

Mass/Energy and Fission/Fusion

$$E = \gamma mc^2 \quad \text{Total Relativistic Energy}$$

This is the famous Einstein equation that shows that energy and mass are equivalent.

If the particle is at rest $\gamma = 1$ and the particle still possesses an enormous amount of energy through its mass.

$$E = mc^2$$

Ex. Energy of a 1-kg object

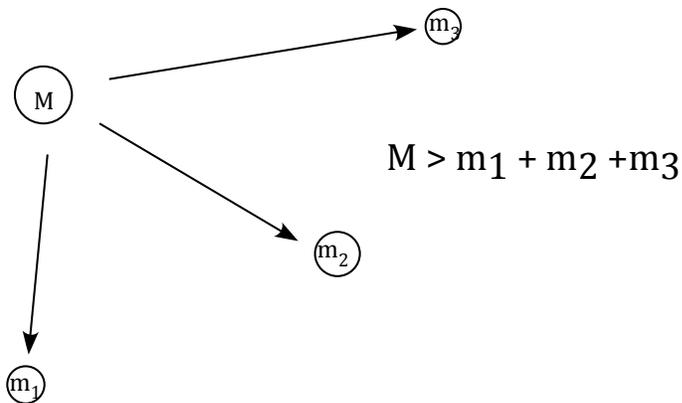
$$E = mc^2 = (1\text{kg})(3 \times 10^8 \text{m/s})^2 = 9.0 \times 10^{16} \text{J}$$

This amount of energy is approximately equal to the energy content of 15 million barrels of oil. About one day's consumption in the U.S.

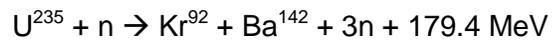
If we knew of a way how to convert mass into energy efficiently, our energy resources would be unlimited. However, in the real world matter is NOT freely converted to energy and we NEED to find a way to do this!

Two processes that are commonly used to convert mass to energy are FISSION and FUSION.

1. **Nuclear Fission** – A heavy nucleus such as U-235 splits (fissions) into smaller particles. The total mass of the products are smaller than the original mass. Discovered in 1938 by Otto Hahn, Lise Meitner, and Fritz Strassmann following research from Enrico Fermi.

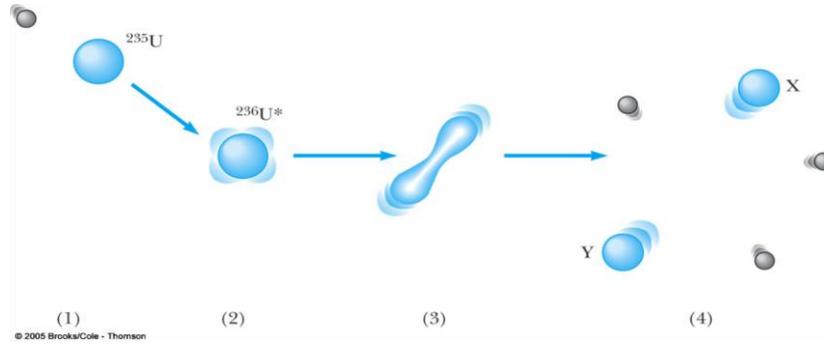


The decrease of mass is released as energy, $\Delta E = \Delta mc^2$!

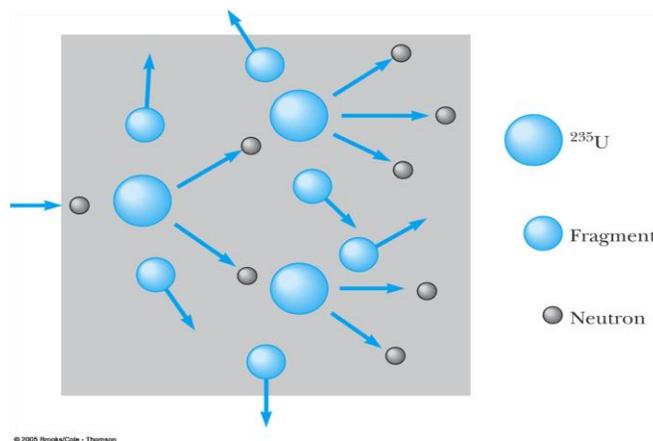


$$1 \text{ kg } U^{235} = 8.53 \times 10^{13} \text{ J}$$

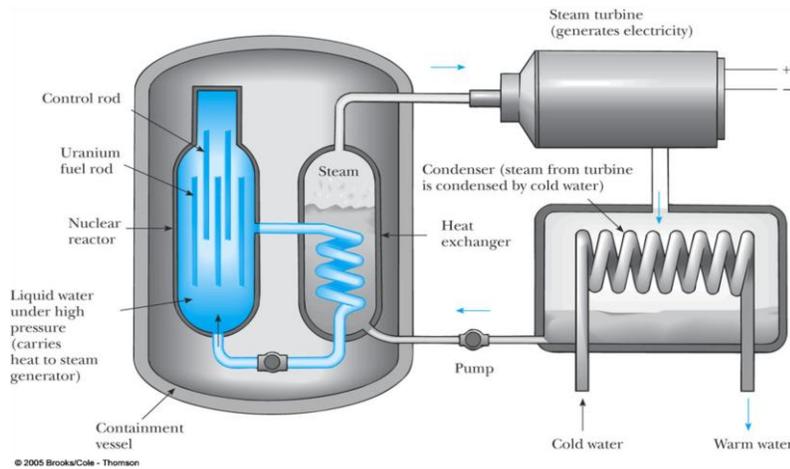
Stages in a nuclear fission event



Nuclear chain reaction initiated by the capture of a neutron

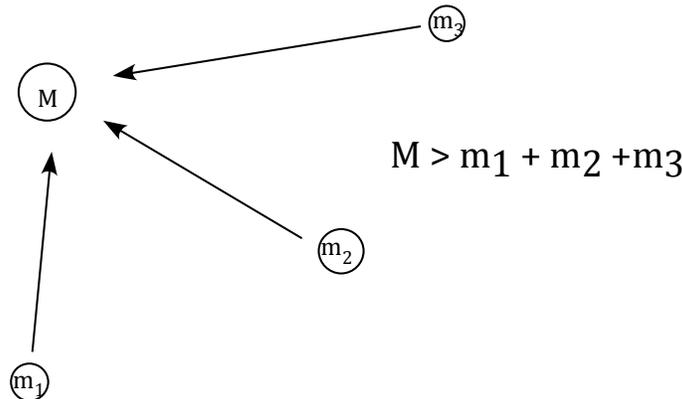


Nuclear Reactor



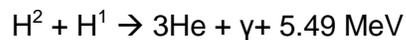
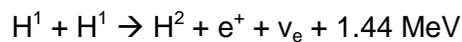
An uncontrolled fission reaction releases an enormous amount of energy in a very short period of time (Atomic bomb – equivalent to 20,000 tons of TNT). The first self-sustained chain reaction was achieved in 1942 by Enrico Fermi at University of Chicago with natural uranium as a fuel. Natural uranium contains 0.7% U^{235} and 99.3% U^{238} . What happened at Fukushima nuclear reactor?

2. **Nuclear Fusion** – Nuclei particles combine (fuse) to form a heavier nucleus.



Again, the decrease of mass is released as energy, $\Delta E = \Delta mc^2$!

Ex. Fusion on the Sun



An uncontrolled thermonuclear fusion reaction releases an ENORMOUS amount of energy very fast (H – bomb equivalent to 10,000,000 tons of TNT!)

Electricity Generation Efficiencies (%)

