848.

<u>Problem 54.65 (RHK)</u>

An 87-kg *worker at a breeder reactor plant accidentally ingests* 2.5 mg *of* ^{239}Pu *dust*. ^{239}Pu *has a half-life of* 24,100 y, *decaying by alpha decay*. *The energy of the emitted* α *particles is* 5.2 MeV, *with a quality factor of* 13. *We may assume that the plutonium resides in the worker's body for* 12 h, *and that* 95% *of the emitted* α *particles are stopped within the body*. *We have to calculate* (a) *the number of plutonium atoms ingested*; (b) *the number that decay during the* 12 h; (c) *the energy absorbed by the body*; (d) *the resulting physical dose in rad*; *and* (e) *the equivalent biological dose in rem.*

<u>Solution:</u>

(a)

The number of ^{239}Pu atoms in 2.5 mg of ^{239}Pu dust will be

$$N = \frac{6.02\times10^{23}\times2.5\times10^{-3}\ \text{g}}{239\ \text{g}} = 6.29\times10^{18}.$$

(b)

The half-life of ^{239}Pu is 24,100 y. Therefore, its disintegration constant will be

$$\lambda = \frac{\ln 2}{24{,}100 \times 3.156 \times 10^{7}\ \text{s}} = 9.11 \times 10^{-13}\ \text{s}^{-1}.$$

The decay rate of 6.29×10^{18} ^{239}Pu-nuclides will be

$$R = N\lambda = 6.29 \times 10^{18} \times 9.11 \times 10^{-13}\ \text{s}^{-1}$$
$$= 5.73 \times 10^{6}\ \text{disintegrations per second.}$$

Therefore, of the 6.29×10^{18} ^{239}Pu-nuclides that would have decayed in 12 h will be

$$5.73 \times 10^{6} \times 12 \times 3600 = 2.47 \times 10^{11}.$$

(c)

The energy of the emitted α particles is 5.2 MeV, with a quality factor of 13 and that 95% of the emitted α particles are stopped within the body. Therefore, the energy absorbed by the body will be

$$= 2.47 \times 10^{11} \times 5.2 \times 1.6 \times 10^{-13} \times 0.95\ \text{J}$$
$$= 195.6\ \text{mJ.}$$

(d)

The strength of radiation is defined as 1 rad if 10^{-5} J g^{-1} of energy is absorbed by the body. Therefore, the resultant physical dose will be

$$\frac{195.6\times10^{-3}\ \text{J}}{87\times10^{3}\ \text{g}} = 2.25\times10^{-6}\ \text{J g}^{-1} = 0.225\ \text{rad.}$$

(e)

As the quality factor of alpha particle radiation is 13, the equivalent biological dose will be $0.225\times13\ \text{rem} = 2.9\ \text{rem}$.