845.

Problem 54.59 (RHK)

The plutonium isotope ^{239}Pu, *atomic mass* 239.05 u, *is produced as a by-product in nuclear reactors and hence is accumulating in reactor fuel elements. It is radioactive, decaying by alpha decay with a half-life of* 2.411×10^{4} y. *But plutonium is also one of the most toxic chemicals known*; *as little as* 2.00 mg *is lethal to a human. We have to answer the following*: (a) *how many nuclei constitute a chemically lethal dose*? (b) *What is the decay rate of this amount*? (s) *What is its activity in curies*?

Solution:

(a)

The atomic mass of ^{239}Pu is 239.05 u. Therefore, number of nuclei of ^{239}Pu contained in 2.00 mg, which is lethal to human beings, will be

$$N(2.0\text{ mg}) = \frac{2.0\times10^{-3}\text{ g}}{239.05\times1.6605\times10^{-24}\text{ g}}$$
$$= 5.04\times10^{18}.$$

(b)

The plutonium isotope ^{239}Pu is radio active and decays by alpha decay with a half-life of 2.411×10^{4} y.

Therefore, its disintegrations constant is

$$\lambda = \frac{\ln 2}{2.411\times10^{4}\times3.156\times10^{7}\ \text{s}}$$
$$= 9.11\times10^{-13}\ \text{s}^{-1}.$$

Therefore, the decay rate of 2.0 mg of the plutonium isotope ^{239}Pu will be

$$R = N(2.0\ \text{mg})\lambda = 5.04\times10^{18}\times9.11\times10^{-13}\ \text{s}^{-1}$$
$$= 4.59\times10^{6}\ \text{disintegrations per second.}$$

(c)

We know that

$1\ \text{curie} = 3.7\times10^{10}$ disintegrations per second.

Therefore, the decay rates in curies is

$$R = \frac{4.59\times10^{6}}{3.7\times10^{10}}\ \text{disintegrations per second}$$
$$= 0.124\ \text{mCi}.$$