8.3.1 Radioactive decay

Certain nuclei are unstable and emit alpha (α) or beta (β) particles and gamma (γ) radiation. We say that they are radioactive. This is a completely random process. If we have a collection of radioactive nuclei, we can't say when a particular nuclei will decay. However, we do have an idea of the fraction that will decay per unit time. This is known as the decay constant λ.

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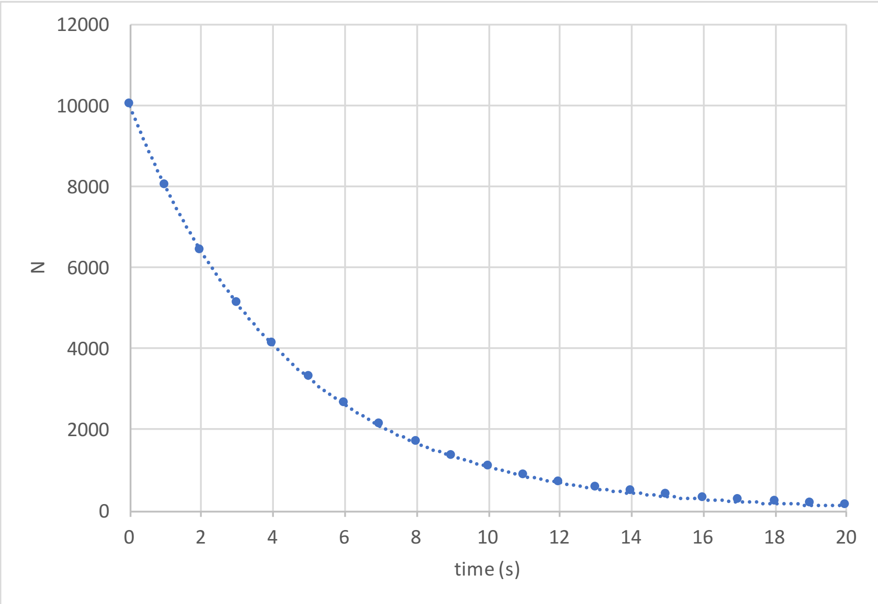
Consider that we have a sample of N radioactive nuclei. The number that decay in a second is known as the activity (A) of the sample.

$$A = \lambda N$$

Activity is measured in $becquerels$ (Bq). $1Bq \equiv 1\ s^{-1}$.

The decay constant

If we graph the number N of nuclei left undecayed with time we end up with a graph that looks like the following:



The shape of this curve follows an exponential decay. We can write:

$$N = N_0 e^{-\lambda t}$$

where N_0 = *number of nuclei to start with*, t = *time*.

(1)✏ λ = fraction of nuclei that decay every second. From the graph, work out a value for λ. What are the units for λ?

It can sometimes be useful to measure time in units other than seconds (e.g. hours or years). When using the exponential decay function, above, it is important that a complementary decay constant is used. E.g. if time is in years (yr) the decay constant should be in yr^{-1}. If time is in hours (h), then the decay constant should be in h^{-1}, etc.

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Half life

Half life ($t_{0.5}$) is the time it takes for half the radioactive nuclei to decay. This is the same no matter how many nuclei you start with.

(2)✏From the graph, above, work out the half life of the sample. To do this, choose a point on the curve and record the start number of nuclei (N_0). Now go to a point on the graph where the number of nuclei is half the start number $\left(=\frac{N_0}{2}\right)$. The time interval between these two points is the half life ($t_{0.5}$).

There is a relationship between half life and the decay constant:

$$N = N_0 e^{-\lambda t}$$

After a time $t = t_{0.5}$, $N = \frac{N_0}{2}$. We can write:

$$\frac{N_0}{2} = N_0 e^{-\lambda t_{0.5}}$$

(3)✏Simplify and rearrange the equation, above, and show that:

$$t_{0.5} = \frac{\ln(2)}{\lambda}$$

Measuring radioactivity

Practically, it would be difficult to record every decay (sometimes called 'disintegration') in a sample. A *Geiger-Müller* (*GM*) tube can be used to detect some of the ionising radiation emitted. Follow the following link to see how a GM tube works:
http://www.explainthatstuff.com/how-geiger-counters-work.html

The GM tube is connected to a counter which displays the count rate. The count rate is the number of ionising radiations detected by the GM tube per second. As there is radiation around us naturally ('background radiation'), a reading is usually taken of the background count rate. This is subtracted from all readings. What is left is called the 'corrected count rate' (C). The corrected count rate will be proportional to the activity (A) of the sample.

$$C = constant \times A = constant \times A_0 e^{-\lambda t} = C_0 e^{-\lambda t}$$

The shape of the graph of count rate versus time will be identical to that of the A versus time, which in turn is identical to that of N versus time.

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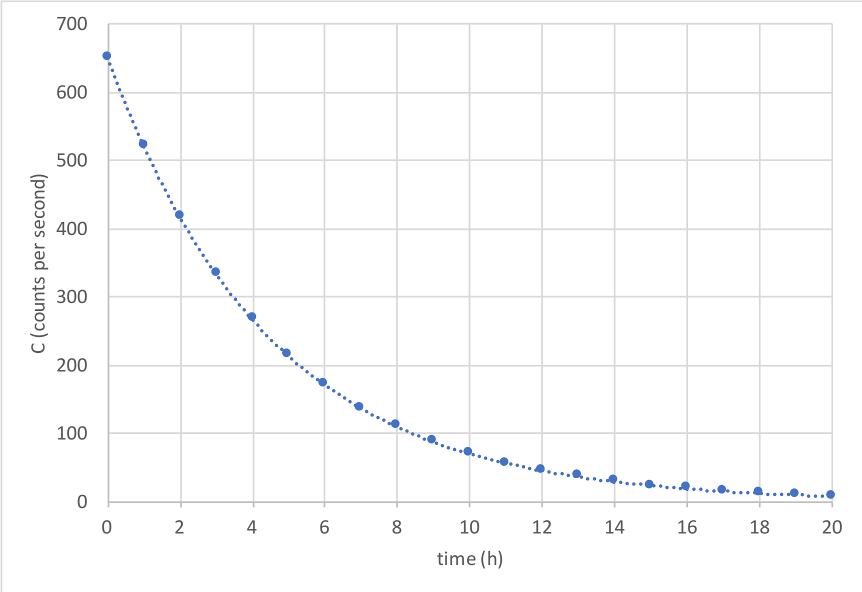
(4)✐A GM tube and counter are used to monitor the radioactive emissions of a sample. A graph of corrected count rate versus time is shown below. From the graph work out the half life and decay constant. (Note: time is in hours.)



(5)✐A radioactive sample has a half life of 1600s. The count rate at the start (C_0)=340counts per second. The background count rate=23counts per second. After what time is a reading of 100counts per second recorded?

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