CHAPTER 1 KEYS TO THE STUDY OF CHEMISTRY

END–OF–CHAPTER PROBLEMS

1.1 Plan: If only the form of the particles has changed and not the composition of the particles, a physical change has taken place; if particles of a different composition result, a chemical change has taken place.
Solution:
a) The result in C represents a **chemical change** as the substances in A (red spheres) and B (blue spheres) have reacted to become a different substance (particles consisting of one red and one blue sphere) represented in C. There are molecules in C composed of the atoms from A and B.
b) The result in D represents a **chemical change** as again the atoms in A and B have reacted to form molecules of a new substance.
c) The change from C to D is a **physical change**. The substance is the same in both C and D (molecules consisting of one red sphere and one blue sphere) but is in the gas phase in C and in the liquid phase in D.
d) The sample has the **same chemical properties** in both C and D since it is the same substance but has **different physical properties**.

1.2 Plan: Apply the definitions of the states of matter to a container. Next, apply these definitions to the examples. Gas molecules fill the entire container; the volume of a gas is the volume of the container. Solids and liquids have a definite volume. The volume of the container does not affect the volume of a solid or liquid.
Solution:
a) The helium fills the volume of the entire balloon. The addition or removal of helium will change the volume of a balloon. Helium is a **gas**.
b) At room temperature, the mercury does not completely fill the thermometer. The surface of the **liquid** mercury indicates the temperature.
c) The soup completely fills the bottom of the bowl, and it has a definite surface. The soup is a **liquid**, though it is possible that solid particles of food will be present.

1.3 Plan: Define the terms and apply these definitions to the examples.
Solution:
Physical property – A characteristic shown by a substance itself, without interacting with or changing into other substances.
Chemical property – A characteristic of a substance that appears as it interacts with, or transforms into, other substances.
a) The change in color (yellow–green and silvery to white), and the change in physical state (gas and metal to crystals) are examples of **physical properties**. The change in the physical properties indicates that a chemical change occurred. Thus, the interaction between chlorine gas and sodium metal producing sodium chloride is an example of a **chemical property**.
b) The sand and the iron are still present. Neither sand nor iron became something else. Colors along with magnetism are **physical properties**. No chemical changes took place, so there are no chemical properties to observe.

1.4 Plan: Define the terms and apply these definitions to the examples.
Solution:
Physical change – A change in which the physical form (or state) of a substance, but not its composition, is altered.
Chemical change – A change in which a substance is converted into a different substance with different composition and properties.
a) The changes in the physical form are **physical changes**. The physical changes indicate that there is also a **chemical change**. Magnesium chloride has been converted to magnesium and chlorine.
b) The changes in color and form are **physical changes**. The physical changes indicate that there is also a **chemical change**. Iron has been converted to a different substance, rust.

1.5 Plan: Apply the definitions of chemical and physical changes to the examples.
Solution:
a) Not a chemical change, but a **physical change —** simply cooling returns the soup to its original form.
b) There is a **chemical change** — cooling the toast will not "un–toast" the bread.
c) Even though the wood is now in smaller pieces, it is still wood. There has been no change in composition, thus this is a **physical change**, and not a chemical change.
d) This is a **chemical change** converting the wood (and air) into different substances with different compositions. The wood cannot be "unburned."

1.6 Plan: If there is a physical change, in which the composition of the substance has not been altered, the process can be reversed by a change in temperature. If there is a chemical change, in which the composition of the substance has been altered, the process cannot be reversed by changing the temperature.
Solution:
a) and c) **can be reversed** with temperature; the dew can evaporate and the ice cream can be refrozen.
b) and d) involve chemical changes and **cannot be reversed** by changing the temperature since a chemical change has taken place.

1.7 Plan: A system has a higher potential energy before the energy is released (used).
Solution:
a) The exhaust is lower in energy than the fuel by an amount of energy equal to that released as the fuel burns. The **fuel** has a higher potential energy.
b) **Wood**, like the fuel, is higher in energy by the amount released as the wood burns.

1.8 Plan: Kinetic energy is energy due to the motion of an object.
Solution:
a) **The sled sliding down the hill** has higher kinetic energy than the unmoving sled.
b) **The water falling over the dam** (moving) has more kinetic energy than the water held by the dam.

1.9 **Observations** are the first step in the scientific approach. The first observation is that the toast has not popped out of the toaster. The next step is a **hypothesis** (tentative explanation) to explain the observation. The hypothesis is that the spring mechanism is stuck. Next, there will be a **test** of the hypothesis. In this case, the test is an additional observation — the bread is unchanged. This observation leads to a new hypothesis — the toaster is unplugged. This hypothesis leads to additional tests — seeing if the toaster is plugged in, and if it works when plugged into a different outlet. The final test on the toaster leads to a new hypothesis — there is a problem with the power in the kitchen. This hypothesis leads to the final test concerning the light in the kitchen.

1.10 A quantitative observation is easier to characterize and reproduce. A qualitative observation may be subjective and open to interpretation.
a) This is **qualitative**. When has the sun completely risen?
b) The astronaut's mass may be measured; thus, this is **quantitative**.
c) This is **qualitative**. Measuring the fraction of the ice above or below the surface would make this a quantitative measurement.
d) The depth is known (measured) so this is **quantitative**.

1.11 A well-designed experiment must have the following essential features:
1) There must be two variables that are expected to be related.
2) There must be a way to control all the variables, so that only one at a time may be changed.
3) The results must be reproducible.

1.12 A model begins as a simplified version of the observed phenomena, designed to account for the observed effects, explain how they take place, and to make predictions of experiments yet to be done. The model is improved by further experiments. It should be flexible enough to allow for modifications as additional experimental results are gathered.

1.13 The unit you begin with (feet) must be in the denominator to cancel. The unit desired (inches) must be in the numerator. The feet will cancel leaving inches. If the conversion is inverted the answer would be in units of feet squared per inch.

1.14 Plan: Review the table of conversions in the chapter or inside the back cover of the book. Write the conversion factor so that the unit initially given will cancel, leaving the desired unit.
Solution:

a) To convert from in^2 to cm^2, use $\dfrac{\mathbf{(2.54\ cm)^2}}{\mathbf{(1\ in)^2}}$; to convert from cm^2 to m^2, use $\dfrac{\mathbf{(1\ m)^2}}{\mathbf{(100\ cm)^2}}$

b) To convert from km^2 to m^2, use $\dfrac{\mathbf{(1000\ m)^2}}{\mathbf{(1\ km)^2}}$; to convert from m^2 to cm^2, use $\dfrac{\mathbf{(100\ cm)^2}}{\mathbf{(1\ m)^2}}$

c) This problem requires two conversion factors: one for distance and one for time. It does not matter which conversion is done first. Alternate methods may be used.
To convert distance, mi to m, use:

$$\left(\frac{1.609\ \text{km}}{1\ \text{mi}}\right)\left(\frac{1000\ \text{m}}{1\ \text{km}}\right) = \mathbf{1.609x10^3\ m/mi}$$

To convert time, h to s, use:

$$\left(\frac{1\ \text{h}}{60\ \text{min}}\right)\left(\frac{1\ \text{min}}{60\ \text{s}}\right) = \mathbf{1\ h/3600\ s}$$

Therefore, the complete conversion factor is $\left(\dfrac{1.609\ \text{x}\ 10^3\ \text{m}}{1\ \text{mi}}\right)\left(\dfrac{1\ \text{h}}{3600\ \text{s}}\right) = \dfrac{\mathbf{0.4469\ m{\bullet}h}}{\mathbf{mi{\bullet}s}}$.

Do the units cancel when you start with a measurement of mi/h?

d) To convert from pounds (lb) to grams (g), use $\dfrac{\mathbf{1000\ g}}{\mathbf{2.205\ lb}}$.

To convert volume from ft^3 to cm^3 use, $\left(\dfrac{(1\ \text{ft})^3}{(12\ \text{in})^3}\right)\left(\dfrac{(1\ \text{in})^3}{(2.54\ \text{cm})^3}\right) = \mathbf{3.531x10^{-5}\ ft^3/cm^3}$.

1.15 Plan: Review the table of conversions in the chapter or inside the back cover of the book. Write the conversion factor so that the unit initially given will cancel, leaving the desired unit.
Solution:
a) This problem requires two conversion factors: one for distance and one for time. It does not matter which conversion is done first. Alternate methods may be used.

To convert distance, cm to in, use: $\left(\dfrac{\mathbf{1\ in}}{\mathbf{2.54\ cm}}\right)$

To convert time, min to s, use: $\left(\dfrac{\mathbf{1\ min}}{\mathbf{60\ s}}\right)$

b) To convert from m^3 to cm^3, use $\dfrac{\mathbf{(100\ cm)^3}}{\mathbf{(1\ m)^3}}$; to convert from cm^3 to in^3, use $\dfrac{\mathbf{(1\ in)^3}}{\mathbf{(2.54\ cm)^3}}$

c) This problem requires two conversion factors: one for distance and one for time. It does not matter which conversion is done first. Alternate methods may be used.

To convert distance, m to km, use: $\left(\dfrac{\mathbf{1\ km}}{\mathbf{1000\ m}}\right)$

To convert time, s^2 to h^2, use:

$$\left(\frac{(60\ \mathrm{s})^2}{(1\ \mathrm{min})^2}\right)\left(\frac{(60\ \mathrm{min})^2}{(1\ \mathrm{h})^2}\right) = \mathbf{\frac{3600\ s^2}{h^2}}$$

d) This problem requires two conversion factors: one for volume and one for time. It does not matter which conversion is done first. Alternate methods may be used.

To convert volume, gal to qt, use: $\left(\mathbf{\frac{4\ qt}{1\ gal}}\right)$; to convert qt to L, use: $\left(\mathbf{\frac{1\ L}{1.057\ qt}}\right)$

To convert time, h to min, use: $\left(\mathbf{\frac{1\ h}{60\ min}}\right)$

1.16 Plan: Review the definitions of extensive and intensive properties.
Solution:
An extensive property depends on the amount of material present. An intensive property is the same regardless of how much material is present.
a) Mass is an **extensive property**. Changing the amount of material will change the mass.
b) Density is an **intensive property**. Changing the amount of material changes both the mass and the volume, but the ratio (density) remains fixed.
c) Volume is an **extensive property**. Changing the amount of material will change the size (volume).
d) The melting point is an **intensive property**. The melting point depends on the substance, not on the amount of substance.

1.17 Plan: Review the definitions of mass and weight.
Solution:
Mass is the quantity of material present, while **weight** is the interaction of gravity on mass. An object has a definite mass regardless of its location; its weight will vary with location. The lower gravitational attraction on the Moon will make an object appear to have approximately one-sixth its Earth weight. The object has the same mass on the Moon and on Earth.

1.18 Plan: Density = $\frac{\text{mass}}{\text{volume}}$. An increase in mass or a decrease in volume will increase the density. A decrease in density will result if the mass is decreased or the volume increased.
Solution:
a) Density **increases**. The mass of the chlorine gas is not changed, but its volume is smaller.
b) Density **remains the same**. Neither the mass nor the volume of the solid has changed.
c) Density **decreases**. Water is one of the few substances that expands on freezing. The mass is constant, but the volume increases.
d) Density **increases**. Iron, like most materials, contracts on cooling; thus the volume decreases while the mass does not change.
e) Density **remains the same**. The water does not alter either the mass or the volume of the diamond.

1.19 Plan: Review the definitions of heat and temperature. The two temperature values must be compared using one temperature scale, either Celsius or Fahrenheit.
Solution:
Heat is the energy that flows between objects at different temperatures while temperature is the measure of how hot or cold a substance is relative to another substance. Heat is an **extensive property** while temperature is an **intensive property**. It takes more heat to boil a gallon of water than to boil a teaspoon of water. However, both water samples boil at the same temperature.

Convert 65°C to °F: T (in °F) = $\frac{9}{5}T$ (in °C) + 32 = $\frac{9}{5}$(65°C) + 32 = 149°F

A temperature of 65°C is 149°F. Heat will flow from the hot water (65°C or 149°F) to the cooler water (65°F). The 65°C water contains more heat than the cooler water.

1.20 There are two differences in the Celsius and Fahrenheit scales (size of a degree and the zero point), so a simple one-step conversion will not work. The size of a degree is the same for the Celsius and Kelvin scales; only the zero point is different so a one-step conversion is sufficient.

1.21 Plan: Use conversion factors from the inside back cover: 1 pm = 10^{-12} m; 10^{-9} m = 1 nm.
Solution:

$$\text{Radius (nm)} = \left(1430\text{ pm}\right)\left(\frac{10^{-12}\text{ m}}{1\text{ pm}}\right)\left(\frac{1\text{ nm}}{10^{-9}\text{ m}}\right) = \mathbf{1.43\ nm}$$

1.22 Plan: Use conversion factors from the inside back cover: 10^{-12} m = 1 pm; 1 pm = 0.01 Å.
Solution:

$$\text{Radius (Å)} = \left(2.22\text{x}10^{-10}\text{ m}\right)\left(\frac{1\text{ pm}}{10^{-12}\text{ m}}\right)\left(\frac{0.01\text{ Å}}{1\text{ pm}}\right) = \mathbf{2.22\ Å}$$

1.23 Plan: Use conversion factors $(1\text{ cm})^2 = (0.01\text{ m})^2$; $(1000\text{ m})^2 = (1\text{ km})^2$ to express the area in km^2. To calculate the cost of the patch, use the conversion factor: $(2.54\text{ cm})^2 = (1\text{ in})^2$.
Solution:

$$\text{a) Area (km}^2) = \left(20.7\text{ cm}^2\right)\left(\frac{(0.01\text{ m})^2}{(1\text{ cm})^2}\right)\left(\frac{(1\text{ km})^2}{(1000\text{ m})^2}\right) = \mathbf{2.07x10^{-9}\ km^2}$$

$$\text{b) Cost} = \left(20.7\text{ cm}^2\right)\left(\frac{(1\text{ in})^2}{(2.54\text{ cm})^2}\right)\left(\frac{\$3.25}{1\text{ in}^2}\right) = 10.4276 = \mathbf{\$10.43}$$

1.24 Plan: Use conversion factors $(1\text{ mm})^2 = (10^{-3}\text{ m})^2$; $(0.01\text{ m})^2 = (1\text{ cm})^2$; $(2.54\text{ cm})^2 = (1\text{ in})^2$; $(12\text{ in})^2 = (1\text{ ft})^2$ to express the area in ft^2.
Solution:

$$\text{a) Area (ft}^2) = \left(7903\text{ mm}^2\right)\left(\frac{(10^{-3}\text{ m})^2}{(1\text{ mm})^2}\right)\left(\frac{(1\text{ cm})^2}{(0.01\text{ m})^2}\right)\left(\frac{(1\text{ in})^2}{(2.54\text{ cm})^2}\right)\left(\frac{(1\text{ ft})^2}{(12\text{ in})^2}\right)$$

$$= 8.5067\text{x}10^{-2} = \mathbf{8.507x10^{-2}\ ft^2}$$

$$\text{b) Time (s)} = \left(7903\text{ mm}^2\right)\left(\frac{45\text{ s}}{135\text{ mm}^2}\right) = 2.634333\text{x}10^3 = \mathbf{2.6x10^3\ s}$$

1.25 Plan: Mass in g is converted to kg in part a) with the conversion factor 1000 g = 1 kg; mass in g is converted to lb in part b) with the conversion factors 1000 g = 1 kg; 1 kg = 2.205 lb. Volume in cm^3 is converted to m^3 with the conversion factor $(1\text{ cm})^3 = (0.01\text{ m})^3$ and to ft^3 with the conversion factors $(2.54\text{ cm})^3 = (1\text{ in})^3$; $(12\text{ in})^3 = (1\text{ ft})^3$. The conversions may be performed in any order.
Solution:

$$\text{a) Density (kg/m}^3) = \left(\frac{5.52\text{ g}}{\text{cm}^3}\right)\left(\frac{(1\text{ cm})^3}{(0.01\text{ m})^3}\right)\left(\frac{1\text{ kg}}{1000\text{ g}}\right) = \mathbf{5.52x10^3\ kg/m^3}$$

$$\text{b) Density (lb/ft}^3) = \left(\frac{5.52\text{ g}}{\text{cm}^3}\right)\left(\frac{(2.54\text{ cm})^3}{(1\text{ in})^3}\right)\left(\frac{(12\text{ in})^3}{(1\text{ ft})^3}\right)\left(\frac{1\text{ kg}}{1000\text{ g}}\right)\left(\frac{2.205\text{ lb}}{1\text{ kg}}\right) = 344.661 = \mathbf{345\ lb/ft^3}$$

1.26 Plan: Length in m is converted to km in part a) with the conversion factor 1000 m = 1 km; length in m is converted to mi in part b) with the conversion factors 1000 m = 1 km; 1 km = 0.62 mi. Time is converted using the conversion factors 60 s = 1 min; 60 min = 1 h. The conversions may be performed in any order.

Solution:

a) Velocity (km/h) = $\left(\frac{2.998\text{x}10^8\text{ m}}{1\text{ s}}\right)\left(\frac{60\text{ s}}{1\text{ min}}\right)\left(\frac{60\text{ min}}{1\text{ h}}\right)\left(\frac{1\text{ km}}{10^3\text{ m}}\right)$ = 1.07928x10^9 = **1.079x10^9 km/h**

b) Velocity (mi/min) = $\left(\frac{2.998\text{x}10^8\text{ m}}{1\text{ s}}\right)\left(\frac{60\text{ s}}{1\text{ min}}\right)\left(\frac{1\text{ km}}{10^3\text{ m}}\right)\left(\frac{0.62\text{ mi}}{1\text{ km}}\right)$ = 1.11526x10^7 = **1.1x10^7 mi/min**

1.27 Plan: Use the conversion factors (1 μm)^3 = (1x10^{-6} m)^3; (1x10^{-3} m)^3 = (1 mm)^3 to convert to mm^3.
To convert to L, use the conversion factors (1 μm)^3 = (1x10^{-6} m)^3; (1x10^{-2} m)^3 = (1 cm)^3; 1 cm^3 = 1 mL;
1 mL = 1x10^{-3} L.
Solution:

a) Volume (mm^3) = $\left(\frac{2.56\ \mu\text{m}^3}{\text{cell}}\right)\left(\frac{\left(1\text{x}10^{-6}\text{ m}\right)^3}{\left(1\ \mu\text{m}\right)^3}\right)\left(\frac{\left(1\text{ mm}\right)^3}{\left(1\text{x}10^{-3}\text{ m}\right)^3}\right)$ = **2.56x10^{-9} mm^3/cell**

b) Volume (L) = $\left(10^5\text{ cells}\right)\left(\frac{2.56\ \mu\text{m}^3}{\text{cell}}\right)\left(\frac{\left(1\text{x}10^{-6}\text{ m}\right)^3}{\left(1\ \mu\text{m}\right)^3}\right)\left(\frac{\left(1\text{ cm}\right)^3}{\left(1\text{x}10^{-2}\text{ m}\right)^3}\right)\left(\frac{1\text{ mL}}{1\text{ cm}^3}\right)\left(\frac{1\text{x}10^{-3}\text{ L}}{1\text{ mL}}\right)$

= 2.56x10^{-10} = **10^{-10} L**

1.28 Plan: For part a), convert from qt to mL (1 qt = 946.4 mL) to L (1 mL = 1x10^{-3} L) to m^3 (1 L = 10^{-3} m^3).
For part b), convert from gal to qt (1 gal = 4 qt) to mL (1 qt = 946.4 mL) to L (1 mL = 10^{-3} L).
Solution:

a) Volume (m^3) = $\left(1\text{ qt}\right)\left(\frac{946.4\text{ mL}}{1\text{ qt}}\right)\left(\frac{10^{-3}\text{ L}}{1\text{ mL}}\right)\left(\frac{10^{-3}\text{ m}^3}{1\text{ L}}\right)$ = **9.464x10^{-4} m^3**

b) Volume (L) = $\left(835\text{ gal}\right)\left(\frac{4\text{ qt}}{1\text{ gal}}\right)\left(\frac{946.4\text{ mL}}{1\text{ qt}}\right)\left(\frac{10^{-3}\text{ L}}{1\text{ mL}}\right)$ = 3.160976x10^3 = **3.16x10^3 L**

1.29 Plan: The mass of the mercury in the vial is the mass of the vial filled with mercury minus the mass of the empty vial. Use the density of mercury and the mass of the mercury in the vial to find the volume of mercury and thus the volume of the vial. Once the volume of the vial is known, that volume is used in part b. The density of water is used to find the mass of the given volume of water. Add the mass of water to the mass of the empty vial.
Solution:
a) Mass (g) of mercury = mass of vial and mercury – mass of vial = 185.56 g – 55.32 g = 130.24 g

Volume (cm^3) of mercury = volume of vial = $\left(130.24\text{ g}\right)\left(\frac{1\text{ cm}^3}{13.53\text{ g}}\right)$ = 9.626016 = **9.626 cm^3**

b) Volume (cm^3) of water = volume of vial = 9.626016 cm^3

Mass (g) of water = $\left(9.626016\text{ cm}^3\right)\left(\frac{0.997\text{ g}}{1\text{ cm}^3}\right)$ = 9.59714 g water

Mass (g) of vial filled with water = mass of vial + mass of water = 55.32 g + 9.59714 g = 64.91714 = **64.92 g**

1.30 Plan: The mass of the water in the flask is the mass of the flask and water minus the mass of the empty flask. Use the density of water and the mass of the water in the flask to find the volume of water and thus the volume of the flask. Once the volume of the flask is known, that volume is used in part b. The density of chloroform is used to find the mass of the given volume of chloroform. Add the mass of the chloroform to the mass of the empty flask.
Solution:
a) Mass (g) of water = mass of flask and water – mass of flask = 489.1 g – 241.3 g = 247.8 g

Volume (cm^3) of water = volume of flask = $(247.8\ \text{g})\left(\frac{1\ \text{cm}^3}{1.00\ \text{g}}\right)$ = 247.8 = **248 cm³**

b) Volume (cm^3) of chloroform = volume of flask = 247.8 cm^3

Mass (g) of chloroform = $(247.8\ \text{cm}^3)\left(\frac{1.48\ \text{g}}{\text{cm}^3}\right)$ = 366.744 g chloroform

Mass (g) of flask and chloroform = mass of flask + mass of chloroform = 241.3 g + 366.744 g
= 608.044 g = **608 g**

1.31 Plan: Calculate the volume of the cube using the relationship Volume = (length of side)^3. The length of side in mm must be converted to cm so that volume will have units of cm^3. Divide the mass of the cube by the volume to find density.

Solution:

Side length (cm) = $(15.6\ \text{mm})\left(\frac{10^{-3}\ \text{m}}{1\ \text{mm}}\right)\left(\frac{1\ \text{cm}}{10^{-2}\ \text{m}}\right)$ = 1.56 cm (convert to cm to match density unit)

Al cube volume (cm^3) = (length of side)^3 = (1.56 cm)^3 = 3.7964 cm^3

Density (g/cm^3) = $\frac{\text{mass}}{\text{volume}} = \frac{10.25\ \text{g}}{3.7964\ \text{cm}^3}$ = 2.69993 = **2.70 g/cm³**

1.32 Plan: Use the relationship $c = 2\pi r$ to find the radius of the sphere and the relationship $V = 4/3\pi r^3$ to find the volume of the sphere. The volume in mm^3 must be converted to cm^3. Divide the mass of the sphere by the volume to find density.

Solution:

$c = 2\pi r$

Radius (mm) = $\frac{c}{2\pi} = \frac{32.5\ \text{mm}}{2\pi}$ = 5.17254 mm

Volume (mm^3) = $\frac{4}{3}\pi r^3 = \left(\frac{4}{3}\right)\pi(5.17254\ \text{mm})^3$ = 579.6958 mm^3

Volume (cm^3) = $(579.6958\ \text{mm}^3)\left(\frac{10^{-3}\ \text{m}}{1\ \text{mm}}\right)^3\left(\frac{1\ \text{cm}}{10^{-2}\ \text{m}}\right)^3$ = 0.5796958 cm^3

Density (g/cm^3) = $\frac{\text{mass}}{\text{volume}} = \frac{4.20\ \text{g}}{0.5796958\ \text{cm}^3}$ = 7.24518 = **7.25 g/cm³**

1.33 Plan: Use the equations given in the text for converting between the three temperature scales.

Solution:

a) T (in °C) = [T (in °F) – 32]$\frac{5}{9}$ = [68°F – 32]$\frac{5}{9}$ = **20.°C**

T (in K) = T (in °C) + 273.15 = 20.°C + 273.15 = 293.15 = **293 K**

b) T (in K) = T (in °C) + 273.15 = –164°C + 273.15 = 109.15 = **109 K**

T (in °F) = $\frac{9}{5}T$ (in °C) + 32 = $\frac{9}{5}$(–164°C) + 32 = –263.2 = **–263°F**

c) T (in °C) = T (in K) – 273.15 = 0 K – 273.15 = –273.15 = **–273°C**

T (in °F) = $\frac{9}{5}T$ (in °C) + 32 = $\frac{9}{5}$(–273.15°C) + 32 = –459.67 = **–460.°F**

1.34 Plan: Use the equations given in the text for converting between the three temperature scales.

Solution:

a) T (in °C) = [T (in °F) – 32]$\frac{5}{9}$ = [106°F – 32]$\frac{5}{9}$ = 41.111 = **41°C**

(106 – 32) = 74 This limits the significant figures.

T (in K) = T (in °C) + 273.15 = 41.111°C + 273.15 = 314.261 = **314 K**

b) T (in °F) = $\frac{9}{5}T$ (in °C) + 32 = $\frac{9}{5}$(3410°C) + 32 = **6170°F**

T (in K) = T (in °C) + 273.15 = 3410°C + 273 = **3683 K**

c) T (in °C) = T (in K) –273.15 = 6.1x10^3 K – 273 = 5.827x10^3 = **5.8 x 10^3°C**

T (in °F) = $\frac{9}{5}T$ (in °C) + 32 = $\frac{9}{5}$(5827°C) + 32 = 1.0521x10^4 = **1.1x10^4°F**

1.35 Plan: Find the volume occupied by each metal by taking the difference between the volume of water and metal and the initial volume of the water (25.0 mL). Divide the mass of the metal by the volume of the metal to calculate density. Use the density value of each metal to identify the metal.

Solution:

Cylinder A: volume of metal = [volume of water + metal] – [volume of water]

volume of metal = 28.2 mL – 25.0 mL = 3.2 mL

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{25.0\text{ g}}{3.2\text{ mL}} = 7.81254 = \mathbf{7.8\ g/mL}$$

Cylinder A contains **iron**.

Cylinder B: volume of metal = [volume of water + metal] – [volume of water]

volume of metal = 27.8 mL – 25.0 mL = 2.8 mL

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{25.0\text{ g}}{2.8\text{ mL}} = 8.92857 = \mathbf{8.9\ g/mL}$$

Cylinder B contains **nickel**.

Cylinder C: volume of metal = [volume of water + metal] – [volume of water]

volume of metal = 28.5 mL – 25.0 mL = 3.5 mL

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{25.0\text{ g}}{3.5\text{ mL}} = 7.14286 = \mathbf{7.1\ g/mL}$$

Cylinder C contains **zinc**.

1.36 Plan: Use 1 in = 2.54 cm to convert length in inches to cm; use 1 cm = 10^{-2} m to convert cm to m.

Solution:

$$\text{Length (m)} = 0.025\,\text{inch}\left(\frac{2.54\text{ cm}}{1\text{ inch}}\right)\left(\frac{10^{-2}\text{ m}}{1\text{ cm}}\right) = 6.35 \text{ x } 10^{-4} = \mathbf{6.4 \text{ x } 10^{-4}\ m}$$

1.37 Plan: Use 1 nm = 10^{-9} m to convert wavelength in nm to m. To convert wavelength in pm to Å, use 1 pm = 0.01 Å.

Solution:

$$\text{a) Wavelength (m)} = (247\text{ nm})\left(\frac{10^{-9}\text{ m}}{1\text{ nm}}\right) = \mathbf{2.47x10^{-7}\ m}$$

$$\text{b) Wavelength (Å)} = (6760\text{ pm})\left(\frac{0.01\text{ Å}}{1\text{ pm}}\right) = \mathbf{67.6\ Å}$$

1.38 Plan: Convert the mass of gold in troy oz to mass in grams and use the density to convert the mass of gold to volume of gold in in^3. Divide the volume of gold by the thickness of the gold foil to find the area of gold in in^2. In part b, find the amount of gold in troy oz that can be purchased, convert troy oz to g, and use the density to convert that mass of gold to volume of gold in cm^3. To find the area of the gold foil, divide the volume by the thickness of the gold foil, expressed in cm.

Solution:

$$\text{a) } (2.0\,\text{tr. oz})\left(\frac{31.1\text{ g}}{1\text{ tr. oz}}\right)\left(\frac{\text{cm}^3}{19.3\text{ g}}\right)\left(\frac{1\text{ in}}{2.54\text{ cm}}\right)^3\left(\frac{1}{1.6\text{x}10^{-5}\text{ in}}\right) = 1.229 \text{ x } 10^4 = \mathbf{1.2 \text{ x } 10^4\ in^2}$$

$$\text{b) } (\$75.00)\left(\frac{1\,\text{tr. oz}}{\$20.00}\right)\left(\frac{31.1\text{ g}}{1\text{ tr. oz}}\right)\left(\frac{\text{cm}^3}{19.3\text{ g}}\right)\left(\frac{1}{1.6\text{x}10^{-5}\text{ in}}\right)\left(\frac{1\text{ in}}{2.54\text{ cm}}\right) = 1.4869 \text{ x } 10^5 = \mathbf{1.49 \text{ x } 10^5\ cm^2}$$

1.39 Plan: Calculate the volume of the cylinder in cm^3 by using the equation for the volume of a cylinder. The diameter of the cylinder must be halved to find the radius. Convert the volume in cm^3 to dm^3 by using the conversion factors $(1\ cm)^3 = (10^{-2}\ m)^3$ and $(10^{-1}\ m)^3 = (1\ dm)^3$.

Solution:

Radius = diameter/2 = 0.85 cm/2 = 0.425 cm

Volume (cm^3) = $\pi r^2 h = \pi(0.425\ cm)^2(9.5\ cm)$ = 5.3907766 cm^3

$$\text{Volume } (dm^3) = \left(5.3907766\ cm^3\right)\left(\frac{10^{-2}\ m}{1\ cm}\right)^3\left(\frac{1\ dm}{10^{-1}\ m}\right)^3 = 5.39078\text{x}10^{-3} = \mathbf{5.4x10^{-3}\ dm^3}$$

1.40 Plan: Use the percent of copper in the ore to find the mass of copper in 5.01 lb of ore. Convert the mass in lb to mass in g. The density of copper is used to find the volume of that mass of copper. Use the volume equation for a cylinder to calculate the height of the cylinder (the length of wire); the diameter of the wire is used to find the radius which must be expressed in units of cm. Length of wire in cm must be converted to m.

Solution:

$$\text{Mass (lb) of copper} = \left(5.01\ lb\ \ Covellite\right)\left(\frac{66\%}{100\%}\right) = 3.3066\ lb\ copper$$

$$\text{Mass (g) of copper} = \left(3.3066\ lb\right)\left(\frac{1\ kg}{2.205\ lb}\right)\left(\frac{1000\ g}{1\ kg}\right) = 1.49959\text{x}10^3\ g$$

$$\text{Volume } (cm^3) \text{ of copper} = \left(1.49959\text{x}10^3\ g\ Cu\right)\left(\frac{cm^3\ \ Cu}{8.95\ g\ Cu}\right) = 167.552\ cm^3\ Cu$$

$V = \pi r^2 h$

$$\text{Radius (cm)} = \left(\frac{6.304\text{x}10^{-3}\ in}{2}\right)\left(\frac{2.54\ cm}{1\ in}\right) = 8.00608\text{x}10^{-3}\ cm$$

$$\text{Height (length) in cm} = \frac{V}{\pi r^2} = \frac{167.552\ cm^3}{(\pi)\left(8.00608\text{x}10^{-3}\ cm\right)^2} = 8.3207\text{x}10^{-5}\ cm$$

$$\text{Length (m)} = \left(8.3207\text{x}10^5\ cm\right)\left(\frac{10^{-2}\ m}{1\ cm}\right) = 8.3207\text{x}10^3 = \mathbf{8.32x10^3\ m}$$

1.41 Plan: The liquid with the larger density will occupy the bottom of the beaker, while the liquid with the smaller density volume will be on top of the more dense liquid.

Solution:

a) Liquid A is more dense than water; liquids B and C are less dense than water.

b) Density of liquid B could be **0.94 g/mL**. Liquid B is more dense than C so its density must be greater than 0.88 g/mL. Liquid B is less dense than water so its density must be less than 1.0 g/mL.

1.42 An exact number is defined to have a certain value (exactly). There is no uncertainty in an exact number. An exact number is considered to have an infinite number of significant figures and, therefore, does not limit the digits in the calculation.

1.43 Plan: Review the rules for significant figures.

Solution:

Initial or leading zeros are never significant; internal zeros (occurring between nonzero digits) are always significant; terminal zeros to the right of a decimal point are significant; terminal zeros to the left of a decimal point are significant **only** if they were measured.

1.44 Plan: Review the rules for significant zeros.

Solution:

a) No significant zeros (leading zeros are not significant)

b) No significant zeros (leading zeros are not significant)

c) $0.041\underline{0}$ (terminal zeros to the right of the decimal point are significant)
d) $4.\underline{0}1\underline{00}\text{x}10^4$ (zeros between nonzero digits are significant; terminal zeros to the right of the decimal point are significant)

1.45 Plan: Review the rules for significant zeros.
Solution:
a) $5.\underline{0}8$ (zeros between nonzero digits are significant)
b) $5\underline{0}8$ (zeros between nonzero digits are significant)
c) $5.\underline{0}8\underline{0}\text{x}10^3$ (zeros between nonzero digits are significant; terminal zeros to the right of the decimal point are significant)
d) $0.05\underline{0}8\underline{0}$ (leading zeros are not significant; zeros between nonzero digits are significant; terminal zeros to the right of the decimal point are significant)

1.46 Plan: Use a calculator to obtain an initial value. Use the rules for significant figures and rounding to get the final answer.
Solution:
a) $\dfrac{(2.795 \text{ m})(3.10 \text{ m})}{6.48 \text{ m}}$ = 1.3371 = **1.34 m** (maximum of 3 significant figures allowed since two of the original numbers in the calculation have only 3 significant figures)

b) V = $\left(\dfrac{4}{3}\right)\pi(17.282 \text{ mm})^3$ = 21,620.74 = **21,621 mm^3** (maximum of 5 significant figures allowed)

c) 1.110 cm + 17.3 cm + 108.2 cm + 316 cm = 442.61 = **443 cm** (no digits allowed to the right of the decimal since 316 has no digits to the right of the decimal point)

1.47 Plan: Use a calculator to obtain an initial value. Use the rules for significant figures and rounding to get the final answer.
Solution:
a) $\dfrac{2.420 \text{ g} + 15.6 \text{ g}}{4.8 \text{ g}}$ = 3.7542 = **3.8** (maximum of 2 significant figures allowed since one of the original numbers in the calculation has only 2 significant figures)

b) $\dfrac{7.87 \text{ mL}}{16.1 \text{ mL} - 8.44 \text{ mL}}$ = 1.0274 = **1.0** (After the subtraction, the denominator has 2 significant figures; only one digit is allowed to the right of the decimal in the value in the denominator since 16.1 has only one digit to the right of the decimal.)
c) V = $\pi(6.23 \text{ cm})^2(4.630 \text{ cm})$ = 564.556 = **565 cm^3** (maximum of 3 significant figures allowed since one of the original numbers in the calculation has only 3 significant figures)

1.48 Plan: Review the procedure for changing a number to scientific notation. There can be only 1 nonzero digit to the left of the decimal point in correct scientific notation. Moving the decimal point to the left results in a positive exponent while moving the decimal point to the right results in a negative exponent.
Solution:
a) **$1.310000\text{x}10^5$** (Note that all zeros are significant.)
b) **$4.7\text{x}10^{-4}$** (No zeros are significant.)
c) **$2.10006\text{x}10^5$**
d) **$2.1605\text{x}10^3$**

1.49 Plan: Review the procedure for changing a number to scientific notation. There can be only 1 nonzero digit to the left of the decimal point in correct scientific notation. Moving the decimal point to the left results in a positive exponent while moving the decimal point to the right results in a negative exponent.
Solution:
a) **$2.820\text{x}10^2$** (Note that the zero is significant.)
b) **$3.80\text{x}10^{-2}$** (Note the one significant zero.)

c) **4.2708x10^3**
d) **5.82009x10^4**

1.50 Plan: Review the examples for changing a number from scientific notation to standard notation. If the exponent is positive, move the decimal back to the right; if the exponent is negative, move the decimal point back to the left.
Solution:
a) **5550** (Do not use terminal decimal point since the zero is not significant.)
b) **10070.** (Use terminal decimal point since final zero is significant.)
c) **0.000000885**
d) **0.003004**

1.51 Plan: Review the examples for changing a number from scientific notation to standard notation. If the exponent is positive, move the decimal back to the right; if the exponent is negative, move the decimal point back to the left.
Solution:
a) **6500.** (Use terminal decimal point since the final zero is significant.)
b) **0.0000346**
c) **750** (Do not use terminal decimal point since the zero is not significant.)
d) **188.56**

1.52 Plan: Calculate a temporary answer by simply entering the numbers into a calculator. Then you will need to round the value to the appropriate number of significant figures. Cancel units as you would cancel numbers, and place the remaining units after your numerical answer.
Solution:

a) $$\frac{\left(6.626\,\text{x}10^{-34}\ \text{J}\bullet\text{s}\right)\left(2.9979\,\text{x}10^{8}\ \text{m/s}\right)}{489\,\text{x}10^{-9}\ \text{m}} = 4.062185\text{x}10^{-19}$$

4.06x10^{-19} J (489x10^{-9} m limits the answer to 3 significant figures; units of m and s cancel)

b) $$\frac{\left(6.022\ \text{x}\ 10^{23}\ \text{molecules/mol}\right)\left(1.23\ \text{x}\ 10^{2}\ \text{g}\right)}{46.07\ \text{g/mol}} = 1.6078\text{x}10^{24}$$

1.61x10^{24} molecules (1.23x10^2 g limits answer to 3 significant figures; units of mol and g cancel)

c) $$\left(6.022\ \text{x}\ 10^{23}\ \text{atoms/mol}\right)\left(2.18\ \text{x}\ 10^{-18}\ \text{J/atom}\right)\left(\frac{1}{2^2}-\frac{1}{3^2}\right) = 1.82333\text{x}10^{5}$$

1.82x10^5 J/mol (2.18x10^{-18} J/atom limits answer to 3 significant figures; unit of atoms cancels)

1.53 Plan: Calculate a temporary answer by simply entering the numbers into a calculator. Then you will need to round the value to the appropriate number of significant figures. Cancel units as you would cancel numbers, and place the remaining units after your numerical answer.
Solution:

a) $$\frac{4.32\,\text{x}10^{7}\ \text{g}}{\frac{4}{3}(3.1416)\left(1.95\text{x}10^{2}\ \text{cm}\right)^3} = 1.3909 = \mathbf{1.39\ g/cm^3}$$

(4.32x10^7 g limits the answer to 3 significant figures)

b) $$\frac{\left(1.84\text{x}10^{2}\ \text{g}\right)\left(44.7\ \text{m/s}\right)^2}{2} = 1.8382\text{x}10^{5} = \mathbf{1.84x10^5\ g{\cdot}m^2/s^2}$$

(1.84x10^2 g limits the answer to 3 significant figures)

c) $$\frac{\left(1.07\,\text{x}10^{-4}\text{mol / L}\right)^2\left(3.8\ \text{x}\ 10^{-3}\text{mol / L}\right)}{\left(8.35\text{x}10^{-5}\text{mol / L}\right)\left(1.48\ \text{x}\ 10^{-2}\text{mol / L}\right)^3} = 0.16072 = \mathbf{0.16\ L/mol}$$

(3.8x10^{-3} mol/L limits the answer to 2 significant figures; mol^3/L^3 in the numerator cancels mol^4/L^4 in the denominator to leave mol/L in the denominator or units of L/mol)

1.54 Plan: Exact numbers are those which have no uncertainty. Unit definitions and number counts of items in a group are examples of exact numbers.
Solution:
a) The height of Angel Falls is a measured quantity. This is **not** an exact number.
b) The number of planets in the solar system is a number count. This **is** an exact number.
c) The number of grams in a pound is not a unit definition. This is **not** an exact number.
d) The number of millimeters in a meter is a definition of the prefix "milli–." This **is** an exact number.

1.55 Plan: Exact numbers are those which have no uncertainty. Unit definitions and number counts of items in a group are examples of exact numbers.
Solution:
a) The speed of light is a measured quantity. It is **not** an exact number.
b) The density of mercury is a measured quantity. It is **not** an exact number.
c) The number of seconds in an hour is based on the definitions of minutes and hours. This **is** an exact number.
d) The number of states is a counted value. This **is** an exact number.

1.56 Plan: Observe the figure, and estimate a reading the best you can.
Solution:
The scale markings are 0.2 cm apart. The end of the metal strip falls between the mark for 7.4 cm and 7.6 cm. If we assume that one can divide the space between markings into fourths, the uncertainty is one-fourth the separation between the marks. Thus, since the end of the metal strip falls between 7.45 and 7.55 we can report its length as **7.50 ± 0.05 cm**. (Note: If the assumption is that one can divide the space between markings into halves only, then the result is 7.5 ± 0.1 cm.)

1.57 Plan: You are given the density values for five solvents. Use the mass and volume given to calculate the density of the solvent in the cleaner and compare that value to the density values given to identify the solvent. Use the uncertainties in the mass and volume to recalculate the density.
Solution:
a) $\text{Density (g/mL)} = \frac{\text{mass}}{\text{volume}} = \frac{11.775\text{ g}}{15.00\text{ mL}}$ = 0.7850 g/mL. The closest value is **isopropanol**.
b) Ethanol is denser than isopropanol. Recalculating the density using the maximum mass = (11.775 + 0.003) g with the minimum volume = (15.00 – 0.02) mL, gives
$\text{Density (g/mL)} = \frac{\text{mass}}{\text{volume}} = \frac{11.778\text{ g}}{14.98\text{ mL}}$ = 0.7862 g/mL. This result is still clearly not ethanol.
Yes, the equipment is precise enough.

1.58 Plan: Calculate the average of each data set. Remember that accuracy refers to how close a measurement is to the actual or true value while precision refers to how close multiple measurements are to each other.
Solution:
a) $I_{avg} = \frac{8.72\text{ g} + 8.74\text{ g} + 8.70\text{ g}}{3} = 8.7200 = \mathbf{8.72\text{ g}}$

$II_{avg} = \frac{8.56\text{ g} + 8.77\text{ g} + 8.83\text{ g}}{3} = 8.7200 = \mathbf{8.72\text{ g}}$

$III_{avg} = \frac{8.50\text{ g} + 8.48\text{ g} + 8.51\text{ g}}{3} = 8.4967 = \mathbf{8.50\text{ g}}$

$IV_{avg} = \frac{8.41\text{ g} + 8.72\text{ g} + 8.55\text{ g}}{3} = 8.5600 = \mathbf{8.56\text{ g}}$

Sets **I** and **II** are most accurate since their average value, 8.72 g, is closest to the true value, 8.72 g.
b) To get an idea of precision, calculate the range of each set of values: largest value – smallest value. A small range is an indication of good precision since the values are close to each other.
I_{range} = 8.74 g – 8.70 g = 0.04 g
II_{range} = 8.83 g – 8.56 g = 0.27 g
III_{range} = 8.51 g – 8.48 g = 0.03 g

IV_{range} = 8.72 g – 8.41 g = 0.31 g
Set III is the most precise (smallest range), but is the least accurate (the average is the farthest from the actual value).
c) **Set I** has the best combination of high accuracy (average value = actual value) and high precision (relatively small range).
d) **Set IV** has both low accuracy (average value differs from actual value) and low precision (has the largest range).

1.59 Plan: Remember that accuracy refers to how close a measurement is to the actual or true value; since the bull's-eye represents the actual value, the darts that are closest to the bull's-eye are the most accurate. Precision refers to how close multiple measurements are to each other; darts that are positioned close to each other on the target have high precision.
Solution:
a) **Experiments II and IV** — the averages appear to be near each other.
b) **Experiments III and IV** — the darts are closely grouped.
c) **Experiment IV and perhaps Experiment II** — the average is in or near the bull's-eye.
d) **Experiment III** — the darts are close together, but not near the bull's-eye.

1.60 Plan: Convert volume in gal to volume in mL. Divide that volume by 500 to find the number of times the 500.-mL cylinder would be used. Divide the remaining volume by 50 to find the number of times the 50.-mL cylinder would be used; divide the remaining volume by 5 to find the number of times the 5-mL cylinder would be used.
Solution:

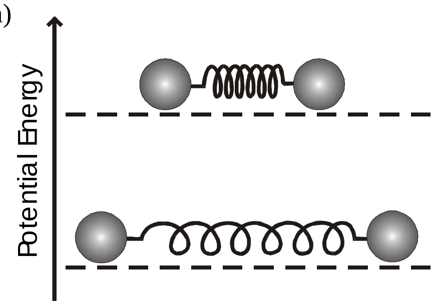
$$\text{Volume (mL)} = \left(2.000\text{ gal}\right)\left(\frac{4\text{ qt}}{1\text{ gal}}\right)\left(\frac{1\text{ L}}{1.057\text{ qt}}\right)\left(\frac{1\text{ mL}}{10^{-3}\text{ L}}\right) = 7.56859\text{x}10^{3}\text{ mL}$$

$$\frac{7.56859\text{ x }10^{3}\text{ mL}}{5.00\text{ x }10^{2}\text{ mL}} = 15.137$$

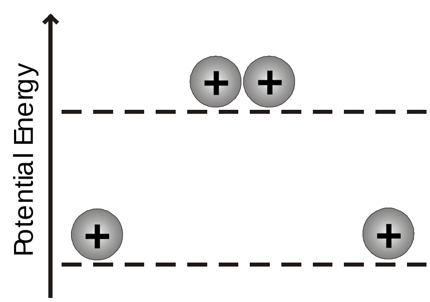
So, use the 500 mL graduated cylinder 15 times to measure (15 x 500 mL) = 7500 mL.
7568.59 mL – 7500 mL = 68.59 mL
Use the 50 mL graduated cylinder once to measure 50 mL for a total of 7550 mL.
7568.59 mL – 7550 mL – 18.59 mL
Use the 5 mL graduated cylinder four times to measure 18.59 mL for a total of 7568.59 mL.

1.61 Plan: If it is necessary to force something to happen, the potential energy will be higher.
Solution:

a)



b)



a) The balls on the relaxed spring have a lower potential energy and are more stable. The balls on the compressed spring have a higher potential energy, because the balls will move once the spring is released. This configuration is less stable.
b) The two + charges apart from each other have a lower potential energy and are more stable. The two + charges near each other have a higher potential energy, because they repel one another. This arrangement is less stable.

1.62 Plan: In part a, convert volume in oz to cm^3 and use the density to find the mass of that volume. In part b, find the volume of one dime in cm^3, and use the density to find the mass of that volume.
Solution:

a) Mass = $(12\ \text{oz})\left(\dfrac{29.57\ \text{cm}^3}{1\ \text{fl. oz}}\right)\left(\dfrac{1.0\ \text{g}}{\text{cm}^3}\right) = 3.5484\text{x}10^2 = \mathbf{3.5x10^2\ g}$

b) Mass = $\left(\dfrac{1\ \text{cm}^3}{5\ \text{dimes}}\right)\left(\dfrac{9.5\ \text{g}}{\text{cm}^3}\right) = 1.9 = \mathbf{2\ g/dime}$

(This is limited to one significant figure because of the approximate volume of 1 cm^3.)

1.63 Plan: A physical change is one in which the physical form (or state) of a substance, but not its composition, is altered. A chemical change is one in which a substance is converted into a different substance with different composition and properties.
Solution:
a) Bonds have been broken in three yellow diatomic molecules. Bonds have been broken in three red diatomic molecules. The six resulting yellow atoms have reacted with three of the red atoms to form three molecules of a new substance. The remaining three red atoms have reacted with three blue atoms to form a new diatomic substance.
b) There has been one physical change as the blue atoms at 273 K in the liquid phase are now in the gas phase at 473 K.

1.64 Plan: Determine the volume of the room in cubic feet, using length x width x height = volume. Next, use the conversions from the inside back cover to convert the volume to liters. Finally, use the air conditioner's rate of exchange to determine the time required.
Solution:
$V_{air} = V_{room} = 11\ \text{ft x } 12\ \text{ft x } 8.5\ \text{ft} = 1.122\text{x}10^3\ \text{ft}^3$
Conversion from ft^3 to L: $(1\ \text{ft})^3 = (12\ \text{inches})^3$; $(1\ \text{inch})^3 = (2.54\ \text{cm})^3$; $1\ \text{cm}^3 = 1\ \text{mL}$; 1000 mL = 1 L

Volume (L) = $\left(1.122\text{x}10^3\ \text{ft}^3\right)\left(\dfrac{12\ \text{in}}{1\ \text{ft}}\right)^3\left(\dfrac{2.54\ \text{cm}}{1\ \text{in}}\right)^3\left(\dfrac{1\ \text{mL}}{1\ \text{cm}^3}\right)\left(\dfrac{10^{-3}\ \text{L}}{1\ \text{mL}}\right) = 3.17715\text{x}10^4\ \text{L}$

At a rate of 1200L/min, how many minutes will it take to replace all the air in the room?

$\left(3.17715\text{x}10^4\ \text{L}\right)\left(\dfrac{1\ \text{min}}{1200\ \text{L}}\right) = 26.476 = \mathbf{26\ minutes}$

Note: additional significant figures were kept in the calculation until the final step.

1.65 Plan: Take 90% of the mass of the coin to find the mass of gold in the coin in g; convert mass in g to mass in troy oz and use the price information to find the value of the gold. In part b, convert the mass of gold in troy oz to mass in g; multiply that mass by a factor of 100/90 since the coin is 90% gold. Divide the resulting mass by the mass of one coin to determine the number of coins with that total mass. In part c, convert the volume of gold from in^3 to cm^3 and use the given density to convert volume to mass in g. Multiply that mass by a factor of 100/90 since the coin is 90% gold. Divide the resulting mass by the mass of one coin to determine the number of coins with that total mass.
Solution:

a) $(33.436\ \text{g})\left(\dfrac{90.0\%}{100.0\%}\right)\left(\dfrac{1\ \text{tr. oz}}{31.1\ \text{g}}\right)\left(\dfrac{\$20.00}{1\ \text{tr. oz}}\right) = 19.3520 = \mathbf{\$19.4}$ before price increase.

$(33.436\ \text{g})\left(\dfrac{90.0\%}{100.0\%}\right)\left(\dfrac{1\ \text{tr. oz}}{31.1\ \text{g}}\right)\left(\dfrac{\$35.00}{1\ \text{tr. oz}}\right) = 33.8660 = \mathbf{\$33.9}$ after price increase.

b) $(50.0\ \text{tr. oz})\left(\dfrac{31.1\ \text{g}}{1\ \text{tr. oz}}\right)\left(\dfrac{100.0\%}{90.0\%}\right)\left(\dfrac{1\ \text{coin}}{33.436\ \text{g}}\right) = 51.674 = \mathbf{51.7\ coins}$

c) $(2.00\ \text{in}^3)\left(\frac{(2.54\ \text{cm})^3}{1\ \text{in}^3}\right)\left(\frac{19.3\ \text{g}}{1\ \text{cm}^3}\right)\left(\frac{100.0\%}{90.0\%}\right)\left(\frac{1\ \text{coin})}{33.436\ \text{g}}\right)$ = 21.0199 = **21.0 coins**

1.66 Plan: Use the concentrations of bromine given.

Solution:

$$\frac{\text{mass bromine in Dead Sea}}{\text{mass bromine in seawater}} = \frac{0.50\ \text{g/L}}{0.065\ \text{g/L}} = \mathbf{7.7 / 1}$$

1.67 Plan: The swimming pool is a rectangle so the volume of the water can be calculated by multiplying the three dimensions of length, width, and the depth of the water in the pool. The depth in ft must be converted to units of m before calculating the volume. The volume in m^3 is then converted to volume in gal. The density of water is used to find the mass of this volume of water.

Solution:

a) Depth of water (m) = $(4.8\ \text{ft})\left(\frac{12\ \text{in}}{1\ \text{ft}}\right)\left(\frac{2.54\ \text{cm}}{1\ \text{in}}\right)\left(\frac{10^{-2}\ \text{m}}{1\ \text{cm}}\right)$ = 1.46304 m

Volume (m^3) = length x width x depth = $(50.0\ \text{m})(25.0\ \text{m})(1.46304\ \text{m})$ = 1828.8 m^3

Volume (gal) = $(1828.8\ \text{m}^3)\left(\frac{10^3\ \text{L}}{1\ \text{m}^3}\right)\left(\frac{1.057\ \text{qt}}{1\ \text{L}}\right)\left(\frac{1\ \text{gal}}{4\ \text{qt}}\right)$ = $4.8326\text{x}10^5$ = $\mathbf{4.8x10^5}$ **gal**

b) Using the density of water = 1.0 g/mL.

Mass (kg) = $(4.8326\text{x}10^5\ \text{gal})\left(\frac{4\ \text{qt}}{1\ \text{gal}}\right)\left(\frac{1000\ \text{mL}}{1.057\ \text{qt}}\right)\left(\frac{1.0\ \text{g}}{\text{mL}}\right)\left(\frac{1\ \text{kg}}{1000\ \text{g}}\right)$ = $1.8288\text{x}10^6$ = $\mathbf{1.8x10^6}$ **kg**

1.68 Plan: In each case, calculate the overall density of the ball and contents and compare to the density of air. The volume of the ball in cm^3 is converted to units of L to find the density of the ball itself in g/L. The densities of the ball and the gas in the ball are additive because the volume of the ball and the volume of the gas are the same.

Solution:

a) Density of evacuated ball: the mass is only that of the sphere itself:

Volume of ball (L) = $(560\ \text{cm}^3)\left(\frac{1\ \text{mL}}{1\ \text{cm}^3}\right)\left(\frac{10^{-3}\ \text{L}}{1\ \text{mL}}\right)$ = 0.560 = 0.56 L

Density of evacuated ball = $\frac{\text{mass}}{\text{volume}} = \frac{0.12\ \text{g}}{0.560} = 0.21\ \text{g/L}$

The evacuated ball will **float** because its density is less than that of air.

b) Because the density of CO_2 is greater than that of air, a ball filled with CO_2 will **sink**.

c) Density of ball + density of hydrogen = 0.0899 + 0.21 g/L = 0.30 g/L

The ball will **float** because the density of the ball filled with hydrogen is less than the density of air.

d) Because the density of O_2 is greater than that of air, a ball filled with O_2 will **sink**.

e) Density of ball + density of nitrogen = 0.21 g/L + 1.165 g/L = 1.38 g/L

The ball will **sink** because the density of the ball filled with nitrogen is greater than the density of air.

f) To sink, the total mass of the ball and gas must weigh $\left(\frac{0.560\ \text{L}}{}\right)\left(\frac{1.189\ \text{g}}{1\ \text{L}}\right)$ = 0.66584 g

For the evacuated ball:

0.66584 – 0.12 g = 0.54585 = **0.55 g**. More than 0.55 g would have to be added to make the ball sink.

For ball filled with hydrogen:

Mass of hydrogen in the ball = $(0.56\ \text{L})\left(\frac{0.0899\ \text{g}}{1\ \text{L}}\right)$ = 0.0503 g

Mass of hydrogen and ball = 0.0503 g + 0.12 g = 0.17 g

0.66584 – 0.17 g = 0.4958 = **0.50 g**. More than 0.50 g would have to be added to make the ball sink.

1.69 Plan: Convert the cross-sectional area of 1.0 μm^2 to mm^2 and then use the tensile strength of grunerite to find the mass that can be held up by a strand of grunerite with that cross-sectional area. Calculate the area of aluminum and steel that can match that mass.

Solution:

$$\text{Cross-sectional area (mm}^2\text{)} = \left(1.0\ \mu\text{m}^2\right)\left(\frac{\left(1\text{x}10^{-6}\text{m}\right)^2}{\left(1\ \mu\text{m}\right)^2}\right)\left(\frac{\left(1\ \text{mm}\right)^2}{\left(1\text{x}10^{-3}\ \text{m}\right)^2}\right) = 1.0\text{x}10^{-6}\ \text{mm}^2$$

Calculate the mass that can be held up by grunerite with a cross-sectional area of 1.0x10^{-6} mm^2:

$$\left(1\text{x}10^{-6}\text{mm}^2\right)\left(\frac{3.5\text{x}10^2\ \text{kg}}{1\ \text{mm}^2}\right) = 3.5\ 10^{-4}\ \text{kg}$$

Calculate the area of aluminum required to match a mass of 3.5x10^{-4} kg:

$$\left(3.5\text{x}10^{-4}\ \text{kg}\right)\left(\frac{2.205\ \text{lb}}{1\ \text{kg}}\right)\left(\frac{1\ \text{in}^2}{2.5\text{x}10^4\ \text{lb}}\right)\left(\frac{\left(2.54\ \text{cm}\right)^2}{\left(1\ \text{in}\right)^2}\right)\left(\frac{\left(10\ \text{mm}\right)^2}{\left(1\ \text{cm}\right)^2}\right) = 1.9916\text{x}10^{-5} = \mathbf{2.0x10^{-5}\ mm^2}$$

Calculate the area of steel required to match a mass of 3.5 x 10^{-4} kg:

$$\left(3.5\text{x}10^{-4}\ \text{kg}\right)\left(\frac{2.205\ \text{lb}}{1\ \text{kg}}\right)\left(\frac{1\ \text{in}^2}{5.0\text{x}10^4\ \text{lb}}\right)\left(\frac{\left(2.54\ \text{cm}\right)^2}{\left(1\ \text{in}\right)^2}\right)\left(\frac{\left(10\ \text{mm}\right)^2}{\left(1\ \text{cm}\right)^2}\right) = 9.9580\text{x}10^{-6} = \mathbf{1.0x10^{-5}\ mm^2}$$

1.70 Plan: To determine if the crown is made of pure gold, the density of the crown must be calculated from its mass and volume. Convert the mass of the crown to g before dividing by the volume to obtain density.

Solution:

$$\text{Mass (oz)} = 4\ \text{lb}\left(\frac{16\ \text{oz}}{1\ \text{lb}}\right) + 13\ \text{oz} = 77\ \text{oz}$$

$$\text{Mass (g)} = \left(77\ \text{oz}\right)\left(\frac{1\ \text{lb}}{16\ \text{oz}}\right)\left(\frac{1\ \text{kg}}{2.205\ \text{lb}}\right)\left(\frac{1000\ \text{g}}{1\ \text{kg}}\right) = 2182.539683\ \text{g}$$

$$\text{Density (g/cm}^3\text{)} = \frac{\left(2182.539683\ \text{g}\right)}{\left(186\ \text{mL}\right)\left(\frac{1\ \text{cm}^3}{1\ \text{mL}}\right)} = 11.734 = 12\ \text{g/cm}^3$$

The crown is not pure gold because its density is not the same as the density of gold.

1.71 Plan: Convert the surface area to m^2 and then use the surface area and the depth to determine the volume of the oceans (area x depth = volume) in m^3. The volume is then converted to liters, and finally to the mass of gold using the density of gold in g/L. Once the mass of the gold is known, its density is used to find the volume of that amount of gold. The mass of gold is converted to troy oz and the price of gold per troy oz gives the total price.

Solution:

$$\text{a) Area of ocean (m}^2\text{)} = \left(3.63\text{x}10^8\ \text{km}^2\right)\left(\frac{\left(1000\ \text{m}\right)^2}{\left(1\ \text{km}\right)^2}\right) = 3.63\text{x}10^{14}\ \text{m}^2$$

Volume of ocean (m^3) = (area)(depth) = (3.63x10^{14} m^2)(3800 m) = 1.3794x10^{18} m^3

$$\text{Mass of gold (g)} = \left(1.3794\text{x}10^{18}\ \text{m}^3\right)\left(\frac{1\ \text{L}}{10^{-3}\ \text{m}^3}\right)\left(\frac{5.8\text{x}10^{-9}\ \text{g}}{\text{L}}\right) = 8.00052\text{x}10^{12} = \mathbf{8.0x10^{12}\ g}$$

b) Use the density of gold to convert mass of gold to volume of gold:

$$\text{Volume of gold (m}^3\text{)} = \left(8.00052\text{x}10^{12}\ \text{g}\right)\left(\frac{1\ \text{cm}^3}{19.3\ \text{g}}\right)\left(\frac{\left(0.01\ \text{m}\right)^3}{\left(1\ \text{cm}\right)^3}\right) = 4.14535\text{x}10^5 = \mathbf{4.1x10^5\ m^3}$$

c) Value of gold = $\left(8.00052\,\text{x}10^{12}\text{ g}\right)\left(\frac{1\text{ tr. oz.}}{31.1\text{ g}}\right)\left(\frac{\$370.00}{1\text{ tr. oz.}}\right)$ = 9.51830x10^{13} = **\$9.5x10^{13}**

1.72 Plan: In part a, convert mass of aluminum in metric tons to lbs. In part b, convert the mass of aluminum to mass in g and use the density to convert mass to volume in cm^3, which is then converted to volume in ft^3.
Solution:

a) $\left(35.1\text{x}10^{6}\text{ t}\right)\left(\frac{1000\text{ kg}}{1\text{ t}}\right)\left(\frac{2.205\text{ lbs}}{1\text{ kg}}\right)$ = 7.73955x10^{10} = **7.74x10^{10} lbs**

b) $\left(35.1\text{x}10^{6}\text{ t}\right)\left(\frac{1000\text{ kg}}{1\text{ t}}\right)\left(\frac{1000\text{ g}}{1\text{ kg}}\right)\left(\frac{\text{cm}^3}{2.70\text{ g}}\right)\left(\frac{1\text{ in}}{2.54\text{ cm}}\right)^3\left(\frac{1\text{ ft}}{12\text{ in}}\right)^3$ = 4.590907x10^{8} = **4.59x10^{8} ft^{3}**

1.73 Plan: Use the equations for temperature conversion given in the chapter. The mass of nitrogen is conserved when the gas is liquefied; the mass of the nitrogen gas equals the mass of the liquid nitrogen. Use the density of nitrogen gas to find the mass of the nitrogen; then use the density of liquid nitrogen to find the volume of that mass of liquid nitrogen.
Solution:

a) T (in °C) = T (in K) – 273.15 = 77.36 K – 273.15 = **–195.79°C**

b) T (in °F) = $\frac{9}{5}T$(in °C) + 32 = $\frac{9}{5}$(–195.79°C) + 32 = –320.422 = **–320.42°F**

c) Mass of liquid nitrogen = mass of gaseous nitrogen = $\left(895.0\text{ L}\right)\left(\frac{4.566\text{ g}}{1\text{ L}}\right)$ = 4086.57 g N_2

Volume of liquid N_2 = $\left(4086.57\text{ g}\right)\left(\frac{1\text{ L}}{809\text{ g}}\right)$ = 5.0514 = **5.05 L**

1.74 Plan: Use conversion factors to convert cm to m and ft to m.
Solution:

rubber: speed (m/s) = $\left(\frac{5.4\,\text{x}10^{3}\text{ cm}}{1\text{ s}}\right)\left(\frac{10^{-2}\text{ m}}{1\text{ cm}}\right)$ = **54 m/s**

granite: speed (m/s) = $\left(\frac{1.97\,\text{x}10^{4}\text{ ft}}{1\text{ s}}\right)\left(\frac{12\text{ in}}{1\text{ ft}}\right)\left(\frac{2.54\text{ cm}}{1\text{ in}}\right)\left(\frac{10^{-2}\text{ m}}{1\text{ cm}}\right)$ = 6.004556x10^{3} = **6.00x10^{3} m/s**

1.75 Plan: Convert the time in hr to min and multiply that time by the number of raindrops that fall each minute to determine the total number of raindrops. Multiply the number of raindrops by the mass of one raindrop and convert that mass to kg.
Solution:

$1.5\text{h}\left(\frac{60\text{ min}}{1\text{ h}}\right)\left(\frac{5.1\text{x}10^{5}\text{ raindrops}}{\text{min}}\right)\left(\frac{0.52\text{ mg}}{\text{raindrop}}\right)\left(\frac{10^{-3}\text{ g}}{1\text{ mg}}\right)\left(\frac{1\text{ kg}}{1000\text{ g}}\right)$ = 23.868 = **24 kg**

1.76 Plan: Determine the volume of a particle (using the equation for the volume of a sphere), and then convert the volume to cm^3. Use the density and volume of the particle to determine the mass of a particle. Find the volume of the room; multiply the room volume by 50. μg to find the total mass of particles in the room. Divide the total mass of particles by the mass of one particle to determine the number of particles in the room. Determine the mass of particles in each breath and divide by the mass of one particle to determine the number of particles in each breath.
Solution:

Volume (μm^3) of one particle = $\left(\frac{4}{3}\right)\pi r^3 = \left(\frac{4}{3}\right)\pi\left(\frac{2.5\ \mu\text{m}}{2}\right)^3$ = 8.1812 = 8.2 μm^3

Volume (cm^3) of one particle = $8.1812\ \mu m^3 \left(\frac{(1\ cm)^3}{(10^4 \mu m)^3}\right) = 8.1812 \times 10^{-12}\ cm^3$

Mass (g) of one particle = $8.1812 x 10^{-12}\ cm^3 \left(\frac{2.5\ g}{cm^3}\right) = 2.045 x 10^{-11} = 2.0 x 10^{-11}$ g each microparticle

Calculate the volume of the room in m^3:
Volume$_{room}$ (ft^3) = 10.0 ft x 8.25 ft x 12.5 ft = 1.031×10^3 ft^3

$$\text{Volume}_{room}\ (m^3) = (1.031x10^3\ ft^3)\left(\frac{(12\ in)^3}{(1\ ft)^3}\right)\left(\frac{(2.54\ cm)^3}{(1\ in)^3}\right)\left(\frac{(10^{-2}\ m)^3}{(1\ cm)^3}\right) = 2.9195x10^1\ m^3$$

$$\text{Total mass of particles (g)} = (2.9195x10^1\ m^3)\left(\frac{50.\ \mu g}{1\ m^3}\right)\left(\frac{10^{-6}\ g}{1\ \mu g}\right)$$

$= 1.460x10^{-3} = 1.5x10^{-3}$ g for all the microparticles in the room

$$\text{Number of microparticles in room} = 1.460 \times 10^{-3}\ g \left(\frac{1\ \text{microparticle}}{2.045 \times 10^{-11}\ g}\right)$$

$= 7.1394 \times 10^7 =$ **7.1×10^7 microparticles in the room**.

$$\text{Mass (g) of particles in one breath} = 0.500\ L \left(\frac{10^{-3} m^3}{1 L}\right)\left(\frac{50\ \mu g}{m^3}\right)\left(\frac{10^{-6} g}{1\ \mu g}\right) = 2.5x10^{-8}\ g \text{ in one 0.500 L breath}$$

$$\text{Number of microparticles in one breath} = \left(2.5x10^{-8}\ g\right)\left(\frac{1\ \text{microparticle}}{2.045 x 10^{-11} g}\right)$$

$= 1.222x10^3 =$ **$1.2x10^3$ microparticles in a breath**.

1.77 Plan: A physical change is one in which the physical form (or state) of a substance, but not its composition, is altered. A chemical change is one in which a substance is converted into a different substance with different composition and properties. A physical property is a characteristic shown by a substance itself, without interacting with or changing into other substances. A chemical property is a characteristic of a substance that appears as it interacts with, or transforms into, other substances.

Solution:

a) **Scene A** shows a physical change. The substance changes from a solid to a gas but a new substance is not formed.

b) **Scene B** shows a chemical change. Two diatomic elements form from a diatomic compound.

c) Both **Scenes A and B** result in different physical properties. Physical and chemical changes result in different physical properties.

d) **Scene B** is a chemical change; therefore, it results in different chemical properties.

e) **Scene A** results in a change in state. The substance changes from a solid to a gas.

1.78 Plan: Determine the total mass of Earth's crust in metric tons (t) by finding the volume of crust (surface area x depth) in km^3 and then in cm^3 and then using the density to find the mass of this volume, using conversions from the inside back cover. The mass of each individual element comes from the concentration of that element multiplied by the mass of the crust.

Solution:

$$\text{Volume of crust (km}^3) = \text{area x depth} = (35\ km)(5.10x10^8\ km^2) = 1.785x10^{10}\ km^3$$

$$\text{Volume of crust (cm}^3) = (1.785x10^{10}\ km^3)\left(\frac{(1000\ m)^3}{(1\ km)^3}\right)\left(\frac{(1\ cm)^3}{(0.01\ m)^3}\right) = 1.785x10^{25}\ cm^3$$

$$\text{Mass of crust (t)} = (1.785x10^{25}\ cm^3)\left(\frac{2.8\ g}{1\ cm^3}\right)\left(\frac{1\ kg}{1000\ g}\right)\left(\frac{1\ t}{1000\ kg}\right) = 4.998x10^{19}\ t$$

$$\text{Mass of oxygen (g)} = \left(4.998\text{x}10^{19}\ \text{t}\right)\left(\frac{4.55\text{x}10^{5}\ \text{g oxygen}}{1\ \text{t}}\right) = 2.2741\text{x}10^{25} = \mathbf{2.3x10^{25}\ g\ oxygen}$$

$$\text{Mass of silicon (g)} = \left(4.998\text{x}10^{19}\ \text{t}\right)\left(\frac{2.72\text{x}10^{5}\ \text{g silicon}}{1\ \text{t}}\right) = 1.3595\text{x}10^{25} = \mathbf{1.4x10^{25}\ g\ silicon}$$

$$\text{Mass of ruthenium} = \text{mass of rhodium} = \left(4.998\text{x}10^{19}\ \text{t}\right)\left(\frac{1\text{x}10^{-4}\ \text{g element}}{1\ \text{t}}\right)$$

$$= 4.998\text{x}10^{15} = \mathbf{5x10^{15}\ g\ each\ of\ ruthenium\ and\ rhodium}$$

1.79 Viscosity would increase from gas to liquid to solid. In the solid state, the submicroscopic particles are located at fixed positions because of the strong forces between them, and this greatly restrains their movement. In the liquid state, the forces are weaker, and, in the gaseous state, the forces between the particles are essentially nonexistent, allowing them to move freely past one another.

1.80 Plan: In visualizing the problem, the two scales can be set next to each other.

Solution:

There are 50 divisions between the freezing point and boiling point of benzene on the °X scale and 74.6 divisions (80.1°C – 5.5°C) on the °C scale. So $°X = \left(\frac{50°X}{74.6°C}\right)°C$

This does not account for the offset of 5.5 divisions in the °C scale from the zero point on the °X scale.

$$\text{So } °X = \left(\frac{50°X}{74.6°C}\right)(°C - 5.5°C)$$

Check: Plug in 80.1°C and see if result agrees with expected value of 50°X.

$$\text{So } °X = \left(\frac{50°X}{74.6°C}\right)(80.1°C - 5.5°C) = 50°X$$

Use this formula to find the freezing and boiling points of water on the °X scale.

$$\text{Freezing point}_{\text{water}}\ (°X) = \left(\frac{50°X}{74.6°C}\right)(0.00°C - 5.5°C) = 3.68°X = \mathbf{-3.7°X}$$

$$\text{Boiling point}_{\text{water}}\ (°X) = \left(\frac{50°X}{74.6°C}\right)(100.0°C - 5.5°C) = \mathbf{63.3°X}$$