Pearson

Exercises

Review Questions

1. What is radioactivity? Who discovered it? How was it discovered?
2. Explain Marie Curie's role in the discovery of radioactivity.
3. Define A, Z, and X in the notation used to specify a nuclide: ${}^{A}_{Z}X$.
4. Use the notation from Question 3 to write symbols for a proton, a neutron, and an electron.
5. What is an alpha particle? What happens to the mass number and atomic number of a nuclide that emits an alpha particle?
6. What is a beta particle? What happens to the mass number and atomic number of a nuclide that emits a beta particle?
7. What is a gamma ray? What happens to the mass number and atomic number of a nuclide that emits a gamma ray?
8. What is a positron? What happens to the mass number and atomic number of a nuclide that emits a positron?
9. Describe the process of electron capture. What happens to the mass number and atomic number of a nuclide that undergoes electron capture?
10. Rank alpha particles, beta particles, positrons, and gamma rays in terms of: (a) increasing ionizing power; (b) increasing penetrating power.
11. Explain why the ratio of neutrons to protons (N/Z) is important in determining nuclear stability. How can you use the (N/Z) ratio of a nuclide to predict the kind of radioactive decay that it might undergo?
12. What are magic numbers? How are they important in determining the stability of a nuclide?
13. Describe the basic way that each device detects radioactivity: (a) thermoluminescent dosimeter; (b) Geiger-Müller counter; and (c) scintillation counter.
14. Explain the concept of half-life with respect to radioactive nuclides. What rate law is characteristic of radioactivity?
15. Explain the main concepts behind the technique of radiocarbon dating. How is radiocarbon dating corrected for changes in atmospheric concentrations of C-14? What range of ages is reliably determined by C-14 dating?
16. How is the uranium to lead ratio in a rock used to estimate its age? How does this dating technique provide an estimate for Earth's age? How old is Earth according to this dating method?
17. Describe fission. Include the concepts of chain reaction and critical mass in your description. How and by whom was fission discovered? Explain how fission is used to generate electricity.
18. What was the Manhattan Project? Briefly describe its development and culmination.
19. Describe the advantages and disadvantages of using fission to generate electricity.
20. The products of a nuclear reaction usually have a different mass than the reactants. Why?
21. Explain the concepts of mass defect and nuclear binding energy. At what mass number does the nuclear binding energy per nucleon peak? What is the significance of this?
22. What is fusion? Why can fusion and fission both produce energy? Explain.
23. What are some of the challenges associated with using fusion to generate electricity?
24. Explain transmutation and provide one or two examples.
25. How does a linear accelerator work? For what purpose is it used?
26. Explain the basic principles of cyclotron function.
27. How does radiation affect living organisms?
28. Explain why different kinds of radiation affect biological tissues differently, even though the amount of radiation exposure may be the same.
29. Explain the significance of the biological effectiveness factor in measuring radiation exposure. What types of radiation would you expect to have the highest biological effectiveness factor?
30. Describe some of the medical uses of radioactivity in both the diagnosis and treatment of disease.

Problems by Topic

Note: Answers to all odd-numbered Problems can be found in Appendix III. Exercises in the Problems by Topic section are paired, with each odd-numbered problem followed by a similar even-numbered problem. Exercises in the Cumulative Problems section are also paired but more loosely. Because of their nature, Challenge Problems and Conceptual Problems are unpaired.

Radioactive Decay and Nuclide Stability

31. Write a nuclear equation for the indicated decay of each nuclide.

a. U-234 (alpha)

b. Th-230 (alpha)

c. Pb-214 (beta)

d. N-13 (positron emission)

e. Cr-51 (electron capture)

32. Write a nuclear equation for the indicated decay of each nuclide.

a. Po-210 (alpha)

b. Ac-227 (beta)

c. Tl-207 (beta)

d. O-15 (positron emission)

e. Pd-103 (electron capture)

33. Write a partial decay series for Th-232 undergoing the sequential decays: α, β, β, α.

34. Write a partial decay series for Rn-220 undergoing the sequential decays: α, α, β, β.

35. Fill in the missing particle in each nuclear equation.

a. $\_\_\_\_ \rightarrow {}^{217}_{85}\text{At} + {}^{4}_{2}\text{He}$

b. ${}^{241}_{94}\text{Pu} \rightarrow {}^{241}_{95}\text{Am} + \_\_\_\_$

c. ${}^{19}_{11}\text{Na} \rightarrow {}^{19}_{10}\text{Ne} + \_\_\_\_$

d. ${}^{75}_{34}\text{Se} + \_\_\_\_ \rightarrow {}^{75}_{33}\text{As}$

36. Fill in the missing particle in each nuclear equation.

a. ${}^{241}_{95}\text{Am} \rightarrow {}^{237}_{93}\text{Np} + \_\_\_\_$

b. $\_\_\_\_ \rightarrow {}^{233}_{92}\text{U} + {}^{0}_{-1}\text{e}$

c. ${}^{237}_{93}\text{Np} \rightarrow \_\_\_\_ + {}^{4}_{2}\text{He}$

d. ${}^{75}_{35}\text{Br} \rightarrow \_\_\_\_ + {}^{0}_{+1}\text{e}$

37. Determine whether or not each nuclide is likely to be stable. State your reasons.

a. Mg-26

b. Ne-25

c. Co-51

d. Te-124

38. Determine whether or not each nuclide is likely to be stable. State your reasons.

a. Ti-48

b. Cr-63

c. Sn-102

d. Y-88

39. The first six elements of the first transition series have the following number of stable isotopes:

Element	Number of Stable Isotopes
Sc	1
Ti	5
V	1
Cr	3
Mn	1
Fe	4

Explain why Sc, V, and Mn each has only one stable isotope while the other elements have several.

40. Neon and magnesium each have three stable isotopes, while sodium and aluminum each have only one. Explain why this might be so.

41. Predict a likely mode of decay for each unstable nuclide.

a. Mo-109

b. Ru-90

c. P-27

d. Sn-100

42. Predict a likely mode of decay for each unstable nuclide.

a. Sb-132

b. Te-139

c. Fr-202

d. Ba-123

43. Which nuclide of each pair would you expect to have the longer half-life?

a. Cs-113 or Cs-125

b. Fe-62 or Fe-70

44. Which one of each pair of nuclides would you expect to have the longer half-life?

a. Cs-149 or Cs-139

b. Fe-45 or Fe-52

The Kinetics of Radioactive Decay and Radiometric Dating

45. One of the nuclides in spent nuclear fuel is U-235, an alpha emitter with a half-life of 703 million years. How long will it take for the amount of U-235 to reach 10.0% of its initial amount?

46. A patient is given 0.050 mg of technetium-99m, a radioactive isotope with a half-life of about 6.0 hours. How long does it take for the radioactive isotope to decay to 1.0×10^{-3} mg? (Assume the nuclide is not excreted from the body.)

47. A radioactive sample contains 1.55 g of an isotope with a half-life of 3.8 days. What mass of the isotope remains after 5.5 days?

48. At 8:00 A.M., a patient receives a 1.5-μg dose of I-131 to treat thyroid cancer. If the nuclide has a half-life of eight days, what mass of the nuclide remains in the patient at 5:00 P.M. the next day? (Assume no excretion of the nuclide from the body.)

49. A sample of F-18 has an initial decay rate of 1.5×10^5 dis/s. How long will it take for the decay rate to fall to 2.5×10^3 dis/s? (F-18 has a half-life of 1.83 hours.)

50. A sample of Tl-201 has an initial decay rate of 5.88×10^4 dis/s. How long will it take for the decay rate to fall to 287 dis/s? (Tl-201 has a half-life of 3.042 days.)

51. A wooden boat discovered just south of the Great Pyramid in Egypt has a carbon-14/carbon-12 ratio that is 72.5% of that found in living organisms. How old is the boat?

52. A layer of peat beneath the glacial sediments of the last ice age has a carbon-14/carbon-12 ratio that is 22.8% of that found in living organisms. How long ago was this ice age?

53. An ancient skull has a carbon-14 decay rate of 0.85 disintegrations per minute per gram of carbon (0.85 dis/min · gC). How old is the skull? (Assume that living organisms have a carbon-14 decay rate of 15.3 dis/min · gC and that carbon-14 has a half-life of 5715 yr.)

54. A mammoth skeleton has a carbon-14 decay rate of 0.48 disintegrations per minute per gram of carbon (0.48 dis/min · gC). When did the mammoth live? (Assume that living organisms have a carbon-14 decay rate of 15.3 dis/min · gC and that carbon-14 has a half-life of 5715 yr.)

55. A rock from Australia contains 0.438 g of Pb-206 to every 1.00 g of U-238. Assuming that the rock did not contain any Pb-206 at the time of its formation, how old is the rock?

56. A meteor has a Pb-206:U-238 mass ratio of 0.855:1.00. What is the age of the meteor? (Assume that the meteor did not contain any Pb-206 at the time of its formation.)

Fission, Fusion, and Transmutation

57. Write the nuclear reaction for the neutron-induced fission of U-235 to form Xe-144 and Sr-90. How many neutrons are produced in the reaction?

58. Write the nuclear reaction for the neutron-induced fission of U-235 to produce Te-137 and Zr-97. How many neutrons are produced in the reaction?

59. Write the nuclear equation for the fusion of two H-2 atoms to form He-3 and one neutron.

59. Write the nuclear equation for the fusion of two H-2 atoms to form He-3 and one neutron.

60. Write the nuclear equation for the fusion of H-3 with H-1 to form He-4.

61. A breeder nuclear reactor is a reactor in which nonfissionable (nonfissile) U-238 is converted into fissionable (fissile) Pu-239. The process involves bombardment of U-238 by neutrons to form U-239, which then undergoes two sequential beta decays. Write nuclear equations for this process.

62. Write the series of nuclear equations to represent the bombardment of Al-27 with a neutron to form a product that subsequently undergoes a beta decay.

63. Rutherfordium-257 was synthesized by bombarding Cf-249 with C-12. Write the nuclear equation for this reaction.

64. Element 107, now named bohrium, was synthesized by German researchers by colliding bismuth-209 with chromium-54 to form a bohrium isotope and one neutron. Write the nuclear equation to represent this reaction.

Energetics of Nuclear Reactions, Mass Defect, and Nuclear Binding Energy

65. If 1.0 g of matter is converted to energy, how much energy is formed?

66. A typical home uses approximately 1.0×10^3 kWh of energy per month. If the energy came from a nuclear reaction, what mass would have to be converted to energy per year to meet the energy needs of the home?

67. Calculate the mass defect and nuclear binding energy per nucleon of each nuclide.

a. O-16 $(\text{atomic mass} = 15.994915\ \text{amu})$

b. Ni-58 $(\text{atomic mass} = 57.935346\ \text{amu})$

c. Xe-129 $(\text{atomic mass} = 128.904780\ \text{amu})$

68. Calculate the mass defect and nuclear binding energy per nucleon of each nuclide.

a. Li-7 $(\text{atomic mass} = 7.016003\ \text{amu})$

b. Ti-48 $(\text{atomic mass} = 47.947947\ \text{amu})$

c. Ag-107 $(\text{atomic mass} = 106.905092\ \text{amu})$

69. Calculate the quantity of energy produced per gram of U-235 $(\text{atomic mass} = 235.043922\ \text{amu})$ for the neutron-induced fission of U-235 to form Xe-144 $(\text{atomic mass} = 143.9385\ \text{amu})$ and Sr-90 $(\text{atomic mass} = 89.907738\ \text{amu})$ (discussed in **Problem 57**).

70. Calculate the quantity of energy produced per mole of U-235 $(\text{atomic mass} = 235.043922\ \text{amu})$ for the neutron-induced fission of U-235 to produce Te-137 $(\text{atomic mass} = 136.9253\ \text{amu})$ and Zr-97 $(\text{atomic mass} = 96.910950\ \text{amu})$ (discussed in **Problem 58**).

71. Calculate the quantity of energy produced per gram of reactant for the fusion of two H-2 $(\text{atomic mass} = 2.014102\ \text{amu})$ atoms to form He-3 $(\text{atomic mass} = 3.016029\ \text{amu})$ and one neutron (discussed in **Problem 59**).

72. Calculate the quantity of energy produced per gram of reactant for the fusion of H-3 $(\text{atomic mass} = 3.016049\ \text{amu})$ with H-1 $(\text{atomic mass} = 1.007825\ \text{amu})$ to form He-4 $(\text{atomic mass} = 4.002603\ \text{amu})$ (discussed in **Problem 60**).

Effects and Applications of Radioactivity

73. A 75-kg man has a dose of 32.8 rad of radiation. How much energy is absorbed by his body? Compare this energy to the amount of energy absorbed by his body if he jumps from a chair to the floor (assume that the chair is 0.50 m from the ground and that the man absorbs all of the energy from the fall).

74. If a 55-g laboratory mouse has a dose of 20.5 rad of radiation, how much energy is absorbed by the mouse's body?

75. PET studies require fluorine-18, which is produced in a cyclotron and decays with a half-life of 1.83 hours. Assuming that the F-18 can be transported at 60.0 miles/hour, how close must the hospital be to the cyclotron if 65% of the F-18 produced makes it to the hospital?

76. Suppose a patient is given 155 μg of I-131, a beta emitter with a half-life of 8.0 days. Assuming that none of the I-131 is eliminated from the person's body in the first 4.0 hours of treatment, what is the exposure (in Ci) during those first four hours?

Cumulative Problems

Cumulative Problems

77. Complete each nuclear equation and calculate the energy change (in J/mol of reactant) associated with each. (Be-9 = 9.012182 amu, Bi-209 = 208.980384 amu, He-4 = 4.002603 amu, Li-6 = 6.015122 amu, Ni-64 = 63.927969 amu, Rg-272 = 272.1535 amu, Ta-179 = 178.94593 amu, and W-179 = 178.94707 amu).

a. $\_\_\_\_ + {}^{9}_{4}\text{Be} \rightarrow {}^{6}_{3}\text{Li} + {}^{4}_{2}\text{He}$

b. ${}^{209}_{83}\text{Bi} + {}^{64}_{28}\text{Ni} \rightarrow {}^{272}_{111}\text{Rg} + \_\_\_\_$

c. ${}^{179}_{74}\text{W} + \_\_\_\_ \rightarrow {}^{179}_{73}\text{Ta}$

78. Complete each nuclear equation and calculate the energy change (in J/mol of reactant) associated with each. (Al-27 = 26.981538 amu, Am-241 = 241.056822 amu, He-4 = 4.002603 amu, Np-237 = 237.048166 amu, P-30 = 29.981801 amu, S-32 = 31.972071 amu, and Si-29 = 28.976495 amu).

a. ${}^{27}_{13}\text{Al} + {}^{4}_{2}\text{He} \rightarrow {}^{30}_{15}\text{P} + \_\_\_\_$

b. ${}^{32}_{16}\text{S} + \_\_\_\_ \rightarrow {}^{29}_{14}\text{Si} + {}^{4}_{2}\text{He}$

c. ${}^{241}_{95}\text{Am} \rightarrow {}^{237}_{93}\text{Np} + \_\_\_\_$

79. Write the nuclear equation for the most likely mode of decay for each unstable nuclide.

a. Ru-114

b. Ra-216

c. Zn-58

d. Ne-31

80. Write the nuclear equation for the most likely mode of decay for each unstable nuclide.

a. Kr-74

b. Th-221

c. Ar-44

d. Nb-85

81. Bismuth-210 is a beta emitter with a half-life of 5.0 days. If a sample contains 1.2 g of Bi-210 (atomic mass = 209.984105 amu), how many beta emissions occur in 13.5 days? If a person's body intercepts 5.5% of those emissions, to what amount of radiation (in Ci) is the person exposed?

82. Polonium-218 is an alpha emitter with a half-life of 3.0 minutes. If a sample contains 55 mg of Po-218 (atomic mass = 218.008965 amu), how many alpha emissions occur in 25.0 minutes? If the polonium is ingested by a person, to what amount of radiation (in Ci) is the person exposed?

83. Radium-226 (atomic mass = 226.025402 amu) decays to radon-224 (a radioactive gas) with a half-life of 1.6×10^3 years. What volume of radon gas (at 25.0 °C and 1.0 atm) does 25.0 g of radium produce in 5.0 days? (Report your answer to two significant digits.)

84. In one of the neutron-induced fission reactions of U-235 (atomic mass = 235.043922 amu), the products are Ba-140 and Kr-93 (a radioactive gas). What volume of Kr-93 (at 25.0 °C and 1.0 atm) is produced when 1.00 g of U-235 undergoes this fission reaction?

85. When a positron and an electron annihilate one another, the resulting mass is completely converted to energy. Calculate the energy associated with this process in kJ/mol.

86. A typical nuclear reactor produces about 1.0 MW of power per day. What is the minimum rate of mass loss required to produce this much energy?

87. Find the binding energy in an atom of ${}^{3}\text{He}$, which has a mass of 3.016030 amu.

88. The overall hydrogen burning reaction in stars can be represented as the conversion of four protons to one α particle. Use the data for the mass of H-1 and He-4 to calculate the energy released by this process.

89. The nuclide ${}^{247}\text{Es}$ is made by bombardment of ${}^{238}\text{U}$ in a reaction that emits five neutrons. Identify the bombarding particle.

90. The nuclide ${}^{6}\text{Li}$ reacts with ${}^{2}\text{H}$ to form two identical particles. Identify the particles.

91. The half-life of ${}^{238}\text{U}$ is 4.5×10^9 yr. A sample of rock of mass 1.6 g produces 29 dis/s. Assuming all the radioactivity is due to ${}^{238}\text{U}$, find the percent by mass of ${}^{238}\text{U}$ in the rock.

92. The half-life of ${}^{232}\text{Th}$ is 1.4×10^{10} yr. Find the number of disintegrations per hour emitted by 1.0 mol of ${}^{232}\text{Th}$.

93. A 1.50-L gas sample at 745 mm Hg and 25.0 °C contains 3.55% radon-220 by volume. Radon-220 is an alpha emitter with a half-life of 55.6 s. How many alpha particles are emitted by the gas sample in 5.00 minutes?

94. A 228-mL sample of an aqueous solution contains 2.35% $MgCl_2$ by mass. Exactly half of the magnesium ions are Mg-28, a beta emitter with a half-life of 21 hours. What is the decay rate of Mg-28 in the solution after 4.00 days? (Assume a density of 1.02 g/mL for the solution.)

95. When a positron and an electron collide and annihilate each other, two photons of equal energy are produced. Find the wavelength of these photons.

96. The half-life of ^{235}U, an alpha emitter, is 7.1×10^{8} yr. Calculate the number of alpha particles emitted by 1.0 mg of this nuclide in 1.0 minute.

97. Given that the energy released in the fusion of two deuterium atoms to a ^{3}He and a neutron is 3.3 MeV, and in the fusion to tritium and a proton it is 4.0 MeV. Calculate the energy change for the process $^{3}\text{He} + {}^{1}\text{n} \rightarrow {}^{3}\text{H} + {}^{1}\text{p}$. Suggest an explanation for why this process occurs at much lower temperatures than either of the first two.

98. The nuclide ^{18}F decays by both electron capture and β^{+} decay. Find the difference in the energy released by these two processes. The atomic masses are $^{18}\text{F} = 18.000950$ and $^{18}\text{O} = 17.9991598$.

Challenge Problems

99. The space shuttle carries about 72,500 kg of solid aluminum fuel, which is oxidized with ammonium perchlorate according to the reaction shown here:

$$10\ \text{Al}(s) + 6\ \text{NH}_4\text{ClO}_4\,(s) \rightarrow 4\ \text{Al}_2\text{O}_3\,(s) + 2\ \text{AlCl}_3\,(s) + 12\ \text{H}_2\text{O}\,(g) + 3\ \text{N}_2\,(g)$$

The space shuttle also carries about 608,000 kg of oxygen (which reacts with hydrogen to form gaseous water).

a. Assuming that aluminum and oxygen are the limiting reactants, determine the total energy produced by these fuels. ($\Delta H_{\text{f}}^{\circ}$ for solid ammonium perchlorate is –295 kJ/mol.)

b. Suppose that a future space shuttle is powered by matter–antimatter annihilation. The matter is normal hydrogen (containing a proton and an electron), and the antimatter is antihydrogen (containing an antiproton and a positron). What mass of antimatter is required to produce the energy equivalent of the aluminum and oxygen fuel currently carried on the space shuttle?

100. Suppose that an 85.0-g laboratory animal ingests 10.0 mg of a substance that contained 2.55% by mass Pu-239, an alpha emitter with a half-life of 24,110 years.

a. What is the animal's initial radiation exposure in curies?

b. If all of the energy from the emitted alpha particles is absorbed by the animal's tissues and if the energy of each emission is 7.77×10^{-12} J, what is the dose in rads to the animal in the first 4.0 hours following the ingestion of the radioactive material? Assuming a biological effectiveness factor of 20, what is the 4.0-hour dose in rems?

101. In addition to the natural radioactive decay series that begins with U-238 and ends with Pb-206, there are natural radioactive decay series that begin with U-235 and Th-232. Both of these series end with nuclides of Pb. Predict the likely end product of each series and the number of a decay steps that occur.

102. The hydride of an unstable nuclide of a Group IIA metal, $\text{MH}_2\,(\text{s})$, decays by alpha emission. A 0.025-mol sample of the hydride is placed in an evacuated 2.0-L container at 298 K. After 82 minutes, the pressure in the container is 0.55 atm. Find the half-life of the nuclide.

103. The nuclide ^{38}Cl decays by beta emission with a half-life of 37.2 min. A sample of 0.40 mol of H^{38}Cl is placed in a 6.24-L container. After 74.4 min, the pressure is 1650 mmHg. What is the temperature of the container?

104. When BF_3 is bombarded with neutrons, the boron undergoes an α decay, but the F is unaffected. A 0.20-mol sample of BF_3 contained in a 3.0-L container at 298 K is bombarded with neutrons until half of the BF_3 has reacted. What is the pressure in the container at 298 K?

Conceptual Problems

105. Closely examine the diagram representing the beta decay of fluorine-21 and draw in the missing nucleus.

106. Approximately how many half-lives must pass for the amount of radioactivity in a substance to decrease to below 1% of its initial level?

107. A person is exposed for 3 days to identical amounts of two different nuclides that emit positrons of roughly equal energy. The half-life of nuclide A is 18.5 days, and the half-life of nuclide B is 255 days. Which of the two nuclides poses the greater health risk?

108. Identical amounts of two different nuclides, an alpha emitter and a gamma emitter, with roughly equal half-lives are spilled in a building adjacent to your bedroom. Which of the two nuclides poses the greater health threat to you while you sleep in your bed? If you accidentally wander into the building and ingest equal amounts of the two nuclides, which one poses the greater health threat?

109. Drugstores in many areas now carry tablets, under such trade names as Iosat and NoRad, to be taken in the event of an accident at a nuclear power plant or a terrorist attack that releases radioactive material. These tablets contain potassium iodide (KI). Can you explain the nature of the protection that they provide?

Questions for Group Work

Active Classroom Learning

Discuss these questions with the group and record your consensus answer.

110. Complete the table of particles involved in radioactive decay.

Particle Name	Symbol	Mass Number	Atomic Number or Charge
alpha particle	$^{4}_{2}He$		
	$^{0}_{-1}e$		−1
gamma ray	$^{0}_{0}\gamma$		
positron		0	
	$^{1}_{0}n$	1	
proton	$^{1}_{1}p$		

111. Have each group member study a different mode of radioactive decay (alpha, beta, gamma, positron emission, or electron capture) and present it to the group. Each presentation should include a description of the process, a description of how the atomic and mass numbers change, and at least one specific example. Presentations should also address the questions: What do all types of nuclear reactions have in common, and how do they differ from each other?

reactions have in common, and how do they differ from each other?

112. Two students were discussing whether or not the total mass changes during a nuclear reaction. The first student insists that mass is conserved. The second student says that mass is converted into energy. Explain the context in which each student is correct and how that fact is applied to solve problems.

113. Write all the balanced nuclear equations for each step of the nuclear decay sequence that starts with U-238 and ends with U-234. Refer to Figure 20.6 for the decay processes involved.

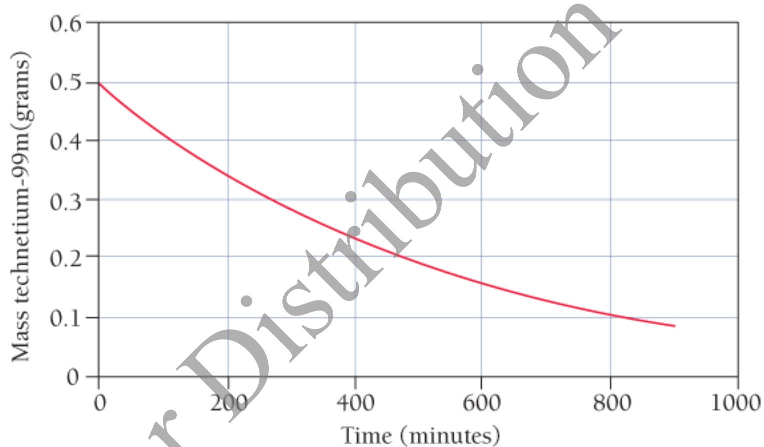
114. Radon-220 undergoes alpha decay with a half-life of 55.6 s. Assume there are 16,000 atoms present initially and make a table showing how many atoms will be present at 0 s, 55.6 s, 111.2 s, 166.8 s, 222.4 s, and 278.0 s (all multiples of the half-life). Now calculate how many atoms will be present at 50 s, 100 s, and 200 s (not multiples of the half-life). Make a graph with the number of atoms present on the y-axis and total time on the x-axis.

Data Interpretation and Analysis

115. A common isotope used in medical imaging is technetium-99m, which emits gamma rays.

$$^{99m}_{43}\text{Tc} \rightarrow {}^{99}_{43}\text{Tc} + {}^{0}_{0}\gamma$$

A sample initially containing 0.500 mg of technetium-99m is monitored as a function of time. Based on its rate of gamma ray emission, a graph, showing the mass of active technetium-99m as a function of time, is prepared. Study the graph and answer the questions that follow.



Mass of Technetium-99m as a Function of Time

a. What is the mass of technetium-99m present at 200 minutes? At 400 minutes?

b. What is the half-life of technetium-99m in minutes? In hours?

c. If a patient is given a 2.0-μg dose of technetium-99m, how much of it is left in the patient's body after 10 hours? (For this problem, assume that the technetium-99m is not biologically removed from the body.)

Answers to Conceptual Connections

Cc 20.1 **(c)** The arrow labeled x represents a decrease of two neutrons and two protons, indicative of alpha decay. The arrow labeled y represents a decrease of one neutron and an increase of one proton, indicative of beta decay.

Cc 20.2 **(b)** The half-life is the time it takes for the number of nuclei to decay to one-half of their original number.

Cc 20.3 **(b)** 0.10 mol. The sample loses one-half of the number of moles per half-life, so over the course of four half-lives, the amount falls to 0.10 mol.

Cc 20.4 lawrencium-256

Cc 20.5 Nuclide A. Because nuclide A has a shorter half-life, more of the nuclides will decay, and therefore produce radiation, before they exit the body.