Chapter 29
Nuclear Physics

Answers to Even Numbered Conceptual Questions

4. An alpha particle is a doubly positive charged helium nucleus, is very massive and does not penetrate very well. A beta particle is a singly negative charged electron and is very light and only slightly more difficult to shield from. A gamma ray is a high energy photon, or high frequency electromagnetic wave, and has high penetrating ability.

6. Beta particles have greater penetrating ability than do alpha particles.

8. The much larger mass of the alpha particle as compared to that of the beta particle ensures that it will not deflect as much as does the beta, which has a mass about 7000 times smaller.

Problem Solutions

29.8 Using $r = r_0 A^{1/3}$, with $r_0 = 1.2 \times 10^{-15}\ \text{m} = 1.2\ \text{fm}$, gives:

(a) For ${}^{4}_{2}\text{He}, A = 4$, and $r = (1.2\ \text{fm})(4)^{1/3} = 1.9\ \text{fm} = \boxed{1.9 \times 10^{-15}\ \text{m}}$

(b) For ${}^{238}_{92}\text{He}, A = 238$, and $r = (1.2\ \text{fm})(238)^{1/3} = 7.4\ \text{fm} = \boxed{7.4 \times 10^{-15}\ \text{m}}$

29.12 $\Delta m = Z m_{\text{H}} + (A - Z) m_n - m$ and $E_b/A = \Delta m\,(931.5\ \text{MeV/u})/A$

Nucleus	Z	$(A - Z)$	m (in u)	Δm (in u)	E_b/A (in MeV)
${}^{55}_{25}\text{Mn}$	25	30	54.938 048	0.517 527	8.765
${}^{56}_{26}\text{Fe}$	26	30	55.934 940	0.528 460	8.786
${}^{59}_{27}\text{Co}$	27	32	58.933 198	0.555 357	8.768

Therefore, ${}^{56}_{26}\text{Fe}$ has a greater binding energy per nucleon than its neighbors. This gives us finer detail than is shown in Figure 29.4.

29.15 The decay constant is $\lambda = \dfrac{\ln 2}{T_{1/2}}$, so the activity is

$$R = \lambda N = \frac{N \ln 2}{T_{1/2}} = \frac{\left(3.0\times 10^{16}\right)\ln 2}{(14\text{ d})\left(8.64\times 10^{4}\text{ s/d}\right)} = 1.7\times 10^{10}\text{ decays/s}$$

or $$R = \left(1.7\times 10^{10}\text{ decays/s}\right)\left(\frac{1\text{ Ci}}{3.7\times 10^{10}\text{ decays/s}}\right) = \boxed{0.46\text{ Ci}}$$

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, $\dfrac{R}{R_0} = \dfrac{N}{N_0} = \dfrac{m}{m_0}$ 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

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

29.22 Using $R = R_0 e^{-\lambda t}$, with $R/R_0 = 0.125$, gives $\lambda t = -\ln\left(R/R_0\right)$

or $$t = -\frac{\ln\left(R/R_0\right)}{\lambda} = -T_{1/2}\left[\frac{\ln\left(R/R_0\right)}{\ln 2}\right] = -\left(5\,730\text{ yr}\right)\left[\frac{\ln\left(0.125\right)}{\ln 2}\right] = \boxed{1.72\times 10^{4}\text{ yr}}$$

29.25 $^{212}_{83}\text{Bi} \rightarrow \boxed{^{208}_{81}\text{Tl}} + {}^{4}_{2}\text{He}$

$^{95}_{36}\text{Kr} \rightarrow \boxed{^{95}_{37}\text{Rb}} + {}^{0}_{-1}\text{e}$

$\boxed{^{144}_{60}\text{Nd}} \rightarrow {}^{4}_{2}\text{He} + {}^{140}_{58}\text{Ce}$

29.30 The energy released in the decay ${}^{238}_{92}\text{U} \rightarrow {}^{4}_{2}\text{He} + {}^{234}_{90}\text{Th}$ is

$$Q = (\Delta m)c^2 = \left[m_{^{238}\text{U}} - \left(m_{^{4}\text{He}} + m_{^{234}\text{Th}}\right)\right]c^2$$

$$= \left[238.050\,784 \text{ u} - \left(4.002\,602 \text{ u} + 234.043\,583 \text{ u}\right)\right]\left(931.5 \text{ MeV/u}\right)$$

$$= \boxed{4.28 \text{ MeV}}$$

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

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