877.

Problem 55.31 (RHK)

One possible method of revealing the presence of concealed nuclear weapons is to detect the neutrons emitted in the spontaneous fission of ^{240}Pu *in the warhead. In an actual trial, a neutron detector of area* $2.5\ \text{m}^2$*, carried on a helicopter, measured a neutron flux of* $4.0\ \text{s}^{-1}$ *at a distance of* $35\ \text{m}$ *from a missile warhead. We have to estimate the mass of* ^{240}Pu *in the warhead. The half-life for spontaneous fission in* ^{240}Pu *is* $1.34\times10^{11}\ \text{y}$ *and* 2.5 *neutrons, on the average, are emitted per fission.*

Solution:

The half-life for spontaneous fission in ^{240}Pu is $1.34\times10^{11}\ \text{y}$ and 2.5 neutrons, on the average, are emitted per fission. The disintegration constant of ^{240}Pu will therefore be

$$\lambda = \frac{\ln 2}{1.34\times10^{11}\times3.156\times10^{7}\ \text{s}} = 1.64\times10^{-19}\ \text{s}^{-1}.$$

Let the warhead contain m g of $^{240}\mathrm{Pu}$. The number of $^{240}\mathrm{Pu}$ nuclides in m g will be

$$N = \frac{6.02 \times 10^{23} \times m}{240} = 2.51 \times 10^{21} \times m.$$

It is given that on an average 2.5 neutrons are emitted per fission of $^{240}\mathrm{Pu}$ nuclide. Therefore, rate of neutron emission of neutrons from m g of $^{240}\mathrm{Pu}$ will be

$$R_{\mathrm{neutron}} = 2.5\lambda N = 2.5 \times 1.64 \times 10^{-19} \times 2.51 \times 10^{21} \times m \ \mathrm{s}^{-1}$$
$$= 10.29 \times 10^{2} \times m \ \mathrm{s}^{-1}.$$

At a distance of 35 m from the missile warhead, a neutron detector of area $2.5\ \mathrm{m}^2$ measures a neutron flux of $4.0\ \mathrm{s}^{-1}$. We can, therefore, obtain the amount of $^{240}\mathrm{Pu}$ in g from the equation

$$\frac{R_{\mathrm{neutron}} \times 2.5\ \mathrm{m}^2}{4\pi\left(35\ \mathrm{m}\right)^2} = 4.0\ \mathrm{s}^{-1},$$

or

$$\frac{10.29 \times 10^{2} \times m \times 2.5\ \mathrm{s}^{-1}}{4\pi\left(35\ \right)^2} = 4.0\ \mathrm{s}^{-1},$$

or

$$m = \frac{4.0 \times 4\pi\left(35\ \right)^2}{10.29 \times 10^{2} \times 2.5} = 23.9.$$

The amount of $^{240}\mathrm{Pu}$ in the warhead is 23.9 g.