GCE Physics Unit 3.5 Nuclear Decay

Alpha, beta & gamma:

Nuclear decay is a spontaneous process, unstable nuclei decay to form more stable nuclei. There are main types of radiation linked to nuclear decay: alpha, α, beta, β, and gamma radiation, γ.

Alpha:

A nucleus decays to a smaller, more stable nucleus, releasing fast moving **helium nuclei**.

$$^{232}_{90}\text{Th} \rightarrow {}^{228}_{88}\text{Ra} + {}^{4}_{2}\text{He}$$

Beta:

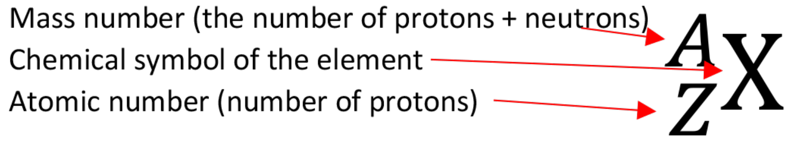
A neutron in an unstable nucleus decays into a proton and releases a fast moving (just less than the speed of light) **electron**.

$$^{42}_{19}\text{K} \rightarrow {}^{42}_{20}\text{Ca} + {}^{0}_{-1}\text{e} + {}^{0}_{0}\bar{\nu}_0$$

Gamma:

An unstable nucleus releases some energy in the form of a **gamma photon**. This often accompanies one of the other types of decay.

Note that the nuclei in the above reactions are represented by symbols in this form $^{A}_{Z}\text{X}$. You will need to be able to use this notation:

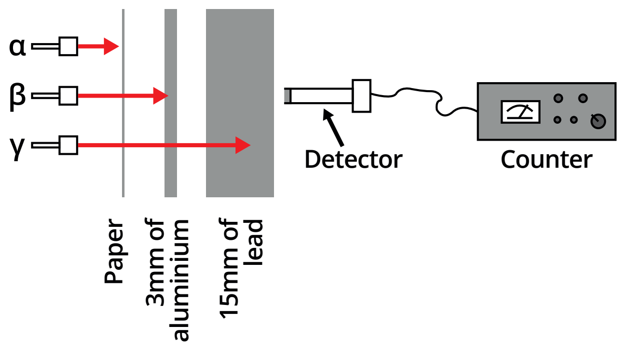


Another important aspect of the equations to note is that the sum of the mass numbers is constant and the sum of the proton numbers is constant.

As radioactivity is a random process, similar to throwing dice, some variation is expected in any results collected for nuclear decay, often in terms of the activity of the sample.

Activity is the rate of decay of a sample of radioactive nuclei. It is measured in Becquerel, Bq, which is equivalent to s^{-1}.

Penetrating properties:



Differentiating between sources of radioactivity can be done by studying their penetrating properties. The more ionising the radiation, the less penetrating it is.

Remember to correct for background radiation in any data used. This involves subtracting the value of the background, either given or calculated from the data with no source present, from the value measured.

Half-life:

Half-life, $T_{½}$, is defined as the time taken for the **number of radioactive nuclei**, N (or the activity A) to **reduce to one half** of the initial value. It does not change for a radioactive sample. After one half-life the activity will halve; after another half-life it will halve again to ¼ of its original value.

The number of nuclei remaining (or activity) can be calculated by this equation:

$$N = \frac{N_0}{2^x} \text{ or in terms of activity } A = \frac{A_0}{2^x}$$

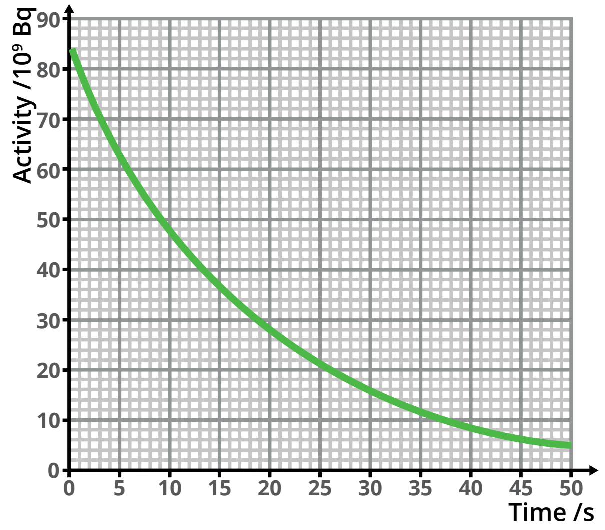
where x is the number of half-lives.

As the rate of decay (A) will be proportional to the number of nuclei (N), it is possible to express this in an equation:

$$A = \lambda N$$

where λ is the decay constant.

Nuclear decay produces an exponential graph.



This means that these equations can be used to calculate the number of nuclei remaining or the activity after time t.

$$N = N_o e^{-\lambda t} \quad \text{or} \quad A = A_o e^{-\lambda t}$$

Derivation of $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$

if the half-life is the time it takes the activity to half, when $t = T_{½}$, $N/N_o = ½$.

$$\frac{1}{2} = e^{-\lambda T_{\frac{1}{2}}}$$

By using log, ln, this can be written as:

$$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$$

A = activity in Bq λ = decay constant in s^{-1} N = number of nuclei t = time in s $T_{½}$ = half-life in s x = number of half lives