4.  
   a. \( \frac{73}{31} \text{Ga} \rightarrow \frac{73}{32} \text{Ge} + \frac{0}{1} \text{e} \)
   b. \( \frac{192}{78} \text{Pt} \rightarrow \frac{188}{76} \text{Os} + \frac{4}{2} \text{He} \)
   c. \( \frac{205}{85} \text{Bi} \rightarrow \frac{205}{82} \text{Pb} + \frac{0}{1} \text{e} \)
   d. \( \frac{241}{96} \text{Cm} + \frac{0}{1} \text{e} \rightarrow \frac{241}{95} \text{Am} \)
   e. \( \frac{60}{27} \text{Co} \rightarrow \frac{60}{28} \text{Ni} + \frac{0}{1} \text{e} \)
   f. \( \frac{97}{43} \text{Tc} + \frac{0}{1} \text{e} \rightarrow \frac{97}{42} \text{Mo} \)
   g. \( \frac{99}{43} \text{Tc} \rightarrow \frac{99}{44} \text{Ru} + \frac{0}{1} \text{e} \)
   h. \( \frac{239}{94} \text{Pu} \rightarrow \frac{235}{92} \text{U} + \frac{4}{2} \text{He} \)

6.  
   a. \( \frac{3}{1} \text{H} \rightarrow \frac{3}{2} \text{He} + \frac{0}{1} \text{e} \)
   b. \( \frac{8}{3} \text{Li} \rightarrow \frac{8}{4} \text{Be} + \frac{0}{1} \text{e} \)
   c. \( \frac{7}{4} \text{Be} + \frac{0}{1} \text{e} \rightarrow \frac{7}{3} \text{Li} \)
   d. \( \frac{8}{5} \text{B} \rightarrow \frac{8}{4} \text{Be} + \frac{0}{1} \text{e} \)

17.  
\[
175 \text{ mg Na}_3\text{PO}_4 \times \frac{32.0 \text{ mg } ^{32}\text{P}}{165.0 \text{ mg Na}_3\text{PO}_4} = 33.9 \text{ mg } ^{32}\text{P}; \ k = \frac{\ln 2}{t_{1/2}}
\]

\[
\ln \left( \frac{N}{N_0} \right) = -kt = \frac{-(0.693 \text{ d})t}{t_{1/2}}, \quad \ln \left( \frac{m}{33.9 \text{ mg}} \right) = \frac{-0.693 \text{ (35.0 d)}}{14.3 \text{ d}}; \text{ carrying extra sig. figs.}:
\]

\[
\ln (m) = -1.696 + 3.523 = 1.827, \quad m = e^{1.827} = 6.22 \text{ mg } ^{32}\text{P} \text{ remains}
\]

21.  
\[
t = 67.0 \text{ yr}; \quad k = \frac{\ln 2}{t_{1/2}}; \quad \ln \left( \frac{N}{N_0} \right) = -kt = \frac{-(0.6931)670 \text{ yr}}{28.9 \text{ yr}} = -1.61, \quad \left( \frac{N}{N_0} \right) = e^{-1.61} = 0.200
\]

20.0\% of the \(^{90}\text{Sr}\) remains as of July 16, 2012.

22.  
Assuming 2 significant figures in 1/100:

\[
\ln (N/N_0) = -kt; \quad N = (0.010)N_0; \quad t_{1/2} = (\ln 2)/k
\]

\[
\ln (0.010) = \frac{-(\ln 2)t}{t_{1/2}} = \frac{-(0.693)t}{8.0 \text{ d}}, \quad t = 53 \text{ days}
\]

25.  
Plants take in \( \text{CO}_2 \) during the photosynthesis process, which incorporates carbon, including \(^{14}\text{C}\), into its molecules. As long as the plant is alive, the \(^{14}\text{C}/^{12}\text{C}\) ratio in the plant will equal the ratio in the atmosphere. When the plant dies, \(^{14}\text{C}\) is not replenished because \(^{14}\text{C}\) decays by beta-particle production. By measuring the \(^{14}\text{C}\) activity today in the artifact and comparing this to the assumed \(^{14}\text{C}\) activity when the plant died to make the artifact, an age can be determined for the artifact. The assumptions are that the \(^{14}\text{C}\) level in the atmosphere is constant or that the \(^{14}\text{C}\) level at the time the plant died can be calculated. A constant \(^{14}\text{C}\) level is a pure assumption, and accounting for variation is complicated. Another problem is that some of the material must be destroyed to determine the \(^{14}\text{C}\) level.
34. For $^1_1$H: mass defect = $\Delta m = \text{mass of } ^1_1\text{H nucleus} - \text{mass of proton} - \text{mass of neutron}$. The mass of the $^1_1\text{H}$ nucleus will equal the atomic mass of $^1_1\text{H}$ minus the mass of the electron in an $^1_1\text{H}$ atom. From the text, the pertinent masses are: $m_e = 5.49 \times 10^{-4}$ amu, $m_p = 1.00728$ amu, and $m_n = 1.00866$ amu.

$$\Delta m = 2.01410 \text{ amu} - 0.000549 \text{ amu} - (1.00728 \text{ amu} + 1.00866 \text{ amu}) = -2.39 \times 10^{-3} \text{ amu}$$

$$\Delta E = \Delta mc^2 = -2.39 \times 10^{-3} \text{ amu} \times \frac{1.6605 \times 10^{-27} \text{ kg}}{\text{amu}} \times (2.998 \times 10^8 \text{ m/s})^2 = -3.57 \times 10^{-13} \text{ J}$$

$$\frac{\text{Binding energy}}{\text{Nucleon}} = \frac{3.57 \times 10^{-13} \text{ J}}{2 \text{ nucleons}} = 1.79 \times 10^{-13} \text{ J/nucleon}$$

For $^3_1$H: $\Delta m = 3.015605 - 0.000549 - [1.00728 + 2(1.00866)] = -9.10 \times 10^{-3}$ amu

$$\Delta E = -9.10 \times 10^{-3} \text{ amu} \times \frac{1.6605 \times 10^{-27} \text{ kg}}{\text{amu}} \times (2.998 \times 10^8 \text{ m/s})^2 = -1.36 \times 10^{-12} \text{ J}$$

$$\frac{\text{Binding energy}}{\text{Nucleon}} = \frac{1.36 \times 10^{-12} \text{ J}}{3 \text{ nucleons}} = 4.53 \times 10^{-13} \text{ J/nucleon}$$

40. $\Delta m = -2(5.486 \times 10^{-4} \text{ amu}) = -1.097 \times 10^{-3} \text{ amu}$

$$\Delta E = \Delta mc^2 = -1.097 \times 10^{-3} \text{ amu} \times \frac{1.6605 \times 10^{-27} \text{ kg}}{\text{amu}} \times (2.9979 \times 10^8 \text{ m/s})^2 = -1.637 \times 10^{-13} \text{ J}$$

$$E_{\text{photon}} = \frac{1}{2} (1.637 \times 10^{-13} \text{ J}) = 8.185 \times 10^{-14} \text{ J} = hc/\lambda.$$ 

$$\lambda = \frac{hc}{E} = \frac{6.6261 \times 10^{-34} \text{ Js} \times 2.9979 \times 10^8 \text{ m/s}}{8.185 \times 10^{-14} \text{ J}} = 2.427 \times 10^{-12} \text{ m} = 2.427 \times 10^{-3} \text{ nm}$$

45. Fission: Splitting of a heavy nucleus into two (or more) lighter nuclei.

Fusion: Combining two light nuclei to form a heavier nucleus.

The maximum binding energy per nucleon occurs at Fe. Nuclei smaller than Fe become more stable by fusing to form heavier nuclei closer in mass to Fe. Nuclei larger than Fe form more stable nuclei by splitting to form lighter nuclei closer in mass to Fe.

50. Radiotracer: a radioactive nuclide introduced into an organism for diagnostic purposes whose pathway can be traced by monitoring its radioactivity. $^{14}\text{C}$ and $^{32}\text{P}$ work well as radiotracers because the molecules in the body contain carbon and/or phosphorus; they will be incorporated into the worker molecules of the body easily, which allows monitoring of the pathways of these worker molecules.
54. Water is produced in this reaction by removing an OH group from one substance and an H from the other substance. There are two ways to do this:

i. \[
\text{CH}_3\text{CO} - \text{OH} + \text{H}{}^18\text{OCH}_3 \rightarrow \text{CH}_3\text{CO}{}^{18}\text{OCH}_3 + \text{HO} - \text{H}
\]

ii. \[
\text{CH}_3\text{CO} - \text{H} + \text{H}{}^18\text{O} - \text{CH}_3 \rightarrow \text{CH}_3\text{CO} - \text{CH}_3 + \text{H}{}^18\text{OH}
\]

Because the water produced is not radioactive, methyl acetate forms by the first reaction where all of the oxygen-18 ends up in methyl acetate.

61. \[
N = 180 \text{ lb} \times \frac{453.6 \text{ g}}{\text{lb}} \times \frac{18 \text{ g C}}{100 \text{ g body}} \times \frac{1.6 \times 10^{-10} \text{ g } ^{14}\text{C}}{100 \text{ g C}} \times \frac{1 \text{ mol } ^{14}\text{C}}{14 \text{ g } ^{14}\text{C}} \times \frac{6.022 \times 10^{23} \text{ nuclei } ^{14}\text{C}}{\text{mol } ^{14}\text{C}} = 1.0 \times 10^{15} \text{ nuclei } ^{14}\text{C}
\]

\[
\text{Rate} = kN; \quad k = \frac{\ln 2}{t_{1/2}} = \frac{0.693}{5730 \text{ yr}} \times \frac{1 \text{ yr}}{365 \text{ d}} \times \frac{1 \text{ d}}{24 \text{ h}} \times \frac{1 \text{ h}}{3600 \text{ s}} = 3.8 \times 10^{-12} \text{ s}^{-1}
\]

\[
\text{Rate} = kN; \quad k = 3.8 \times 10^{-12} \text{ s}^{-1} (1.0 \times 10^{15} \text{ nuclei } ^{14}\text{C}) = 3800 \text{ decays/s}
\]

A typical 180 lb person produces 3800 beta particles each second.