874.

Problem 55.27 (RHK)

The thermal energy generated when radiation from radio nuclides are absorbed in matter can be used as the basis for a small power source for use in satellites, remote weather stations, and so on. Such radionuclides are manufactured in abundance in nuclear power reactors and may be separated from the spent fuel. One suitable radionuclide is $^{238}\mathrm{Pu}\ \left(t_{1/2}=87.7\ \mathrm{y}\right)$ *which is an alpha emitter with* $Q=5.59\ \mathrm{MeV}$. *We have to find the rate at which thermal energy is being generated in* 1.00 kg *of this material.*

Solution:

We are considering a 1.00 kg of radionuclide $^{238}\mathrm{Pu}\ \left(t_{1/2}=87.7\ \mathrm{y}\right)$, which is an alpha emitter, as a small power source. For alpha emissions from this radionuclide Q is 5.59 MeV. The disintegration constant for alpha emission of the radionuclide $^{238}\mathrm{Pu}$ will be

$$\lambda = \frac{\ln 2}{87.7 \text{ y}} = \frac{\ln 2}{87.7 \times 3.156 \times 10^{7} \text{ s}} = 2.50 \times 10^{-10} \text{ s}^{-1}.$$

The number of nuclides contained in 1.00 kg of

^{238}Pu will be

$$N = \frac{6.02 \times 10^{23}}{238 \times 10^{-3}} = 2.53 \times 10^{24}.$$

Therefore, rate of alpha emissions in 1.00 kg of

^{238}Pu will be

$$R = N\lambda = 2.53 \times 10^{24} \times 2.50 \times 10^{-10} \text{ s}^{-1}$$

$$= 6.33 \times 10^{14} \ \alpha \text{ emissions per second.}$$

As for alpha emissions Q is 5.59 MeV, the rate at which energy is produced will be

$$P = 6.33 \times 10^{14} \times 5.59 \text{ MeV per second}$$

$$= 6.33 \times 10^{14} \times 5.59 \times 1.6 \times 10^{-13} \text{ J s}^{-1}$$

$$= 566 \text{ W}.$$