9. (a) The mass of a single atom of $^{235}$U is

$$m_0 = (235\text{ u})(1.661 \times 10^{-27}\text{ kg/u}) = 3.90 \times 10^{-25}\text{ kg},$$

so the number of atoms in $m$ = 1.0 kg is

$$N = m/m_0 = (1.0\text{ kg})/(3.90 \times 10^{-25}\text{ kg}) = 2.56 \times 10^{24} \approx 2.6 \times 10^{24}.$$

An alternate approach (but essentially the same once the connection between the "u" unit and $N_A$ is made) would be to adapt Eq. 42-21.

(b) The energy released by $N$ fission events is given by $E = NQ$, where $Q$ is the energy released in each event. For 1.0 kg of $^{235}$U,

$$E = (2.56 \times 10^{24})(200 \times 10^{6}\text{ eV})(1.60 \times 10^{-19}\text{ J/eV}) = 8.19 \times 10^{13}\text{ J} \approx 8.2 \times 10^{13}\text{ J}.$$

(c) If $P$ is the power requirement of the lamp, then

$$t = E/P = (8.19 \times 10^{13}\text{ J})/(100\text{ W}) = 8.19 \times 10^{11}\text{ s} = 2.6 \times 10^{4}\text{ y}.$$

The conversion factor $3.156 \times 10^7$ s/y is used to obtain the last result.

10. The energy released is

$$\begin{aligned} Q &= (m_{\text{U}} + m_n - m_{\text{Cs}} - m_{\text{Rb}} - 2m_n)c^2 \\ &= (235.04392\text{ u} - 1.00867\text{ u} - 140.91963\text{ u} - 92.92157\text{ u})(931.5\text{ MeV/u}) \\ &= 181\text{ MeV}. \end{aligned}$$

12. (a) Consider the process $^{239}\text{U} + \text{n} \rightarrow {}^{140}\text{Ce} + {}^{99}\text{Ru} + \text{Ne}.$ We have

$$Z_f - Z_i = Z_{\text{Ce}} + Z_{\text{Ru}} - Z_{\text{U}} = 58 + 44 - 92 = 10.$$

Thus the number of beta-decay events is 10.

(b) Using Table 37-3, the energy released in this fission process is

$$\begin{aligned} Q &= (m_{\text{U}} + m_n - m_{\text{Ce}} - m_{\text{Ru}} - 10m_e)c^2 \\ &= (238.05079\text{ u} + 1.00867\text{ u} - 139.90543\text{ u} - 98.90594\text{ u})(931.5\text{ MeV/u}) - 10(0.511\text{ MeV}) \\ &= 226\text{ MeV}. \end{aligned}$$

21. If $R$ is the decay rate then the power output is $P = RQ$, where $Q$ is the energy produced by each alpha decay. Now

$$R = \lambda N = N \ln 2/T_{1/2},$$

where $\lambda$ is the disintegration constant and $T_{1/2}$ is the half-life. The relationship $\lambda = (\ln 2)/T_{1/2}$ is used. If $M$ is the total mass of material and $m$ is the mass of a single $^{238}$Pu nucleus, then

$$N = \frac{M}{m} = \frac{1.00 \text{ kg}}{(238 \text{ u})(1.661 \times 10^{-27} \text{ kg/u})} = 2.53 \times 10^{24}.$$

Thus,

$$P = \frac{NQ \ln 2}{T_{1/2}} = \frac{(2.53 \times 10^{24})(5.50 \times 10^{6} \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})(\ln 2)}{(87.7 \text{ y})(3.156 \times 10^{7} \text{ s/y})} = 557 \text{ W}.$$