- Solve the equation for the *find* quantity (ΔT).
- Substitute the appropriate quantities into the equation and compute the answer to the correct number of significant figures.

Solution:

$$q = m \cdot C \cdot \Delta T$$

$$\Delta T = \frac{q}{mC}$$

$$\Delta T = \frac{3.4 \times 10^4 \text{ J}}{355 \text{ g} \times 4.18 \text{ J/g °C}}$$

$$= 22.91 \text{ °C} = 23 \text{ °C}$$

- Check the answer.

The answer has the correct units, and the magnitude seems correct. If the magnitude of the answer were a huge number—3×10^6, for example—we would go back and look for a mistake. If water were to go above 100 °C, it would boil, so such a large answer would be unlikely.

KEY TERMS

amorphous [3.3]
atoms [3.2]
calorie (cal) [3.8]
Calorie (Cal) [3.8]
Celsius (°C) scale [3.10]
chemical change [3.6]
chemical energy [3.8]
chemical properties [3.5]
chemical reaction [3.7]
compound [3.4]
compressible [3.3]
crystalline [3.3]
decanting [3.6]
distillation [3.6]
electrical energy [3.8]
element [3.4]
endothermic [3.9]
energy [3.8]
exothermic [3.9]
Fahrenheit (°F) scale [3.10]
filtration [3.6]
gas [3.3]
heat capacity [3.11]
heterogeneous mixture [3.4]
homogeneous mixture [3.4]
Kelvin (K) scale [3.10]
kilowatt-hour (kWh) [3.8]
kinetic energy [3.8]
law of conservation of energy [3.8]
liquid [3.3]
matter [3.2]
mixture [3.4]
molecules [3.2]
physical change [3.6]
physical properties [3.5]
potential energy [3.8]
products [3.7]
properties [3.5]
pure substance [3.4]
reactants [3.7]
solid [3.3]
specific heat capacity (specific heat) [3.11]
state of matter [3.3]
volatile [3.6]

EXERCISES

Questions

Answers to all odd-numbered questions (numbered in blue) appear in the Answers section at the back of the book.

1. Define matter and give some examples.
2. What is matter composed of?
3. What are the three states of matter?
4. What are the properties of a solid?
5. What is the difference between a crystalline solid and an amorphous solid?
6. What are the properties of a liquid?
7. What are the properties of a gas?
8. Why are gases compressible?
9. What is a mixture?
10. What is the difference between a homogeneous mixture and a heterogeneous mixture?
11. What is a pure substance?
12. What is an element? A compound?
13. What is the difference between a mixture and a compound?
14. What is a physical property? What is a chemical property?
15. What is the difference between a physical change and a chemical change?
16. What is the law of conservation of mass?
17. What is the definition of energy?
18. What is the law of conservation of energy?
19. Name some different kinds of energy.

20. What are three common units for energy?
21. What is an exothermic reaction? Which has greater energy in an exothermic reaction, the reactants or the products?
22. What is an endothermic reaction? Which has greater energy in an endothermic reaction, the reactants or the products?
23. What are three common units for measuring temperature?
24. How do the three temperature scales differ?
25. What is heat capacity?
26. Why are coastal geographic regions normally cooler in the summer than inland geographic regions?
27. The following equation can be used to convert Fahrenheit temperature to Celsius temperature.

$$°C = \frac{(°F - 32)}{1.8}$$

Use algebra to change the equation to convert Celsius temperature to Fahrenheit temperature.

28. The following equation can be used to convert Celsius temperature to Kelvin temperature.

$$K = °C + 273$$

Use algebra to change the equation to convert Kelvin temperature to Celsius temperature.

Problems

Note: The exercises in the Problems section are paired, and the answers to the odd-numbered exercises (numbered in blue) appear in the Answers section at the back of the book.

Classifying Matter

29. Classify each of the following pure substances as an element or a compound.
    (a) aluminum
    (b) sulfur
    (c) methane
    (d) acetone

30. Classify each of the following pure substances as an element or a compound.
    (a) carbon
    (b) baking soda (sodium bicarbonate)
    (c) nickel
    (d) gold

31. Classify each of the following mixtures as homogeneous or heterogeneous.
    (a) coffee
    (b) chocolate sundae
    (c) apple juice
    (d) gasoline

32. Classify each of the following mixtures as homogeneous or heterogeneous.
    (a) baby oil
    (b) chocolate chip cookie
    (c) water and gasoline
    (d) wine

33. Classify each of the following 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) helium gas
    (b) clean air
    (c) rocky road ice cream
    (d) concrete

34. Classify each of the following 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) urine
    (b) pure water
    (c) Snickers™ bar
    (d) soil

Physical and Chemical Properties and Physical and Chemical Changes

35. Classify each of the following properties as physical or chemical.
    (a) the tendency of silver to tarnish
    (b) the shine of chrome
    (c) the color of gold
    (d) the flammability of propane gas

36. Classify each of the following properties as physical or chemical.
    (a) the boiling point of ethyl alcohol
    (b) the temperature at which dry ice evaporates
    (c) the flammability of ethyl alcohol
    (d) the smell of perfume

37. The following list contains several properties of ethylene (a ripening agent for bananas). Which are physical properties and which are chemical?
- colorless
- odorless
- flammable
- gas at room temperature
- 1 L has a mass of 1.260 g under standard conditions
- mixes with acetone
- polymerizes to form polyethylene

38. The following list contains several properties of ozone (a pollutant in the lower atmosphere but part of a protective shield against UV light in the upper atmosphere). Which are physical and which are chemical?
- bluish color
- pungent odor
- very reactive
- decomposes on exposure to ultraviolet light
- gas at room temperature

39. Determine whether each of the following changes is physical or chemical.
(a) A balloon filled with hydrogen gas explodes upon contact with a spark.
(b) The liquid propane in a barbecue evaporates away because the user left the valve open.
(c) The liquid propane in a barbecue ignites upon contact with a spark.
(d) Copper metal turns green on exposure to air and water.

40. Determine whether each of the following changes is physical or chemical.
(a) Sugar dissolves in hot water.
(b) Sugar burns in a pot.
(c) A metal surface becomes dull because of continued abrasion.
(d) A metal surface becomes dull on exposure to air.

41. A block of aluminum is **(a)** ground into aluminum powder and then **(b)** ignited. It then emits flames and smoke. Classify **(a)** and **(b)** as chemical or physical changes.

42. Several pieces of graphite from a mechanical pencil are **(a)** broken into tiny pieces. Then the pile of graphite is **(b)** ignited with a hot flame. Classify **(a)** and **(b)** as chemical or physical changes.

The Conservation of Mass

43. An automobile gasoline tank holds 42 kg of gasoline. When the gasoline burns, 168 kg of oxygen are consumed and carbon dioxide and water are produced. What is the total combined mass of carbon dioxide and water that is produced?

44. In the explosion of a hydrogen-filled balloon, 0.50 g of hydrogen reacted with 4.0 g of oxygen to form how many grams of water vapor? (Water vapor is the only product.)

45. Are the following data sets on chemical changes consistent with the law of conservation of mass?
(a) A 7.5-g sample of hydrogen gas completely reacts with 60.0 g of oxygen gas to form 67.5 g of water.
(b) A 60.5-g sample of gasoline completely reacts with 243 g of oxygen to form 206 g of carbon dioxide and 88 g of water.

46. Are the following data sets on chemical changes consistent with the law of conservation of mass?
(a) A 12.8-g sample of sodium completely reacts with 19.6 g of chlorine to form 32.4 g of sodium chloride.
(b) An 8-g sample of natural gas completely reacts with 32 g of oxygen gas to form 17 g of carbon dioxide and 16 g of water.

47. In a butane lighter, 9.7 g of butane combine with 34.7 g of oxygen to form 29.3 g carbon dioxide and how many grams of water?

48. A 56-g sample of iron reacts with 24 g of oxygen to form how many grams of iron oxide?

Conversion of Energy Units

49. Perform each of the following conversions.
(a) 28.7 J to calories
(b) 452 cal to joules
(c) 22.8 kJ to calories
(d) 155 cal to kilojoules

50. Perform each of the following conversions.
(a) 654 cal to joules
(b) 12.9 J to Calories
(c) 167 kJ to Calories
(d) 99.3 Cal to joules

51. Perform each of the following conversions.
(a) 25 kWh to joules
(b) 249 cal to Calories
(c) 113 cal to kilowatt-hours
(d) 44 kJ to calories

52. Perform each of the following conversions.
(a) 345 Cal to kilowatt-hours
(b) 23 J to calories
(c) 5.7×10^3 J to kilojoules
(d) 326 kJ to joules

53. Complete the following table:

J	cal	Cal	kWh
225 J	____	5.38×10^{-2} Cal	____
____	8.21×10^5 cal	____	____
____	____	____	295 kWh
____	____	155 Cal	____

54. Complete the following table:

J	cal	Cal	kWh
7.88×10^6 J	1.88×10^6 cal	____	____
____	____	1154 Cal	____
____	88.4 cal	____	____
____	____	____	125 kWh

55. An energy bill indicates that the customer used 955 kWh in July. How many joules did the customer use?

56. A television uses 25 kWh of energy per year. How many joules does it use?

57. An adult eats food whose nutritional energy totals approximately 2.2×10^3 Cal per day. The adult burns 2.0×10^3 Cal per day. How much excess nutritional energy, in kilojoules, does the adult consume per day? If 1 lb of fat is stored by the body for each 14.6×10^3 kJ of excess nutritional energy consumed, how long will it take this person to gain 1 lb?

58. How many joules of nutritional energy are in a bag of chips whose label reads 245 Cal? If 1 lb of fat is stored by the body for each 14.6×10^3 kJ of excess nutritional energy consumed, how many bags of chips contain enough nutritional energy to result in 1 lb of body fat?

Energy and Chemical and Physical Change

59. A common type of handwarmer contains iron powder that reacts with oxygen to form an oxide of iron. As soon as the handwarmer is exposed to air, the reaction begins and heat is emitted. Is the reaction between the iron and oxygen exothermic or endothermic? Draw an energy diagram showing the relative energies of the reactants and products in the reaction.

60. In a chemical cold pack, two substances are kept separate by a divider. When the divider is broken, the substances mix and absorb heat from the surroundings. The chemical cold pack feels cold. Is the reaction exothermic or endothermic? Draw an energy diagram showing the relative energies of the reactants and products in the reaction.

61. Determine whether each of the following is exothermic or endothermic.
(a) gasoline burning in a car
(b) isopropyl alcohol evaporating from skin
(c) water condensing as dew during the night

62. Determine whether each of the following is exothermic or endothermic.
(a) dry ice subliming (changing from a solid directly to a gas)
(b) the wax in a candle burning
(c) a match burning

Converting between Temperature Scales

63. Perform each of the following temperature conversions.
(a) 212 °F to Celsius (temperature of boiling water)
(b) 77 K to Fahrenheit (temperature of liquid nitrogen)
(c) 25 °C to kelvins (room temperature)
(d) 98.6 °F to kelvins (body temperature)

64. Perform each of the following temperature conversions.
(a) 102 °F to Celsius
(b) 0 K to Fahrenheit
(c) −48 °C to Fahrenheit
(d) 273 K to Celsius

65. The coldest temperature ever measured in the United States was −80 °F on January 23, 1971, in Prospect Creek, Alaska. Convert that temperature to degrees Celsius and Kelvin. (Assume that −80 °F is accurate to two significant figures.)

66. The warmest temperature ever measured in the United States was 134 °F on July 10, 1913, in Death Valley, California. Convert that temperature to degrees Celsius and Kelvin.

67. Vodka will not freeze in the freezer because it contains a high percentage of ethanol. The freezing point of pure ethanol is −114 °C. Convert that temperature to degrees Fahrenheit and Kelvin.

68. Liquid helium boils at 4.2 K. Convert this temperature to degrees Fahrenheit and Celsius.

69. Complete the following table.

Kelvin	Fahrenheit	Celsius
0.0 K	____	−273.0 °C
____	82.5 °F	____
____	____	8.5 °C

70. Complete the following table.

Kelvin	Fahrenheit	Celsius
273.0 K	____	0.0 °C
____	−40.0 °F	____
385 K	____	____

Energy, Heat Capacity, and Temperature Changes

71. Calculate the amount of heat required to raise the temperature of a 85-g sample of water from 32 °C to 65 °C.

72. Calculate the amount of heat required to raise the temperature of a 27-g sample of water from 7 °C to 18 °C.

73. Calculate the amount of heat required to heat a 45-kg sample of ethanol from 11.0 °C to 19.0 °C.

74. Calculate the amount of heat required to heat a 3.5-kg gold bar from 21 °C to 67 °C.

75. If 89 J of heat are added to a pure gold coin with a mass of 12 g, what is its temperature change?

76. If 57 J of heat are added to an aluminum can with a mass of 17.1 g, what is its temperature change?

77. An iron nail with a mass of 12 g absorbs 15 J of heat. If the nail was initially at 28 °C, what is its final temperature?

78. A 45-kg sample of water absorbs 345 kJ of heat. If the water was initially at 22.1 °C, what is its final temperature?

79. Calculate the temperature change that occurs when 248 cal of heat are added to 24 g of water.

80. A lead fishing weight with a mass of 57 g absorbs 146 cal of heat. If its initial temperature is 47 °C, what is its final temperature?

81. An unknown metal with a mass of 28 g absorbs 58 J of heat. Its temperature rises from 31.1 °C to 39.9 °C. Calculate the heat capacity of the metal and identify it using Table 3.4.

82. An unknown metal is suspected to be gold. When 2.8 J of heat are added to 5.6 g of the metal, its temperature rises by 3.9 °C. Are these data consistent with the metal being gold?

83. When 56 J of heat are added to 11 g of a liquid, its temperature rises from 10.4 °C to 12.7 °C. What is the heat capacity of the liquid?

84. When 47.5 J of heat are added to 13.2 g of a liquid, its temperature rises by 1.72 °C. What is the heat capacity of the liquid?

85. Two identical coolers are packed for a picnic. Each cooler is packed with eighteen 12-oz soft drinks and 3 lb of ice. However, the drinks that went into cooler A were refrigerated for several hours before they were packed in the cooler, while the drinks that went into cooler B were packed at room temperature. When the two coolers are opened three hours later, most of the ice in cooler A is still ice, while nearly all of the ice in cooler B has melted. Explain this difference.

86. A 100-g block of iron metal and 100 g of water are each warmed to 75 °C and placed into two identical insulated containers. Two hours later, the two containers are opened and the temperature of each substance is measured. The iron metal has cooled to 38 °C while the water has cooled only to 69 °C. Explain this difference.

Cumulative Problems

87. Calculate the final temperature of 245 mL of water initially at 32 °C upon absorption of 17 kJ of heat.

88. Calculate the final temperature of 32 mL of ethanol initially at 11 °C upon absorption of 562 J of heat. (density of ethanol = 0.789 g/mL)

89. A pure gold ring with a volume of 1.57 cm^3 is initially at 11.4 °C. When it is put on, it warms to 29.5 °C. How much heat did the ring absorb? (density of gold = 19.3 g/cm^3)

90. A block of aluminum with a volume of 98.5 cm^3 absorbs 67.4 J of heat. If its initial temperature was 32.5 °C, what is its final temperature? (density of aluminum = 2.70 g/cm^3)

91. How much heat in kilojoules is required to heat 56 L of water from 85 °F to 212 °F?

92. How much heat in joules is required to heat a 43-g sample of aluminum from 72 °F to 145 °F?

93. What is the temperature change in Celsius when 29.5 L of water absorbs 2.3 kWh of heat?

94. If 1.45 L of water is initially at 25.0 °C, what will its temperature be after absorption of 9.4×10^{-2} kWh of heat?

95. A water heater contains 55 gal of water. How many kilowatt-hours of energy are necessary to heat the water in the water heater by 25 °C?

96. A room contains 48 kg of air. How many kilowatt-hours of energy are necessary to heat the air in the house from 7 °C to 28 °C? The heat capacity of air is 1.03 J/g °C.

97. A backpacker wants to carry enough fuel to heat 2.5 kg of water from 25 °C to 100.0 °C. If the fuel he carries produces 36 kJ of heat per gram when it burns, how much fuel should he carry? (For the sake of simplicity, assume that the transfer of heat is 100% efficient.)

98. A cook wants to heat 1.35 kg of water from 32.0 °C to 100.0 °C. If he uses the combustion of natural gas (which is exothermic) to heat the water, how much natural gas will he need to burn? Natural gas produces 49.3 kJ of heat per gram. (For the sake of simplicity, assume that the transfer of heat is 100% efficient.)

99. Evaporating sweat cools the body because evaporation is endothermic and absorbs 2.44 kJ per gram of water evaporated. Estimate the mass of water that must evaporate from the skin to cool a body by 0.50 °C, if the mass of the body is 95 kg and its heat capacity is 4.0 J/g °C. (Assume that the heat transfer is 100% efficient.)

100. When ice melts, it absorbs 0.33 kJ per gram. How much ice is required to cool a 12.0-oz drink from 75 °F to 35 °F, if the heat capacity of the drink is 4.18 J/g °C? (Assume that the heat transfer is 100% efficient.)

101. A 15.7-g aluminum block is warmed to 53.2 °C and plunged into an insulated beaker containing 32.5 g of water initially at 24.5 °C. The aluminum and the water are allowed to come to thermal equilibrium. Assuming that no heat is lost, what is the final temperature of the water and aluminum?

102. 25.0 mL of ethanol (density = 0.789 g/mL) initially at 7.0 °C is mixed with 35.0 mL of water (density = 1.0 g/mL) initially at 25.3 °C in an insulated beaker. Assuming that no heat is lost, what is the final temperature of the mixture?

103. The wattage of an appliance indicates the average power consumption in watts (W), where 1 W = 1 J/s. What is the difference in the number of kJ of energy consumed per month between a refrigeration unit that consumes 625 W and one that consume 855 W? If electricity costs $0.15 per kWh, what is the monthly cost difference to operate the two refrigerators? (Assume 30.0 days in one month and 24.0 hours per day.)

104. A portable electric water heater transfers 255 watts (W) of power to 5.5 L of water, where 1 W = 1 J/s. How much time (in minutes) will it take for the water heater to heat the 5.5 L of water from 25 °C to 42 °C? (Assume that the water has a density of 1.0 g/mL.)

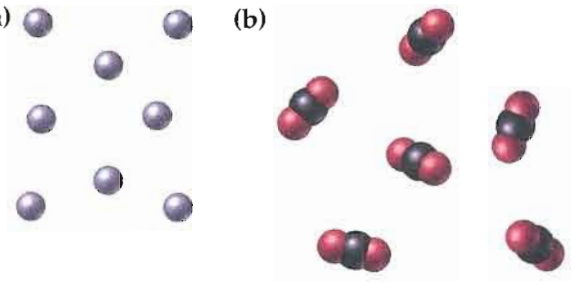
105. What temperature is the same whether it is expressed in the Celsius or Fahrenheit scale?

106. What temperature on the Celsius scale is equal to twice its value when expressed on the Farhenheit scale?

Highlight Problems

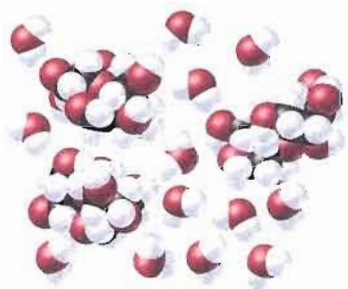
107. Classify each of the following molecular pictures as a pure substance or a mixture.

(a) (b)



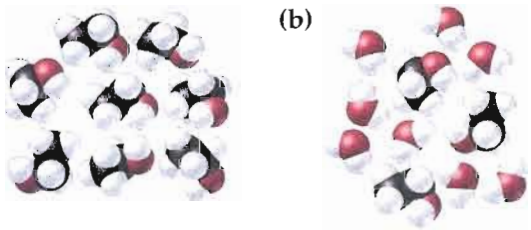
(c)

(d)



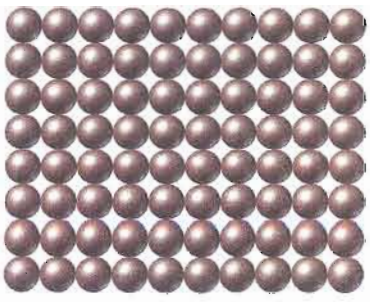
108. Classify each of the following molecular pictures as a pure substance or a mixture. If it is a pure substance, classify it as an element or a compound. If it is a mixture, classify it as homogeneous or heterogeneous.

(a) (b)

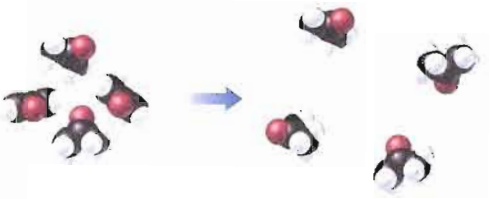


(c)

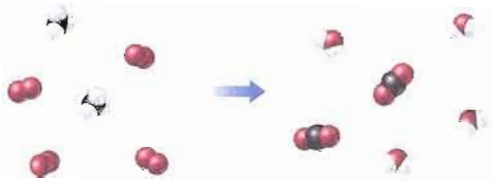
(d)



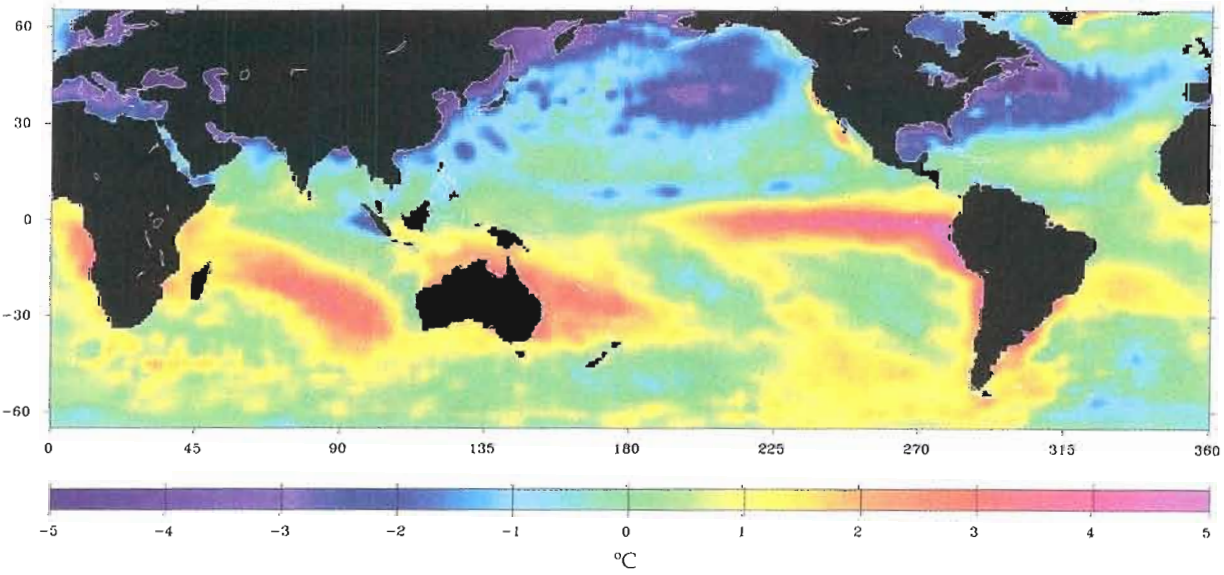
109. The following molecular drawing shows images of acetone molecules before and after a change. Was the change chemical or physical?



110. The following molecular drawing shows images of methane molecules and oxygen molecules before and after a change. Was the change chemical or physical?



111. A major event affecting global climate is the El Niño/La Niña cycle. In this cycle, equatorial Pacific Ocean waters warm by several degrees Celsius above normal (El Niño) and then cool by several degrees Celsius below normal (La Niña). This cycle affects weather not only in North and South America, but as far away as Africa. Why does a seemingly small change in ocean temperature have such a large impact on weather?



▲ Temperature anomaly plot of the world's oceans for December 23, 1997. The red section off the western coast of South America is the El Niño effect, a warming of the Pacific Ocean along the equator.

112. Global warming refers to the rise in average global temperature due to the increased concentration of certain gases, called greenhouse gases, in our atmosphere. Earth's oceans, because of their high heat capacity, can absorb heat and therefore act to slow down global warming. How much heat would be required to warm Earth's oceans by 1.0 °C? Assume that the volume of Earth's oceans is 137×10^7 km^3 and that the density of seawater is 1.03 g/cm^3. Also assume that the heat capacity of seawater is the same as that of water.

◀ Earth's oceans moderate temperatures by absorbing heat during warm periods.

113. Examine the following data for the maximum and minimum average temperatures of San Francisco and Sacramento in the summer and in the winter.

San Francisco (Coastal City)

January		August	
High	Low	High	Low
57.4 °F	43.8 °F	64.4 °F	54.5 °F

Sacramento (Inland City)

January		August	
High	Low	High	Low
53.2 °F	37.7 °F	91.5 °F	57.7 °F

(a) Notice the difference between the August high in San Francisco and Sacramento. Why is it much hotter in the summer in Sacramento?

(b) Notice the difference between the January low in San Francisco and Sacramento. How might the heat capacity of the ocean contribute to this difference?

Answers to Skillbuilder Exercises

Skillbuilder 3.1 **(a)** pure substance, element; **(b)** mixture, homogeneous; **(c)** mixture, heterogeneous; **(d)** pure substance, compound

Skillbuilder 3.2 **(a)** chemical **(b)** physical **(c)** physical **(d)** physical

Skillbuilder 3.3 **(a)** chemical **(b)** physical **(c)** physical **(d)** chemical

Skillbuilder 3.4 27 g

Skillbuilder 3.5 2.14 kJ

Skillbuilder Plus, p. 67 6.57×10^6 cal

Skillbuilder 3.6 **(a)** exothermic **(b)** exothermic

Skillbuilder 3.7 85 °C

Skillbuilder 3.8 282 °F

Skillbuilder 3.9 77 K

Skillbuilder 3.10 50.1 J

Skillbuilder Plus, p. 74 7.4 g

Skillbuilder 3.11 $\Delta T = 4.21$ °C; $T_f = 29.2$ °C

Answers to Conceptual Checkpoints

3.1 (a) Vaporization is a physical change, so the water molecules must be the same before and after the boiling.

3.2 No In the vaporization, the liquid water becomes gaseous, but its mass does not change. Like chemical changes, physical changes also must follow the law of conservation of mass.

3.3 (d) kWh is the largest of the four units listed, so the numerical value of the yearly energy consumption would be lowest if expressed in kWh.

3.4 (d) You can confirm this by substituting each of the Fahrenheit temperatures into the equation in Section 3.10 and solving for the Celsius temperature.

3.5 (a) Because copper has the lowest specific heat capacity of the three metals, it will experience the greatest temperature change for a given energy input.