Chapter 2
Atomic Structure and Radioisotopes

41 Iodine is concentrated in the thyroid gland.
42 The common sources of iodine in foods are dried seaweed, yogurt, turkey breast, tuna, eggs, potatoes, strawberries, and cranberries.
43 The symptoms of an iodine deficiency in an adult are an enlarged thyroid or goiter. Severe iodine deficiency is linked to high infant mortality and physical and learning disabilities.
44 Iron requires a daily intake of 8–18 mg.
45 Hemoglobin is a substance in red blood cells that transports oxygen.
46 Iron is found in red meat, pork, poultry, beans, seafood, dark green leafy vegetables, dried fruit, and cereal.
47 A person is anemic when they have a diminished number of red blood cells produced.
48 Fluoride builds strong bones and tooth enamel. Fluoride is found in fluoridated water.
49 Zinc is necessary for wound healing and fighting infection. Zinc is found in oysters, breakfast cereal, beef, pork, chicken, yogurt, baked beans, and nuts.
50 The smallest stable component of matter is an *atom*.
51 Protons, neutrons, and electrons are three subatomic particles found in an atom. The protons and neutrons are found in the nucleus, whereas the electrons are found in electron orbitals.
52 A proton has a +1 charge; a neutron has no charge; and an electron has a −1 charge.
53 the proton and the neutron
54 the proton and the neutron
55 the electron
56 The heavier particles (the protons and the neutrons) are concentrated in the small volume of the nucleus. Therefore, the nucleus is extremely dense.
57 The mass of a proton is 1.007 amu and 1.6726×10^{-24} g.
58 The atomic number represents the number of protons in an atom.
59 **a.** Sb, antimony **b.** As, arsenic **c.** Al, aluminum **d.** Ra, radium
60 **a.** Mg, magnesium **b.** Si, silicon **c.** Ba, barium **d.** Se, selenium
61 **a.** carbon, C **b.** thallium, Tl **c.** uranium, U **d.** platinum, Pt **e.** cobalt, Co
62 **a.** Beryllium, Be **b.** Manganese, Mn **c.** Palladium, Pd **d.** Thorium, Th **e.** Seaborgium, Sg
63 Lead is located between thallium and bismuth. Lead has 82 protons; thallium has 81 protons; bismuth has 83 protons.
64 Titanium is located between scandium and vanadium.
65 **a.** boron, B, atomic number 5, 5 protons and 5 electrons **b.** cesium, Cs, atomic number 55, 55 protons and 55 electrons **c.** gallium, Ga, atomic number 31, 31 protons and 31 electrons **d.** strontium, Sr, atomic number 38, 38 protons and 38 electrons
66 **a.** rubidium, Rb, atomic number 37, 37 protons and 37 electrons **b.** argon, Ar, atomic number 18, 18 protons and 18 electrons **c.** helium, He, atomic number 2, 2 protons and 2 electrons **d.** cadmium, Cd, atomic number 48, 48 protons and 48 electrons

67 **a.** oxygen, atomic number 8 **b.** sodium, atomic number 11 **c.** copper, atomic number 29 **d.** tin, atomic number 50 **e.** ruthenium, atomic number 44 **f.** tungsten, atomic number 74 **g.** europium, atomic number 63.

68 **a.** fluorine, atomic number 9 **b.** radium, atomic number 88 **c.** osmium, atomic number 76 **d.** silver, atomic number 47 **e.** mercury, atomic number 80 **f.** americium, atomic number 95 **g.** molybdenum atomic number 42

69 **a.** Oxygen has 8 protons and 8 electrons. **b.** Chromium has 24 protons and 24 electrons. **c.** Phosphorus has 15 protons and 15 electrons.

70 **a.** Vanadium has 23 protons and 23 electrons. **b.** Sulfur has 16 protons and 16 electrons. **c.** Magnesium has 12 protons and 12 electrons.

71 The mass number of an isotope represents the sum of the *protons* and *neutrons*.

72 Isotopes are atoms that have the same number of protons but a different number of neutrons. Isotopes of an element differ in the number of neutrons they contain. Isotopes of an element have the same number of protons and electrons.

73 ${}^{16}_{8}O$, ${}^{17}_{8}O$, ${}^{18}_{8}O$

74 Tc-99 has 43 protons, 43 electrons, and 56 neutrons. ${}^{99}_{43}Tc$

75

Isotope	Atomic Number	Number of Protons	Number of Neutrons	Mass Number
Sulfur-32	**16**	**16**	**16**	**32**
Sulfur-33	**16**	**16**	**17**	**33**
Sulfur-34	**16**	**16**	**18**	**34**
Sulfur-36	**16**	**16**	**20**	**36**

76 All the sulfur isotopes have the same number of protons and the same number of electrons.

77 Sulfur-32 has the smallest mass.

78 The natural abundance and the mass of each isotope are used to calculate a weighted average, which is the atomic mass.

79 **a.** The atomic number for both isotopes is 35. **b.** The mass numbers are 79 and 81. **c.** One of the isotopes has two more neutrons than the other one. **d.** The average atomic mass is 79.90. Yes, it does. **e.** There are roughly equal amounts of both isotopes present in bromine.

80 **a.** iron-54 **b.** iron-58 **c.** iron-56 **d.** iron-54 **e.** Iron-56 is present in the greatest amount, but there are three other isotopes of iron that contribute to the mass of iron.

81 A family or group of elements has elements in the same column in the periodic table.

82 Group 1A (alkali metals), group 2A (alkaline earth metals), group 3A, group 4A, group 5A, group 6A, group 7A (halogens), and group 8A (noble gases) are the groups of the main group elements. The transition metal elements are located between group 2A and group 3A. The inner transition metal elements are located between group 3B and 4B.

83 Elements within a group exhibit similar physical and chemical properties.

84 a period

85 **a.** group 2A, alkaline earth metal **b.** group 8A, noble gases **c.** group 7A, halogens
d. group 1A, alkali metals **e.** group 7A, halogens

86 **a.** group 1A, alkali metals **b.** group 4A **c.** group 8B **d.** group 3A
e. group 8A, noble gases

87 Nonmetals are dull; can exist as solids, liquids, or gases at room temperature; are poor conductors of electricity; and can be brittle, hard, or soft. Metals are shiny, exist as solids at room temperature (except for mercury), are good conductors of electricity, and are malleable.

88 **a.** nonmetal **b.** metalloid **c.** nonmetal **d.** metal

89 **a.** metal **b.** nonmetal **c.** metalloid **d.** metal **e.** nonmetal

90 **a.** potassium **b.** radon

91 **a.** palladium **b.** uranium

92 The macronutrients are Na, K, Mg, Ca, P, S, and Cl.

93 The micronutrients are V, Cr, Mn, Fe, Co, Cu, Zn, Mo, Si, Se, F, and I.

94 the electron

95 less energy

96 more energy

97 The group number equals the number of valence electrons for the elements in that group.

98

	Element Name	**Atomic Symbol**	**Atomic Number**	**Group Number**	**Period Number**	**Number of Electrons**		
						$n = 1$	$n = 2$	$n = 3$
a.	boron	**B**	**5**	3A	**2**	**2**	**3**	**0**
b.	phosphorus	P	**15**	**5A**	**3**	**2**	**8**	**5**
c.	sodium	Na	11	**1A**	**3**	**2**	**8**	**1**
d.	**sulfur**	**S**	**16**	**6A**	**3**	2	8	6

99

	Element Name	**Atomic Symbol**	**Atomic Number**	**Group Number**	**Period Number**	**Number of Electrons**		
						$n = 1$	$n = 2$	$n = 3$
a.	**oxygen**	**O**	**8**	**6A**	**2**	2	6	0
b.	**beryllium**	**Be**	4	**2A**	**2**	**2**	**2**	**0**
c.	argon	**Ar**	**18**	**8A**	**3**	**2**	**8**	**8**
d.	**fluorine**	F	**9**	**7A**	**2**	**2**	**7**	**0**

100 halogens, group 7A

101 group 4A

102 noble gases, group 8A

103 Boron has three valence electrons in the $n = 2$ level; aluminum has three valence electrons in the $n = 3$ level.

104 eight electrons

105 two electrons

106 **a.** $n = 4$, two valence electrons **b.** $n = 3$, one valence electron **c.** $n = 5$, eight valence electrons **d.** $n = 2$, six valence electrons **e.** $n = 1$, one valence electron

107 Radioisotopes are unstable isotopes of an element. They have an imbalance in the ratio of neutrons to protons in the nucleus.

108 Radioactive decay occurs when an unstable radioisotope produces a more stable nucleus by releasing radiation.

109 α and β particles. The nuclear symbols are ${}^{4}_{2}\alpha$ and ${}^{0}_{-1}\beta$, respectively.

110 **a.** ${}^{213}_{83}\text{Bi} \rightarrow {}^{209}_{81}\text{Tl} + {}^{4}_{2}\alpha$ **b.** The daughter nuclide is thallium-209**.**

111 **a.** ${}^{211}_{85}\text{At} \rightarrow {}^{207}_{83}\text{Bi} + {}^{4}_{2}\alpha$ **b.** The daughter nuclide is bismuth-207.

112 **a.** ${}^{153}_{62}\text{Sm} \rightarrow {}^{153}_{63}\text{Eu} + {}^{0}_{-1}\beta$ **b.** The daughter nuclide is europium-153.

113 **a.** ${}^{32}_{15}\text{P} \rightarrow {}^{32}_{16}\text{S} + {}^{0}_{-1}\beta$ **b.** The daughter nuclide is sulfur-32.

114 **a.** ${}^{26}_{11}\text{Na} \rightarrow {}^{26}_{12}\text{Mg} + {}^{0}_{-1}\beta$ **b.** ${}^{232}_{81}\text{Tl} \rightarrow {}^{228}_{79}\text{Au} + {}^{4}_{2}\alpha$

115 **a.** ${}^{225}_{89}\text{Ac} \rightarrow {}^{221}_{87}\text{Fr} + {}^{4}_{2}\alpha$ **b.** ${}^{107}_{46}\text{Pd} \rightarrow {}^{107}_{47}\text{Ag} + {}^{0}_{-1}\beta$

116 16 g (initial amount), 8 g (one half-life), 4 g (two half-lives); 4 g remains after 156 hours or two half-lives.

117 18.0 g (initial amount), 9.0 g (one half-life), 4.5 g (two half-lives), 2.25 g (three half-lives), 1.125g (four half-lives); 1.125 g remains after 32 days or four half-lives.

118 28 g (initial amount), 14 g (one half-life), 7 g (two half-lives), 3.5 g (three half-lives), 1.75 g (four half-lives)

$$4 \text{ half-lives} \times \frac{44 \text{ days}}{1 \text{ half-life}} = 176 \text{ days}$$

It takes 4 half-lives or 176 days for 28 g of iron-59 to decay to 1.75 g.

119 It has a very short half-life and won't remain in the body for a long time.

120 $$24 \cancel{\text{ days}} \times \frac{1 \text{ half-life}}{8 \cancel{\text{ days}}} = 3 \text{ half-lives}$$

25.0 mg (initial amount), 12.5 mg (one half-life), 6.25 mg (two half-lives), 3.125 mg (three half-lives)

3.125 mg will remain after 24 days.

121 66 hours

122 Electromagnetic radiation is a form of energy that travels through space, as a wave, at the speed of light.

123 light

124 gamma rays, x-rays, ultraviolet, visible, infrared, microwave, and radio waves

125 **a.** radio waves **b.** x-ray **c.** visible

126 **a.** visible **b.** ultraviolet light **c.** γ-rays

127 α particles, neutrons, and β particles

128 When a daughter nuclide is an "exited state," it has excess energy in the nucleus. The letter *m* after the mass number is used to denote the metastable state.

129 Irradiating fruits and vegetables destroys disease-causing microorganisms and reduces spoilage caused by bacteria. When food is irradiated, only the energy from electromagnetic radiation emitted, not the radioisotope itself, comes in contact with the food.
130 Ionizing radiation has sufficient energy to dislodge a valence electron from an atom.
131 Ionizing radiation can kill cells. It can also cause gene mutations in the cells.
132 The mutations that ionizing radiation causes are passed when a cell reproduces, which can be the beginning of cancer.
133 Ionizing radiation affects rapidly dividing cells such as lymphocytes (white blood cells), blood-producing cells, and cancer cells.
134 the energy and penetrating power of the radiation
135 X-rays have more penetrating power than radio waves. Therefore, when you go to the dentist you need to wear a lead apron.
136 An α particle is high in energy and very destructive to human tissue. If you swallow an α emitter, the high energy is close to the tissue. An α particle is also heavy and slow moving, so it has little penetrating power. It can be stopped by a piece of paper.
137 The lead apron protects your neck and chest from the penetrating power of the x-rays.
138 **a.** γ-rays **b.** α particles **c.** β particles
139 **a.** β particles **b.** γ-rays **c.** γ-rays
140 An α particle has the highest amount of energy, but the least penetrating power.
141 α particles, β particles, and x-rays
142 An absorbed dose measures the energy of radiation absorbed per mass of tissue but does not take into account the penetrating power of the radiation. The effective dose takes into account both the penetrating power of radiation and the amount of energy to give a biological effect. The unit for absorbed dose used in medicine is the Gray. The effective dose in medicine is measured in Sieverts.
143 **a.** chronic exposure **b.** acute exposure **c.** chronic exposure **d.** acute exposure
144 You can expect loss of hair all over the body, fatigue, general illness, and a high risk of infection for an exposure to 2.4 Sv of radiation.
145 An LD_{50} indicates a level of exposure that would result in death in 50% of the population in 30 days. An effective dose of 3–4 Sv is LD_{50} for radiation exposure.
146 Radiation-based diagnostic techniques allow medical professionals to "see" internal organs and systems for the purpose of diagnosis. Imaging techniques can eliminate the need for exploratory surgery.
147 X-ray imaging and CT scans. X-rays are high-energy forms of electromagnetic radiation.
148 The detectors in a CT are arranged in a circular array that surrounds the body.
149 The quarter is higher in density than the tissue in the esophagus. The quarter absorbed more x-rays and is lighter in color than the tissue of the esophagus.
150 A CT scan can be used to detect a brain hemorrhage. A regular x-ray can be used to detect a simple fracture.

151 The building block elements make up the structure of the majority of compounds found in living organisms. They are carbon, 4 valence electrons; hydrogen, 1 valence electron; nitrogen, 5 valence electrons; oxygen, 6 valence electrons; phosphorus, 5 valence electrons; and sulfur, 6 valence electrons.

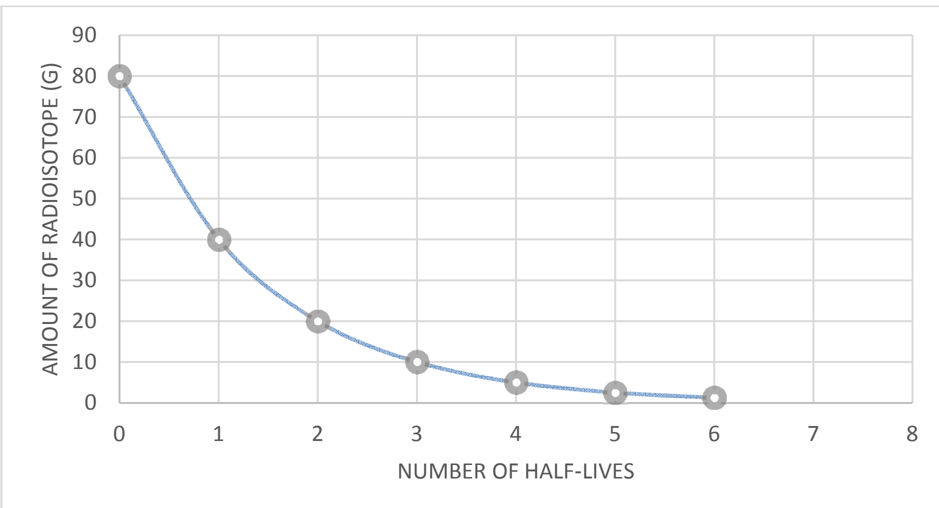
152 Astatine has seven valence electrons. They are in the $n = 6$ energy level.

153 A helium atom has the smaller diameter and volume because it has fewer electrons. As the number of electrons increases, the outermost electrons spend more of their time in larger orbitals that extend farther from the nucleus, thereby increasing the diameter of the atom. The helium atom would be lighter since it only has 2 protons, whereas gold has 79 protons.

154 A selenium atom has the larger diameter because it has more electrons, which take up more space around the nucleus.

155 $\text{average atomic mass} = (78.9183)(.5069) + (80.9163)(.4931) = 79.904$

156



157 The danger of nuclear waste is that some of the radioisotopes have very long half-lives. Yes, hospitals produce nuclear waste, but the half-lives of the radioisotopes used in hospitals range from a few hours to a few days, not thousands of years.

158 **a.** γ-ray has more penetrating power and can cause more damage to biological tissue.
b. Ultraviolet light is higher in energy than visible light and can cause more damage.

159 α decay and β decay

160 **a.** ${}^{210}_{86}\text{Rn} \rightarrow {}^{206}_{84}\text{Po} + {}^{4}_{2}\alpha$ **b.** ${}^{90}_{39}\text{Y} \rightarrow {}^{90}_{40}\text{Zr} + {}^{0}_{-1}\beta$

161 **a.** ${}^{177}_{71}\text{Lu} \rightarrow {}^{177}_{72}\text{Hf} + {}^{0}_{-1}\beta$
b. Hf-177
c. A high-energy β particle and a small amount of electromagnetic radiation (γ-rays) are released.

162 **a.** technetium **b.** atomic number 43 **c.** 43 protons and 43 electrons **d.** 10 mCi **e.** γ-rays
e. Tc-99 The daughter nuclide is not metastable.

163 **a.** atomic number 77 **b.** 77 protons 192 − 77 = 115 neutrons **c.** ${}^{192}_{77}\text{Ir} \rightarrow {}^{192m}_{78}\text{Pt} + {}^{0}_{-1}\beta$
${}^{192m}_{78}\text{Pt} \rightarrow {}^{192}_{78}\text{Pt} + {}^{0}_{0}\gamma$ **d.** a thick lead apron

164 I-131 is probably responsible for thyroid cancer.