Energy

Let's take a moment to talk more about energy and the equations that were just derived.

$$E_0 = mc^2$$

This is one of the most famous equations out there. It's so cute and simple, yet has pretty wild implications. It means that *energy* and *mass* are actually the same thing and are not the completely separate concepts the way we typically talk. It turns out, we shouldn't talk about *Conservation of Mass* and *Conservation of Energy*; they are not two separate concepts. There is actually only the Conservation of Mass-Energy.

E_0 is the *rest energy* of a mass. It gives the energy equivalent of mass – 1 kg of matter is equivalent to 9 x 10^{16} J of energy. Please note that it has nothing to do with a mass moving at the speed of light, which is impossible. Basically, any reaction that releases energy does so because it has lost mass. The lost mass is immeasurably small for normal chemical or mechanical reactions, but is measurable in nuclear reactions.

$$K = (\gamma - 1)mc^2$$

This equation gives the *kinetic energy* of a particle, and is also written as $K = (\gamma - 1)E_0$. Remember that for lower "every day" speeds, $K = \frac{1}{2}mv^2$ is the correct equation to use. You only need to use the relativistic form when the gamma term starts to get noticeably bigger than 1.

$$E = \gamma mc^2$$

This equation gives the *total energy* of a particle, but that only means a particle's kinetic energy plus its rest energy ($E = K + E_0$.). This ignores any potential energies or other work done on the particle. Since special relativity typically only involves constant speeds, this is perfectly fine. It is also often written as $E = \gamma E_0$.

Fusion vs Fission

Fusion is the process of taking two smaller nuclei and forcing them together into a larger nucleus. For small nuclei, the total mass of the smaller nuclei is usually less than the mass of the fused nucleus. When that happens, the missing mass appears as energy, usually in form of photons. With a few exceptions, fusing small nuclei releases energy up until the fused nucleus is iron. Fusing smaller nuclei usually releases energy, while fusing larger nuclei requires energy.

Fission is the process of splitting a nucleus into smaller nuclei, and usually a few other neutrons. When large atoms (bigger than iron) are broken up, the total mass of all the smaller parts is smaller than the mass of the original nucleus, and that missing mass shows up as energy, typically as photons and the kinetic energies of all the parts. When bigger nuclei break apart, energy is usually released, but breaking apart smaller nuclei requires energy.

One last comment about units. When plugging in masses in kilograms and speeds in meters/second to calculate energies, we (obviously) get our answer in Joules. However, there is another very common unit of energy used when dealing with particles called the *electron-Volt* (eV).

$$1\ eV = 1.6 \times 10^{-19}\ J$$

The electron-Volt unit comes from electricity and is the amount of energy given to an electron when it is accelerated with 1 Volt. This is useful because charged particles are accelerated using very large voltages.