Pair production and annihilation

A.C. Norman
anorman@bishopheber.cheshire.sch.uk

Stable particles

The following particles are the only particles which are stable:

Name	Symbol	Charge (Q) / e	Rest mass / kg	Rest energy / MeV
	e^-		9.1×10^{-31}	0.511
	e^+		9.1×10^{-31}	0.511
	p		1.6×10^{-27}	938
	$\overline{p}$		1.6×10^{-27}	938
	ν			
	$\overline{\nu}$			

Notes

1. The electron volt (eV) is a unit of . In atomic and nuclear physics, the joule is too large a unit for convenience. The electron volt was introduced, being the energy gained by an electron when accelerated through a potential difference of 1 volt. and $1\,\text{MeV} = 10^6\,\text{eV}$.

2. The antiparticles are stable in isolation: in practice, they would encounter a particle and annihilate.

3. Some particles are identical to their anti-particle, e.g. .

4. In general, particle symbols are made into their antiparticle by .

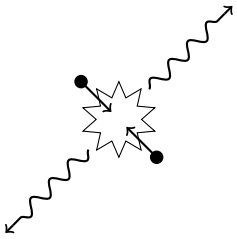
Annihilation

When a particle meets , the particles annihilate. They cease to exist, and in their place **two**[1] photons are created, of energies.

The mass of the particles is converted into .

[1] Two photons are needed to conserve both energy and momentum.

Consider the annihilation of an electron and a positron:

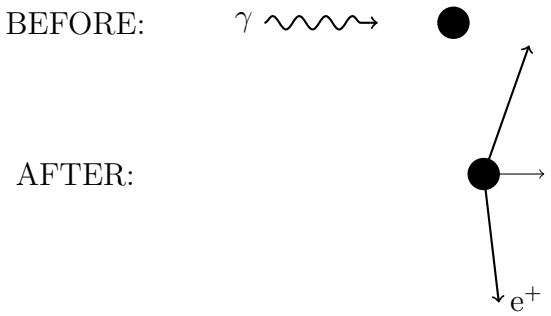


The energy they contain due to their masses is $2m_{\mathrm{e}}c^2$, where m_{e} is the rest mass of an electron. The total energy of the two photons produced is also $2m_{\mathrm{e}}c^2$, due to conservation of energy[2], and each photons has energy $m_{\mathrm{e}}c^2 (=\quad)$. This allows the frequency of the gamma ray photons to be identified (which gives an indication of which particles annihilated).

Pair production

A photon of electromagnetic radiation can interact with an atomic nucleus or an electron and create a

. It has to interact with a nucleus or electron to conserve both and ; the nucleus or electron recoils (consider the time-reversal of this process in the zero-momentum frame to see this):



Commonly, electron–positron pairs are produced, as these are relatively , and so the of the incoming photon does not have to be too high.

For pair production, the total mass produced is $2m_{\mathrm{e}}c^2$, so the minimum energy of the photon must be . Any excess energy of the photon goes into of the electron and positron.

In detectors, a magnetic field is applied, and pair production can be easily seen as the pair curve away in opposite directions due to .

[2]The annihilating particles are assumed to be at rest.