63. How long must you wait (in half-lives) for a radioactive sample to drop to 1.00% of its original activity?

64. If the potassium isotope $^{40}_{19}K$ gives 60 decays/s in a liter of milk, estimate how much $^{40}_{19}K$ and regular $^{39}_{19}K$ are in a liter of milk. Use Appendix B.

65. (*a*) In α decay of, say, a $^{226}_{88}Ra$ nucleus, show that the nucleus carries away a fraction $1/(1 + \frac{1}{4}A_D)$ of the total energy available, where A_D is the mass number of the daughter nucleus. [*Hint*: use conservation of momentum as well as conservation of energy.] (*b*) Approximately what percentage of the energy available is thus carried off by the α particle in the case cited?

66. Strontium-90 is produced as a nuclear fission product of uranium in both reactors and atomic bombs. Look at its location in the periodic table to see what other elements it might be similar to chemically, and tell why you think it might be dangerous to ingest. It has too many neutrons, and it decays with a half-life of about 29 yr. How long will we have to wait for the amount of $^{90}_{38}Sr$ on the Earth's surface to reach 1% of its current level, assuming no new material is scattered about? Write down the decay reaction, including the daughter nucleus. The daughter is radioactive: write down its decay.

67. The nuclide $^{191}_{76}Os$ decays with β^- energy of 0.14 MeV accompanied by γ rays of energy 0.042 MeV and 0.129 MeV. (*a*) What is the daughter nucleus? (*b*) Draw an energy-level diagram showing the ground states of the parent and daughter and excited states of the daughter. To which of the daughter states does β^- decay of $^{191}_{76}Os$ occur?

68. Determine the activities of (*a*) 1.0 g of $^{131}_{53}I$ $\left(T_{\frac{1}{2}} = 8.02 \text{ days}\right)$ and (*b*) 1.0 g of $^{238}_{92}U$ $\left(T_{\frac{1}{2}} = 4.47 \times 10^9 \text{ yr}\right)$.

69. Estimate the total binding energy for copper and then estimate the energy, in joules, needed to break a 3.0-g copper penny into its constituent nucleons. [*Hint*: use Fig. 30–1.]

70. Instead of giving atomic masses for nuclides as in Appendix B, some Tables give the *mass excess*, Δ, defined as $\Delta = M - A$, where A is the atomic number and M is the mass in u. Determine the mass excess, in u and in MeV/c^2, for: (*a*) $^{4}_{2}He$; (*b*) $^{12}_{6}C$; (*c*) $^{107}_{47}Ag$; (*d*) $^{235}_{92}U$. (*e*) From a glance at Appendix B, can you make a generalization about the sign of Δ as a function of Z or A?

71. (*a*) A 92-gram sample of natural carbon contains the usual fraction of $^{14}_{6}C$. Estimate how long it will take before there is only one $^{14}_{6}C$ nucleus left. (*b*) How does the answer in (*a*) change if the sample is 280 grams? What does this tell you about the limits of carbon dating?

72. If the mass of the proton were just a little closer to the mass of the neutron, the following reaction would be possible even at low collision energies:

$$e^- + p \rightarrow n + \nu.$$

Why would this situation be catastrophic? By what percentage would the proton's mass have to be increased to make this reaction possible?

73. What is the ratio of the kinetic energies for an alpha particle and a beta particle if both make tracks with the same radius of curvature in a magnetic field, oriented perpendicular to the paths of the particles?

74. A 1.00-g sample of natural samarium emits α particles at a rate of $120\ s^{-1}$ due to the presence of $^{147}_{62}Sm$. The natural abundance of $^{147}_{62}Sm$ is 15%. Calculate the half-life for this decay process.

75. Almost all of naturally occurring uranium is $^{238}_{92}U$ with a half-life of 4.468×10^9 yr. Most of the rest of natural uranium is $^{235}_{92}U$ with a half-life of 7.038×10^8 yr. Today a sample contains 0.72% $^{235}_{92}U$. (*a*) What was this percentage 1.0 billion years ago? (*b*) What percentage of the sample would be $^{235}_{92}U$ in 100 million years?

76. A typical banana contains 400 mg of potassium, of which a small fraction is the radioactive isotope $^{40}_{19}K$ (see Appendix B). Estimate the activity of an average banana due to $^{40}_{19}K$.

77. The practical limit for carbon-14 dating is about 60,000 years. If a bone contains 1.0 kg of carbon, and the animal died 60,000 years ago, what is the activity today?

78. Decay series, such as that shown in Fig. 30–11, can be classified into four families, depending on whether the mass numbers have the form $4n$, $4n + 1$, $4n + 2$, or $4n + 3$, where n is an integer. Justify this statement and show that for a nuclide in any family, all its daughters will be in the same family.

Answers to Exercises

A: 0.0421 u.

B: 7.98 MeV/nucleon.

C: $1.37 \times 10^{-11}\ s^{-1}$.

D: No: $\left(\frac{1}{2}\right)\left(\frac{1}{2}\right) = \frac{1}{4}$ will be left.