detecting Radiation:

- radiation cannot be seen, heard, felt, or smelled...
- therefore, warning signs and radiation-detection instruments must be used to alert people to the presence of radiation
Geiger Counter:

- detects beta radiation
- radiation enters the tube and ionizes the gas inside
- the free electrons that are produced conduct electricity
- the bursts of electric current cause audible “clicks”
Scintillation Counter:

- uses a special coating that *lights up when radiation hits it*
- similar to a TV screen
Film Badge:

- used by people who work near radiation sources;
- contains several layers of photographic film;
- periodically, the film is removed and developed
Using Radiation – TRACERS:

- one reactant in a reaction is “labeled” with a radioactive isotope;
- after the reaction is complete, the radiation of the product is measured;
- helps chemists study and understand how particular reactions work.
Using Radiation – TRACERS:

- can be used to test the effects of chemicals in agriculture or in the environment
Using Radiation – MEDICINE:

- patients are given a radioactive isotope and then scanned to detect a particular body function;

- **EXAMPLE:**
  - iodine-131 is used to detect thyroid problems
  - patient is scanned to see how much iodine is taken up by thyroid
Radioactive iodine is ingested

Gamma probe measuring thyroid gland radioactivity
Using Radiation – MEDICINE:

**EXAMPLES:**
- technetium-99 is used to detect brain tumors and liver disorders
- phosphorus-32 is used to detect skin cancer
Using Radiation – CANCER TREATMENT:

- cancer cells are more susceptible to damage by gamma rays than healthy cells;
- cancerous tumors can be treated with radiation to kill cancer cells
- **RISK**: healthy cells are also damaged!