

Problem III.2 ... Mišo doesn't want to die

3 points; průměr 2,52;

řešilo 98 studentů

Mišo found an old radioactive source that contains ^{90}Sr at work. In 1974, it had an activity of 5 mCi. How long would Mišo have to be irradiated evenly with this radioactive source to reach a lethal dose of 10 Sv? Assume that all subsequent decays are instantaneous and that all decay products are absorbed uniformly by Mišo. Mišo weighs 65 kg and the source was discovered in 2020. *Mišo found a radioactive source at work.*

According to the decay chain, ^{90}Sr transforms via β -decay into ^{90}Y , releasing energy $e_1 \approx 0.55$ MeV. ^{90}Y subsequently decays via β -decay into ^{90}Zr , releasing energy $e_2 \approx 2.28$ MeV. Since we consider all decays after the transformation of ^{90}Sr to be instantaneous, we will only account for the half-life of ^{90}Sr , which is $t_{1/2} \approx 29$ years. From this, we obtain the decay constant $\lambda = \ln 2/t_{1/2} \approx 0.024$ (years) $^{-1}$.

The energy E sufficient to kill Mišo can be obtained from the following equation

$$A = \frac{E}{m} \quad \Rightarrow \quad E = Am,$$

where A is the effective dose needed to kill Mišo and m is his mass. Now, we can easily determine the number of decays ΔN needed to emit this energy

$$\Delta N = \frac{E}{e_1 + e_2} = \frac{Am}{e_1 + e_2}.$$

Next, we need to determine the activity R_1 of the source in the year 2020. We use the following formula

$$R_1 = R_0 e^{-\lambda T} \doteq 1.7 \text{ mCi},$$

where $T = 46$ years is the time span of interest, and R_0 is the initial activity of the original source. The conversion formula for activity R_1 and the number of particles N_1 in 2020 is

$$R_1 = N_1 \lambda;$$

thus, for N_1 , we have

$$N_1 = \frac{R_0}{\lambda} e^{-\lambda T}.$$

Additionally, $N_2 = N_1 - \Delta N$ represents the number of particles at the time of Mišo's potential death. Using the equation

$$N_2 = N_1 e^{-\lambda t},$$

we can obtain the time of exposure t that would kill Mišo as

$$t = -\frac{\ln \frac{N_2}{N_1}}{\lambda} = -\frac{1}{\lambda} \ln \left(\frac{N_1 - \Delta N}{N_1} \right) = -\frac{1}{\lambda} \ln \left(1 - \frac{Am\lambda e^{\lambda T}}{(e_1 + e_2) R_0} \right) \doteq 2.7 \cdot 10^2 \text{ days}.$$

After substituting, we conclude that Mišo would die after approximately 270 days of exposure to the radiation source.

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