Particles, antiparticles and photons

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The photon model of electromagnetic radiation

Light, and all of the spectrum, can be described as a , and this adequately explains effects such as and reflexion. However, physicists found that some phenomena, such as the effect[1] and the radiation spectrum[2], could not be described in this way.

In 1900, came up with a suggestion that objects which emit electromagnetic radiation do so in discrete amounts. He said that the energy was proportional to the frequency of the radiation, i.e.

$$E \propto f, \text{ or}$$

$$E = \quad ,$$

where h is the Planck constant, .

The individual packets, or , of electromagnetic radiation are called photons. Photons are indivisible, and when they collide with e.g. an electron, all or none of the energy is given to the electron.

Examples

1. Calculate the photon energy of

   (a) a gamma ray of frequency 2×10^{22} Hz
   $E = hf = 6.64\times10^{-34}$ J s $\times 2\times10^{22}$ s^{-1} = J.

   (b) red light of wavelength 7.8×10^{-7} m
   $E = hf$, as $c = f\lambda$ (where $c = 3\times10^{8}$ m s^{-1})

[1] This will be discussed in more detail later in the module. Briefly, it is the emission of electrons from the surface of a metal. It is noted that (i) there is a minimum frequency of light to cause emission (the electrons need a minimum energy to escape) and (ii) the kinetic energy of the electrons emitted increases as the frequency of the light increases (photons have more energy to give to the electrons).

[2] which you don't have to know about at A-level.

$E =$ $= 2.55 \times 10^{-19}$ J.

2. A sodium light emits yellow light of frequency 5.1×10^{14} Hz. If it is a 30 W lamp, how many photons are emitted per second?
   30 W = 30 J s^{-1}.
   $P = \frac{E}{t} =$ photon number per unit time $\times hf$,
   photon number per unit time $= \quad = \frac{30 \text{ J s}^{-1}}{6.64 \times 10^{-34} \text{ J s } \times 5.1 \times 10^{14} \text{ Hz}} =$ 8.9×10^{19} s^{-1}.

Particles and Antiparticles

Every particle that exists has an antiparticle. Antiparticles do not exist as constituents of ordinary matter, but are easily created in , and are produced in radioactive decay and .

For every particle:

- its antiparticle has the same
- its antiparticle has equal (as well as other associated numbers)
- an unstable particle has the same as its antiparticle

Neutrinos

The neutrino was predicted to exist in 1930, and was postulated due to the of beta particles in radioactive beta decay.

Neutrinos are the most common particles in the universe, outnumbering the number of protons by about to one. They are emitted in nuclear reactions such as those that occur inside .

They are very difficult to detect, even though 6×10^{10} pass through every square centimetre of the earth every second. They interact very weakly, and this is why their mass was not discovered until recently, and is an area of ongoing research.