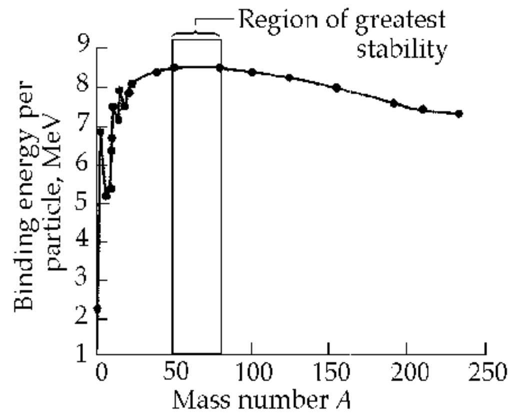
***30.9** $\Delta E_b = E_{bf} - E_{bi}$



For $A = 200,\quad \dfrac{E_b}{A} = 7.4 \text{ MeV}$

so $E_{bi} = 200(7.4 \text{ MeV}) = 1480 \text{ MeV}$

For $A \cong 100,\quad \dfrac{E_b}{A} \cong 8.4 \text{ MeV}$

so $E_{bf} = 2(100)(8.4 \text{ MeV}) = 1680 \text{ MeV}$

$\Delta E_b = E_{bf} - E_{bi}$: $E_b = 1680 \text{ MeV} - 1480 \text{ MeV} = \boxed{200 \text{ MeV}}$

30.10 Using atomic masses as given in Table A.3,

(a) For ${}^2_1\text{H}$: $\dfrac{-2.014102 + 1(1.008665) + 1(1.007825)}{2}$

$$E_b / A = (0.001194 \text{ u})\left(\frac{931.5 \text{ MeV}}{\text{u}}\right) = \boxed{1.11 \text{ MeV/nucleon}}$$

(b) For ${}^4_2\text{He}$: $\dfrac{2(1.008665) + 2(1.007825) - 4.002602}{4}$

$$E_b / A = 0.00759 \text{ u}c^2 = \boxed{7.07 \text{ MeV/nucleon}}$$

(c) For ${}^{56}_{26}\text{Fe}$: $30(1.008665) + 26(1.007825) - 55.934940 = 0.528 \text{ u}$

$$E_b / A = \frac{0.528}{56} = 0.00944 \text{ u}c^2 = \boxed{8.79 \text{ MeV/nucleon}}$$

(d) For ${}^{238}_{92}\text{U}$: $146(1.008665) + 92(1.007825) - 238.050784 = 1.9342 \text{ u}$

$$E_b / A = \frac{1.9342}{238} = 0.00813 \text{ u}c^2 = \boxed{7.57 \text{ MeV/nucleon}}$$

30.13 $\dfrac{dN}{dt} = -\lambda N$

so $\lambda = \dfrac{1}{N}\left(-\dfrac{dN}{dt}\right) = (1.00 \times 10^{-15})(6.00 \times 10^{11}) = 6.00 \times 10^{-4} \text{ s}^{-1}$

$$T_{1/2} = \frac{\ln 2}{\lambda} = \boxed{1.16 \times 10^3 \text{ s}} \ (= 19.3 \text{ min})$$

30.15 (a) From $R = R_0 e^{-\lambda t}$,

$$\lambda = \frac{1}{t}\ln\left(\frac{R_0}{R}\right) = \left(\frac{1}{4.00\text{ h}}\right)\ln\left(\frac{10.0}{8.00}\right) = 5.58\times10^{-2}\text{ h}^{-1} = \boxed{1.55\times10^{-5}\text{ s}^{-1}}$$

$$T_{1/2} = \frac{\ln 2}{\lambda} = \boxed{12.4\text{ h}}$$

(b) $$N_0 = \frac{R_0}{\lambda} = \frac{10.0\times10^{-3}\text{ Ci}}{1.55\times10^{-5}/\text{s}}\left(\frac{3.70\times10^{10}/\text{s}}{1\text{ Ci}}\right) = \boxed{2.39\times10^{13}\text{ atoms}}$$

(c) $$R = R_0 e^{-\lambda t} = (10.0\text{ mCi})\exp(-5.58\times10^{-2}\times30.0) = \boxed{1.87\text{ mCi}}$$

***30.18** (a) $$4.00\text{ pCi/L} = \left(\frac{4.00\times10^{-12}\text{ Ci}}{1\text{ L}}\right)\left(\frac{3.70\times10^{10}\text{ Bq}}{1\text{ Ci}}\right)\left(\frac{1.00\times10^{3}\text{ L}}{1\text{ m}^3}\right) = \boxed{148\text{ Bq/m}^3}$$

(b) $$N = \frac{R}{\lambda} = R\left(\frac{T_{1/2}}{\ln 2}\right) = \left(148\text{ Bq/m}^3\right)\left(\frac{3.82\text{ d}}{\ln 2}\right)\left(\frac{86400\text{ s}}{1\text{ d}}\right) = \boxed{7.05\times10^{7}\text{ atoms/m}^3}$$

(c) $$\text{mass} = \left(7.05\times10^{7}\text{ atoms/m}^3\right)\left(\frac{1\text{ mol}}{6.02\times10^{23}\text{ atoms}}\right)\left(\frac{222\text{ g}}{1\text{ mol}}\right) = 2.60\times10^{14}\text{ g/m}^3$$

Since air has a density of 1.20 kg/m^3, the fraction consisting of radon is

$$\text{fraction} = \frac{2.60\times10^{-14}\text{ g/m}^3}{1.20\text{ kg/m}^3} = \boxed{2.17\times10^{-17}}$$

30.20 (a) A gamma ray has zero charge and it contains no protons or neutrons. So for a gamma ray $Z = 0$ and $A = 0$. Keeping the total values of Z and A for the system conserved then requires $Z = 28$ and $A = 65$ for X. With this atomic number it must be nickel, and the nucleus must be in an exited state, so it is ${}^{65}_{28}\text{Ni}^*$.

(b) $\alpha = {}^{4}_{2}\text{He}$ has $Z = 2$ and $A = 4$

so for X we require $Z = 84 - 2 = 82$

for Pb and $A = 215 - 4 = 211$, $X = {}^{211}_{82}\text{Pb}$

(c) A positron $e^+ = {}^{0}_{1}e$ has charge the same as a nucleus with $Z = 1$. A neutrino ${}^{0}_{0}\nu$ has no charge. Neither contains any protons or neutrons. So X must have by conservation $Z = 26 + 1 = 27$. It is Co. And $A = 55 + 0 = 55$. It is ${}^{55}_{27}\text{Co}$.

Similar reasoning about balancing the sums of Z and A across the reaction reveals:

(d) ${}^{0}_{-1}e$

(e) ${}^{1}_{1}\text{H}$ (or p)

30.22 $$N_C = \left(\frac{0.0210\ \text{g}}{12.0\ \text{g/mol}}\right)\left(6.02\times10^{23}\ \text{molecules/mol}\right)$$

$\left(N_C = 1.05\times10^{21}\ \text{carbon atoms}\right)$ of which 1 in 7.70×10^{11} is a ^{14}C atom

$(N_0)_{\text{C-14}} = 1.37\times10^{9}$, $\quad \lambda_{\text{C-14}} = \dfrac{\ln 2}{5730\ \text{yr}} = 1.21\times10^{-4}\ \text{yr}^{-1} = 3.83\times10^{-12}\ \text{s}^{-1}$

$$R = \lambda N = \lambda N_0 e^{-\lambda t}$$

At $t = 0$, $\quad R_0 = \lambda N_0 = \left(3.83\times10^{-12}\ \text{s}^{-1}\right)\left(1.37\times10^{9}\right)\left[\dfrac{7(86400\ \text{s})}{1\ \text{week}}\right] = 3.17\times10^{3}\ \dfrac{\text{decays}}{\text{week}}$

At time t, $\quad R = \dfrac{837}{0.88} = 951\ \text{decays/week}$

Taking logarithms, $\ln\dfrac{R}{R_0} = -\lambda t \quad$ so $\quad t = \dfrac{-1}{\lambda}\ln\left(\dfrac{R}{R_0}\right)$

$$t = \frac{-1}{1.21\times10^{-4}\ \text{yr}^{-1}}\ln\left(\frac{951}{3.17\times10^{3}}\right) = \boxed{9.96\times10^{3}\ \text{yr}}$$

30.25 (a) $\boxed{e^- + p \rightarrow n + \nu}$

(b) For nuclei, $\quad ^{15}\text{O} + e^- \rightarrow {}^{15}\text{N} + \nu$

Add seven electrons to both sides to obtain $\quad \boxed{{}^{15}_{8}\text{O atom} \rightarrow {}^{15}_{7}\text{N atom} + \nu}$

(c) From Table A.3, $\quad m\left(^{15}\text{O}\right) = m\left(^{15}\text{N}\right) + \dfrac{Q}{c^2}$

$$\Delta m = 15.003\,065\ \text{u} - 15.000\,108\ \text{u} = 0.002\,957\ \text{u}$$

$$Q = (931.5\ \text{MeV/u})(0.002957\ \text{u}) = \boxed{2.75\ \text{MeV}}$$

***30.42** The number of nuclei in 0.155 kg of ^{210}Po is

$$N_0 = \left(\frac{155\text{ g}}{209.98\text{ g/mol}}\right)\left(6.02\times10^{23}\text{ nuclei/mol}\right) = 4.44\times10^{23}\text{ nuclei}$$

The half-life of ^{210}Po is 138.38 days, so the decay constant is given by

$$\lambda = \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{(138.38\text{ d})\left(8.64\times10^{4}\text{ s/d}\right)} = 5.80\times10^{-8}\text{ s}^{-1}$$

The initial activity is

$$R_0 = \lambda N_0 = \left(5.80\times10^{-8}\text{ s}^{-1}\right)\left(4.44\times10^{23}\text{ nuclei}\right) = 2.58\times10^{16}\text{ Bq}$$

The energy released in each $^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{Pb} + {}^{4}_{2}\text{He}$ reaction is

$$Q = \left[M_{^{210}_{84}\text{Po}} - M_{^{206}_{82}\text{Pb}} - M_{^{4}_{2}\text{He}}\right]c^2:$$

$$Q = \left[209.982848 - 205.974440 - 4.002602\right]\text{ u }(931.5\text{ MeV/u}) = 5.41\text{ MeV}$$

Thus, assuming a conversion efficiency of 1.00%, the initial power output of the battery is

$$\mathcal{P} = (0.0100)R_0Q = (0.0100)\left(2.58\times10^{16}\ \frac{\text{decays}}{\text{s}}\right)\left(5.41\ \frac{\text{MeV}}{\text{decay}}\right)\left(1.60\times10^{-13}\ \frac{\text{J}}{\text{MeV}}\right) = \boxed{223\text{ W}}$$

***30.47** (a) One liter of milk contains this many ^{40}K nuclei:

$$N = (2.00\text{ g})\left(\frac{6.02\times10^{23}\text{ nuclei/mol}}{39.1\text{ g/mol}}\right)\left(\frac{0.0117}{100}\right) = 3.60\times10^{18}\text{ nuclei}$$

$$\lambda = \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{1.28\times10^{9}\text{ yr}}\left(\frac{1\text{ yr}}{3.156\times10^{7}\text{ s}}\right) = 1.72\times10^{-17}\text{ s}^{-1}$$

$$R = \lambda N = \left(1.72\times10^{-17}\text{ s}^{-1}\right)\left(3.60\times10^{18}\right) = \boxed{61.8\text{ Bq}}$$

(b) For the iodine, $R = R_0 e^{-\lambda t}$ with $\lambda = \dfrac{\ln 2}{8.04\text{ d}}$

$$t = \frac{1}{\lambda}\ln\left(\frac{R_0}{R}\right) = \frac{8.04\text{ d}}{\ln 2}\ln\left(\frac{2000}{61.8}\right) = \boxed{40.3\text{ d}}$$