831.

Problem 54.33 (RHK)

^{239}Pu, *atomic mass* = 239 u, *decays by* α *decay with a half-life of* 24,100 y. *We have to calculate the amount of helium in grams produced by an initially pure* 12.0-g *sample of* ^{239}Pu *after* 20,000 y. *We recall that* α *particle is a helium nucleus and has an atomic mass of* 4.00 u.

Solution:

^{239}Pu, atomic mass = 239 u, decays by α decay with a half-life of 24,100 y. The decay constant of ^{239}Pu will therefore be

$$\lambda = \frac{\ln 2}{24{,}100}\ \text{y}^{-1} = 2.876\times10^{-5}\ \text{y}^{-1}.$$

The atomic mass of ^{239}Pu is 239 u. Therefore, the number of nuclides in a 12.0 g sample of pure ^{239}Pu will be

$$N_0 = \frac{12.0}{239\times1.6605\times10^{-24}} = 3.02\times10^{22}.$$

In 20,000 y the number of α particles produced by radioactive decay of 3.02×10^{25} $^{239}\mathrm{Pu}$ nuclides would be given by

$$3.02\times10^{22}\left(1-e^{-2.876\times10^{-5}\times2.0\times10^{4}}\right)$$

$$=3.02\times10^{22}\left(1-e^{-0.5752}\right)$$

$$=3.02\times10^{22}\left(1-0.562\right)=1.32\times10^{22}.$$

As α particle is a helium nucleus and has an atomic mass of 4.00 u the amount of helium produced by 12.0 g of $^{239}\mathrm{Pu}$ in 20,000 y will therefore be

$$1.32\times10^{22}\times4\times1.6605\times10^{-24}\ \mathrm{g}=8.77\times10^{-2}\ \mathrm{g}.$$