Modern Physics

Nuclear Decay

Problem 1.- How many years will be required for 25 Ci of ^{60}Co to decay to 5 mCi?

The half-life of ^{60}Co is 5.27 years.

Solution: We can find an approximate solution by dividing the initial 25Ci by two 12 times, as follows:

$$
\begin{aligned}
&25\text{Ci}/2 \Rightarrow 12.5\text{Ci}/2\\
&\Rightarrow 6.25\text{Ci}/2 \Rightarrow 3.125\text{Ci}/2\\
&\Rightarrow 1.5625\text{Ci}/2 \Rightarrow 0.78125\text{Ci}/2\\
&\Rightarrow 0.390625\text{Ci}/2 \Rightarrow 0.195313\text{Ci}/2\\
&\Rightarrow 0.097656\text{Ci}/2 \Rightarrow 0.048828\text{Ci}/2\\
&\Rightarrow 0.024414\text{Ci}2 \Rightarrow 0.012207\text{Ci}/2\\
&\Rightarrow 0.006104\text{Ci}
\end{aligned}
$$

These 12 divisions by 2 take us from 25 Ci to 0.006104 Ci (or 6.104 mCi), so we actually need a bit more than 12 half-lives to get to 5 mCi, so we need slightly more than

$12\times5.27\text{years}$ = **63years.**

A more precise result comes from using the formula:

$$Decay\_Time = Half-Life \times \left(\frac{\log\left(\dfrac{Initial\_Intensity}{Final\_Intensity}\right)}{\log(2)} \right)$$

In our present problem:

$$DecayTime = 5.27\,years \left(\frac{\log\left(\dfrac{25\text{Ci}}{5\times10^{-3}\text{Ci}}\right)}{\log(2)} \right) = \mathbf{64.8\ years}$$

Problem 2.- If 10.0 mCi of ^{24}Na were shipped Friday at 12:00 noon to be used in an experiment at 10:00 AM on Monday, how many dpm of ^{24}Na would be left?

^{24}Na has a half-life of 15 hours.

Solution: Between 12:00 noon Friday and 10:00 am Monday we have 70 hours, so there are close to five half-lives in that time. The sample would have decayed to almost 1/32 of the original intensity. Instead of 10.0mCi you will have 10.0mCi/32 = 0.3125mCi.

In dpm this intensity is:

$$0.3125\times10^{-3}\,\mathrm{Ci}\left(\frac{2.22\times10^{12}\,\mathrm{dpm}}{\mathrm{Ci}}\right) = \mathbf{7.0\times10^{8}dpm}$$

A more precise result comes from using the formula:

$$\mathrm{Intensity} = \mathrm{Intensity}_{\mathrm{initial}} \times 2^{-\frac{\mathrm{time}}{\mathrm{HalfLife}}}$$

So, in this case:

$$\mathrm{Intensity} = (10.0\mathrm{mCi})\mathrm{x}2^{-\frac{70\mathrm{hours}}{15\mathrm{hours}}} = 0.394\ \mathrm{mCi}$$

Converting this to dpm:

$$0.394\times10^{-3}\,\mathrm{Ci}\left(\frac{2.22\times10^{12}\,\mathrm{dpm}}{\mathrm{Ci}}\right) = \mathbf{8.7\times10^{8}\,dpm}$$