8.2 Radioactive emissions

Unstable nuclei decay by emitting alpha and beta particles and gamma radiation. They do this to achieve a more stable (lower energy) state.

Alpha emission

An alpha particle consists of 2 protons and 2 neutrons.

(1)✎ What charge (in coulombs) does an alpha particle have? What is its relative charge compared to a proton?

(2)✎ Why is the symbol for an alpha particle often written as $^{4}_{2}He$?

Alpha particle emission occurs for large nuclei which have a proton to neutron ratio which is too large to be stable.

(3)✎ Radium-226 decays by alpha particle emission. Complete the nuclear equation for this:

$$^{226}_{88}Ra \rightarrow \quad Rn + {}^{4}_{2}\alpha$$

(4)✎ For the decay above, work out the proton to neutron ratio for radium-226 and radon-222. What do you notice?

The kinetic energy of the emitted alpha particle is always a constant for a particular radioactive isotope.

Beta minus (β^-) emission

A beta particle consists of an electron.

(5)✎ What charge (in coulombs) does beta minus particle have? What is its relative charge compared to a proton?

Beta minus emission occurs in nuclei in which the proton to neutron ratio is too low. A neutron in the nucleus changes into a proton and emits an electron and an anti-electron neutrino.

(6)✎ Carbon-14 decays by beta minus emission. Complete the nuclear equation for this:

$$^{14}_{6}C \rightarrow \quad N + {}^{0}_{-1}\beta + \overline{\nu_e}$$

(7) For the decay above, work out the proton to neutron ratio for carbon-14 and nitrogen-14. What do you notice?

(8) The kinetic energy of the beta minus particles, emitted from a particular radioactive isotope, can vary up to a maximum value. Looking at the nuclear equation for beta minus emission, why do you think this is?

Beta plus (β^+) emission

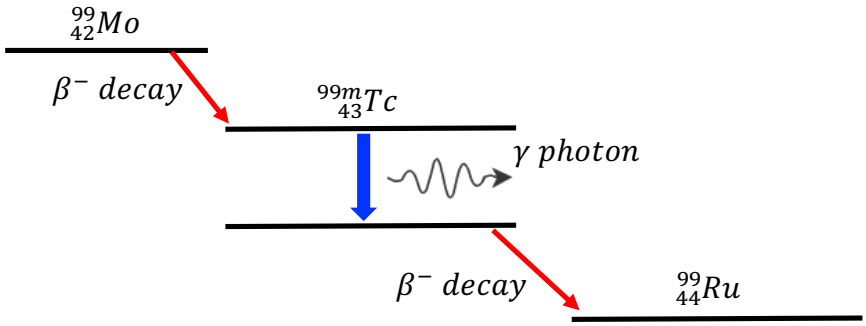
Beta plus emission occurs for nuclei which have a proton to neutron ratio that is too small. A proton changes to a neutron and a positron (beta plus) particle is emitted, along with an electron neutrino. Beta plus emission isn't observed for naturally occurring radioactive nuclei.

(9) Sodium-22 decays by beta plus emission. Write a nuclear formula for this.

Gamma ray emission

Gamma ray emission often accompanies alpha or beta decay. Alpha and beta decay often leave the nucleus in an excited state. The nucleus transitions to a lower energy state by emitting a gamma ray photon. The emitted gamma ray photons will have frequencies which are characteristic of a particular radioactive isotope.

Consider the following decay diagram for a radioactive isotope which is used in medicine to produce a useful source of gamma ray photons.



Molybdenum-99 decays by beta minus emission to an excited state of technetium-99. The technetium nucleus transitions to a lower energy state and emits a gamma ray photon. This is followed by a decay by beta minus emission to ruthenium-99.

(10) The loss of energy in the transition that produces the gamma ray photon is 140.5keV. Work out the frequency of the emitted photon.