847.

Problem 54.63 (RHK)

One of the dangers of radioactive fallout from a nuclear bomb is ^{90}Sr, *which beta decays with a half-life of* 29-y *half-life. Because it has chemical properties much like calcium, the strontium, if eaten by a cow, becomes concentrated in its milk and ends up in the bones of whoever drinks the milk. The energetic decay electrons damage the bone marrow and thus impair the production of red blood cells. A* 1- megaton *bomb produces approximately* 400 g *of* ^{90}Sr. *Assuming that the fallout spreads uniformly over a* $2000\ \text{km}^2$ *area, we have to find the area that would have radioactivity equal to the allowed bone burden for one person of* 0.002 mCi. *The atomic mass of* ^{90}Sr is 89.9 u.

Solution:

The atomic mass of ^{90}Sr is 89.9 u. A 1- megaton bomb produces approximately 400 g of ^{90}Sr. Therefore, the number of ^{90}Sr atoms in 400 g will be

$$N = \frac{400\ \text{g}}{89.9 \times 1.6605 \times 10^{-24}\ \text{g}} = 2.68 \times 10^{24}.$$

Assuming that the fallout spreads uniformly over a $2000\ \text{km}^2$ area, the number of ^{90}Sr atoms per m^2 will be

$$n_{\text{area}} = \frac{2.68 \times 10^{24}}{2.0 \times 10^{3} \times 10^{6}} = 1.34 \times 10^{15}\ \text{atoms per m}^2.$$

The beta decay half-life of ^{90}Sr is 29 y. Therefore, its disintegration constant will be

$$\lambda = \frac{\ln 2}{29 \times 3.156 \times 10^{7}\ \text{s}} = 7.57 \times 10^{-10}\ \text{s}^{-1}.$$

We are given that the radioactivity equal to the allowed bone burden for one person is 0.002 mCi, or

$0.002 \times 10^{-3} \times 3.7 \times 10^{10} = 74{,}000$ disintegrations per second.

Therefore, the element of area, a, that will have the activity of 0.002 mCi will be given by

$n_{\text{area}} a\lambda = 74{,}000\ \text{s}^{-1}$,

or

$1.34 \times 10^{15} \times 7.57 \times 10^{-10} \times a\ \text{m}^{-2}\ \text{s}^{-1} = 7.4 \times 10^{4}\ \text{s}^{-1}$,

or

$$a = \frac{7.4 \times 10^{4}\ \text{s}^{-1}}{1.34 \times 10^{15} \times 7.57 \times 10^{-10}\ \text{m}^{-2}\ \text{s}^{-1}} = 7.295 \times 10^{-2}\ \text{m}^2$$

$$= 730\ \text{cm}^2.$$