30–8 to 30–11 Half-Life, Decay Rates, Decay Series, Dating

36. (I) A radioactive material produces 1280 decays per minute at one time, and 4.6 h later produces 320 decays per minute. What is its half-life?

37. (I) (*a*) What is the decay constant of $^{238}_{92}\text{U}$ whose half-life is 4.5×10^9 yr? (*b*) The decay constant of a given nucleus is $8.2 \times 10^{-5}\,\text{s}^{-1}$. What is its half-life?

38. (I) What is the activity of a sample of $^{14}_{6}\text{C}$ that contains 3.1×10^{20} nuclei?

39. (I) What fraction of a sample of $^{68}_{32}\text{Ge}$, whose half-life is about 9 months, will remain after 3.0 yr?

40. (I) What fraction of a sample is left after exactly 6 half-lives?

41. (II) How many nuclei of $^{238}_{92}\text{U}$ remain in a rock if the activity registers 640 decays per second?

42. (II) In a series of decays, the nuclide $^{235}_{92}\text{U}$ becomes $^{207}_{82}\text{Pb}$. How many α and β^- particles are emitted in this series?

43. (II) The iodine isotope $^{131}_{53}\text{I}$ is used in hospitals for diagnosis of thyroid function. If 682 μg are ingested by a patient, determine the activity (*a*) immediately, (*b*) 1.0 h later when the thyroid is being tested, and (*c*) 6 months later. Use Appendix B.

44. (II) $^{124}_{55}\text{Cs}$ has a half-life of 30.8 s. (*a*) If we have 8.8 μg initially, how many Cs nuclei are present? (*b*) How many are present 2.0 min later? (*c*) What is the activity at this time? (*d*) After how much time will the activity drop to less than about 1 per second?

45. (II) Calculate the mass of a sample of pure $^{40}_{19}\text{K}$ with an initial decay rate of $2.0 \times 10^5\,\text{s}^{-1}$. The half-life of $^{40}_{19}\text{K}$ is 1.28×10^9 yr.

46. (II) Calculate the activity of a pure 9.7-μg sample of $^{32}_{15}\text{P}$ $\left(T_{\frac{1}{2}} = 1.23 \times 10^6\,\text{s}\right)$.

47. (II) The activity of a sample of $^{35}_{16}\text{S}$ $\left(T_{\frac{1}{2}} = 7.55 \times 10^6\,\text{s}\right)$ is 2.65×10^5 decays per second. What is the mass of the sample?

48. (II) A sample of $^{233}_{92}\text{U}$ $\left(T_{\frac{1}{2}} = 1.59 \times 10^5\,\text{yr}\right)$ contains 7.50×10^{19} nuclei. (*a*) What is the decay constant? (*b*) Approximately how many disintegrations will occur per minute?

49. (II) The activity of a sample drops by a factor of 10 in 8.6 minutes. What is its half-life?

50. (II) A 285-g sample of pure carbon contains 1.3 parts in 10^{12} (atoms) of $^{14}_{6}\text{C}$. How many disintegrations occur per second?

51. (II) A sample of $^{40}_{19}\text{K}$ is decaying at a rate of 6.70×10^2 decays/s. What is the mass of the sample?

52. (II) The rubidium isotope $^{87}_{37}\text{Rb}$, a β emitter with a half-life of 4.75×10^{10} yr, is used to determine the age of rocks and fossils. Rocks containing fossils of ancient animals contain a ratio of $^{87}_{38}\text{Sr}$ to $^{87}_{37}\text{Rb}$ of 0.0160. Assuming that there was no $^{87}_{38}\text{Sr}$ present when the rocks were formed, estimate the age of these fossils. [*Hint*: use Eq. 30–3.]

53. (II) Use Fig. 30–11 and calculate the relative decay rates for α decay of $^{218}_{84}\text{Po}$ and $^{214}_{84}\text{Po}$.

54. (II) $^{7}_{4}\text{Be}$ decays with a half-life of about 53 d. It is produced in the upper atmosphere, and filters down onto the Earth's surface. If a plant leaf is detected to have 450 decays/s of $^{7}_{4}\text{Be}$, (*a*) how long do we have to wait for the decay rate to drop to 15 per second? (*b*) Estimate the initial mass of $^{7}_{4}\text{Be}$ on the leaf.

55. (II) Two of the naturally occurring radioactive decay sequences start with $^{232}_{90}\text{Th}$, and $^{235}_{92}\text{U}$. The first five decays of these two sequences are:

$$\alpha, \beta, \beta, \alpha, \alpha$$

and

$$\alpha, \beta, \alpha, \beta, \alpha.$$

Determine the resulting intermediate daughter nuclei in each case.

56. (II) An ancient wooden club is found that contains 290 g of carbon and has an activity of 8.0 decays per second. Determine its age assuming that in living trees the ratio of $^{14}\text{C}/^{12}\text{C}$ atoms is about 1.3×10^{-12}.

57. (III) At $t = 0$, a pure sample of radioactive nuclei contains N_0 nuclei whose decay constant is λ. Determine a formula for the number of daughter nuclei, N_D, as a function of time; assume the daughter is stable and that $N_\text{D} = 0$ at $t = 0$.

General Problems

58. Which radioactive isotope of lead is being produced in a reaction where the measured activity of a sample drops to 1.050% of its original activity in 4.00 h?

59. An old wooden tool is found to contain only 6.0% of $^{14}_{6}\text{C}$ that a sample of fresh wood would. How old is the tool?

60. A neutron star consists of neutrons at approximately nuclear density. Estimate, for a 10-km-diameter neutron star, (*a*) its mass number, (*b*) its mass (kg), and (*c*) the acceleration of gravity at its surface.

61. The $^{3}_{1}\text{H}$ isotope of hydrogen, which is called *tritium* (because it contains three nucleons), has a half-life of 12.33 yr. It can be used to measure the age of objects up to about 100 yr. It is produced in the upper atmosphere by cosmic rays and brought to Earth by rain. As an application, determine approximately the age of a bottle of wine whose $^{3}_{1}\text{H}$ radiation is about $\frac{1}{10}$ that present in new wine.

62. Some elementary particle theories (Section 32–11) suggest that the proton may be unstable, with a half-life $\geq 10^{32}$ yr. How long would you expect to wait for one proton in your body to decay (consider that your body is all water)?