

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.



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Alpha emission

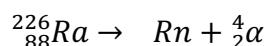
An alpha particle consists of 2 protons and 2 neutrons.

(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 ${}^4_2\text{He}$?*

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:*



(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.

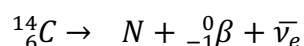
Beta minus (β^-) emission

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:*



(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

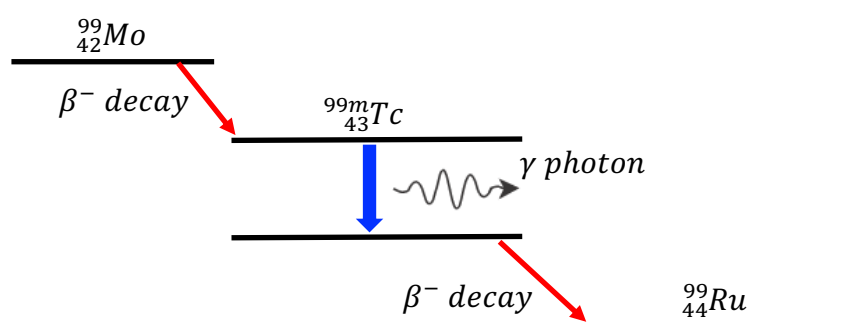
Beta plus emission occurs for nuclei which have a proton to neutron ratio that is too high. A proton changes to a neutron and a positron (beta plus) particle is emitted, along with an electron neutrino. Beta plus emission isn't observed for naturally occurring radioactive nuclei.

(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.*