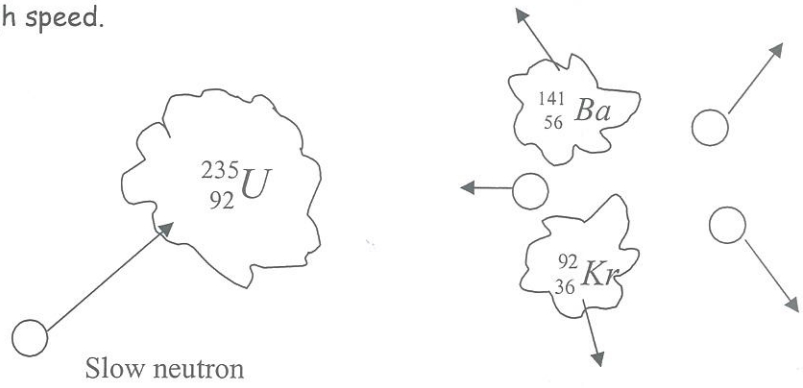
A slow-moving neutron penetrates the $^{235}_{92}U$ nucleus. The nucleus swells, then ..Splits.. into two large pieces. The two pieces are sometimes (but not always) barium and krypton. As well as the two large pieces, some extra ..Neutrons..fly out at high speed.



Write the reaction equation

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$$

The reaction releases ..energy.. This is why the neutrons come out fast. This reaction is called **fission** (which means ..splitting..), and we say that uranium-235 is **fissile** (it can be split by low-energy neutrons).

Ex. Calculate the energy released (in Joules.)

U-235 : 390.2480 x 10^{-27} kg Kr-92 : 152.5794 x 10^{-27} kg
Ba-141 : 233.9616 x 10^{-27} kg n : 1.6747 x 10^{-27} kg

$\Delta E = -3.2 \times 10^{-11}$ J

Nb, because the energy of each reaction is very small, energies are often quoted in electron Volts (or eV). One eV = 1.6 x 10^{-19} J.

Convert the above energy to electron Volts.

$\Delta E = 2 \times 10^{8}$ eV

Ex. Suppose we start with just 1 kg of U-235 in a nuclear reactor. (It would be a block the size of a 50 gram Mars Bar). After the fission reactions are complete, there is still 999 grams of material left.
Calculate the energy of the missing gram . (This is sometimes called the ..mass defecit..)

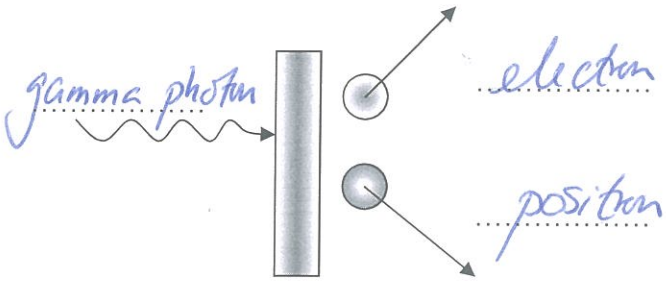
9×10^{16} *joules*

5.6×10^{32} *eV*

This is about the same amount of energy as there is in 3 million litres of LPG
(When 1.0 kg of coal burns, its mass decreases by about 0.0001 g.)

Pair Production

It used to be thought that matter was indestructible and couldn't be created or destroyed. Physicists have however found that matter can be converted into radiation and vice versa.

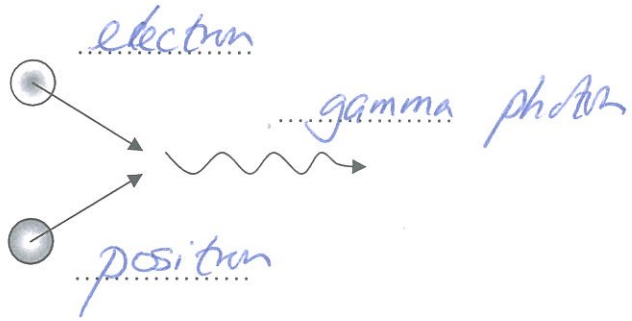


Experiments have shown that when a high energy gamma photon smacks into a massive nucleus, it can lose all its energy. This energy is used to create two particles, an electron and a positron (This is called anti-matter). The energy of the photon is equivalent to the mass of the particles. Note that all the conservation laws still apply.

Eg. Calculate the minimum energy the photon must have to create the pair.
(m_e= 9.1 x 10^{-31} kg)

$E = 1.6 \times 10^{-13}$ J

The reverse also occurs. Describe what happens in this case



Ex:

Deuterium (H_2) and tritium (H_3)nuclei may fuse together, as illustrated in the equation below.

$$ {}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n $$

The masses involved in the above reaction are:

mass of deuterium = 3.34250×10^{-27} kg
mass of tritium = 5.00573×10^{-27} kg
mass of helium = 6.62609×10^{-27} kg
mass of neutron = 1.67438×10^{-27} kg

Speed of light = 3.00×10^{8} m s^{-1}
Charge on the electron = -1.60×10^{-19} C

(a) Show that the amount of energy released in the above reaction is 4.30×10^{-12} J.

$\Delta m = -4.776 \times 10^{-29}$

$E = \Delta m c^2$

*(b) Explain why energy is **released** during this reaction.*

The particles have less potential energy after the reaction ∴ The mass decreases and energy is released

(c) Convert 4.30×10^{-12} J into mega electron-volts (MeV).

26.9 MeV

The reaction described above is one of the possible reactions that occur in the sun.
The sun obtains its radiant energy from a thermonuclear fusion process.
Over its lifetime 1.4×10^{28} kg of its mass will be converted by the fusion process into radiation energy.

(d) The sun radiates at a constant rate of 4.0×10^{26} Joules per second. Estimate the lifetime of the sun, assuming that the sun only loses energy by radiation.

$\Delta E = 1.26 \times 10^{45}$ J

$t = \frac{E}{P}$

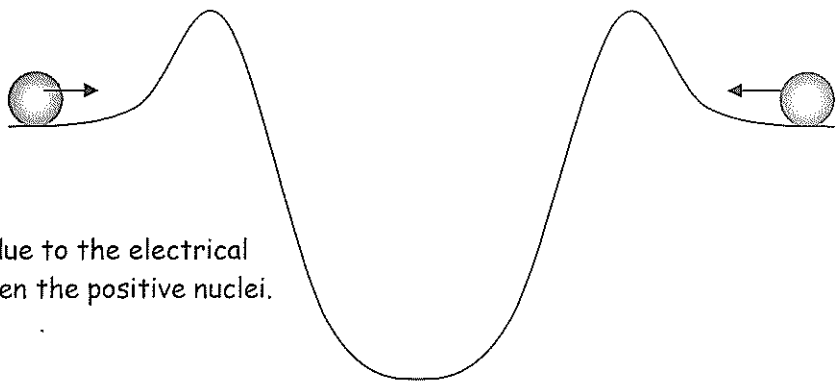
lifetime = $10^{"}$ years.

These diagrams may help show how mass can decrease and energy can be released during fission and fusion.

Fusion is the joining of two small nucleii to make a larger one.

The *Potential Energy* is less, so *Energy* is released, and its *mass* decreases.

$$m = \frac{E}{c^2}$$

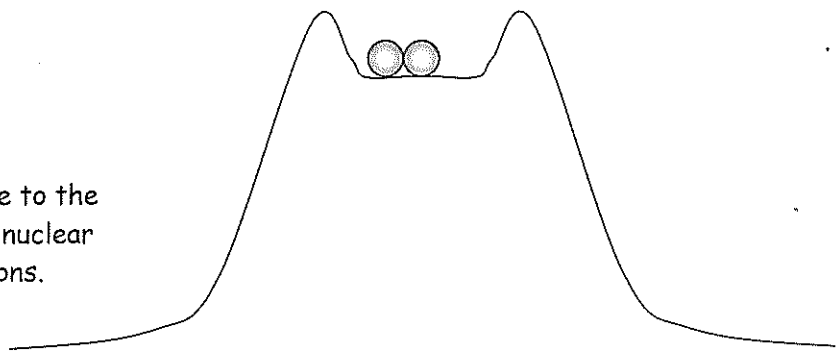


The energy barrier is due to the electrical repulsive forces between the positive nuclei.

Fission is the splitting of a large nucleus to make two small nucleii.

The *Potential Energy* is less, so *Energy* is released, and its *mass* decreases.

$$m = \frac{E}{c^2}$$



The energy barrier is due to the attraction of the strong nuclear force between the nucleons.