CONCEPTS

Atoms and Molecules (1.1)

- All matter is composed of atoms and molecules.
- Chemistry is the science that investigates the properties of matter by examining the atoms and molecules that compose it.

The Scientific Approach to Knowledge (1.2)

- Science begins with the observation of the physical world. A number of related observations can be summarized in a statement or generalization called a scientific law.
- A hypothesis is a tentative interpretation or an explanation of observations. One or more well-established hypotheses may prompt the development of a scientific theory, a model for nature that explains the underlying reasons for observations and laws.
- Laws, hypotheses, and theories all give rise to predictions that can be tested by experiments, carefully controlled procedures designed to produce critical new observations. If scientists cannot confirm the predictions, they must modify or replace the law, hypothesis, or theory.

The Classification of Matter (1.3)

- We classify matter according to its state (solid, liquid, or gas) or according to its composition (pure substance or mixture).
- A pure substance can either be an element, which cannot be chemically broken down into simpler substances, or a compound, which is composed of two or more elements in fixed proportions.
- A mixture can be either homogeneous, with the same composition throughout, or heterogeneous, with different compositions in different regions.

The Properties of Matter (1.4)

- We classify the properties of matter into two types: physical and chemical. Matter displays its physical properties without changing its composition.
- Changes in matter in which composition does not change are physical changes. Changes in matter in which composition does change are chemical changes.

Energy (1.5)

- In chemical and physical changes, matter often exchanges energy with its surroundings. In these exchanges, the total energy is always conserved; energy is neither created nor destroyed.
- Systems with high potential energy tend to change in the direction of lower potential energy, releasing energy into the surroundings.

The Units of Measurement and Significant Figures (1.6, 1.7)

- Scientists use SI units, which are based on the metric system. The SI base units include the meter (m) for length, the kilogram (kg) for mass, the second (s) for time, and the kelvin (K) for temperature.
- Derived units are formed from a combination of other units. Common derived units include those for volume (cm^3 or m^3) and density (g/cm^3).
- The number of digits in a reported measurement reflects the uncertainty in the measurement. Significant figures are the non–place-holding digits in a reported number.

EQUATIONS AND RELATIONSHIPS

Relationship between Kelvin (K) and Celsius (°C) Temperature Scales (1.6)

$$K = °C + 273.15$$

Relationship between Celsius (°C) and Fahrenheit (°F) Temperature Scales (1.6)

$$°C = \frac{(°F - 32)}{1.8}$$

Relationship between Density (d), Mass (m), and Volume (V) (1.6)

$$d = \frac{m}{V}$$

LEARNING OUTCOMES

Chapter Objectives	Assessment
Apply the scientific approach (1.2)	Exercises 33–36
Classify matter according to its composition (1.3)	Exercises 37–42
Classify the properties and changes in matter as chemical or physical (1.4)	Example 1.1 **For Practice** 1.1 **Exercises** 43–50
Compare the Fahrenheit, Celsius, and Kelvin temperature scales (1.6)	Example 1.2 **For Practice** 1.2 **Exercises** 51–54
Express measurements using appropriate prefix multipliers (1.6)	Exercises 55–64
Apply the density relationship to problems involving mass and volume (1.6)	Example 1.3 **For Practice** 1.3 **For More Practice** 1.3 **Exercises** 65–72
Determine the number of significant figures in a measurement or reported number (1.7)	Examples 1.4, 1.5 **For Practice** 1.4, 1.5 **Exercises** 73–82
Determine the number of significant figures in the result of a given calculation (1.7)	Example 1.6 **For Practice** 1.6 **Exercises** 83–90
Convert between units using dimensional analysis (1.8)	Examples 1.7, 1.8, 1.9, 1.10 **For Practice** 1.7, 1.8, 1.9, 1.10 **For More Practice** 1.9, 1.10 **Exercises** 91–104
Solve problems involving equations (1.8)	Examples 1.11, 1.12 **For Practice** 1.11, 1.12

EXERCISES

Mastering Chemistry provides end-of-chapter exercises, feedback-enriched tutorial problems, animations, and interactive activities to encourage problem-solving practice and deeper understanding of key concepts and topics.

REVIEW QUESTIONS

1. Explain this statement in your own words and give an example. *The properties of the substances around us depend on the atoms and molecules that compose them.*
2. Explain the main goal of chemistry.
3. Describe the scientific approach to knowledge. How does it differ from other approaches?
4. Explain the differences between a hypothesis, a law, and a theory.
5. What observations did Antoine Lavoisier make? What law did he formulate?
6. What theory did John Dalton formulate?
7. What is wrong with the expression "That is just a theory," if by *theory* the speaker is referring to a scientific theory?
8. What are two different ways to classify matter?
9. How do solids, liquids, and gases differ?
10. What is the difference between a crystalline solid and an amorphous solid?
11. Explain the difference between a pure substance and a mixture.
12. Explain the difference between an element and a compound.
13. Explain the difference between a homogeneous and a heterogeneous mixture.
14. What kind of mixtures can be separated by filtration?
15. Explain how distillation is used to separate mixtures.
16. What is the difference between a physical property and a chemical property?
17. What is the difference between a physical change and a chemical change? List some examples of each.
18. Explain the significance of the law of conservation of energy.
19. What kind of energy is chemical energy? In what way is an elevated weight similar to a tank of gasoline?
20. What are the standard SI base units of length, mass, time, and temperature?
21. What are the three common temperature scales? Does the size of a degree differ among them?
22. What are prefix multipliers? List some examples.
23. What is a derived unit? List an example.
24. Explain the difference between density and mass.
25. Explain the difference between *intensive* and *extensive* properties.
26. What is the meaning of the number of digits reported in a measured quantity?
27. When multiplying or dividing measured quantities, what determines the number of significant figures in the result?
28. When adding or subtracting measured quantities, what determines the number of significant figures in the result?
29. What are the rules for rounding off the results of calculations?
30. Explain the difference between precision and accuracy.
31. Explain the difference between random error and systematic error.
32. What is dimensional analysis?

PROBLEMS BY TOPIC

Note: *Answers to all odd-numbered Problems, numbered in blue, 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. Challenge Problems and Conceptual Problems, because of their nature, are unpaired.*

The Scientific Approach to Knowledge

33. Classify each statement as an observation, a law, or a theory. **MISSED THIS?** *Read Section 1.2*

a. All matter is made of tiny, indestructible particles called atoms.
b. When iron rusts in a closed container, the mass of the container and its contents does not change.
c. In chemical reactions, matter is neither created nor destroyed.
d. When a match burns, heat is released.

34. Classify each statement as an observation, a law, or a theory.

a. Chlorine is a highly reactive gas.
b. If elements are listed in order of increasing mass of their atoms, their chemical reactivities follow a repeating pattern.
c. Neon is an inert (or nonreactive) gas.
d. The reactivity of elements depends on the arrangement of their electrons.

35. A chemist decomposes several samples of carbon monoxide into carbon and oxygen and weighs the resultant elements. The results are shown in the table. **MISSED THIS?** *Read Section 1.2*

Sample	Mass of Carbon (g)	Mass of Oxygen (g)
1	6	8
2	12	16
3	18	24

a. Do you notice a pattern in these results?

Next, the chemist decomposes several samples of hydrogen peroxide into hydrogen and oxygen. The results are shown in the table.

Sample	Mass of Hydrogen (g)	Mass of Oxygen (g)
1	0.5	8
2	1	16
3	1.5	24

b. Do you notice a similarity between these results and those for carbon monoxide in part a?
c. Can you formulate a law from your observations in a and b?
d. Can you formulate a hypothesis that might explain your law in c?

36. When astronomers observe distant galaxies, they can tell that most of them are moving away from one another. In addition, the more distant the galaxies, the more rapidly they are likely to be moving away from each other. Can you devise a hypothesis to explain these observations?

The Classification and Properties of Matter

37. Classify each substance as a pure substance or a mixture. If it is a pure substance, classify it as an element or a compound. If it is a mixture, classify it as homogeneous or heterogeneous.
MISSED THIS? *Read Section 1.3; Watch KCV 1.3*
a. sweat **b.** carbon dioxide
c. aluminum **d.** vegetable soup

38. Classify each substance as a pure substance or a mixture. If it is a pure substance, classify it as an element or a compound. If it is a mixture, classify it as homogeneous or heterogeneous.
a. wine **b.** beef stew
c. iron **d.** carbon monoxide

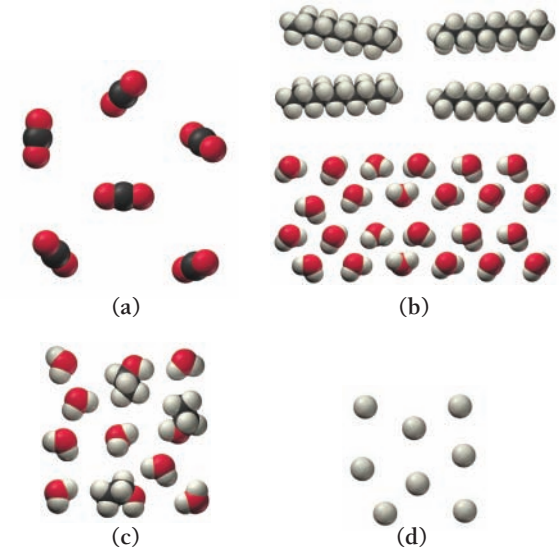
39. Complete the table.
MISSED THIS? *Read Section 1.3; Watch KCV 1.3*

Substance	Pure or mixture	Type
aluminum	pure	element
apple juice	_____	_____
hydrogen peroxide	_____	_____
chicken soup	_____	_____

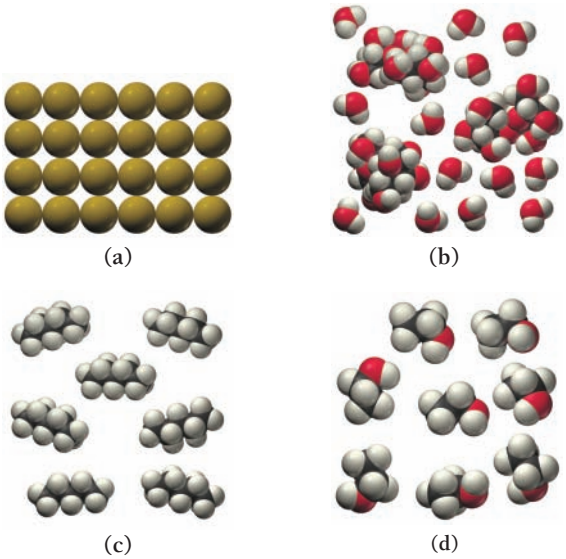
40. Complete the table.

Substance	Pure or mixture	Type
water	pure	compound
coffee	_____	_____
ice	_____	_____
carbon	_____	_____

41. Determine whether each molecular diagram represents a pure substance or a mixture. If it represents a pure substance, classify the substance as an element or a compound. If it represents a mixture, classify the mixture as homogeneous or heterogeneous.
MISSED THIS? *Read Section 1.3; Watch KCV 1.3*


(a) (b) (c) (d)

42. Determine whether each molecular diagram represents a pure substance or a mixture. If it represents a pure substance, classify the substance as an element or a compound. If it represents a mixture, classify the mixture as homogeneous or heterogeneous.


(a) (b) (c) (d)

43. Classify each of the listed properties of isopropyl alcohol (also known as rubbing alcohol) as physical or chemical.
MISSED THIS? *Read Section 1.4*
a. colorless **b.** flammable
c. liquid at room temperature **d.** density = 0.79 g/mL
e. mixes with water

44. Classify each of the listed properties of ozone (a pollutant in the lower atmosphere but part of a protective shield against UV light in the upper atmosphere) as physical or chemical.
a. bluish color
b. pungent odor
c. very reactive
d. decomposes on exposure to ultraviolet light
e. gas at room temperature

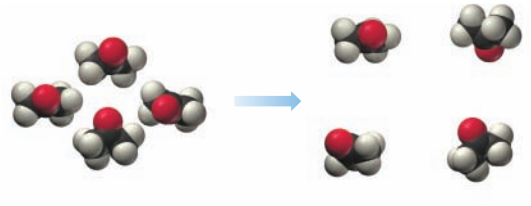
45. Classify each property as physical or chemical.
MISSED THIS? *Read Section 1.4*
a. the tendency of ethyl alcohol to burn
b. the shine on silver
c. the odor of paint thinner
d. the flammability of propane gas

46. Classify each property as physical or chemical.
a. the boiling point of ethyl alcohol
b. the temperature at which dry ice evaporates
c. the tendency of iron to rust
d. the color of gold

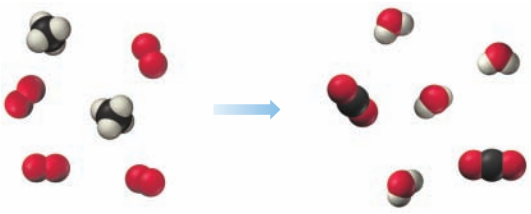
47. Classify each change as physical or chemical.
MISSED THIS? *Read Section 1.4*
a. Natural gas burns in a stove.
b. The liquid propane in a gas grill evaporates because the valve was left open.
c. The liquid propane in a gas grill burns in a flame.
d. A bicycle frame rusts on repeated exposure to air and water.

48. Classify each change as physical or chemical.
a. Sugar burns when heated in a skillet.
b. Sugar dissolves in water.
c. A platinum ring becomes dull because of continued abrasion.
d. A silver surface becomes tarnished after exposure to air for a long period of time.

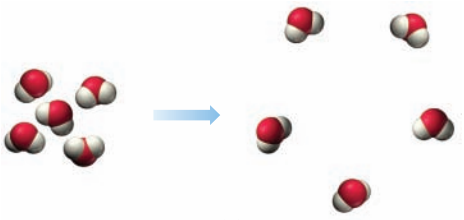
49. Based on the molecular diagram, classify each change as physical or chemical. **MISSED THIS?** *Read Section 1.4*



(a)

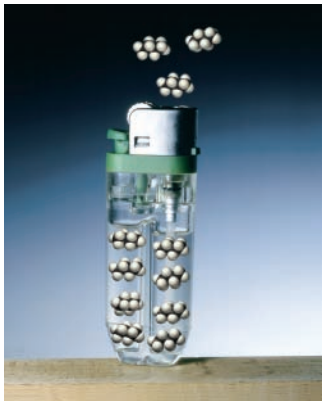


(b)



(c)

50. Based on the molecular diagram, classify each change as physical or chemical.



(a)

(b)

(c)

Units in Measurement

51. Convert each temperature.
MISSED THIS? *Read Section 1.6; Watch KCV 1.6*
a. 32 °F to °C (temperature at which water freezes)
b. 77 K to °F (temperature of liquid nitrogen)
c. −109 °F to °C (temperature of dry ice)
d. 98.6 °F to K (body temperature)

52. Convert each temperature.
a. 212 °F to °C (temperature of boiling water at sea level)
b. 22 °C to K (approximate room temperature)
c. 0.00 K to °F (coldest temperature possible, also known as absolute zero)
d. 2.735 K to °C (average temperature of the universe as measured from background black body radiation)

53. The coldest ground-level temperature ever measured on Earth is −128.6 °F, recorded on July 21, 1983, in Antarctica. Convert that temperature to °C and K.
MISSED THIS? *Read Section 1.6; Watch KCV 1.6*

54. The warmest temperature ever measured in the United States is 134 °F, recorded on July 10, 1913, in Death Valley, California. Convert that temperature to °C and K.

55. Use the prefix multipliers to express each measurement without exponents. **MISSED THIS?** *Read Section 1.6; Watch KCV 1.6*
a. 1.2×10^{-9} m
b. 22×10^{-15} s
c. 1.5×10^{9} g
d. 3.5×10^{6} L

56. Use prefix multipliers to express each measurement without exponents.
a. 38.8×10^{5} g
b. 55.2×10^{-10} s
c. 23.4×10^{11} m
d. 87.9×10^{-7} L

57. Use scientific notation to express each quantity with only base units (no prefix multipliers).
MISSED THIS? *Read Section 1.6; Watch KCV 1.6*
a. 4.5 ns
b. 18 fs
c. 128 pm
d. 35 μm

58. Use scientific notation to express each quantity with only base units (no prefix multipliers).
a. 35 μL
b. 225 Mm
c. 133 Tg
d. 1.5 cg

59. Complete the table.
MISSED THIS? *Read Section 1.6; Watch KCV 1.6*

a.	1245 kg	1.245×10^{6} g	1.245×10^{9} mg
b.	515 km	_____dm	_____cm
c.	122.355 s	_____ms	_____ks
d.	3.345 kJ	_____J	_____mJ

60. Complete the table.

a.	355 km/s	_____cm/s	_____m/ms
b.	1228 g/L	_____g/mL	_____kg/mL
c.	554 mK/s	_____K/s	_____μK/ms
d.	2.554 mg/mL	_____g/L	_____μg/mL

61. Express the quantity 254,998 m in each unit.
MISSED THIS? *Read Section 1.6; Watch KCV 1.6*
a. km
b. Mm
c. mm
d. cm

62. Express the quantity 556.2×10^{-12} s in each unit.
a. ms **b.** ns **c.** ps **d.** fs

63. How many 1-cm squares would it take to construct a square that is 1 m on each side? **MISSED THIS?** *Read Section 1.6*

64. How many 1-cm cubes would it take to construct a cube that is 4 cm on edge?

Density

65. A new penny has a mass of 2.49 g and a volume of 0.349 cm^3. Is the penny made of pure copper? Explain your answer.
MISSED THIS? *Read Section 1.6; Watch KCV 1.6*

66. A titanium bicycle frame displaces 0.314 L of water and has a mass of 1.41 kg. What is the density of the titanium in g/cm^3?

67. Glycerol is a syrupy liquid often used in cosmetics and soaps. A 3.25 L sample of pure glycerol has a mass of 4.10×10^3 g. What is the density of glycerol in g/cm^3?
MISSED THIS? *Read Section 1.6; Watch KCV 1.6*

68. A supposedly gold nugget displaces 19.3 mL of water and has a mass of 371 g. Could the nugget be made of gold?

69. Ethylene glycol (antifreeze) has a density of 1.11 g/cm^3.
MISSED THIS? *Read Section 1.6; Watch KCV 1.6, IWE 1.10*
a. What is the mass in g of 417 mL of ethylene glycol?
b. What is the volume in L of 4.1 kg of ethylene glycol?

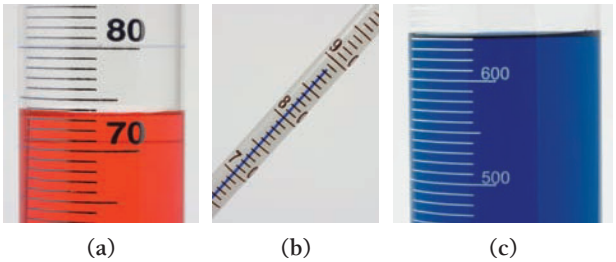
70. Acetone (nail polish remover) has a density of 0.7857 g/cm^3.
a. What is the mass in g of 28.56 mL of acetone?
b. What is the volume in mL of 6.54 g of acetone?

71. A small airplane takes on 245 L of fuel. If the density of the fuel is 0.821 g/mL, what mass of fuel has the airplane taken on?
MISSED THIS? *Read Section 1.6; Watch KCV 1.6, IWE 1.10*

72. Human fat has a density of 0.918 g/cm^3. How much volume (in cm^3) is gained by a person who gains 10.0 lb of pure fat?

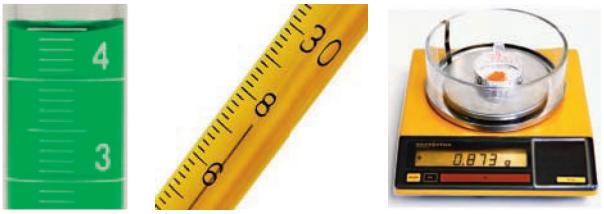
The Reliability of a Measurement and Significant Figures

73. Read each measurement to the correct number of significant figures. Laboratory glassware should always be read from the bottom of the meniscus. **MISSED THIS?** *Read Section 1.7*



(a) (b) (c)

74. Read each measurement to the correct number of significant figures. Laboratory glassware should always be read from the bottom of the meniscus. Digital balances normally display mass to the correct number of significant figures for that particular balance.



(a) (b) (c)

75. For each number, underline the zeroes that are significant and draw an **x** through the zeroes that are not.
MISSED THIS? *Read Section 1.7; Watch KCV 1.6, IWE 1.5*
a. 1,050,501 km
b. 0.0020 m
c. 0.000000000000002 s
d. 0.001090 cm

76. For each number, underline the zeroes that are significant and draw an **x** through the zeroes that are not.
a. 180,701 mi
b. 0.001040 m
c. 0.005710 km
d. 90,201 m

77. How many significant figures are in each number?
MISSED THIS? *Read Section 1.7; Watch KCV 1.6, IWE 1.5*
a. 0.000312 m
b. 312,000 s
c. 3.12×10^5 km
d. 13,127 s
e. 2000

78. How many significant figures are in each number?
a. 0.1111 s
b. 0.007 m
c. 108,700 km
d. 1.563300×10^{11} m
e. 30,800

79. Which numbers are exact (and therefore have an unlimited number of significant figures)?
MISSED THIS? *Read Section 1.7; Watch KCV 1.6, IWE 1.5*
a. $\pi = 3.14$
b. 12 in = 1 ft
c. EPA gas mileage rating of 26 miles per gallon
d. 1 gross = 144

80. Indicate the number of significant figures in each number. If the number is an exact number, indicate an unlimited number of significant figures.
a. 325,365,189 (July 4, 2017 U.S. population)
b. 2.54 cm = 1 in
c. 11.4 g/cm^3 (density of lead)
d. 12 = 1 dozen

81. Round each number to four significant figures.
MISSED THIS? *Read Section 1.7; Watch KCV 1.7*
a. 156.852
b. 156.842
c. 156.849
d. 156.899

82. Round each number to three significant figures.
a. 79,845.82
b. 1.548937×10^7
c. 2.3499999995
d. 0.000045389

Significant Figures in Calculations

83. Calculate to the correct number of significant figures. **MISSED THIS?** *Read Section 1.7; Watch KCVs 1.6, 1.7, IWEs 1.5, 1.6*
a. $9.15 \div 4.970$
b. $1.54 \times 0.03060 \times 0.69$
c. $27.5 \times 1.82 \div 100.04$
d. $(2.290 \times 10^6) \div (6.7 \times 10^4)$

84. Calculate to the correct number of significant figures.
a. $89.3 \times 77.0 \times 0.08$
b. $(5.01 \times 10^5) \div (7.8 \times 10^2)$
c. $4.005 \times 74 \times 0.007$
d. $453 \div 2.031$

85. Calculate to the correct number of significant figures. **MISSED THIS?** *Read Section 1.7; Watch KCVs 1.6, 1.7, IWEs 1.5, 1.6*
a. $43.7 - 2.341$
b. $17.6 + 2.838 + 2.3 + 110.77$
c. $19.6 + 58.33 - 4.974$
d. $5.99 - 5.572$

86. Calculate to the correct number of significant figures.
a. $0.004 + 0.09879$
b. $1239.3 + 9.73 + 3.42$
c. $2.4 - 1.777$
d. $532 + 7.3 - 48.523$

87. Calculate to the correct number of significant figures. **MISSED THIS?** *Read Section 1.7; Watch KCVs 1.6, 1.7, IWEs 1.5, 1.6*
a. $(24.6681 \times 2.38) + 332.58$
b. $(85.3 - 21.489) \div 0.0059$
c. $(512 \div 986.7) + 5.44$
d. $[(28.7 \times 10^5) \div 48.533] + 144.99$

88. Calculate to the correct number of significant figures.
a. $[(1.7 \times 10^6) \div (2.63 \times 10^5)] + 7.33$
b. $(568.99 - 232.1) \div 5.3$
c. $(9443 + 45 - 9.9) \times 8.1 \times 10^6$
d. $(3.14 \times 2.4367) - 2.34$

89. A flask containing 11.7 mL of a liquid weighs 132.8 g with the liquid in the flask and 124.1 g when empty. Calculate the density of the liquid in g/mL to the correct number of significant digits. **MISSED THIS?** *Read Section 1.6; Watch KCV 1.7, IWE 1.6*

90. A flask containing 9.55 mL of a liquid weighs 157.2 g with the liquid in the flask and 148.4 g when empty. Calculate the density of the liquid in g/mL to the correct number of significant digits.

Unit Conversions

91. Perform each unit conversion. **MISSED THIS?** *Read Section 1.8; Watch KCV 1.8, IWE 1.8*
a. 27.8 L to cm^3
b. 1898 mg to kg
c. 198 km to cm

92. Perform each unit conversion.
a. 28.9 nm to μm
b. 1432 cm^3 to L
c. 1211 Tm to Gm

93. Perform each unit conversion. **MISSED THIS?** *Read Section 1.8; Watch KCV 1.8, IWE 1.8*
a. 154 cm to in
b. 3.14 kg to g
c. 3.5 L to qt
d. 109 mm to in

94. Perform each unit conversion.
a. 1.4 in to mm
b. 116 ft to cm
c. 1845 kg to lb
d. 815 yd to km

95. A runner wants to run 10.0 km. Her running pace is 7.5 mi per hour. How many minutes must she run? **MISSED THIS?** *Read Section 1.8; Watch KCV 1.8, IWE 1.8*

96. A cyclist rides at an average speed of 18 mi per hour. If she wants to bike 212 km, how long (in hours) must she ride?

97. A certain European automobile has a gas mileage of 17 km/L. What is the gas mileage in miles per gallon? **MISSED THIS?** *Read Section 1.8; Watch KCV 1.8, IWE 1.8*

98. A gas can holds 5.0 gal of gasoline. Express this quantity in cm^3.

99. A house has an area of 195 m^2. What is its area in each unit? **MISSED THIS?** *Read Section 1.8; Watch KCV 1.8, IWE 1.9*
a. km^2
b. dm^2
c. cm^2

100. A bedroom has a volume of 115 m^3. What is its volume in each unit?
a. km^3
b. dm^3
c. cm^3

101. The average U.S. farm occupies 435 acres. How many square miles is this? (1 acre = 43,560 ft^2, 1 mile = 5280 ft) **MISSED THIS?** *Read Section 1.8; Watch KCV 1.8, IWE 1.9*

102. Total U.S. farmland occupies 954 million acres. How many square miles is this? (1 acre = 43,560 ft^2, 1 mi = 5280 ft). Total U.S. land area is 3.537 million square miles. What percentage of U.S. land is farmland?

103. An acetaminophen suspension for infants contains 80 mg/0.80 mL suspension. The recommended dose is 15 mg/kg body weight. How many mL of this suspension should be given to an infant weighing 14 lb? (Assume two significant figures.) **MISSED THIS?** *Read Section 1.8; Watch KCV 1.8, IWE 1.8*

104. An ibuprofen suspension for infants contains 100 mg/5.0 mL suspension. The recommended dose is 10 mg/kg body weight. How many mL of this suspension should be given to an infant weighing 18 lb? (Assume two significant figures.)

CUMULATIVE PROBLEMS

105. There are exactly 60 seconds in a minute, exactly 60 minutes in an hour, exactly 24 hours in a mean solar day, and 365.24 solar days in a solar year. How many seconds are in a solar year? Give your answer with the correct number of significant figures.

106. Determine the number of picoseconds in 2.0 hours.

107. Classify each property as intensive or extensive.
a. volume
b. boiling point
c. temperature
d. electrical conductivity
e. energy

108. At what temperatures are the readings on the Fahrenheit and Celsius thermometers the same?

109. Suppose you design a new thermometer called the X thermometer. On the X scale the boiling point of water is 130 °X, and the freezing point of water is 10 °X. At what temperature are the readings on the Fahrenheit and X thermometers the same?

110. On a new Jekyll temperature scale, water freezes at 17 °J and boils at 97 °J. On another new temperature scale, the Hyde scale, water freezes at 0 °H and boils at 120 °H. If methyl alcohol boils at 84 °H, what is its boiling point on the Jekyll scale?

111. Force is defined as mass times acceleration. Starting with SI base units, derive a unit for force. Using SI prefixes, suggest a convenient unit for the force resulting from a collision with a 10-ton trailer truck moving at 55 mi per hour and for the force resulting from the collision of a molecule of mass around 10^{-20} kg moving almost at the speed of light (3×10^8 m/s) with the wall of its container. (Assume a 1-second deceleration time for both collisions.)

112. A temperature measurement of 25 °C has three significant figures, while a temperature measurement of −196 °C has only two significant figures. Explain.

113. Do each calculation without your calculator and give the answers to the correct number of significant figures.
a. $1.76 \times 10^{-3}/8.0 \times 10^{2}$
b. $1.87 \times 10^{-2} + 2 \times 10^{-4} - 3.0 \times 10^{-3}$
c. $[(1.36 \times 10^{5})(0.000322)/0.082](129.2)$

114. The value of the euro was recently $1.15 U.S., and the price of 1 liter of gasoline in France is 1.42 euro. What is the price of 1 gallon of gasoline in U.S. dollars in France?

115. A thief uses a can of sand to replace a solid gold cylinder that sits on a weight-sensitive, alarmed pedestal. The can of sand and the gold cylinder have exactly the same dimensions (length = 22 and radius = 3.8 cm).
a. Calculate the mass of each cylinder (ignore the mass of the can itself). (density of gold = 19.3 g/cm^3, density of sand = 3.00 g/cm^3)
b. Does the thief set off the alarm? Explain.

116. The proton has a radius of approximately 1.0×10^{-13} cm and a mass of 1.7×10^{-24} g. Determine the density of a proton. For a sphere, $V = (4/3)\pi r^3$.

117. The density of titanium is 4.51 g/cm^3. What is the volume (in cubic inches) of 3.5 lb of titanium?

118. The density of iron is 7.86 g/cm^3. What is its density in pounds per cubic inch (lb/in^3)?

119. A steel cylinder has a length of 2.16 in, a radius of 0.22 in, and a mass of 41 g. What is the density of the steel in g/cm^3?

120. A solid aluminum sphere has a mass of 85 g. Use the density of aluminum to find the radius of the sphere in inches.

121. A backyard swimming pool holds 185 cubic yards (yd^3) of water. What is the mass of the water in pounds?

122. An iceberg has a volume of 7655 ft^2. What is the mass of the ice (in kg) composing the iceberg (at 0 °C)?

123. The Toyota Prius, a hybrid electric vehicle, has an EPA gas mileage rating of 52 mi/gal in the city. How many kilometers can the Prius travel on 15 L of gasoline?

124. The Honda Insight, a hybrid electric vehicle, has an EPA gas mileage rating of 41 mi/gal in the city. How many kilometers can the Insight travel on the amount of gasoline that would fit in a soda can? The volume of a soda can is 355 mL.

125. The single proton that forms the nucleus of the hydrogen atom has a radius of approximately 1.0×10^{-13} cm. The hydrogen atom itself has a radius of approximately 52.9 pm. What fraction of the space within the atom is occupied by the nucleus?

126. A sample of gaseous neon atoms at atmospheric pressure and 0 °C contains 2.69×10^{22} atoms per liter. The atomic radius of neon is 69 pm. What fraction of the space do the atoms themselves occupy? What does this reveal about the separation between atoms in the gaseous phase?

127. The diameter of a hydrogen atom is 212 pm. Find the length in kilometers of a row of 6.02×10^{23} hydrogen atoms. The diameter of a ping pong ball is 4.0 cm. Find the length in kilometers of a row of 6.02×10^{23} ping pong balls.

128. The world record in the men's 100-m dash is 9.58 s, and in the 100-yd dash it is 9.07 s. Find the speed in mi/hr of the runners who set these records. (Assume three significant figures for 100 m and 100 yd.)

129. Table salt contains 39.33 g of sodium per 100 g of salt. The U.S. Food and Drug Administration (FDA) recommends that adults consume less than 2.40 g of sodium per day. A particular snack mix contains 1.25 g of salt per 100 g of the mix. What mass of the snack mix can an adult consume and still be within the FDA limit? (Assume three significant figures for 100 g.)

130. Lead metal can be extracted from a mineral called galena, which contains 86.6% lead by mass. A particular ore contains 68.5% galena by mass. If the lead can be extracted with 92.5% efficiency, what mass of ore is required to make a lead sphere with a 5.00-cm radius?

131. A length of #8 copper wire (radius = 1.63 mm) has a mass of 24.0 kg and a resistance of 2.061 ohm per km (Ω/km). What is the overall resistance of the wire?

132. Rolls of aluminum foil are 304 mm wide and 0.016 mm thick. What maximum length of aluminum foil can be made from 1.10 kg of aluminum?

133. Liquid nitrogen has a density of 0.808 g/mL and boils at 77 K. Researchers often purchase liquid nitrogen in insulated 175 L tanks. The liquid vaporizes quickly to gaseous nitrogen (which has a density of 1.15 g/L at room temperature and atmospheric pressure) when the liquid is removed from the tank. Suppose that all 175 L of liquid nitrogen in a tank accidentally vaporized in a lab that measured 10.00 m × 10.00 m × 2.50 m. What maximum fraction of the air in the room could be displaced by the gaseous nitrogen?

134. Mercury is often used in thermometers. The mercury sits in a bulb on the bottom of the thermometer and rises up a thin capillary as the temperature rises. Suppose a mercury thermometer contains 3.380 g of mercury and has a capillary that is 0.200 mm in diameter. How far does the mercury rise in the capillary when the temperature changes from 0.0 °C to 25.0 °C? The density of mercury at these temperatures is 13.596 g/cm^3 and 13.534 g/cm^3, respectively.

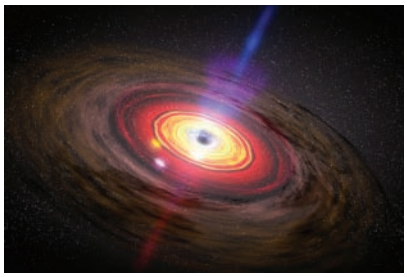
CHALLENGE PROBLEMS

135. A force of 2.31×10^4 N is applied to a diver's face mask that has an area of 125 cm^2. Find the pressure in atm on the face mask.

136. The SI unit of force is the newton, derived from the base units by using the definition of force, $F = ma$. The dyne is a non-SI unit of force in which mass is measured in grams and time is measured in seconds. The relationship between the two units is 1 dyne $= 10^{-5}$ N. Find the unit of length used to define the dyne.

137. Kinetic energy can be defined as $\frac{1}{2}mv^2$ or as $\frac{3}{2}PV$. Show that the derived SI units of each of these terms are those of energy. (Pressure is force/area and force is mass × acceleration.)

138. In 1999, scientists discovered a new class of black holes with masses 100 to 10,000 times the mass of our sun that occupy less space than our moon. Suppose that one of these black holes has a mass of 1×10^3 suns and a radius equal to one-half the radius of our moon. What is the density of the black hole in g/cm^3? The radius of our sun is 7.0×10^5 km, and it has an average density of 1.4×10^3 kg/m^3. The diameter of the moon is 2.16×10^3 mi.



139. Suppose that polluted air has carbon monoxide (CO) levels of 15.0 ppm. An average human inhales about 0.50 L of air per breath and takes about 20 breaths per minute. How many milligrams of carbon monoxide does the average person inhale in an 8-hour period at this level of carbon monoxide pollution? Assume that the carbon monoxide has a density of 1.2 g/L. (*Hint*: 15.0 ppm CO means 15.0 L CO per 10^6 L air.)

140. Nanotechnology, the field of building ultrasmall structures one atom at a time, has progressed in recent years. One potential application of nanotechnology is the construction of artificial cells. The simplest cells would probably mimic red blood cells, the body's oxygen transporters. Nanocontainers, perhaps constructed of carbon, could be pumped full of oxygen and injected into a person's bloodstream. If the person needed additional oxygen—due to a heart attack perhaps, or for the purpose of space travel—these containers could slowly release oxygen into the blood, allowing tissues that would otherwise die to remain alive. Suppose that the nanocontainers were cubic and had an edge length of 25 nm.

- **a.** What is the volume of one nanocontainer? (Ignore the thickness of the nanocontainer's wall.)
- **b.** Suppose that each nanocontainer could contain pure oxygen pressurized to a density of 85 g/L. How many grams of oxygen could each nanocontainer contain?
- **c.** Air typically contains about 0.28 g of oxygen per liter. An average human inhales about 0.50 L of air per breath and takes about 20 breaths per minute. How many grams of oxygen does a human inhale per hour? (Assume two significant figures.)
- **d.** What is the minimum number of nanocontainers that a person would need in his or her bloodstream to provide 1 hour's worth of oxygen?
- **e.** What is the minimum volume occupied by the number of nanocontainers calculated in part d? Is such a volume feasible, given that total blood volume in an adult is about 5 L?

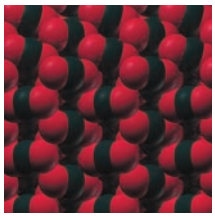
141. Approximate the percent increase in waist size that occurs when a 155-lb person gains 40.0 lb of fat. Assume that the volume of the person can be modeled by a cylinder that is 4.0 ft tall. The average density of a human is about 1.0 g/cm^3, and the density of fat is 0.918 g/cm^3.

142. A box contains a mixture of small copper spheres and small lead spheres. The total volume of both metals is measured by the displacement of water to be 427 cm^3, and the total mass is 4.36 kg. What percentage of the spheres are copper?

CONCEPTUAL PROBLEMS

143. A volatile liquid (one that easily evaporates) is put into a jar, and the jar is then sealed. Does the mass of the sealed jar and its contents change upon the vaporization of the liquid?

144. The diagram shown first represents solid carbon dioxide, also known as dry ice. Which of the other diagrams best represents the dry ice after it has sublimed into a gas?



(a) (b) (c)

145. A cube has an edge length of 7 cm. If it is divided into 1-cm cubes, how many 1-cm cubes are there?

146. Substance A has a density of 1.7 g/cm^3. Substance B has a density of 1.7 kg/m^3. Without doing any calculations, determine which substance is more dense.

147. For each box, examine the blocks attached to the balances. Based on their positions and sizes, determine which block is more dense (the dark block or the lighter-colored block), or if the relative densities cannot be determined. (Think carefully about the information being shown.)

(a) (b) (c)

148. Let a triangle represent atoms of element A and a circle represent atoms of element B.

a. Draw an atomic-level view of a homogeneous mixture of elements A and B.

b. Draw an atomic view of the compound AB in a liquid state (molecules close together).

c. Draw an atomic view of the compound AB after it has undergone a physical change (such as evaporation).

d. Draw an atomic view of the compound after it has undergone a chemical change (such as decomposition of AB into A and B).

149. Identify each statement as being most like an observation, a law, or a theory.

a. All coastal areas experience two high tides and two low tides each day.

b. The tides in Earth's oceans are caused mainly by the gravitational attraction of the moon.

c. Yesterday, high tide in San Francisco Bay occurred at 2:43 A.M. and 3:07 P.M.

d. Tides are higher at the full moon and new moon than at other times of the month.

QUESTIONS FOR GROUP WORK

Active Classroom Learning

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

150. Using white and black circles to represent different kinds of atoms, make a drawing that accurately represents each sample of matter: a solid element, a liquid compound, and a heterogeneous mixture. Make a drawing (clearly showing *before* and *after*) depicting your liquid compound undergoing a physical change. Make a drawing depicting your solid element undergoing a chemical change.

151. Look up the measurement of the approximate thickness of a human hair.

a. Convert the measurement to an SI unit (if it isn't already).

b. Write it in scientific notation.

c. Write it without scientific notation.

d. Write it with an appropriate prefix on a base unit.

Now repeat these steps using the distance from Earth to the sun.

152. The following statements are all true.

a. Jessica's house is 5 km from the grocery store.

b. Jessica's house is 4.73 km from the grocery store.

c. Jessica's house is 4.73297 km from the grocery store.

How can all the statements be true? What does the number of digits in each statement communicate? What sort of device would Jessica need to make the measurement in each statement?

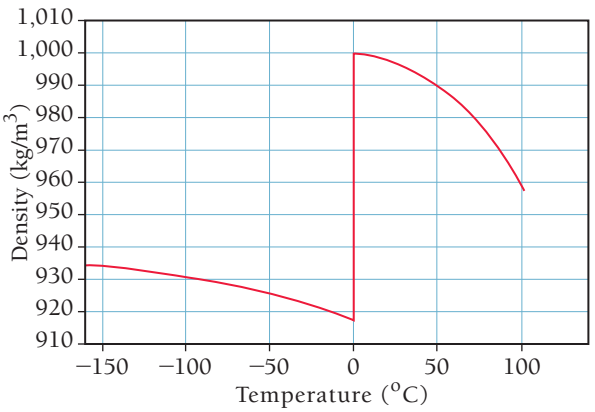
153. One inch is equal to 2.54 cm. Draw a line that is 1 in long, and mark the centimeters on the line. Draw a cube that is 1 in on each side. Draw lines on each face of the cube that are 1 cm apart. How many cubic centimeters are there in 1 in^3?

154. Convert the height of each member in your group from feet and inches to meters. Once you have your heights in meters, calculate the sum of all the heights. Use appropriate rules for significant figures at each step.

DATA INTERPRETATION AND ANALYSIS

Density of Water

155. The density of a substance can change with temperature. The graph that follows displays the density of water from −150 °C to 100 °C. Examine the graph and answer the questions.



a. Water undergoes a large change in density at 0 °C as it freezes to form ice. Calculate the percent change in density that occurs when liquid water freezes to ice at 0 °C.

(*Hint*: % change $= \dfrac{\text{final value} - \text{initial value}}{\text{initial value}} \times 100\%$)

b. Calculate the volume (in cm^3) of 54 g of water at 1 °C and the volume of the same mass of ice at −1 °C. What is the change in volume?

c. Antarctica contains 26.5 million cubic kilometers of ice. Assume the temperature of the ice is −20 °C. If all of this ice were heated to 1 °C and melted to form water, what volume of liquid water would form?

d. A 1.00-L sample of water is heated from 1 °C to 100 °C. What is the volume of the water after it is heated?

Cc ANSWERS TO CONCEPTUAL CONNECTIONS

Laws and Theories

1.1 **(b)** A law only summarizes a series of related observations; a theory gives the underlying reasons for them.

Pure Substances and Mixtures

1.2 **(a)** This image is a pure substance. More specifically, because it contains two different type of atoms bonded together, it is a pure compound.

Chemical and Physical Changes

1.3 View **(a)** best represents the water after vaporization. Vaporization is a physical change, so the molecules must remain the same before and after the change.

Energy

1.4 **(c)** Chemical energy is a type of potential energy that results from the electrostatic forces between the charged particles that compose atoms and molecules.

Temperature Scale

1.5 **(a)** The Kelvin scale has no negative temperatures because 0 Kelvin is the coldest possible temperature. Lower temperatures do not exist. Both the Celsius scale and the Fahrenheit scale have negative temperatures.

Prefix Multipliers

1.6 **(c)** The prefix micro (10^{-6}) is appropriate. The measurement would be reported as 55.7 μm.

Density

1.7 **(c)** The copper sample expands. However, because its mass remains constant while its volume increases, its density decreases.