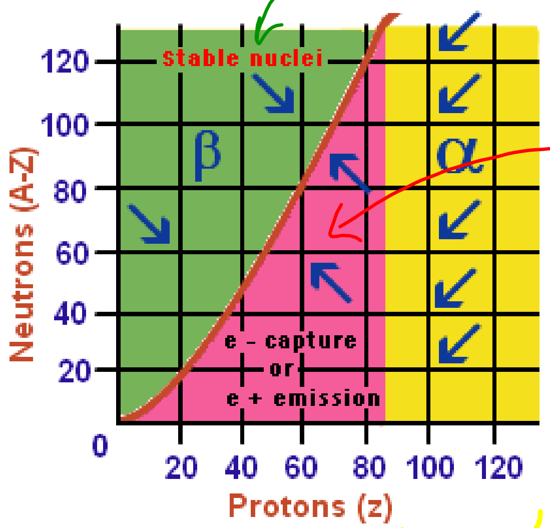
The neutro-proton ratio curve for stable nuclei

too many neutrons

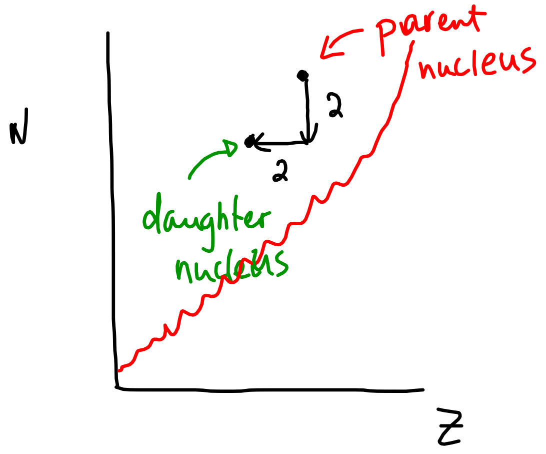


too many protons.

too big (Z>83)

- For small nuclei, N = Z
- For larger nuclei, N > Z

Alpha-Decay

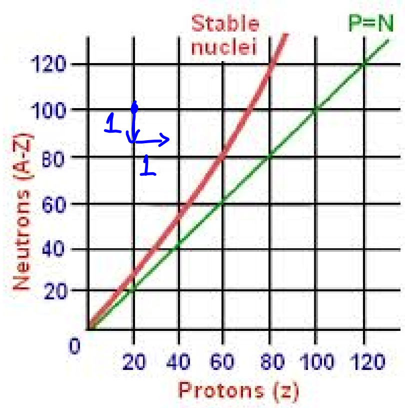


If Z > 83, then alpha decay helps to increase the stability

$$Po^{214}_{84} \rightarrow Pb^{210}_{82} + He^{4}_{2}$$

The nucleus has lost an equal number of protons and neutrons so the daughter nucleus is above (further to the left) of the stability band in the region of too many neutrons.

Beta Decay



Nuclei that are above the stability band have too many neutrons + are beta emitters (changing a neutron into a proton)

$$n_0^1 \rightarrow p_1^1 + e_{-1}^0 + \bar{\nu}$$

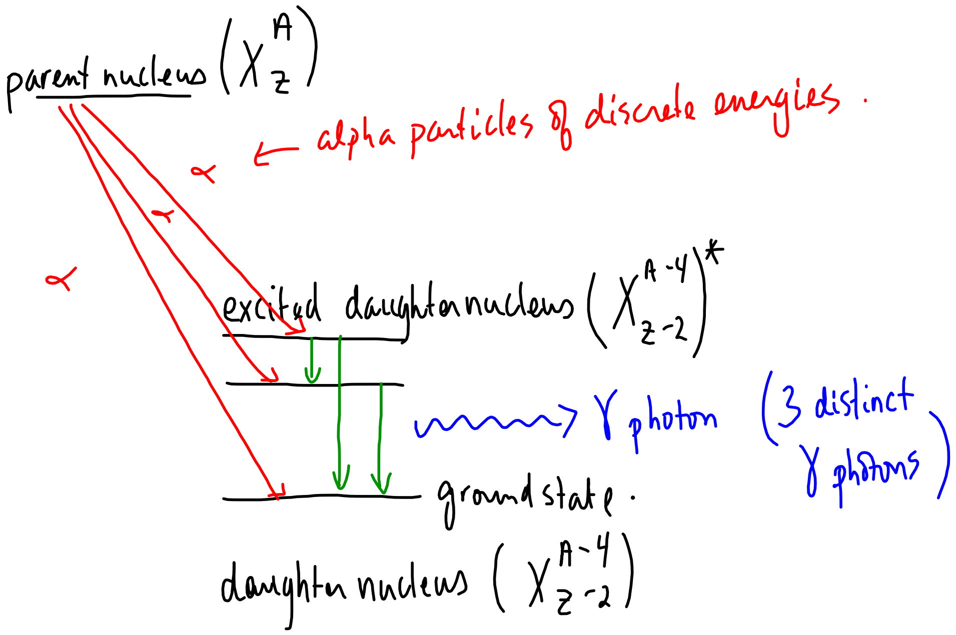
Daughter nucleus has one more proton and 1 less neutron and is further right towards stability band (so more stable)

$$C_6^{14} \rightarrow N_7^{14} + e_{-1}^0 + \bar{\nu}$$

Gamma Decay

When a nucleus goes through alpha or beta decay, the nucleus is in an excited state.

This excited nucleus decays to the ground state by emitting one or more γ photons.



The rate of decay of a radioactive substance

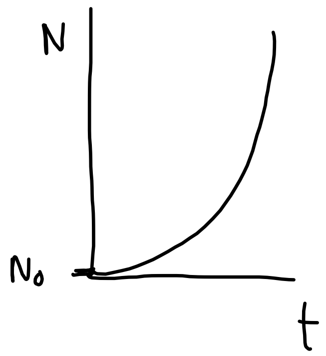
- a completely random process
- impossible to predict which nucleus will decay.
- impossible to induce a particular nucleus to decay

(the process is completely spontaneous)

Exponential Changes

Rabbit population

$$N = N_0 e^{bt}$$



Coffee Cooling

$$T = T_0 e^{-bt}$$

The number of radioactive nuclei present in a sample at a given time → an exponential decrease.

The rate at which the number N of radioactive nuclei at a given sample of radioactive element decays $\frac{\Delta N}{\Delta t}$ at any time t is proportional to the number of radioactive nuclei present at that time.

$$\frac{\Delta N}{\Delta t} \propto -N$$

Activity A of a radioactive sample

This quantity $\frac{\Delta N}{\Delta t}$ is called the activity of a radioactive sample.

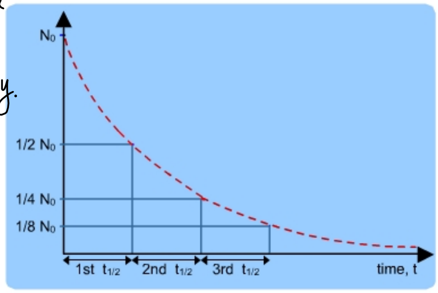
$$A = -\frac{\Delta N}{\Delta t}$$

units: disintegrations per second
s^{-1}
becquel (Bq)

If 5×10^3 nuclei of radium in a given sample decay into radon each second at a particular time, the activity is 5×10^3 Bq at that time

Any quantity that reduces to half its initial value in a constant time decays exponentially.

$t_{\frac{1}{2}}$ is the half-life.



It is the time it takes for half of the radioactive nuclei to transmute into the daughter nuclei.

It is the time for the activity of the radioactive sample to decrease to half its initial activity.
(OR) It is also the time for the rate of decay of the radioactive substance to reduce to half that rate

Example
The half life of protactinium-234 (Pa^{234}) is 72s.
Determine how long before:

a) $\frac{1}{8}$th of the original number of nuclei remains (3 half-lives) $(3 \times 72s)$ = 216s

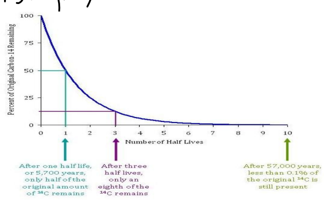
b) 75% has decayed ($\frac{1}{4}$ → 2 half-lives) $2 \times 72 =$ 144s

If a sample of Pa^{234} produces 500 counts per second on a Geiger counter, how many counts per second will there be after 360s? $\frac{360s}{72s} = 5$ half lives

$$500 \text{ counts } s^{-1} \left(\frac{1}{2^5}\right) = \frac{500}{32} = 15.6 \text{ counts } s^{-1}$$

Example (Radiocarbon dating)
A sample of dead wood contains $\frac{1}{16}$th of the amount of C^{14} that it contained when it was alive. How old is the wood sample? ($t_{1/2} = 5730$ yrs) → 4 half lives

age of wood = 4(5730 yrs)
= 22900 yrs.



Parent - Daughter Curves