834.

Problem 54.36(RHK)

There was a speculation that the free proton may not actually be a stable particle but may be radioactive, with a half-life of about 1×10^{32} y. *If this turns out to be true, we have to estimate how long one would have to wait to be reasonably sure that at least one proton in one's body has decayed. We may assume that person is made of water and has a mass of* 70 kg.

Solution:

We will assume that the half-life of decay of a proton is 1×10^{32} y. The disintegration constant for proton decay will therefore be

$$\lambda = \frac{\ln 2}{1.0\times10^{32}\ \text{y}} = 0.693\times10^{-32}\ \text{y}^{-1}.$$

We may assume that a person is made of water and has a mass of 70 kg. Each molecule of water, H_2O, has 10 protons. As the mass of 1 mol of H_2O molecules is 18 g, the number of protons in 70 kg of water will be

$$N = \frac{6.02\times10^{23}\times10\times70\times10^{3}}{18} = 2.34\times10^{28}.$$

Proton decay rate in 70 kg of water will be

$$R = \left|\frac{dN}{dt}\right| = \lambda N = 0.693\times10^{-32}\times2.34\times10^{28} \text{ protons per year}$$

$$= 1.62\times10^{-4} \text{ protons per year.}$$

Therefore, the time period in which one proton may decay will be about

$$t = \frac{1}{R} = \frac{1}{1.62\times10^{-4}} \text{ y} = 6{,}164 \text{ y.}$$