32. (II) Show that the energies carried off by the $^4_2$He nucleus and the neutron for the reaction of Eq. 31–8c are about 3.5 MeV and 14 MeV, respectively. Are these fixed values, independent of the plasma temperature?

33. (II) Suppose a fusion reactor ran on "d–d" reactions, Eqs. 31–8a and b. Estimate how much water, for fuel, would be needed per hour to run a 1000-MW reactor, assuming 30% efficiency.

34. (III) How much energy (J) is contained in 1.00 kg of water if its natural deuterium is used in the fusion reaction of Eq. 31–8a? Compare to the energy obtained from the burning of 1.0 kg of gasoline, about 5×10^7 J.

35. (III) The energy output of massive stars is believed to be due to the *carbon cycle* (see text). (*a*) Show that no carbon is consumed in this cycle and that the net effect is the same as for the proton–proton cycle. (*b*) What is the total energy release? (*c*) Determine the energy output for each reaction and decay. (*d*) Why does the carbon cycle require a higher temperature $(\approx 2 \times 10^7\,\text{K})$ than the proton–proton cycle $(\approx 1.5 \times 10^7\,\text{K})$?

36. (III) (*a*) Compare the energy needed for the first reaction of the carbon cycle to that for a deuterium–tritium reaction (Example 31–9). (*b*) If a deuterium–tritium reaction requires $T \approx 3 \times 10^8\,\text{K}$, estimate the temperature needed for the first carbon-cycle reaction.

31–5 Dosimetry

37. (I) A dose of 4.0 Sv of γ rays in a short period would be lethal to about half the people subjected to it. How many grays is this?

38. (I) Fifty rads of α-particle radiation is equivalent to how many rads of X-rays in terms of biological damage?

39. (I) How many rads of slow neutrons will do as much biological damage as 75 rads of fast neutrons?

40. (I) How much energy is deposited in the body of a 65-kg adult exposed to a 2.0-Gy dose?

41. (II) A 0.025-μCi sample of $^{32}_{15}$P is injected into an animal for tracer studies. If a Geiger counter intercepts 25% of the emitted β particles, what will be the counting rate, assumed 85% efficient?

42. (II) A cancer patient is undergoing radiation therapy in which protons with an energy of 1.2 MeV are incident on a 0.25-kg tumor. (*a*) If the patient receives an effective dose of 1.0 rem, what is the absorbed dose? (*b*) How many protons are absorbed by the tumor? Assume QF $\approx$ 1.

43. (II) A 1.0-mCi source of $^{32}_{15}$P (in $NaHPO_4$), a β emitter, is implanted in a tumor where it is to administer 36 Gy. The half-life of $^{32}_{15}$P is 14.3 days, and 1 mCi delivers about 10 mGy/min. Approximately how long should the source remain implanted?

44. (II) About 35 eV is required to produce one ion pair in air. Show that this is consistent with the two definitions of the roentgen given in the text.

45. (II) $^{57}_{27}$Co emits 122-keV γ rays. If a 70-kg person swallowed 1.85 μCi of $^{57}_{27}$Co, what would be the dose rate (Gy/day) averaged over the whole body? Assume that 50% of the γ-ray energy is deposited in the body. [*Hint*: determine the rate of energy deposited in the body and use the definition of the gray.]

46. (II) What is the mass of a 1.00-μCi $^{14}_{6}$C source?

47. (II) Huge amounts of radioactive $^{131}_{53}$I were released in the accident at Chernobyl in 1986. Chemically, iodine goes to the human thyroid. (Doctors can use it for diagnosis and treatment of thyroid problems.) In a normal thyroid, $^{131}_{53}$I absorption can cause damage to the thyroid. (*a*) Write down the reaction for the decay of $^{131}_{53}$I. (*b*) Its half-life is 8.0 d; how long would it take for ingested $^{131}_{53}$I to become 10% of the initial value? (*c*) Absorbing 1 mCi of $^{131}_{53}$I can be harmful; what mass of iodine is this?

48. (III) Assume a liter of milk typically has an activity of 2000 pCi due to $^{40}_{19}$K. If a person drinks two glasses (0.5 L) per day, estimate the total effective dose (in Sv and in rem) received in a year. As a crude model, assume the milk stays in the stomach 12 hr and is then released. Assume also that very roughly 10% of the 1.5 MeV released per decay is absorbed by the body. Compare your result to the normal allowed dose of 100 mrem per year. Make your estimate for (*a*) a 50-kg adult, and (*b*) a 5-kg baby.

49. (III) Radon gas, $^{222}_{86}$Rn, is considered a serious health hazard (see discussion in text). It decays by α-emission. (*a*) What is the daughter nucleus? (*b*) Is the daughter nucleus stable or radioactive? If the latter, how does it decay, and what is its half-life? (*c*) Is the daughter nucleus also a noble gas, or is it chemically reacting? (*d*) Suppose 1.0 ng of $^{222}_{86}$Rn seeps into a basement. What will be its activity? If the basement is then sealed, what will be the activity 1 month later? [*Hint*: see Fig. 30–11.]

31–9 NMR

50. (II) Calculate the wavelength of photons needed to produce NMR transitions in free protons in a 1.000-T field. In what region of the spectrum does it lie?

General Problems

51. J. Chadwick discovered the neutron by bombarding $^9_4$Be with the popular projectile of the day, alpha particles. (*a*) If one of the reaction products was the then unknown neutron, what was the other product? (*b*) What is the Q-value of this reaction?

52. Fusion temperatures are often given in keV. Determine the conversion factor from kelvins to keV using, as is common in this field, $\overline{\text{KE}} = kT$ without the factor $\frac{3}{2}$.

53. One means of enriching uranium is by diffusion of the gas UF_6. Calculate the ratio of the speeds of molecules of this gas containing $^{235}_{92}$U and $^{238}_{92}$U, on which this process depends.

54. (*a*) What mass of $^{235}_{92}$U was actually fissioned in the first atomic bomb, whose energy was the equivalent of about 20 kilotons of TNT (1 kiloton of TNT releases 5×10^{12} J)? (*b*) What was the actual mass transformed to energy?

55. In a certain town the average yearly background radiation consists of 21 mrad of X-rays and γ rays plus 3.0 mrad of particles having a QF of 10. How many rem will a person receive per year on the average?

56. Deuterium makes up 0.0115% of natural hydrogen on average. Make a rough estimate of the total deuterium in the Earth's oceans and estimate the total energy released if all of it were used in fusion reactors.