29.10 (a) For ${}^{2}_{1}\text{H}$,

$$\Delta m = 1(1.007\,825\,\text{u}) + 1(1.008\,665\,\text{u}) - (2.014\,102\,\text{u}) = 0.002\,388\,\text{u}$$

and $$\frac{E_b}{A} = \frac{(\Delta m)c^2}{A} = \frac{(0.002\,388\,\text{u})(931.5\ \text{MeV/u})}{2} = \boxed{1.11\ \text{MeV/nucleon}}$$

(b) For ${}^{4}_{2}\text{He}$,

$$\Delta m = 2(1.007\,825\,\text{u}) + 2(1.008\,665\,\text{u}) - (4.002\,602\,\text{u}) = 0.030\,378\,\text{u}$$

and $$\frac{E_b}{A} = \frac{(\Delta m)c^2}{A} = \frac{(0.030\,378\,\text{u})(931.5\ \text{MeV/u})}{4} = \boxed{7.07\ \text{MeV/nucleon}}$$

(c) For ${}^{56}_{26}\text{Fe}$,

$$\Delta m = 26(1.007\,825\,\text{u}) + 30(1.008\,665\,\text{u}) - (55.934\,940) = 0.528\,460\,\text{u}$$

and $$\frac{E_b}{A} = \frac{(\Delta m)c^2}{A} = \frac{(0.528\,460\,\text{u})(931.5\ \text{MeV/u})}{56} = \boxed{8.79\ \text{MeV/nucleon}}$$

(d) For ${}^{238}_{92}\text{U}$,

$$\Delta m = 92(1.007\,825\,\text{u}) + 146(1.008\,665\,\text{u}) - (238.050\,784) = 1.934\,206\,\text{u}$$

and $$\frac{E_b}{A} = \frac{(\Delta m)c^2}{A} = \frac{(1.934\,206\,\text{u})(931.5\ \text{MeV/u})}{238} = \boxed{7.57\ \text{MeV/nucleon}}$$

29.13 For ${}^{23}_{11}\text{Na}$,

$$\Delta m = 11(1.007\,825\,\text{u}) + 12(1.008\,665\,\text{u}) - (22.989\,770\,\text{u}) = 0.200\,285\,\text{u}$$

and $$\frac{E_b}{A} = \frac{(\Delta m)c^2}{A} = \frac{(0.200\,285\,\text{u})(931.5\ \text{MeV/u})}{23} = 8.111\ \text{MeV/nucleon}$$

For ${}^{23}_{12}\text{Mg}$,

$$\Delta m = 12(1.007\,825\,\text{u}) + 11(1.008\,665\,\text{u}) - (22.994\,127\,\text{u}) = 0.195\,088\,\text{u}$$

so $$\frac{E_b}{A} = \frac{(\Delta m)c^2}{A} = \frac{(0.195\,088\,\text{u})(931.5\ \text{MeV/u})}{23} = 7.901\ \text{MeV/nucleon}$$

The binding energy per nucleon is

greater for ${}^{23}_{11}\text{Na}$ by $\boxed{0.210\ \text{MeV/nucleon}}$

This is attributable to $\boxed{\text{less proton repulsion in } {}^{23}_{11}\text{Na}}$

29.20 Recall that the activity of a radioactive sample is directly proportional to the number of radioactive nuclei present and hence, to the mass of the radioactive material present.

Thus, $\frac{R}{R_0} = \frac{N}{N_0} = \frac{m}{m_0}$ and $R = R_0 e^{-\lambda t}$ becomes $m = m_0 e^{-\lambda t}$

The decay constant is $$\lambda = \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{3.83\ \text{d}} = 0.181\ \text{d}^{-1}$$

If $m_0 = 3.00\ \text{g}$ and the elapsed time is $t = 1.50\ \text{d}$, the mass of radioactive material remaining is

$$m = m_0 e^{-\lambda t} = (3.00\ \text{g})e^{-(0.181\ \text{d}^{-1})(1.50\ \text{d})} = \boxed{2.29\ \text{g}}$$

29.23 (a) The initial activity is $R_0 = 10.0\ \text{mCi}$, and at $t = 4.00\ \text{h}$, $R = 8.00\ \text{mCi}$. Then, from $R = R_0\, e^{-\lambda t}$, the decay constant is

$$\lambda = -\frac{\ln(R/R_0)}{t} = -\frac{\ln(0.800)}{4.00\ \text{h}} = \boxed{5.58\times10^{-2}\ \text{h}^{-1}}$$

and the half-life is $$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{5.58\times10^{-2}\ \text{h}^{-1}} = \boxed{12.4\ \text{h}}$$

(b) $$N_0 = \frac{R_0}{\lambda} = \frac{(10.0\times10^{-3}\ \text{Ci})(3.70\times10^{10}\ \text{s}^{-1}/1\ \text{Ci})}{(5.58\times10^{-2}\ \text{h}^{-1})(1\ \text{h}/3\,600\ \text{s})} = \boxed{2.39\times10^{13}\ \text{nuclei}}$$

(c) $$R = R_0\, e^{-\lambda t} = (10.0\ \text{mCi})e^{-(5.58\times10^{-2}\ \text{h}^{-1})(30\ \text{h})} = \boxed{1.9\ \text{mCi}}$$

29.32 (a) $\boxed{{}^{66}_{28}\text{Ni} \rightarrow {}^{66}_{29}\text{Cu} + {}^{0}_{-1}\text{e} + \bar{\nu}}$

(b) Because of the mass differences, neglect the kinetic energy of the recoiling daughter nucleus in comparison to that of the other decay products. Then, the maximum kinetic energy of the beta particle occurs when the neutrino is given zero energy. That maximum is

$$KE_{\max} = \left(m_{^{66}\text{Ni}} - m_{^{66}\text{Cu}}\right)c^2 = \left(65.929\,1\text{ u} - 65.928\,9\text{ u}\right)\left(931.5\text{ MeV/u}\right)$$

$$= 0.186\text{ MeV} = \boxed{186\text{ keV}}$$

29.34 The initial activity of the 1.00-kg carbon sample would have been

$$R_0 = \left(1.00\times 10^3\text{ g}\right)\left(\frac{15.0\text{ counts/min}}{1.00\text{ g}}\right) = 1.50\times 10^4\text{ min}^{-1}$$

From $R = R_0 e^{-\lambda t}$, and $T_{1/2} = 5\,730\text{ yr}$ for ${}^{14}\text{C}$ (Appendix B), the age of the sample is

$$t = -\frac{\ln\left(R/R_0\right)}{\lambda} = -T_{1/2}\frac{\ln\left(R/R_0\right)}{\ln 2}$$

$$= -\left(5\,730\text{ yr}\right)\frac{\ln\left(\dfrac{2.00\times 10^3\text{ min}^{-1}}{1.50\times 10^4\text{ min}^{-1}}\right)}{\ln 2} = \boxed{1.67\times 10^4\text{ yr}}$$

29.53 From $R = R_0 e^{-\lambda t}$, the elapsed time is

$$t = -\frac{\ln\left(R/R_0\right)}{\lambda} = -T_{1/2}\frac{\ln\left(R/R_0\right)}{\ln 2} = -\left(14.0\text{ d}\right)\frac{\ln\left(20.0\text{ mCi}/200\text{ mCi}\right)}{\ln 2} = \boxed{46.5\text{ d}}$$