1.4 Particles and Antiparticles

Antimatter is familiar to all readers of science fiction but it *is* real. There ought to be as much antimatter in the Universe as there is matter but, for a reason cosmologists still do not fully understand, there is far more matter than antimatter.

This is just as well because when a particle and its antiparticle meet, they **annihilate** each other, converting their mass into pure energy or radiation, according to Einstein's famous equation

$$E = mc^2$$

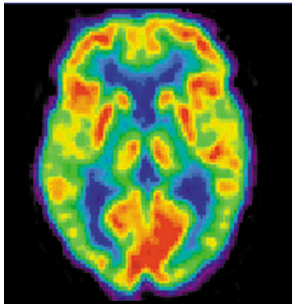
Where E is the energy equivalent, in joules, of a mass m kilograms. c is the speed of light in vacuum.

Positron Emission Tomography (PET)

Far from being the stuff of science fiction, antimatter is used every day in our hospitals for the type of brain imaging known as PET scanning. In this process, the patient has a radioactive isotope injected into his bloodstream. The blood then carries it to the brain. These isotopes, such as carbon-11, emit positrons, (the antiparticle of an electron). Since the brain is made of matter, not antimatter, each positron only travels a few mm at the most, before it encounters an electron.

The positron and electron annihilate each other, converting their mass into radiation in the form of two identical gamma rays travelling in opposite directions. Detectors placed around the head pick up these gamma rays and, by timing their arrival, can pinpoint exactly where the positron was emitted.

This information is used to build up a detailed picture of the patient's brain, often in 3-dimensions.



PET image of the brain of a 20 year-old man

1.4 Photons

Positron Emission

This takes place when a proton in a nucleus changes into a neutron. A positron and a neutrino are emitted. Example:

$$^{11}_{6}C \longrightarrow {}^{11}_{5}B + {}^{0}_{+1}\beta + \nu$$

Antiparticles

An antiparticle has the same mass as its corresponding matter particle but opposite charge. (Some other quantum numbers are opposite as well).

Energy released in annihilation

When an electron and a positron annihilate each other the two gamma rays produced fly off in opposite directions at the same speed, because of the law of conservation of momentum. The *minimum* energy of each photon produced is given by $hf_{min} = E_0$ where E_0 is the rest energy of an electron and f_{min} is the minimum frequency of each gamma ray.

Pair Production

In addition to the annihilation process discussed overleaf, matter and antimatter can be created from pure energy by the process of **pair production**. A photon passing close to a nucleus may convert its energy into a particle and its antiparticle. The minimum energy of photon needed to do this is given by $hf_{min} = 2E_0$ where E_0 is the rest energy of one of the particles produced.

Discovery of the Positron

Paul Dirac predicted the existence of antimatter in 1928. The positron was discovered by Carl Anderson four years later in the cloud chamber image opposite. He was investigating how beta particles were slowed down by a lead plate. One particle behaved like all the others but deflected in the opposite direction in a magnetic field. It was the positive beta particle – the positron.