Unit 1
Particles, Quantum Phenomena and Electricity

1.2 Stable and Unstable Nuclei

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The Strong Nuclear Force

The protons in a nucleus repel each other via the electrostatic force. At such tiny distances, the force is huge, (230 N between two protons 10^{-15} m apart).
The nucleus should blow itself apart but the fact that most nuclei are stable and do not disintegrate tells us that another, even stronger force must exist to hold it together. This is known as the **strong nuclear force** or **strong interaction**. Its properties are:

- It acts on both protons and neutrons equally
- It is an attractive force with a range of 3-4 fm (about 10^{-15} m). Outside this range, its effects are negligible.
- At distances of less than 0.5 fm, it becomes a strongly repulsive force, (otherwise the nucleus would be crushed to a point!)

Radioactive Decay

Some nuclei are not stable and disintegrate in the process known as radioactive decay. The naturally occurring radioactive isotopes emit three types of radiation:
Alpha particles consist of two protons and two neutrons, so when a nucleus emits an alpha particle, its proton number decreases by 2 and its nucleon number decreases by 4, as the following decay equation shows:

$$^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$$

Beta particles are high-energy electrons but they are emitted from the nucleus, not from the surrounding electron cloud. A neutron in the nucleus decays into a proton, so the proton number increases by 1 but the nucleon number remains unchanged.

$$^{A}_{Z}X \longrightarrow {}_{Z+1}^{\;\;\;A}Y + {}^{\;\;0}_{-1}\beta + \bar{\nu}$$

$\bar{\nu}$ is the symbol for an antineutrino, (see overleaf).

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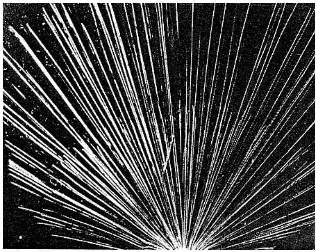
Pauli Predicts the Neutrino

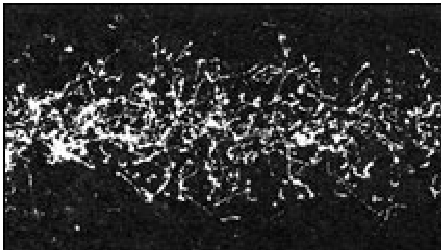
Beta particles are emitted with a range of energies up to a maximum. If these were the only particles emitted, however, conservation of energy tells us that they all ought to come out with the *same* energy. **Wolfgang Pauli** realised that the extra energy, in the cases when the beta particles emerged with less than the maximum, must be carried away by another particle emitted at the same time. These were eventually named **neutrinos** and their antiparticles, **antineutrinos**. His prediction was sound but it took experimental physicists 26 years to detect the antineutrino! The reason is that neutrinos interact only very weakly with matter. Billions of neutrinos from the Sun pass straight through you every second.

Gamma Radiation (γ)

This is electromagnetic radiation of very short wavelength, (about 10^{-15} m). It is emitted from nuclei which have been left in an unstable state by the emission of a beta particle or an alpha particle.

Cloud Chamber Tracks produced by alpha, beta and gamma radiation:





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