Chem I Notes

Atomic Energy: Fission and Fusion

I. Nuclear Fission: Splitting large atoms

1. The nucleus of an atom is held together by a balance between the nuclear force (which attracts) and the electrical force (which repels). In all known nuclei, the nuclear force dominates. In many large atoms, like uranium, this domination is tenuous.

2. If the nucleus deforms a bit, the electrical force can take over and split it. This is nuclear fission.

3. For most radioactive atoms, this occurs spontaneously. There are some, however, that can be made to split by bombarding them with neutrons. This is called induced fission.

Examples: the two main isotopes of uranium

a. U-238

$${}^{1}_{0}n + {}^{238}_{92}U \dashrightarrow {}^{239}_{93}Np + {}^{0}_{-1}e$$

Neutron absorbed, one little beta particle released, end of story. No big deal.

b. U-235

$${}^{1}_{0}n + {}^{235}_{92}U \dashrightarrow {}^{91}_{36}Kr + {}^{142}_{56}Ba + {}^{1}_{0}n + {}^{1}_{0}n + {}^{1}_{0}n + \text{energy}$$

This energy is enormous- about 7 million times the energy released by the explosion of one TNT molecule. This energy is in the form of the kinetic energy of the products (speed) and gamma radiation.

The main thing to notice is the three neutrons that are produced. If there are more U-235 atoms around, each of those three can split another atom, producing more energy and 3 more neutrons, which in turn can split more atoms.... the result is a chain reaction.
Note: there are other ways the U-235 can split. Sometimes the split results in two neutrons, sometimes in three.

4. Chain reactions will only occur if there's enough U-235 around to keep the reaction going This amount is known as the critical mass, and for U-235 it's about the size of a baseball. If there's less than critical mass, the neutrons that result from one fission event will just go flying off into space without causing another reaction. It'll be a dud.

5. The design of nuclear bombs is simple: keep small chunks of U-235 separate until you want them to explode. Have a firing mechanism that will bring the chunks together, and voila!

6. Fortunately for us, only one out of 140 atoms of uranium is U-235. Not only are they naturally found in subcritical quantities, but the U-238 also absorbs any neutrons that any splitting U-235's might produce.

7. The temperature of an atomic bomb can reach 1,000,000,000 °F!

a. Where does the energy come from? Some of the mass of the U-235 is converted into energy according to Einstein's famous formula, $E=mc^2$:

E = energy
m=mass
c = the speed of light

The mass of the nucleus is not equal to the sum of the masses of the parts. Some of the mass is converted into energy!

II. Nuclear Fusion

1. Fusion is the process of combining light nuclei to form a heavier nucleus.

a. Very high temperatures are required, (350 million degrees) because nuclei are positively charged and don't like getting anywhere near each other. That's why it's called thermonuclear fusion - it's gotta be hot.

b. Energy is released. WHY? Again, some of the mass is converted into energy according to Einstein's famous formula, $E=mc^2$:

E = energy
m=mass
c = the speed of light

c. For example, on the sun, every second 657 million tons of hydrogen are converted to 653 million tons of helium. The missing 4 million tons are discharged as radiant energy!

d. Examples:

$${}^{2}_{1}H + {}^{2}_{1}H \dashrightarrow {}^{3}_{2}He + {}^{1}_{0}n + \text{energy}$$

$${}^{2}_{1}H + {}^{6}_{3}Li \dashrightarrow {}^{4}_{2}He + {}^{4}_{2}He + \text{energy}$$

2. Most of the thermonuclear devices, or hydrogen bombs, used a fission reaction (uranium or plutonium) in order to get the temperatures high enough for the fusion reaction to take place.

3. Fusion has no radioactive waste, so one of the main goals of scientists these days is to find a way to use fusion to power nuclear reactors. The problem is the incredibly high temperatures it takes to get it started. Melts everything!