3 Radiometric dating

The radioactive decay of an element is essentially a random event. Radioactive decay occurs due to a quantum process ocurring within the nucleus of an atom.

The end result is that we cannot predict precisely when a particular radioactive nucleus will decay. However, we can make a statistical statement as to when it will occur. We can measure the time taken for half of a large sample of radioactive atoms to decay.

This is referred to as the half-life, or t_{half}.

Consider a sample of 8 million radioactive atoms with a half-life $t_{half} = 20$ minutes. We start the experiment at $t = 0$. After 20 minutes half the sample, 4 million atoms, remains undecayed. After a further 20 minutes 2 million atoms remain undecayed, i.e. $1/2 \times 1/2 = 1/4$ of the original sample. We can express the proportion of the sample remaining as

$$\frac{\text{current amount}}{\text{original amount}} = \left(\frac{1}{2}\right)^{t/t_{half}} .$$

In the case of rock dating, t is the time since the rock formed. By rearranging our first equation we obtain

$$t = t_{half} \times \frac{\log_{10}(\text{current}/\text{original})}{\log_{10}(1/2)}$$

Consider the following problem: you analyse a small sample of meteoritic rock. Potassium-40 and argon-40 are present in the ratio of 0.85 units of potassium-40 atoms to 9.15 units of argon-40 atoms. How old is the meteorite?

Because no argon gas could have been present in the meteorite when it formed, the 9.15 units of argon-40 must have been potassium-40 that has decayed with a half-life of 1.25 billion years. The original amount of potassium-40 must have been $0.85 + 9.15 = 10$ units. The age of the meteorite is then

$$\begin{aligned} t &= 1.25 \text{ billion yr} \times \frac{\log_{10}(0.85/10.0)}{\log_{10}(1/2)} \\ &= 1.25 \text{ billion yr} \times \frac{-1.07}{-0.301} \\ &= 4.45 \text{ billion yr.} \end{aligned}$$

Therefore, the meteorite solidified 4.45 billion years ago.