Instructor Solutions Manual

Chemistry & Chemical Reactivity

TENTH EDITION

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Table of Contents

Chapter 1
Basic Concepts of Chemistry

Applying Chemical Principles

CO_2 in the Oceans
1.1.1.Name of CO_2: carbon dioxide

1.1.2. Symbols for metals mentioned in the article:

calcium, Ca; copper, Cu; manganese, Mn; iron, Fe

1.1.3. Most dense metal: Cu (8920 kg/m^3) Least dense metal: Ca (1550 kg/m^3)

Data taken from www.ptable.com

1.1.4. $CaCO_3$ (calcium carbonate) contains Ca, C, and O.

PRACTICING SKILLS

Nature of Science

1.1. (a) Proposal that pressure increases with decreased volume—hypothesis

(b) Over time experiments indicate that pressure and volume are inversely proportional—law

(c) Proposal that more molecules colliding per given area results in increased pressure--theory

1.2. Categorize as hypothesis, theory, or law: Hypothesis--a tentative explanation or prediction in accord with current knowledge.

Green Chemistry

1.3. Sustainable development means meeting today's needs while ensuring that future generations will be able to meet theirs.

1.4. Green chemistry refers to practices that reduce waste products during chemical processes, use materials wisely, use renewable materials, generate substances with the lowest possible toxicity, and conserve energy as well as materials.

1.5. Practices of Green Chemistry described:

- Preventing waste
- Energy saved
- Synthetic methods to generate substances with little or no toxicity
- Raw materials (solid catalyst) should be renewable
- To a lesser extent—ALL the practices are used in the new process

1.6. Practices of Green Chemistry described:

- Raw materials (yeast) renewable
- Energy saved—processes run near room temperature and pressure
- Synthesis uses products with low or no toxicity (palm kernel or coconut oil) and not nitric acid or produce a greenhouse gas
- Substances used to minimize hazards (no nitric acid)
- To a lesser extent—ALL the practices are used in the new process

Matter: Elements and Atoms, Compounds and Molecules

1.7. The name of each of the elements:

(a)	C	carbon	(c)	Cl	chlorine	(e)	Mg	magnesium—typically confused with manganese (Mn)
(b)	K	potassium—from *Latin*, Kalium	(d)	P	phosphorus—frequently confused with Potassium	(f)	Ni	nickel

1.8. The names of each of the elements:

(a)	Mn	manganese--typically confused with magnesium (Mg)	(c)	Na	sodium	(e)	Xe	xenon
(b)	Cu	copper	(d)	Br	bromine	(f)	Fe	iron

1.9. The symbol for each of the elements:

(a)	barium	Ba	(c)	chromium	Cr	(e)	arsenic	As
(b)	titanium	Ti	(d)	lead	Pb	(f)	zinc	Zn

1.10. The symbol for each of the elements:

(a)	silver	Ag	(c)	plutonium	Pu	(e)	technetium	Tc
(b)	aluminum	Al	(d)	tin	Sn	(f)	krypton	Kr

1.11. In each of the pairs, decide which is an element and which is a compound:

[HINT: If the isolated symbol is on the periodic table, it's an element!]

(a) Na and NaCl—Sodium(Na) is an element and Sodium chloride(NaCl) is a compound.

(b) Sugar and carbon—Sugar($C_xH_yO_x$) is a compound, and carbon(C) is an element.

(c) Gold and gold chloride—Gold(Au) is an element, and gold chloride ($AuCl_x$) is a compound.

1.12. In each of the pairs, decide which is an element and which is a compound:

[HINT: If the isolated symbol is on the periodic table, it's an element!]

(a) $Pt(NH_3)_2Cl_2$ is a compound; Pt is an element

(b) Copper is an element; copper(II) oxide is a compound

(c) Silicon is an element; sand is a compound

1.13. Masses of hydrogen and oxygen gases prepared from 27 g of water?

An 18 g sample of water contains 2 g of hydrogen gas and 16 g of oxygen gas. A 27 g sample will contain the same proportion of hydrogen and oxygen.

$\frac{2 \text{ g hydrogen}}{18 \text{ g water}} = \frac{x}{27 \text{ g water}} \quad x = \frac{(2 \cdot 27)}{18} =$ 3 g hydrogen The amount of oxygen would be 27-3 or 24 g oxygen. Obviously one could have used the ratio of oxygen to water to solve for the amount of oxygen in 27 g water.

The Law of Constant Composition (or the Law of Definite Proportions) is used.

1.14. 60. g of magnesium produces 100. g of magnesium oxide. A simple ratio will tell us the amount of oxide formed when 30. g of magnesium are used (An example of The Law of Constant Composition or the Law of Definite Proportions).

$$\frac{60. \text{ g magnesium}}{40. \text{ g oxygen}} = \frac{30. \text{ g magnesium}}{x} \quad x = \frac{(30. \cdot 40.)}{60.} = 20. \text{ g oxygen}$$

Physical and Chemical Properties

1.15. Determine if the property is a physical or chemical property for the following:

(a) color a physical property

(b) transformed into rust a chemical property

(c) explode a chemical property

(d) density a physical property

(e) melts a physical property

(f) green a physical property (as in (a))

Physical properties are those that can be observed or measured without changing the composition of the substance. Exploding or transforming into rust results in substances that are **different** from the original substances—and represent chemical properties.

1.16. Determine if the following represent physical or chemical changes:

[HINT: Physical changes are usually **easily reversible**, while chemical changes are not.]

(a) chemical change—not easy to change the color of the sheet back to purple

(b) physical change—the vapor (gaseous) and liquid states of matter are easily interconverted

(c) chemical change—the carbon dioxide is chemically changed when making sugar

(d) physical change—as in (b), the various states of butter can be easily interconverted

1.17. Descriptors of physical versus chemical properties:

(a) Color and physical state are physical properties (colorless, liquid) while **burning** reflects a chemical property.

(b) Shiny, metal, orange, and liquid are physical properties while **reacts readily** describes a chemical property.

1.18. Descriptors of physical versus chemical properties:

(a) Physical properties: color (white), physical state (solid), density (2.71 g/cm^3)
Chemical properties: reactivity towards acid (reacts to produce gaseous carbon dioxide)

(b) Physical property: color (gray zinc, purple iodine, white compound)
Chemical property: reactivity (zinc and iodine react to give a white compound)

Energy

1.19. To move the lever, one uses mechanical energy. The energy resulting is manifest in electrical energy (which produces light); thermal (radiant) energy would be released as the bulb in the flashlight glows.

1.20. Mechanical energy propels the car, electrical energy recharges the batteries, (thermal) radiant energy is released as the sun shines on the solar panels.

1.21. Which represents potential energy and which represents kinetic energy:

(a) thermal energy represents matter in motion—kinetic
(b) gravitational energy represents the attraction of the earth for an object—and therefore energy due to position—potential
(c) chemical energy represents the energy stored in fuels—potential
(d) electrostatic energy represents the energy of separated charges—and therefore potential energy.

1.22. Kinetic to Potential or vice versa:

(a) Potential → kinetic as water falls
(b) Kinetic → potential as foot moves football to higher position
(c) Potential → kinetic as electrons move during battery discharge
(d) Kinetic → potential as liquid water is converted to gaseous water

1.23. Since 1500 J of energy is lost by the metal, the water must gain 1500 J of energy, as dictated by the Law of Conservation of Energy.

1.24. The energy lost by the falling book is gained by the floor (which typically doesn't move owing to a larger mass). Some of the energy is gained by surrounding air molecules in the form of sound.

GENERAL QUESTIONS

1.25. For the gemstone turquoise:

(a) Qualitative: blue-green color Quantitative: density; mass
(b) Extensive: Mass Intensive: Density; Color; Physical state
(c) Volume: $\frac{2.5\text{ g}}{1} \cdot \frac{1\text{ cm}^3}{2.65\text{ g}} = 0.94\text{ cm}^3$

1.26. Qualitative vs Quantitative observations; Extensive vs Intensive observations:

(a) Qualitative: shiny golden metallic appearance, crystals in form of perfect cubes
Quantitative: length of 0.40 cm on a side, mass of 0.064 g
(b) Extensive: Mass and length; Intensive: color, luster, and crystalline form

(c) Density = Mass/Volume = 0.064 g/(0.40 cm)^3 = 0.064 g/0.064 cm^3 = 1.0 g/cm^3
= 1.0 g/mL

1.27. Of the observations below, those which identify chemical properties:
[Chemical properties, in general, are those observed during a chemical change—as opposed to during a physical change.]
(a) Sugar soluble in water--Physical
(b) Water boils at 100°C--Physical
(c) UV light converts O_3 to O_2--Chemical
(d) Ice is less dense than water—Physical

1.28. Of the observations below, those which identify chemical properties:
[Chemical properties, in general, are those observed during a chemical change—as opposed to during a physical change.]
(a) Sodium metal reacts—a chemical property as sodium metal and water react
(b) Octane combustion—a chemical property as C_8H_{18} form CO_2 and H_2O
(c) Chlorine is a green gas—a physical property (observable without a chemical reaction)
(d) Ice melting from heat—a physical property (observable without a chemical reaction)

1.29. Regarding fluorite:
(a) The symbols for the elements in fluorite: Ca (calcium) and F (fluorine);
(b) Shape of the crystals: cubic
Arrangement of ions in the crystal: indicates that the fluoride ions are arranged around the calcium ions in the lattice in such a way as to form a cubic lattice.

1.30. Regarding azurite:
(a) Symbols of the elements: Copper, Cu; Carbon, C; Oxygen, O
(b) Oxygen is a gas, while copper, carbon, and azurite are solids at room temperature. Oxygen is colorless, while copper has a reddish color and carbon is gray/black. The gemstone is a bluish color.

1.31. A solution is a mixture, so the components can be separated using a physical technique. If one heats the NaCl solution to dryness, evaporating all the water, the NaCl solid remains behind. Hence the physical property of boiling points is useful in this separation.

1.32. The non-uniform appearance of the mixture indicates that samples taken from different regions of the mixture would be different—a characteristic of a heterogeneous mixture. Recalling that iron is attracted to a magnetic field while sand is generally not attracted suggests that passing a magnet through the mixture would separate the sand and iron.

1.33. Identify physical or chemical changes:

(a) As there is no change in the composition of the carbon dioxide in the sublimation process, this represents a physical change.

(b) A change in density as a function of temperature does not reflect a change in the composition of the substance (mercury), so this phenomenon represents a physical change.

(c) The combustion of methane represents a change in the substance present as methane is converted to the oxides of hydrogen and carbon that we call water and carbon dioxide—a chemical change.

(d) Dissolving NaCl in water represents a physical change as the solid NaCl ion pairs are separated by the solvent, water. This same phenomenon, the separation of ions, also occurs during melting.

1.34. Identify physical or chemical changes:

(a) The desalination of sea water represents a physical change—as the salts and solvent (water) are separated.

(b) The formation of SO_2 as sulfur-containing coal is burned represents a combination of sulfur and oxygen—a chemical change.

(c) The tarnishing of silver represents a chemical change as silver compounds form on the exterior of the silver object.

(d) Iron is heated to red heat. Changing the temperature of an object is a physical change.

1.35. A segment of Figure 1.2 is shown here:

The macroscopic view is the large crystal in the lower left of the figure, and the particulate view is the representation in the upper right. If one imagines reproducing the particulate (sometimes called submicroscopic) in all three dimensions—imagine a molecular duplicating machine—the macroscopic view results.

1.36. The orange solid and liquid in the bowl (top right) and the orange liquid and gas in the round-bottom flask (bottom right) represent the macroscopic views. The spheres (left column) represent the particulate view. The particulate view of the solid displays molecules of bromine tightly packed to produce the solid.

The liquid view displays molecules of Br_2 with space separating the individual molecules. The gas view displays molecules of Br_2, with the molecules being farther apart than in the liquid view.

1.37. A substance will float in any liquid whose density is greater than its own, and sink in any liquid whose density is less. The piece of plastic soda bottle (d =1.37 g/cm^3) will float in liquid CCl_4 and the piece of aluminum (d = 2.70 g/cm^3) will sink in the liquid CCl_4.

1.38. Liquids: mercury and water ; Solid: copper

Of the substances shown, mercury is most dense and water is least dense.

1.39. Categorize each as an element, a compound, or a mixture:

(a) Sterling silver is a mixture—an alloy—of silver and other metals, to improve the mechanical properties. Silver is a very soft metal, so it is frequently alloyed with copper to produce a material with better “handling” characteristics.

(b) Carbonated mineral water is a mixture. It certainly contains the compound water AND carbon dioxide. The term “mineral” implies that other dissolved materials are present.

(c) Tungsten—an element

(d) Aspirin—a compound, with formula $C_9H_8O_4$

1.40. Categorize each as an element, a compound, or a mixture:

(a) Air is a mixture of several gases.

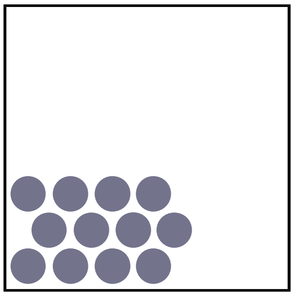
(b) Fluorite is a compound of calcium and fluorine.

(c) Brass is a mixture of copper and zinc.

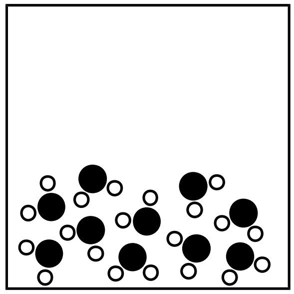
(d) Gold (18-carat) is a mixture of gold and other metals to improve “handling” characteristics.

1.41. Indicate the relative arrangements of the particles in each of the following:

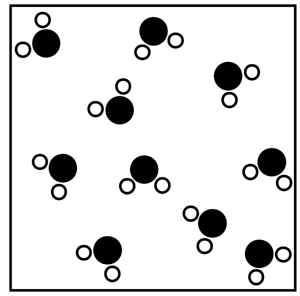
(a) solid iron



(b) liquid water

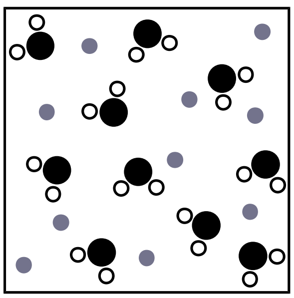


(c) gaseous water

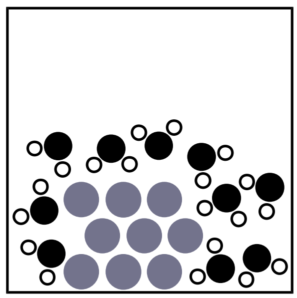


1.42. Indicate the relative arrangements of the particles in each of the following:

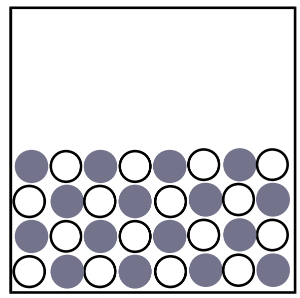
(a) $H_2O(g)$ & $He(g)$



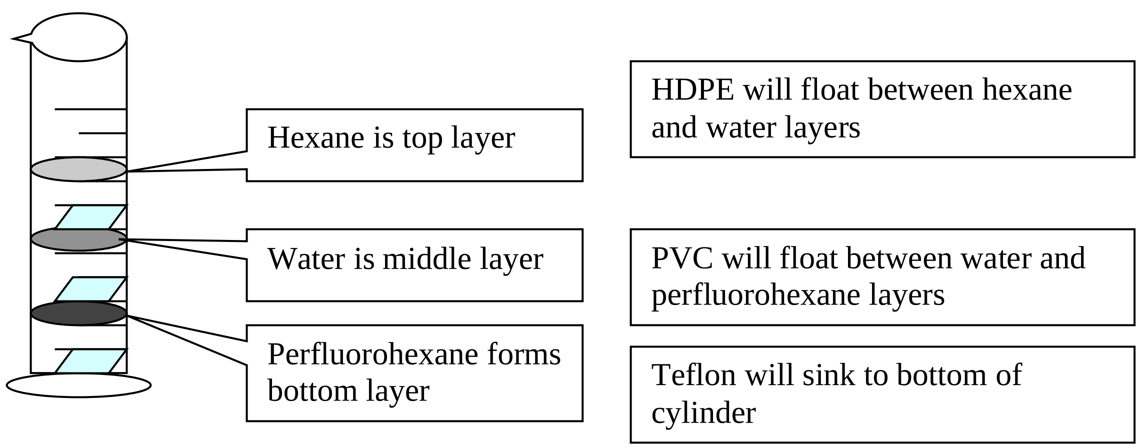
(b) $H_2O(\ell)$ & $Al(s)$



(c) $Cu(s)$ & $Zn(s)$



1.43. When the three liquids are placed into the graduated cylinder, they will "assemble" in layers with increasingly smaller densities (from the bottom to the top) in the cylinder.



[Shadings are added to the top of each layer to provide clarity only (NOT to indicate the color of the liquids). Similarly the parallelogram symbols indicating the plastic samples are shaded—only to provide clarity in locating them—and not to imply any specific colors.]

1.44. Use the melting point. Sugar melts around 160-186 °C while table salt melts about 800 °C.

1.45. HDPE with a density of 0.97 g/mL will float in any liquid whose density is greater than 0.97 g/mL and sink in any liquid whose density is less than that of HDPE. Of the liquids listed, HDPE should float in ethylene glycol, water, acetic acid, and glycerol.

1.46. Measure the density and melting point of the silvery metal and compare to published data points for silver.

1.47. Water, a large component of milk, expands as it is converted to the solid state—as the density of solid water is less than that of liquid water. The expanded solid escapes via the avenue of least resistance—the cap.

1.48. First, weigh the object. Then immerse it in a liquid (e.g. in a graduated cylinder) in which it sinks. If you measure the volume of liquid before and after you immerse the metal, the difference in volume is the volume of the object. Calculate the density of the object by dividing the mass by its volume.

1.49. If one excretes too much sugar, the concentration of the sugar "solution" in the body would decrease, resulting in urine with a higher density. If one excretes too much water, the concentration of the sugar "solution" in the body would increase, with a concomitant decrease in density of the urine.

1.50. To determine the identity, use the physical properties of water: measure the density of the unknown liquid. Freeze and boil the liquid. If the density of the liquid is about 1g/cm^3, if the liquid freezes about 0 ˚C and boils about 100 ˚C, the liquid is probably water. To test for the presence of salt, use a conductivity device. Water containing dissolved salts will conduct an electric current while pure water will not.

1.51. For the reaction of elemental potassium reacting with water:

(a) States of matter involved: **Solid** potassium reacts with **liquid** water to produce **gaseous** hydrogen and **aqueous** potassium hydroxide solution (a homogenous mixture).

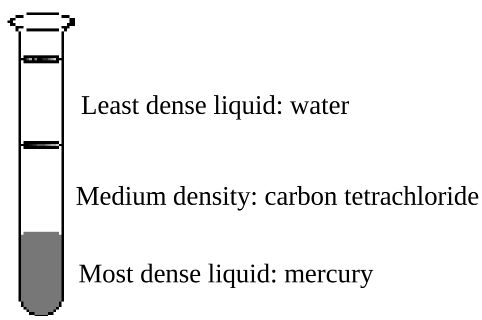
(b) The observed change is **chemical**. The products (hydrogen and potassium hydroxide) are quite different from elemental potassium and water. Litmus paper would also provide the information that while the original water was neither acidic nor basic, the solution produced would be basic. (The color of red litmus paper would change to blue.)

(c) The **reactants**: potassium and water

The **products**: hydrogen, potassium hydroxide solution, heat, and light

(d) Potassium reacts **vigorously** with water. Potassium is less dense than water, and floats atop the surface of the water. The reaction produces enough heat to ignite the hydrogen gas evolved. The flame observed is typically violet-purple in color. The potassium hydroxide formed is soluble in water (and therefore not visible).

1.52. The three liquids with the least dense liquid at the top and most dense liquid at bottom:



1.53. Since gases rise to an area with a similar density as their own, balloons with helium and neon—with densities less than that of dry air--will float (and, if untethered, float away), while the balloons containing argon and krypton will “sink”—to the lowest nearby surface.

1.54. Use the physical properties of copper. One could easily measure the density of the metal and compare it to the published density of copper.

1.55. The dissolution of iodine in ethanol (to make a solution) is a **physical** change, with iodine being the solute and ethanol the solvent.

1.56. For the mixture:

(a) Density of the mixture:

Calculate the mass of each substance (multiply density by volume):

Mass of $CHCl_3$: 10.0 mL · 1.492 g/mL = 14.92 g
Mass of $CHBr_3$: 5.0 mL · 2.890 g/mL = 14.45 g
The mass of the solution is: 14.92 g + 14.45 g or 29.37 g (29 to 2sf) and a volume of 15.0 mL
The density of the mixture is then: 29 g/15.0 mL = 1.9 g/mL (to 2 significant figures).

(b) Density of yellow crystal:

Mass of solution = 2.07 g/mL · 20.0 mL = 41.4 g

Mass of solution = mass $CHCl_3$ + mass $CHBr_3$

Let x = volume $CHCl_3$ and (20.0 mL – x) = volume $CHBr_3$

Then, mass of solution = (1.492 g/mL)x + (2.890 g/mL)(20.0 mL – x) = 41.4 g

x = 11.7 mL $CHCl_3$ and (20.0 – x) = 8.3 mL $CHBr_3$

So to obtain 20.0 mL of solution with d = 2.07 g/cm^3, mix 11.7 mL $CHCl_3$ and 8.3 mL $CHBr_3$.

1.57. For the wedding band in question:

(a) Gold- Au; Copper- Cu; Silver- Ag

(b) The reported density of Iridium (according to www.ptable.com) is 22.65 g/cm^3, making it the most dense element.

(c) As the band is 18-carat (or 75% gold), we can multiply the mass of the ring by 75%.

$$\frac{5.58 \text{ g ring}}{1} \cdot \frac{75 \text{ g gold}}{100 \text{ g ring}} = 4.185 \text{ g} = 4.2 \text{ g (to 2 sf)}$$

(d) Mass of lost gold:

$$\frac{6.15 \times 10^{-3} \text{ g Au lost}}{1 \text{ ring}} \cdot \frac{112 \times 10^{6} \text{ rings}}{1} = 6.9 \times 10^{5} \text{ g Au lost (2 sf)}$$

Value of lost gold:

$$\frac{6.89 \times 10^{5} \text{ g Au lost}}{1} \cdot \frac{1 \text{ troy oz}}{31.1 \text{ g Au}} \cdot \frac{\$1620}{1 \text{ troy oz}} = \$3.59 \times 10^{7} \text{ or \$36 million (2 sf)}$$

Note the assumption in the first calculation that each married couple would have 2 rings.

Chapter 1
Let's Review

Applying Chemical Principles

Out of Gas!

LR.1.1. Fuel density in kg/L: $\frac{1.77\ \text{lb}}{1\ \text{L}} \cdot \frac{0.4536\ \text{kg}}{1.0\ \text{lb}} = 0.803\ \text{kg/L}$

LR.1.2. Mass and volume of fuel that should have been loaded:

Article states that mass of fuel = 22,300 kg

Using the density calculated above: $\frac{22300\ \text{kg}}{1} \cdot \frac{1\ \text{L}}{0.803\ \text{kg}} = 27775\ \text{L}$ (or 27800 to 3 sf)

Ties in Swimming and Significant Figures

LR.2.1. Distance traveled in 0.001 s (at world record rate of 20.91 s for 50-m):

$$\frac{50\ \text{m}}{20.91\ \text{s}} \cdot \frac{0.001\ \text{s}}{1} \cdot \frac{1000\ \text{mm}}{1\ \text{m}} = 2.4\ \text{mm (2sf)}$$

LR.2.2. Time to travel 3.0 cm at world record rate:

$$\frac{20.91\ \text{s}}{50\ \text{m}} \cdot \frac{1\ \text{m}}{100\ \text{cm}} \cdot \frac{3.0\ \text{cm}}{1} = 0.0125\ \text{s or } 0.013\ \text{s (2sf)}$$

LR.2.3. Percent error if lane is 3.0 cm longer than 50.00 m

Actual length of lane is 50.03 m (3.0 cm + 50.00 m converted to units of m)

$$\%\ \text{error} = \frac{\text{error in measurement}}{\text{accepted value}} = \frac{0.030\ \text{m}}{50.00\ \text{m}} \times 100 = 0.060\ \%\ \text{(2 sf)}$$

PRACTICING SKILLS

Temperature Scales

LR.1. Express 25 ˚C in kelvins:

K = (25 °C+ 273) or 298 K

LR.2. Express 5.5×10^3 °C in kelvins: $(5.5 \times 10^3\ °\text{C} + 273.15\ °\text{C}) \frac{1\ \text{K}}{1\ °\text{C}} = 5.8 \times 10^3\ \text{K}$

LR.3. Make the following temperature conversions:

˚C	K
(a) 16	16 + 273.15 = 289
(b) 370 - 273 or 97	370
(c) 40	40 + 273.15 = 310

Note no decimal point after 40

LR.4. Make the following temperature conversions:

˚C	K
(a) 77 - 273.15 = –196	77
(b) 63	63 + 273.15 = 336
(c) 1450 – 273.15 =1177	1450

Length, Volume, Mass, and Density

LR.5. The distance of a marathon (42.195 km) in meters; in miles:

$$\frac{42.195\text{ km}}{1}\cdot\frac{1000\text{ m}}{1\text{ km}} = 42195\text{ m} \qquad \frac{42.195\text{ km}}{1}\cdot\frac{0.62137\text{ miles}}{1\text{ km}} = 26.219\text{ miles}$$

The factor (0.62137 mi/km) is found inside the back cover of the text.

LR.6. Length of a 19 cm pencil in mm; in m:

$$\frac{19\text{ cm}}{1}\cdot\frac{10\text{ mm}}{1\text{ cm}} = 190\text{ mm} \qquad \frac{19\text{ cm}}{1}\cdot\frac{1\text{ m}}{100\text{ cm}} = 0.19\text{ m}$$

LR.7. Express the area of a 2.5 cm × 2.1 cm stamp in cm^2 ; in m^2 :

$$2.5\text{ cm} \cdot 2.1\text{ cm} = 5.3\text{ cm}^2$$

$$\frac{5.3\text{ cm}^2}{1}\cdot\left(\frac{1\text{ m}}{100\text{ cm}}\right)^2 = 5.3 \times 10^{-4}\text{ m}^2$$

LR.8. Surface area of a compact disc in cm^2:

$$\text{Area} = \pi r^2 = \pi\left(\frac{11.8\text{cm}}{2}\right)^2 = 109\text{ cm}^2$$

$$109\text{ cm}^2 \cdot \left(\frac{1\text{ m}}{100\text{ cm}}\right)^2 = 1.09 \times 10^{-2}\text{ m}^2$$

LR.9. Express volume of 250. mL beaker in cm^3; in liters (L); in m^3 ; in dm^3:

$$\frac{250.\ \text{mL}}{1\ \text{beaker}} \cdot \frac{1\ \text{cm}^3}{1\ \text{mL}} = \frac{250.\ \text{cm}^3}{1\ \text{beaker}}$$

$$\frac{250.\ \text{cm}^3}{1\ \text{beaker}} \cdot \frac{1\ \text{L}}{1000\ \text{cm}^3} = \frac{0.250\ \text{L}}{1\ \text{beaker}}$$

$$\frac{250.\ \text{cm}^3}{1\ \text{beaker}} \cdot \frac{1\ \text{m}^3}{1\times10^6\ \text{cm}^3} = \frac{2.50 \times 10^{-4}\ \text{m}^3}{1\ \text{beaker}}$$

$$\frac{250.\ \text{cm}^3}{1\ \text{beaker}} \cdot \frac{1\ \text{L}}{1000\ \text{cm}^3} \cdot \frac{1\ \text{dm}^3}{1\ \text{L}} = \frac{0.250\ \text{dm}^3}{1\ \text{beaker}}$$

LR.10. Volume of bottle in mL; in cm^3 ; in dm^3:

$$1.5\ \text{L} \cdot \frac{10^3\ \text{mL}}{1\ \text{L}} = 1.5 \times 10^3\ \text{mL}$$

$$1.5\ \text{L} \cdot \frac{10^3\ \text{mL}}{1\ \text{L}} \cdot \frac{1\ \text{cm}^3}{1\ \text{mL}} = 1.5 \times 10^3\ \text{cm}$$

$$1.5\ \text{L} \cdot \frac{10^3\ \text{mL}}{1\ \text{L}} \cdot \frac{1\ \text{cm}^3}{1\ \text{mL}} \cdot \left(\frac{1\ \text{dm}}{10\ \text{cm}}\right)^3 = 1.5\ \text{dm}^3$$

LR.11. Convert book's mass of 2.52 kg into grams:

$$\frac{2.52\ \text{kg}}{1\ \text{book}} \cdot \frac{1 \times 10^3\text{g}}{1\ \text{kg}} = \frac{2.52 \times 10^3\ \text{g}}{1\ \text{book}}$$

LR.12. Mass of 2.265 g in kg; in mg:

$$2.265\ \text{g} \cdot \frac{1\ \text{kg}}{1\times 10^3\text{g}} = 2.265\times 10^{-3}\text{kg}$$

$$2.265\ \text{g} \cdot \frac{1 \times 10^3\ \text{mg}}{1\ \text{g}} = 2.265\times 10^3\ \text{mg}$$

LR.13. What mass of ethylene glycol (in grams) possesses a volume of 500. mL of the liquid?

$$\frac{500.\ \text{mL}}{1} \cdot \frac{1\ \text{cm}^3}{1\ \text{mL}} \cdot \frac{1.11\ \text{g}}{\text{cm}^3} = 555\ \text{g}$$

LR.14. Volume of 2.365 g of silver: $2.365\ \text{g} \cdot \dfrac{1\ \text{cm}^3}{10.5\ \text{g}} = 0.225\ \text{cm}^3$

LR.15. To determine the density, given the data, one must first convert each length to units of cm:

$$\left[\frac{1.05\text{ mm}}{1}\cdot\frac{1\text{ cm}}{10\text{ mm}}\right]\cdot\frac{2.35\text{ cm}}{1}\cdot\frac{1.34\text{ cm}}{1} = 0.3306\text{ cm}^3\ (0.331\text{ to 3sf})$$

Density is Mass/Volume or $\frac{2.361\text{ g}}{0.3306\text{ cm}^3} = 7.14\frac{\text{g}}{\text{cm}^3}$.

Given the selection of metals, the identity of the metal is **zinc**.

LR.16. Larger volume, 600 g of water or 600 g of lead:

$$600\text{ g }H_2O\cdot\frac{1\text{ cm}^3}{0.995\text{ g}} = 600\text{ cm}^3 \quad 600\text{ g lead}\cdot\frac{1\text{ cm}^3}{11.35\text{ g}} = 50\text{ cm}^3$$

Energy Units

LR.17. Express the energy of a 1200 Calories/day diet in joules:

$$\frac{1200\text{ Cal}}{1\text{ day}}\cdot\frac{1000\text{ calorie}}{1\text{ Cal}}\cdot\frac{4.184\text{ J}}{1\text{ cal}} = 5.0\times10^6\text{ Joules/day}$$

LR.18. Express 1670 kJ in dietary Calories: $1670\text{ kJ}\cdot\frac{10^3\text{J}}{1\text{ kJ}}\cdot\frac{1\text{ cal}}{4.184\text{ J}}\cdot\frac{1\text{ Cal}}{10^3\text{cal}} = 399\text{ Cal}$

LR.19. Compare 170 kcal/serving and 280 kJ/serving.

$$\frac{170\text{ kcal}}{1\text{ serving}}\bullet\frac{1000\text{ calorie}}{1\text{ kcal}}\bullet\frac{4.184\text{ J}}{1\text{ cal}}\bullet\frac{1\text{ kJ}}{1000\text{ J}} = 710\text{ kJoules/serving}$$

So 170 kcal/serving has a greater energy content.

LR.20. Greater energy per mL, berry juice or soft drink:

Soft drink: $130\text{ Cal}\cdot\frac{10^3\text{cal}}{1\text{ Cal}}\cdot\frac{4.184\text{ J}}{1\text{ cal}} = 5.4\times10^5\text{J}$ or 540 kJ

With the berry juice providing 630 kJ, the JUICE provides more energy.

$$\frac{540\text{ kJ}}{335\text{ mL}} = \frac{1.6\text{ kJ}}{1\text{ mL}} \qquad \frac{630\text{ kJ}}{295\text{ mL}} = \frac{2.1\text{ kJ}}{1\text{ mL}}$$

The juice also provides more energy per milliliter.

Accuracy, Precision, Error, and Standard Deviation

LR.21. Using the data provided, the averages and their deviations are as follows:

Data point	Method A	deviation	Method B	deviation
1	2.2	0.2	2.703	0.777
2	2.3	0.1	2.701	0.779
3	2.7	0.3	2.705	0.775
4	2.4	0.0	5.811	2.331
Averages:	2.4	0.2	3.480	1.166

Note that the deviations for both methods are calculated by first determining the average of the four data points, and then subtracting the individual data points from the average (without regard to sign).

(a) The average density for method A is 2.4 ± 0.2 g/cm^3 while the average density for method B is 3.480 ± 1.166 g/cm^3—if one includes all the data points. *Data point 4* in *Method B* has a large deviation, and *should probably be excluded* from the calculation. If one omits data point 4, Method B gives a density of 2.703 ± 0.001 g/cm^3.

(b) The percent error for each method:

Error = experimental value - accepted value

From Method A   error = (2.4 - 2.702) = 0.3 g/cm^3

From Method B   error = (2.703 - 2.702) = 0.001 g/cm^3 (omitting data point 4)

error = (3.480 - 2.702) = 0.778 (including all data points)

and the percent error is then:

(Method A) = $\frac{0.3}{2.702} \cdot \frac{100}{1}$ = about 10% to 1 sf

(Method B) = $\frac{0.001}{2.702} \cdot \frac{100}{1}$ = about 0.04% to 1 sf)

(c) The standard deviation for each method:

Method A: $\sqrt{\frac{(0.2)^2 + (0.1)^2 + (0.3)^2 + (0.0)^2}{3}} = \sqrt{\frac{0.14}{3}}$ = 0.216 or 0.2 (to 1 sf)

Method B: $\sqrt{\frac{(0.777)^2 + (0.779)^2 + (0.775)^2 + (2.331)^2}{3}} = \sqrt{\frac{7.244}{3}}$ = 1.55 (to 3 sf)

(d) If one counts all data points, the deviations **for all data points** of Method A are less than those for **the data points of** Method B, Method A offers *better precision*. On the other hand, omitting data point 4, Method B offers both *better accuracy* (average closer to the accepted value) and *better precision* (since the value is known to a greater number of significant figures).

LR.22. Calculate percent errors:

(a) Student A: Average = 135 °C   Percent error = $\frac{135 - 135}{135} \times 100\ \%$ = 0%

Student B: Average = 138 °C   Percent error = $\frac{138 - 135}{135} \times 100\ \%$ = 2%

(b) Student B is more precise; Student A is more accurate

Exponential Notation and Significant Figures

LR.23. Express the following numbers in exponential (or scientific) notation:

(a) 0.054 = 5.4×10^{-2} To locate the decimal behind the first non-zero digit, we move the decimal place to the right by 2 spaces (-2); 2 significant figures

(b) 5462 = 5.462×10^{3} To locate the decimal behind the first non-zero digit, we move the decimal place to the left by 3 spaces (+3); 4 significant figures

(c) 0.000792 = 7.92×10^{-4} To locate the decimal behind the first non-zero digit, we move the decimal place to the right by 4 spaces (-4); 3 significant figures

(d) 1600 = 1.6×10^{3} To locate the decimal behind the first non-zero digit, we move the decimal place to the left by 3 spaces (+3); 2 significant figures

LR.24. Number of significant figures:

(a) 1623 (4 significant figures)

(b) 0.000257 (3 significant figures) (zeroes between decimal point and 2 are **not** significant)

(c) 0.0632 (3 significant figures) (zero between decimal point and 6 are **not** significant)

(d) 3404 (4 significant figures)

LR.25. Perform operations and report answers to proper number of sf:

(a) $(1.52)(6.21 \times 10^{-3}) = 9.44 \times 10^{-3}$ (3 sf - each term in the product has 3)

(b) $(6.217 \times 10^{3}) - (5.23 \times 10^{2}) = 5.694 \times 10^{3}$ [Convert 5.23×10^{2} to 0.523×10^{3} and subtract, leaving 5.694×10^{3}. With 3 decimal places to the right of the decimal place in both numbers, we can express the difference with 3 decimal places.

(c) $(6.217 \times 10^{3}) \div (5.23 \times 10^{2}) = 11.887$ or 11.9 (3 sf)

Recall that in multiplication and division, the result should have the same number of significant figures as the **term** with the fewest significant figures.

(d) $(0.0546)(16.0000)\left[\frac{7.779}{55.85}\right]$=0.121678 or 0.122 (3 sf)

the same rule applies, as in part (c) above: The first term has 3 sf, the second term 6 sf—yes the zeroes count, and the third term 4 sf.
Dividing the two terms in the last quotient gives an answer with 4 sf. So with 3,6, and 4 sf in the terms, the answer should have **no more than** 3 sf

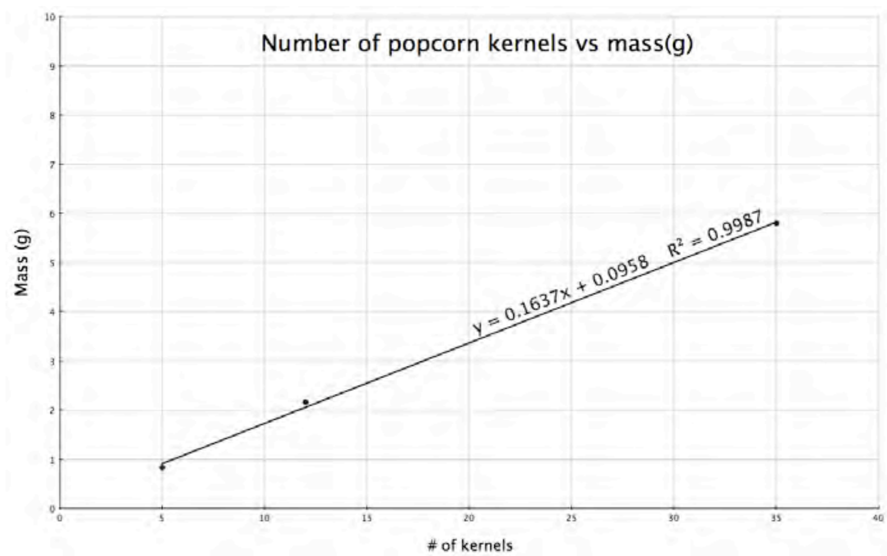
LR.26. Provide result of calculation with proper number of significant figures:

In all calculations, each component has 3 sf

(a) 2.44×10^{8} (c) 0.133
(b) 4.85×10^{-2} (d) 0.0286

Graphing

LR.27. Plot the data for number of kernels of popcorn versus mass (in grams):



The best straight line has the equation, y = 0.1637x + 0.0958, with a slope of 0.1637. This slope indicates that the mass increases by a factor of 0.1637grams with each kernel of popcorn. The mass of 20 kernels would be:
mass = (0.1637)(20) + 0.0958 or 3.370 grams.
To determine the number of kernels (x) with a mass of 20.88 grams, substitute 20.88 for mass (i.e. y) and solve for the number of kernels.
20.88 g = 0.1637(x) + 0.0958; (20.88 – 0.0958) = 0.1637x and dividing by the slope: $\frac{[20.88 - 0.0958]}{0.1637} = x$ or 126.96 kernels—approximately 127 kernels.

LR.28. Using the provided graph:

(a) The value of x when y = 4.0 is 0.21

(b) The value of y when x is 0.30 is 5.6

(c) slope = $\frac{5.6 - 4.0}{0.30 - 0.21}$ = 18; intercept = 0.20

(d) The value of y when x = 1.0: $y = 18x + 0.20 = (18)(1.0) + 0.20 = 18$

LR.29. Using the graph shown, determine the values of the equation of the line:

(a) Using the first and last data points, we calculate the slope (rise/run):

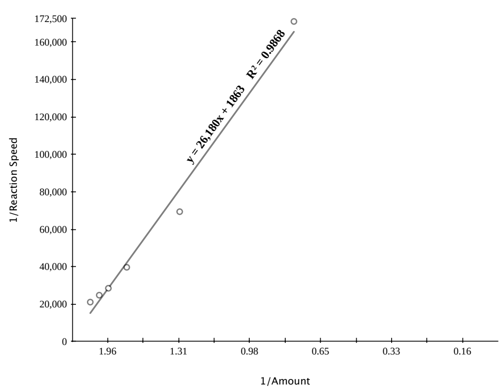
$$\frac{20.00 - 0.00}{0.00 - 5.00} = -4.00$$

The intercept (b) is the y value when the x value is zero (0).
Substituting into the equation for the line: Y = (-4.00)(0) + b
We can read the value of b from the graph (20.00).
The equation for the line is: Y = -4.00x + 20.00

(b) The value of y when x = 6.0 is: Y = (-4.00)(6.00) + 20.00 or -4.00.

LR.30. (a) The data (and the reciprocals) are as follows:

Amount of water	1/Amount	Reaction Speed	1/Speed
1.96	0.510204082	4.75E-05	21052.63158
1.31	0.763358779	4.03E-05	24813.89578
0.98	1.020408163	3.51E-05	28490.02849
0.65	1.538461538	2.52E-05	39682.53968
0.33	3.03030303	1.44E-05	69444.44444
0.16	6.25	5.85E-06	170940.1709



(b) y = 26180x + 1863 or 2.62×10^4 x + 1860 with a slope of 2.62×10^4 and intercept = 1860.

Solving Equations

LR.31. Solving the equation for "C":

(0.502)(123) = (750.)C and rearranging the equation by dividing by 750. gives

$$\frac{(0.502)(123)}{750.} = C = 0.0823 \text{ (3 sf)}$$

LR.32. Solving the equation for *n*:

(2.34)(15.6) = *n*(0.0821)(273) Rearranging: $\frac{(2.34)(15.6)}{(0.0821)(273)} = n$

Solving for n gives 1.63 to 3 sf

LR.33. Solve the following equation for T:

$(4.184)(244)(T - 292.0) + (0.449)(88.5)(T - 369.0) = 0$

1020.9T – 298101.6 + 39.74T- 14663 = 0

1060.64T – 312764 = 0; Solving for T: $\frac{312764}{1060.64} = T$ and T = 295 (3 sf)

LR.34. Solving the equation for n:

$-246.0 = 1312\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$ Simplify by dividing by 1312: $\frac{-246.0}{1312} = \left[\frac{1}{2^2} - \frac{1}{n^2}\right]$

$-0.1875 = \left[\frac{1}{4} - \frac{1}{n^2}\right]$ Substituting 0.25 for 1/4, $-0.1875 = 0.25 - \frac{1}{n^2}$

$\frac{1}{n^2} = 0.4375$; Multiply by n^2, divide by 0.4375 and take the square root of both sides to obtain: $\sqrt{\frac{1}{0.4375}} = n$; n = 1.5 and to 1 sf, n = 2.

GENERAL QUESTIONS

LR.35. Express the length 1.97 Angstroms in nanometers; In picometers;

$$\frac{1.97 \text{ Angstrom}}{1} \cdot \frac{1\times10^{-10}\text{m}}{1 \text{ Angstrom}} \cdot \frac{1\times10^{9} \text{ nm}}{1 \text{ m}} = 0.197 \text{ nm}$$

$$\frac{1.97 \text{ Angstrom}}{1} \cdot \frac{1\times10^{-10}\text{m}}{1 \text{ Angstrom}} \cdot \frac{1\times10^{12} \text{ pm}}{1 \text{ m}} = 197 \text{ pm}$$

LR.36. Separation between C atoms in diamond is 0.154 nm.

(a) In meters: $\frac{0.154\ \text{nm}}{1} \cdot \frac{1\ \text{m}}{1 \times 10^{9}\ \text{nm}} = 1.54 \times 10^{-10}\ \text{m}$

(b) In picometers: $1.54 \times 10^{-10}\ \text{m} \cdot \frac{1\ \text{pm}}{1 \times 10^{-12}\ \text{m}} = 154\ \text{pm}$

(c) In Angstroms: $1.54 \times 10^{-10}\ \text{m} \cdot \frac{1\ \mathring{\text{A}}}{1 \times 10^{-10}\ \text{m}} = 1.54\ \mathring{\text{A}}$

LR.37. Diameter of red blood cell = 7.5 μm

(a) In meters: $\frac{7.5\ \mu\text{m}}{1} \cdot \frac{1\ \text{m}}{1 \times 10^{6}\ \mu\text{m}} = 7.5 \text{ x } 10^{-6}\text{m}$

(b) In nanometers: $\frac{7.5\ \mu\text{m}}{1} \cdot \frac{1\ \text{m}}{1 \times 10^{6}\ \mu\text{m}} \cdot \frac{1 \times 10^{9}\text{nm}}{1\text{m}} = 7.5 \times 10^{3}\text{nm}$

(c) In picometers: $\frac{7.5\ \mu\text{m}}{1} \cdot \frac{1\ \text{m}}{1 \times 10^{6}\ \mu\text{m}} \cdot \frac{1 \times 10^{12}\text{m}}{1\text{m}} = 7.5 \times 10^{6}\ \text{pm}$

LR.38. $1.53\ \text{g cisplatin} \cdot \frac{65.0\ \text{g Pt}}{100.0\ \text{g cisplatin}} = 0.995\ \text{g Pt}$

LR.39. Mass of procaine hydrochloride (in mg) in 0.50 mL of solution

$$\frac{0.50\ \text{mL}}{1} \cdot \frac{1.0\ \text{g}}{1\ \text{mL}} \cdot \frac{10.\ \text{g procaine HCl}}{100\ \text{g solution}} \cdot \frac{10^{3}\ \text{mg procaine HCl}}{1\ \text{g procaine HCl}} = 50.\ \text{mg procaine HCl}$$

LR.40. Length of a cube of Al to have a mass of 7.6 grams:

$7.6\ \text{g} \cdot \frac{1\ \text{cm}^3}{2.698\ \text{g}} = 2.8\ \text{cm}^3$; The cube has dimensions of the length^3.

The cube edge = $\sqrt[3]{2.8\ \text{cm}^3} = 1.4\ \text{cm}$

LR.41. Average density of a marble: $\frac{95.2\ \text{g}}{(99 - 61)\ \text{mL}} \cdot \frac{1\ \text{mL}}{1\ \text{cm}^3} = 2.5\ \text{g/cm}^3$

LR.42. Calculate the density of the solid and identify the compound:

$$\frac{18.82\ \text{g}}{(15.3 - 8.5)\ \text{mL}} \cdot \frac{1\ \text{mL}}{1\ \text{cm}^3} = 2.8\ \text{g/cm}^3$$

The white solid’s density matches that of (c) KBr.

LR.43. For the sodium chloride unit cell:

(a)The volume of the unit cell is the (edge length)^3

With an edge length of 0.563 nm, the volume is (0.563 nm)^3 or 0.178 nm^3 The volume in cm^3 is calculated by first expressing the edge length in cm:

$$\frac{0.563\text{ nm}}{1}\cdot\frac{1\times 10^{2}\text{cm}}{1\times 10^{9}\text{nm}} = 5.63\times 10^{-8}\text{cm}$$, so the volume is 1.78 x 10^{-22} cm^3

(b) The mass of the unit cell is:

$$M = V\cdot D = 1.78\times 10^{-22}\text{cm}^3\cdot 2.17\text{ g/cm}^3 = 3.87\times 10^{-22}\text{g}$$

(c) Given the unit cell contains 4 NaCl "molecules", the mass of one "molecule is:

$$\frac{3.87\times 10^{-22}\text{ g for 4 NaCl pairs}}{4\text{ NaCl pairs}} = 9.68\times 10^{-23}\text{ g/ion pair}$$

LR.44. Volume of a 1.50-carat diamond:

$$1.50\text{ carat}\cdot\frac{0.200\text{ g}}{1\text{ carat}}\cdot\frac{1\text{ cm}^3}{3.513\text{ g}} = 0.0854\text{ cm}^3$$

LR.45. The accepted value for a normal human temperature is 98.6 ˚F. On the Celsius scale this corresponds to: $˚\text{C} = \frac{5}{9}(98.6 - 32) = 37\,˚\text{C}$

Since the melting point of gallium is 29.8 ˚C, the gallium should melt in your hand.

LR.46. A good estimate for the density would be between that at 15 °C and that at 25 °C. If one assumes is it halfway between those densities, a better estimate would be 0.99810 g/cm^3. It should be noted that the decrease in density with increasing temperature is not linear.

LR.47. The heating of popcorn causes the loss of water.

(a) The percentage of mass lost upon popping:

$$\frac{(0.125\text{g} - 0.106\text{g})}{0.125\text{g}}\times 100 = 15\%$$

(b) With an average mass of 0.125 g, the number of kernels in a pound of popcorn:

$$\frac{1\text{ kernel}}{0.125\text{g}}\cdot\frac{453.6\text{g}}{1\text{ lb}} = 3628.8\text{ kernels or 3630 (3 sf)}$$

LR.48. What is the thickness of the aluminum foil in millimeters?

$$\text{Volume} = \frac{12\text{ oz}}{1}\cdot\frac{28.4\text{ g}}{1\text{ oz}}\cdot\frac{1\text{ cm}^3}{2.70\text{ g}} = 126\text{ cm}^3$$

$$\text{Area} = 75 \text{ ft}^2 \left(\frac{12 \text{ in}}{1 \text{ ft}}\right)^2 \left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)^2 = 7.0 \times 10^4 \text{ cm}^2$$

$$\text{Thickness} = \frac{\text{volume}}{\text{area}} = \frac{126 \text{ cm}^3}{7.0 \times 10^4 \text{ cm}^2} = 1.8 \times 10^{-3} \text{ cm} = 1.8 \times 10^{-2} \text{ mm}$$

LR.49. The mass of NaF needed for 150,000 people for a year:

One way to do this problem is to begin with a factor that contains the units of the "answer" (mass NaF in kg). Since NaF is 45% fluoride (and 55 %Na), we can write the factor: $\frac{100.0 \text{ kg NaF}}{45.0 \text{ kg F}^-}$. Note that the expression of kg/kg has the same value as the expression g/g—and provides the "desired" units of our answer.

A concentration of 1 ppm can be expressed as: $\frac{1.00 \text{ kg F}^-}{1.00 \times 10^6 \text{ kg H}_2\text{O}}$ [We could use the fraction with the masses expressed in **grams**, but we would have to convert grams to kg. Note this factor can be derived from the factor using grams if you multiply BOTH numerator and denominator by 1000.]. Using the data provided in the problem, plus conversion factors (found in the rear cover of your textbook)

$$\frac{100.0 \text{ kg NaF}}{45.0 \text{ kg F}^-} \cdot \frac{1.00 \text{ kg F}^-}{1.00 \times 10^6 \text{ kg H}_2\text{O}} \cdot \frac{1 \text{ kg H}_2\text{O}}{1 \times 10^3 \text{ cm}^3\text{H}_2\text{O}} \cdot \frac{1 \times 10^3 \text{ cm}^3\text{H}_2\text{O}}{1.0567 \text{ qt H}_2\text{O}} \cdot \frac{4.00 \text{ qt H}_2\text{O}}{1 \text{ gal H}_2\text{O}} \cdot$$

$$\frac{170 \text{ gal H}_2\text{O}}{1 \text{ person-day}} \cdot \frac{1.50 \times 10^5 \text{person}}{1} \cdot \frac{365 \text{ day}}{1 \text{ year}} = 8.0 \times 10^4 \text{ kg NaF/year}$$

Note that 170 gal of water per day limits the answer to 2 sf.

LR.50. Area in cm^2: $0.5 \text{ acre} \cdot \frac{1.0 \times 10^4 \text{ m}^2}{2.47 \text{ acres}} \left(\frac{100 \text{ cm}}{1 \text{ m}}\right)^2 = 2 \times 10^7 \text{ cm}^2$

$$\text{thickness} = \frac{\text{volume}}{\text{area}} = \frac{5 \text{ cm}^3}{2 \times 10^7 \text{ cm}^2} = 2 \times 10^{-7} \text{ cm}$$

This is likely related to the "length" of oil molecules.

LR.51. Mass of sulfuric acid in 500. mL (or 500. cm^3)solution.

$$\frac{38.08 \text{ g sulfuric acid}}{100.00 \text{ g solution}} \cdot \frac{1.285 \text{ g solution}}{1.000 \text{ cm}^3 \text{ solution}} \cdot \frac{500.\text{cm}^3\text{solution}}{1} = 244.664 \text{ g}$$

or 245 g sulfuric acid (3 sf—note 500. has 3 sf)

LR.52. The volume is: $\frac{279 \text{ kg}}{1} \cdot \frac{10^3 \text{ g}}{1 \text{ kg}} \cdot \frac{1 \text{ cm}^3}{19.3 \text{ g}} = 1.45 \times 10^4 \text{cm}^3$

Since volume = (area)(thickness) $1.45 \times 10^4 \text{ cm}^3 = (\text{area}) \left(0.0015 \text{ mm} \times \frac{1 \text{ cm}}{10 \text{ mm}}\right)$

Solve for area: $\frac{1.45 \times 10^4 \text{ cm}^3}{\left(0.0015 \text{ mm} \cdot \frac{1 \text{ cm}}{10 \text{ mm}}\right)}$ area = $9.6 \times 10^7 \text{ cm}^2$

Converting to m^2 : $\left(\frac{1 \text{ m}}{100 \text{ cm}}\right)^2 = 9.6 \times 10^3 \text{ m}^2$

LR.53. Density of water changes with state:

(a) Volume of solid water at –10°C when a 250. mL can is filled with liquid water at 25°C: The volume of liquid water at 25 degrees is 250. mL (or cm^3). The mass of that water is:

$$\frac{0.997 \text{ g water}}{1.000 \text{ cm}^3 \text{ water}} \cdot \frac{250. \text{ cm}^3}{1} = 249.25 \text{ g water (249 to 3 sf)}$$

That mass of water at the lower temperature will occupy:

$$\frac{1.000 \text{ cm}^3 \text{ water}}{0.917 \text{ g water}} \cdot \frac{249.25 \text{ g water}}{1} = 271.81 \text{ (or 272 cm}^3 \text{ to 3 sf)}$$

(b) With the can being filled to 250. mL at room temperature, the expansion (an additional 22 mL) can not be contained in the can. (Get out the sponge—there’s a mess to clean up.)

LR.54. Volume of room and mass of air:

(a) Volume of room = (length)(width)(height)

$$= (18 \text{ ft})(15 \text{ ft})(8.5 \text{ ft}) \left(\frac{12 \text{ in}}{1 \text{ ft}}\right)^3 \left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)^3 \left(\frac{1 \text{ m}}{100 \text{ cm}}\right)^3 = 65 \text{ m}^3$$

$$\text{and } 65 \text{ m}^3 \cdot \frac{1 \text{ L}}{10^{-3} \text{ m}^3} = 6.5 \times 10^4 \text{ L}$$

(b) Mass of air in kg: $\frac{6.5\times10^4\text{ L}}{1}\cdot\frac{1.2\text{ g}}{1\text{ L}}\cdot\frac{1\text{ kg}}{10^3\text{ g}}$ = 78 kg

and in pounds: $\frac{78\text{ kg}}{1}\cdot\frac{10^3\text{ g}}{1\text{ kg}}\cdot\frac{1\text{ lb}}{454\text{ g}}$ = 170 lb

LR.55. Calculate the density of steel if a steel sphere of diameter 9.40 mm has a mass of 3.475 g:

The radius of the sphere is (0.5)(9.40mm) or 4.70mm. Since density is usually expressed in cm^3, express the radius in cm (0.470cm) and substitute into the volume equation:

$$V=\frac{4}{3}\Pi r^3 = \frac{4}{3}(3.1416)(0.470\text{cm})^3 = 0.435\text{ cm}^3(\text{to 3 sf})$$

The density is 3.475 g /0.435 cm^3 = 7.99 g/cm^3.

LR.56. Identify the liquid:

(a) density = $\frac{16.08\text{ g} - 12.20\text{ g}}{3.50\text{ mL}}\cdot\frac{1\text{ mL}}{1\text{ cm}^3}$ = 1.11 g/cm^3.

Of the liquids supplied, the liquid is most likely ethylene glycol.

(b) With 2 sf, the calculated density would be 1.1 g/cm^3. While this value still suggests that the liquid is ethylene glycol, it is close to the value for acetic acid. Additional testing would be needed to uniquely identify the liquid.

LR.57. (a) Calculate the density of an irregularly shaped piece of metal:

$$D=\frac{M}{V}=\frac{74.122\text{ g}}{(36.7\text{ cm}^3 - 28.2\text{ cm}^3)} = \frac{74.122\text{ g}}{8.5\text{ cm}^3} = 8.7\text{ g/cm}^3$$

Note that the subtraction of volumes leaves only 2 sf, limiting the density to 2 sf

(b) From the list of metals provided, one would surmise that the metal is **cadmium**. Since the major uncertainty is in the volume, one can substitute 8.4 and 8.6 cm^3 as the volume, and calculate the density (resulting in 8.82 and 8.62 g/cm^3 respectively). The hypothesis that the metal is cadmium is reasonably sound.

LR.58. (a) Density = $\frac{3.2745\text{ g}}{5.0\text{ mL}}$ = 0.65 g/mL

(b) No, all five hydrocarbon density values fall within the range of possible values for the liquid.

(c) No, all five hydrocarbon density values fall within the range of possible values.

(d) Using a volume of (4.93 ± 0.01) mL, calculated maximum and minimum density values are 0.666 g/mL and 0.663 g/mL. The liquid is 2-methylpentane.

LR.59. Mass of Hg in the capillary:

Mass of capillary with Hg	3.416 g
Mass of capillary without Hg	3.263 g
Mass of Hg	0.153 g

To determine the volume of the capillary, calculate the volume of Hg that is filling it.

$$\frac{0.153\text{ g Hg}}{1}\cdot\frac{1\text{ cm}^3}{13.546\text{ g Hg}} = 1.13\times10^{-2}\text{ cm}^3(3\text{ sf})$$

Now that we know the volume of the capillary, and the length of the tubing (given as 16.75 mm—or 1.675 cm), we can calculate the radius of the capillary using the equation: Volume = $\pi r^2 l$.

$1.13 \times 10^{-2}\text{ cm}^3 = (3.1416)r^2(1.675\text{ cm})$, and solving for r^2:

$$\frac{1.13\times10^{-2}\text{ cm}^3}{(3.1416)(1.675\text{ cm})} = 2.15\times10^{-3}\text{ cm}^2 = r^2 \text{ and } r = 4.63\times10^{-2}\text{ cm.}$$

The diameter would be twice this value or 9.27×10^{-2} cm.

LR.60. Volume of this amount of copper: $57\text{ kg}\cdot\frac{10^3\text{ g}}{1\text{ kg}}\cdot\frac{1\text{ cm}^3}{8.96\text{ g}} = 6.4\times10^3\text{ cm}^3$ copper

The length of wire = $\frac{\text{volume}}{(\pi)(\text{radius})^2} = \frac{6.4\times10^3\text{ cm}^3}{(\pi)(0.950/2\text{ cm})^2} = 9.0\times10^3\text{ cm}$

and expressed in meters: $9.0\times10^3\text{ cm}\cdot\frac{1\text{ m}}{100\text{ cm}} = 90.\text{ m}$

LR.61. Regarding a cube of Cu:

(a) The number of Cu atoms in a cube whose mass is 0.1206g.

$$\frac{0.1206\text{ g}}{\text{cube}}\cdot\frac{1\text{ atom Cu}}{1.055\times10^{-22}\text{g}} = 1.143\times10^{21}\text{ atoms Cu}$$

Fraction of the lattice that contains Cu atoms:

Given the radius of a Cu atom as 128 pm, and the number of Cu atoms, the total volume occupied by the Cu atoms is the volume occupied by ONE atom ($4/3\ \Pi r^3$) multiplied by the total number of atoms:

Volume of one atom: $4/3 \cdot 3.1416 \cdot (128\text{pm})^3 = 8.78 \times 10^6 \text{ pm}^3$

Total volume:(8.78×10^6 pm^3/Cu atom)(1.143×10^{21} atoms Cu)
= 1.00×10^{28} pm^3.

The lattice cube has a volume of (0.236 cm)^3 or (2.36×10^9pm)^3 or
1.31×10^{28} pm^3.

The fraction occupied is: total volume of Cu atoms/total volume of lattice cube:

$$\frac{1.00 \times 10^{28} \text{ pm}^3}{1.31 \times 10^{28} \text{ pm}^3} = 0.763 \text{ or } 76\% \text{ occupied (2 sf)}$$

The empty space in a lattice is due to the inability of spherical atoms to totally fill a given volume. A macroscopic example of this phenomenon is visible if you place four marbles in a square arrangement. At the center of the square there are voids. In a cube, there are obviously repeating incidents.

(b) Estimate the number of Cu atoms in the smallest repeating unit:

Since we know the length of the smallest repeating unit (the unit cell), let's calculate the volume (first converting the length to units of centimeters:

L = 361.47 pm so $L = 361.47 \text{ pm} \cdot \dfrac{1 \times 10^2 \text{ cm}}{1 \times 10^{12} \text{ pm}} = 361.47 \times 10^{-10}\text{cm}$

$V = L^3 = (3.6147 \times 10^{-8})^3 = 4.723 \times 10^{-23} \text{ cm}^3$

Since we know the density, we can calculate the mass of one unit cell:

D x V = 8.960 g/ cm^3 × 4.723×10^{-23} cm^3 = 4.23×10^{-22} g

Knowing the mass of one copper atom (1.055×10^{-22} g) we can calculate the number of Cu atoms in that mass: $\dfrac{4.23 \times 10^{-22} \text{ g}}{1.055 \times 10^{-22} \text{ g/Cu atom}} = 4.0$ Cu atoms

As you will learn later, the number of atoms for a face-centered cubic lattice is 4.

LR.62. Determine the density of lead, average density, percent error, and standard deviation using the provided data:

Data	Density (g/cm^3)
1	11.6
2	11.8
3	11.5
4	12.0
Average	11.7
St. Dev.	0.2

$$\text{Percent error} = \frac{\text{error in measurement}}{\text{accepted value}} = \frac{11.7 - 11.3}{11.3} \times 100\% = 3.54\%$$

Standard Deviation is calculated as usual:

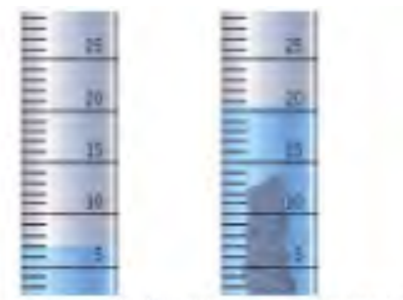
Data	Density (g/cm^3)	Difference (Measurement - Average)	Square of Difference
1	11.6	- 0.1	1×10^{-2}
2	11.8	0.1	1×10^{-2}
3	11.5	- 0.2	4×10^{-2}
4	12.0	0.3	9×10^{-2}

The sum of squares is then 0.15 and square root of 0.15/3 = 0.2 (as noted above)

IN THE LABORATORY

LR.63. The metal will displace a volume of water that is equal to the volume of the metal.

The difference in volumes of water (20.2-6.9) corresponds to the volume of metal. Since 1 mL = 1 cm^3, the density of the metal is then: $\frac{\text{Mass}}{\text{Volume}} = \frac{37.5\text{ g}}{13.3\text{ cm}^3}$ = or $2.82\ \frac{\text{g}}{\text{cm}^3}$



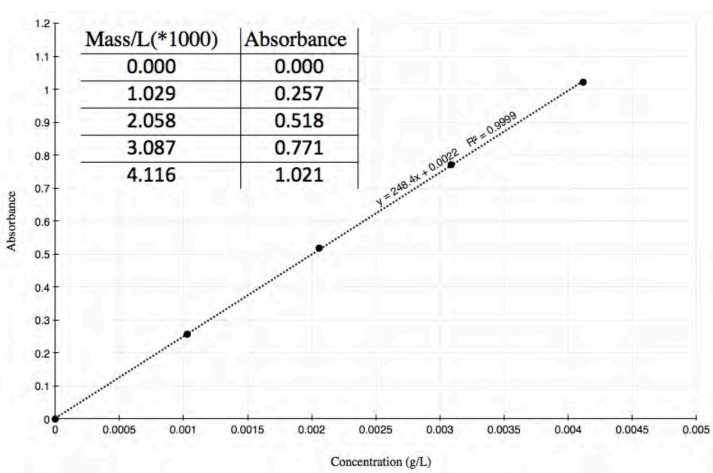
Graduated cylinders with unknown metal (right)

From the list of metals provided, the metal with a density closest to this is **Aluminum**.

LR.64. Calculate the density of the sample: $\frac{23.5\text{ g}}{(52.2 - 47.5)\text{ mL}} \cdot \frac{1\text{ mL}}{1\text{ cm}^3} = 5.0\text{ g/cm}^3$

The sample's density matches that of fool's gold.

LR.65. Plot of Absorbance vs mass of compound (g/L):



The best straight line indicates that the slope is 248.4 and the intercept is 0.0022

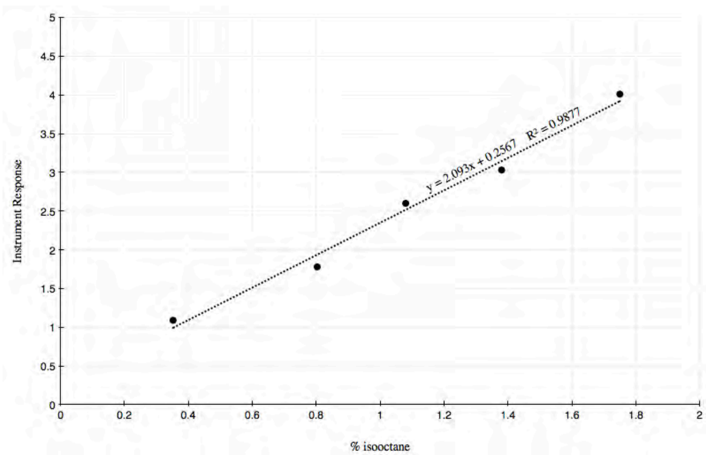
If Absorbance is 0.635, what is the mass of Cu in g/L and mg/mL:

Substituting into the equation for the line:

$$0.635 = (248.4)(\text{concentration}) + 0.0022; \text{ concentration} = 2.55 \times 10^{-3} \text{ g/L}$$

$$\frac{2.55 \times 10^{-3} \text{ g}}{\text{L}} \cdot \frac{1 \text{ L}}{10^3 \text{ mL}} \cdot \frac{10^3 \text{ mg}}{1 \text{ g}} = 2.55 \times 10^{-3} \text{ mg/mL}$$

LR.66. Use data to determine % isooctane:



The best straight line indicates that the slope is 2.093 and the intercept is 0.2567

Substituting into the equation for the line with instrument response = 2.75:

2.75 = 2.0925(% isooctane) + 0.2567 and solving for (% isooctane)

% isooctane = 1.19%

LR.67. Insert the data in a spreadsheet (here, Excel is used), to obtain the results:

Student	% Acetic Acid
1	5.22
2	5.28
3	5.22
4	5.30
5	5.19
6	5.23
7	5.33
8	5.26
9	5.15
10	5.22
Average	5.24
St.Dev	0.05

Only the values 5.30%, 5.33%, and 5.15% fall *outside* the Average ± St.Dev, so seven points fall within the range $5.19 \leq x \leq 5.29$.