Question

Cross Section: Natural cobalt consists entirely of the isotope ^{59}Co whose cross section for thermal neutron capture is 37 $b\,(barn)$. When ^{59}Co absorbs a neutron, it becomes ^{60}Co, which is gamma-radioactive with a half-life of 5.27 y. If a 10.0 g cobalt sample is exposed to a thermal-neutron flux of $5 \times 10^{17}\, neutrons/m^2\, s$ for 10.0 h, what is the activity of the sample afterward?

Solution

Number of atoms in ^{59}Co sample

$$n = \frac{10.0 \times 10^{-3}}{59(1.66 \times 10^{-27})} = 1.021 \times 10^{23}$$

Total cross-section for thermal neutron capture

$$n\sigma = 1.021 \times 10^{23} \times 37\, b = (1.021 \times 10^{23})(3.777 \times 10^{37 \times 10^{-28}}) = 3.778 \times 10^{-4}\, m^2$$

Total neutrons absorbed in $10\, h$ period

$$N = (3.778 \times 10^{-4})(5 \times 10^{17})(10 \times 60 \times 60) = 6.80 \times 10^{18}$$

The sample will now contain this number of ^{60}Co atoms.

The decay constant λ for ^{60}Co

$$\lambda = 0.693/T_{1/2} = 0.693/5.27\, y = 0.693/(5.27 \times 365 \times 24 \times 60 \times 60) = 4.170 \times 10^{-9}\, /s$$

Activity of sample

$$\begin{aligned} R &= \lambda N \\ &= (4.170 \times 10^{-9})(6.80 \times 10^{18}) \\ &= 2.835 \times 10^{10}\, /s \\ &= (2.835 \times 10^{10})/(3.70 \times 10^{10})\, Ci \\ &= 0.7663 \end{aligned}$$

The activity of the sample after the exposure is $0.766\, Ci$.