CH. 21 Answers to Selected Problems

2. In each of the following nuclear reactions, supply the missing particle.
   a. $^{73}Ga \rightarrow {}^{73}Ge + ?$? = beta particle
   b. $^{192}Pt \rightarrow {}^{188}Os + ?$? = alpha particle
   c. $^{205}Bi \rightarrow {}^{205}Pb + ?$? = positron
   d. $^{241}Cm + ? \rightarrow {}^{241}Am$? = beta particle

4. One type of commercial smoke detector contains a minute amount of radioactive americium-241, which decays by α-particle production. The α-particles ionize molecules in the air, allowing it to conduct an electric current. When smoke particles enter, the conductivity of the air changes and the alarm buzzes.
   a. Write the equation for the decay of ^{241}Am by α-particle production.

      $${}^{241}_{95}Am \longrightarrow {}^{4}_{2}\alpha + {}^{237}_{93}Np$$

   b. The complete decay of 241Am involves successively α, α, β, α, α, β, α, α, α, β, α, β production. What is the final stable nuclide produces in this decay series?
      If I count correctly, there are 8 a-particle emissions and 4 b-particle emissions. That means that we need to subtract 32 from the mass number (8 x 4), and 12 from the atomic number (8 x 2 + 4 x -1). That leaves us with ${}^{209}_{83}Bi$.
   c. Identify the 11 intermediate nuclides.

      $${}^{241}_{95}Am \rightarrow {}^{4}_{2}\alpha + {}^{237}_{93}Np \rightarrow {}^{4}_{2}\alpha + {}^{233}_{91}Pa \rightarrow {}^{0}_{-1}\beta + {}^{233}_{92}U \rightarrow {}^{4}_{2}\alpha + {}^{229}_{90}Th \rightarrow {}^{4}_{2}\alpha + {}^{225}_{88}Ra \rightarrow$$
      $${}^{0}_{-1}\beta + {}^{225}_{89}Ac \rightarrow {}^{4}_{2}\alpha + {}^{221}_{87}Fr \rightarrow {}^{4}_{2}\alpha + {}^{217}_{85}At \rightarrow {}^{4}_{2}\alpha + {}^{213}_{83}Bi \rightarrow {}^{0}_{-1}\beta + {}^{213}_{84}Po \rightarrow {}^{4}_{2}\alpha + {}^{209}_{82}Pb$$
      $$\rightarrow {}^{0}_{-1}\beta + {}^{209}_{83}Bi$$

12. Cobalt-60 is commonly used as a source of b-particles. How long does it take for 87.5% of a sample of cobalt-60 to decay (half-life = 5.26 years)?

If 87.5% has decayed, then 12.5% is still there. 12.5% happens to be in the path of half decays: 100 → 50 → 25 → 12.5. Each arrow represents a half-life, so we have three half-lives worth of decay. 3(5.26 years) = 15.8 years.

16. Iodine-131 is used in the diagnosis and treatment of thyroid disease and has a half-life of 8.1 days. If a patient with thyroid disease consumes a sample of $Na^{131}I$ containing 10 μg of ^{131}I, how long will it take for the amount of ^{131}I to decrease to 1/100 of the original amount?

The first step in problem of this type is to find the rate of decay (since 1/100 is not along the path of half decays), so

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{8.1\ d} = 0.085_6\ d^{-1}$$

Once we know k, we can work towards finding the amount of time the specified decay takes:

$$\ln\left[\frac{1}{100}\right] = -kt$$

$$\ln(0.01) = -(0.085_6\ d^{-1})\ t$$

$$-4.6 = -(0.085_6\ d^{-1})\ t$$

$$t = 54\ \text{days}$$

Notice that we don't use the actual amount of $Na^{131}I$ that was consumed, only the ratio of how much was left when we ended to what we started with!

22. A proposed system for storing nuclear wastes involves storing the radioactive material in caves or deep mine shafts. One of the most toxic nuclides that must be disposed of is plutonium-239, which is produced in breeder reactors and has a half-life of 24,100 years. A suitable storage place must be geologically stable long enough for the activity of plutonium-239 to decrease to 0.1% of its original value. How long is this period for plutonium-239?

This problem is done exactly the same as the previous problem. $k = 2.87_6 x10^{-5}\ y^{-1}$ and the ratio used in the brackets is 0.1/100. If you solve for t, you find that it will take 240000 years!