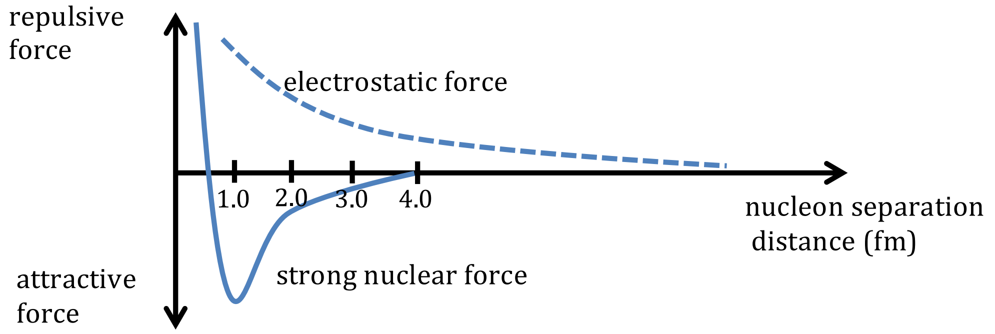
2.2 Stable and unstable nuclei

In the nucleus of an atom we find two types of particle – neutrons and protons. Protons are positively charged, so they electrostatically repel each other.
In order to hold the nucleus together we need another force, the strong nuclear force. The strong nuclear force acts between nucleons (proton-proton and proton-neutron).

Have a look at the following diagram, which shows how the electrostatic force and strong nuclear force vary with separation of nucleons. (Note: only the protons will experience the electrostatic force.)



(1)✐ *Describe how the electrostatic force changes with separation, for two protons.*

(2)✐ *Describe how the strong nuclear force varies with separation for protons and neutrons.*

(3)✐ *Over what range is the strong nuclear force attractive?*

The strong nuclear force becomes repulsive below 0.5fm (1 femtometre = 10^{-15} m). This means that nucleons will be held at an equilibrium separation of around 0.5fm from each other.

Radioactive Decay

Some nuclei are unstable, and they decay into more stable nuclei. These nuclei are radioactive, releasing alpha or beta particles and gamma radiation. Radioactive decay is a completely random process.

Alpha decay

In large nuclei, where the ratio of protons to neutrons is too high, an alpha particle can be ejected from the nucleus. An alpha particle consists of two protons and two neutrons. The symbol notation for an alpha particle is:

$$ {}^{4}_{2}\alpha $$

In alpha decay, the nucleus loses two protons and 2 neutrons.
(4)✐ *How does this affect the proton number (Z)?*

(5)✐ *How does this affect the nucleon number (A)?*

Complete the following nuclear equation showing how thorium-229 decays to radium, releasing an alpha particle:

$$ {}^{229}_{90}Th \rightarrow \quad Ra + {}^{4}_{2}\alpha $$

Beta minus decay

Beta minus decay occurs for nuclei where the ratio of protons to neutrons is too low ('proton poor') for stability. In the nucleus, a neutron will transform to a proton, and beta minus particle is emitted. A beta minus particle is an electron. The symbol notation for a beta minus particle is:

$$ {}^{\ 0}_{-1}\beta $$

(6)✐ *How does beta minus decay affect the proton number?*

(7)✐ *How does beta minus decay affect the nucleon number?*

Complete the following nuclear equation showing how nickel-65 decays to copper, releasing a beta minus particle.

$$ {}^{65}_{28}Ni \rightarrow \quad Cu + {}^{\ 0}_{-1}\beta + \overline{\nu} $$

You will note that there is an additional particle released, $\overline{\nu}$. This is an <u>antineutrino</u>. When the nucleus decays it loses a set (constant) amount of energy. However, we find that the kinetic energies of the beta particles emitted aren't a constant, but vary up to a maximum value. The antineutrino shares the energy with the beta particle, and this explains why the beta particle can have a range of energies, depending on the share of the energy is receives.

Gamma radiation

Gamma radiation is high energy electromagnetic radiation which is released by an unstable nucleus. It often accompanies alpha and beta decay, but has no effect on the proton or nucleon number.