Radioactivity and Radiometric Dating

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April 14, 2013

Many creationists question radiometric dating but don't actually know the equations are derived. The experimental facts used are

- Radioactive decay is random.
- The decay of one atom will not affect the decay of another atom.

So we will then have to calculate the probability of decay and is independent of the other atom decaying. The probability of decay of N radioactive atoms to $N - dN$ atoms in a time interval dt is given by dN/N. This number is independent of time because decay is random and is independent of N because a decay of one particular atom won't affect the decay of another atom, and so dN/N is constant. However if we increase the time interval which we're measuring the probability will increase, so dN/N is proportional to dt, denoting the proportionality constant by $-k$, we have,

$$dN/dt = -kN. \tag{1}$$

This is a simple model but it uses the main physics that have been observed in radioactive decay. In the derivation we have not considered interactions for which a full quantum model will be required. If we have N_0 atom at the beginning then the equation can be solved to get:

$$N = N_0 e^{-kt}. \tag{2}$$

The constant k, can be related to the half life, let $t_{\frac{1}{2}}$ denote the period of time for half the atoms to decay, so using equation (2), we have:

$$\frac{N_0}{2} = N_0 e^{-kt_{\frac{1}{2}}}. \tag{3}$$

Then using some algebra:

$$t_{\frac{1}{2}} = \frac{\ln 2}{k}. \tag{4}$$

It is equation (2) which will be used for radiometric dating. Suppose at time t_0 there are $N_p(t_0)$ parent atoms and suppose at time $t_1 > t_0$, there are $N_d(t_1)$ daughter atoms, them:

$$N_p(t_0) = N_p(t_1) + N_d(t_1), \tag{5}$$

along with:

$$N_p(t_1) = N_p(t_0)e^{-k(t_1-t_0)}. \tag{6}$$

Then with simple algebra,

$$t_1 - t_0 = \ln(1 + N_d(t_1)/N_p(t_1))/k. \tag{7}$$

Thus it is possible to determine the age of a sample by measuring the ratio of the daughter to parent atom.

Let us extend the analysis slightly. Suppose we allow the presence of daughter nuclei at time t_0, then we have:

$$N_D(t_1) + N_P(t_1) = N_D(t_0) + N_P(t_0) \tag{8}$$

Because we have another unknown, it is no longer possible to solve directly for the age of the sample. However if there is also present a different isotope of the daughter D' which is neither radioactive nor formed from the decay of a long live parent then it is possible to find the age of the sample. Is the number of atoms of the isotope of D' is represented by $N_{D'}$, and is D' is stable then:

$$N_{D'}(t_0) = N_{D'}(t_1). \tag{9}$$

Then

$$(N_D(t_1) + N_P(t_1))/N_{D'}(t_1) = (N_D(t_0) + N_P(t_0))/N_{D'}(t_0). \tag{10}$$

This can be arranged to obtain:

$$N_D(t_1)/N_{D'}(t_1) = (e^{k(t_1-t_0)} - 1)N_P(t_1)/N_{D'}(t_1) + N_D(t_0)/N_{D'}(t_0) \tag{11}$$

Now this is in the form of $y = mx + c$, where $y = N_D(t_1)/N_{D'}(t_1)$, $x = N_P(t_1)/N_{D'}(t_1)$, and there fore the slope of the graph will be given as $e^{k(t_1-t_0)} - 1$ and the y-intercept as $N_D(t_0)/N_{D'}(t_0)$.

The quantities $N_D(t_1)/N_{D'}(t_1)$ and $N_P(t_1)/N_{D'}(t_1)$ can be measured in a lab and plotted. For this method to be applicable the points should conform to a linear fit (which they do) and this is what justified the assumption for no loss of parent or daughter nuclei. If the point weren't a good linear fit then then it would show that this method of dating couldn't be used. Points which do not lie on the line mean that there has been material either added or taken away and then this would show that the data points are no suitable for the dating analysis.