Tutorial 3 Question

- Text: Ch. 43: Pr. 48.
- ${}^{57}_{27}$Co emits $122\ \mathrm{keV}$ γ-rays. If a $70\ \mathrm{kg}$ person swallowed $1.85\ \mu\mathrm{Ci}$ of ${}^{57}_{27}$Co, what would be the dose rate ($\mathrm{rad/day}$) averaged over the whole body? Assume that 50 percent of the γ-ray energy is deposited in the body.
- Other information:
  - $1\ \mathrm{keV} = 1.60 \times 10^{-16}\ \mathrm{J}$.
  - Cobalt-57 has a half-life of $270\ \mathrm{days}$.

Solution

- The absorbed dose is $\boxed{\mathrm{dose_{abs}} = E/m}$. We want to find the dose rate,

$$\text{dose rate} = \frac{\mathrm{dose_{abs}}}{\Delta t} = \frac{E}{m\,\Delta t},$$

  where $\Delta t = 1\ \mathrm{day}$.
- We are given the mass of the absorbing material, $m = 70\ \mathrm{kg}$ so all we need to find is the energy absorbed E over interval Δt.

Solution, contd

- We are given the activity of the sample and the energy emitted per decay. To calculate the energy absorbed we first need the total number of decays in a day,

$$\begin{aligned}\Delta N &= \left|\frac{dN}{dt}\right| \Delta t \\ &= 1.85 \times 10^{-6}\ \mathrm{Ci} \times \frac{3.70 \times 10^{10}\ \mathrm{decays/s}}{1\ \mathrm{Ci}} \times 1\ \mathrm{day} \times \frac{86400\ \mathrm{s}}{1\ \mathrm{day}} \\ &= 5.91 \times 10^{9}\ \mathrm{decays}.\end{aligned}$$

  (This assumes that the half-life of ${}^{57}_{27}$Co is much longer than a day, so that the activity is roughly constant throughout the day.)

Solution, contd

- Given the number of decays and the energy emitted per decay we can calculate the total energy absorbed (50 percent of the emitted energy),

$$\begin{aligned}E &= 50\% \times \Delta N \times (\text{energy per decay}) \\ &= 0.50 \times 5.91 \times 10^{9}\ \mathrm{decays} \times 122\ \mathrm{keV} \times \frac{1.60 \times 10^{-16}\ \mathrm{J}}{1\ \mathrm{keV}} \\ &= 5.77 \times 10^{-5}\ \mathrm{J}.\end{aligned}$$

- So the dose rate is

$$\begin{aligned}\text{dose rate} &= \frac{E}{m\,\Delta t} = \frac{5.77 \times 10^{-5}\ \mathrm{J}}{70\ \mathrm{kg} \times 1\ \mathrm{day}} \times \frac{1\ \mathrm{rad}}{0.01\ \mathrm{J/kg}} \\ &= 8.24 \times 10^{-5}\ \mathrm{rad/day}. \quad \square\end{aligned}$$