Instructor Solutions Manual

Chemistry for Engineering Students

FOURTH EDITION

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Chapter 1

Introduction to Chemistry

INSIGHT Critical Materials

1.1 Are the elements designated as critical materials all rare?
Explain your answer.

They are not all necessarily rare, but many are found in only a few locations around the world and as such are subject to supply disruptions.

1.2 In what country is most of the world's cobalt mined? What events in that country dramatically affected the price of cobalt?

The Democratic Republic of Congo produces most of the world's cobalt. Political unrest in that country once caused a 600% spike in the price of cobalt. Political instability continues as well as issues with forced child labor in the mining of cobalt.

1.3 In what types of technology do the elements designated as critical materials generally play important roles?

They are important in light emission, magnetism, and a variety of applications associated with clean energy and electronics.

1.4 Based on the information in Figure 1.1, which three elements would you argue are the most critical among the "critical materials"? Justify your answer.

Neodymium, dysprosium, and terbium. Neodymium and dysprosium have the highest ranking in importance for clean energy. Dysprosium and terbium are ranked highest in terms of potential supply risk.

1.5 In what region of the periodic table are most of the elements that are listed as critical materials found?

Most of the critical elements are located in the middle of the periodic table, specifically the region known as the lanthanide series and to a lesser extent the transition elements.

1.6 What agency of the U.S. government is responsible for identifying an element as a critical material? What sorts of applications are the primary concern of this agency?

The Department of Energy (DOE) and an organization that it manages called the Critical Materials Institute. Primary concerns are energy-related technologies, especially clean energy applications such as wind and solar energy and electric cars.

The Study of Chemistry

1.7 When making observations in the laboratory, which perspective of chemistry are we normally using?

We make observations in the laboratory using the macroscopic perspective of chemistry, unless very sophisticated instruments are used.

1.8 Which of the following items are matter and which are not? **(a)** a flashlight, **(b)** sunlight, **(c)** an echo, **(d)** air at sea level, **(e)** air at the top of Mount Everest

(a) matter, (b) not matter, (c) not matter, (d) matter, (e) matter

1.9 Which macroscopic characteristics differentiate solids, liquids, and gases? (List as many as possible.)

Solids maintain a definite shape; liquids and gases do not. Gases expand to completely occupy their container; liquids assume the shape of the container but do not fully occupy it. Solids tend to have high densities, liquids usually slightly lower, and gases typically have very low densities, comparatively.

1.10 Do the terms *element* and *atom* mean the same thing? If not how do they differ?

No. An element is a pure substance, but the naturally occurring form of the element may contain more than one atom. An example of this is elemental nitrogen (N_2). In this case the element has two atoms.

1.11 Label each of the following as either a physical process or a chemical process: **(a)** rusting of an iron bridge, **(b)** melting of ice, **(c)** burning of a wooden stick, **(d)** digestion of a baked potato, **(e)** dissolving of sugar in water.

A chemical change involves a change in the *composition* of matter; that is, some new substances are formed. A physical change only involves a change in the *physical state* of matter; no new substances are formed.

(a) rusting of an iron bridge	**Chemical, rust forms when iron and oxygen react chemically.**
(b) melting of ice	**Physical, change from the solid to the liquid state.**
(c) burning of a wooden stick	**Chemical, the molecules in the wood are changed into carbon dioxide and water during combustion.**
(d) digestion of a baked potato	**Chemical, larger food molecules are changed into smaller ones and eventually oxidized ("burned") to produce energy.**
(e) dissolving of sugar in water	**Physical, the sugar molecules are not changed they just become surrounded by water molecules in solution.**

1.12 Why do physical properties play a role in chemistry if they do not involve any chemical changes?

Physical properties can be used to identify substances in qualitative and quantitative analysis and can provide a wide range of useful information.

1.13 Physical properties may change because of a chemical change. For example, the color of an egg "white" changes from clear to white because of a chemical change when it is cooked. What is another common situation in which a chemical change also leads to a physical change?

The "rusting" of iron is a chemical change. A chemical reaction changes the metal to a new compound. The rust formed is a brittle, orange-red compound with very different properties than iron.

1.14 Which part of the description of a compound or element refers to its physical properties and which to its chemical properties?

(a) Calcium carbonate is a white solid with a density of 2.71 g/cm^3. It reacts readily with an acid to produce gaseous carbon dioxide.
(b) Gray powdered zinc metal reacts with purple iodine to give a white compound.

(a) The first sentence describes physical properties; the second sentence describes a chemical property.
(b) The sentence generally describes a chemical property, however the stated colors are physical properties.

Observations and Models

1.15 We used the example of a football game to emphasize the nature of observations. Describe another example where deciding how to "count" subjects of interest could affect the observation.

The number of cities located in a state depends on how a city is defined. We would need to specify what population size is makes a city. Our results would vary depending on that size.

1.16 Complete the following statement: Data that have a small random error but otherwise fall in a narrow range are **(a)** accurate, **(b)** precise, or **(c)** neither.

These data could be precise but not necessarily accurate.

1.17 Complete the following statement: Data that have a large systematic error are (a) accurate, (b) precise, (c) neither.

(**b) Precise. Data that have large systematic error may still be precise. Accuracy is how close our data is to the actual value. Large systematic error means the data will not be**

close to the actual value but they will be off by about the <u>same</u> amount. Precision is the repeatability of your data. Precise data will agree closely but may not be close to the true value.

1.18 Two golfers are practicing shots around a putting green. Each golfer takes 20 shots. Golfer 1 has 7 shots within 1 meter of the hole, and the other 13 shots are scattered around the green. Golfer 2 has 17 shots go into a small sand trap near the green and three just on the green near the trap. Which golfer is more precise? Which is more accurate?

Golfer 2 is more precise because his efforts are grouped more tightly about a central point (mean) even if it's not the intended spot. Golfer 1 is more accurate as there are more shots very close to the accepted "value" (the hole).

1.19 Use your own words to explain the difference between deductive and inductive reasoning.

In deductive reasoning, facts are considered and conclusions are drawn from this information. In inductive reasoning, you first infer what seems to be accurate or true, and then find ways to determine if later observations fit the inferred conclusion.

1.20 Suppose you are waiting at a corner for a bus. Three different routes pass this particular corner. You see busses pass by from the two routes you are not interested in taking. When you say to yourself, "My bus must be next," what type of reasoning (deductive or inductive) are you using? Explain your answer.

Deductive reasoning is being applied in this case. The first two buses represent pieces of information that are processed and lead to the conclusion that the "desired" bus must be next.

1.21 When a scientist looks at an experiment and then predicts the results of other related experiments, which type of reasoning is she using? Explain your answer.

This is inductive reasoning. Inductive reasoning is the reverse of deductive. A scientist makes predictions and then tries to prove the prediction by later observations. Deductive reasoning involves starting with facts and then drawing conclusions from those.

1.22 What is the difference between a hypothesis and a question?

A hypothesis is a statement related to observation(s). The hypothesis is either accepted or rejected based upon experimentation. A question is simply posed.

1.23 Should the words *theory* and *model* be used interchangeably in the context of science? Defend your answer using web information.

The word "theory" implies something more advanced and supported than a model. When a model makes predictions and all observations are consistent with these observations, then the model may be described as a theory.

1.24 What is a law of nature? Are all scientific laws examples of laws of nature?

A law of nature is an irrefutable, self-evident fact. Not all scientific laws are examples of laws of nature.

Numbers and Measurements

1.25 Describe a miscommunication that can arise because units are not included as part of the information.

Discussing the time of day and omitting PM or AM. If you are supposed to meet someone at 9:00 but they didn't say in the evening or in the morning, the meeting might not occur. Another example might be negotiating a price while trying to buy something.

1.26 What is the difference between a qualitative and a quantitative measurement?

A quantitative measurement provides information as to *how much* analyte is present. A qualitative measurement answers the question, 'is the analyte present?'

1.27 Identify which of the following units are base units in the SI system: grams, meters, joules, liters, and amperes.

Meters and amperes are base units. The other base units are: kilograms, seconds, kelvins, moles, and candelas. Therefore grams are not a base unit. Joules and liters are both derived units.

1.28 What is a "derived" unit?

A derived unit is a unit that is made up of two or more base units.

1.29 Rank the following prefixes in order of increasing size of the number they represent: centi−, giga−, nano−, and kilo−.

In order of smallest to largest: nano− (10^{-9}), centi− (10^{-2}), kilo− (10^{3}), giga− (10^{9}).

1.30 The largest computers now include disk storage space measured in petabytes. How many bytes are in a petabyte? (Recall that in computer terminology, the prefix is only "close" to the value it designates in the metric system.)

1 petabyte = 1,000,000,000,000,000 bytes

1.31 Historically, some unit differences reflected the belief that the quantity measured was different when it was later revealed to be a single entity. Use the web to look up the origins of the energy units *erg* and *calorie*, and describe how they represent an example of this type of historical development.

The erg was an energy unit associated with work done, while the calorie was an energy unit associated with heat. At the time scientists thought heat and work were different things – instead of forms of energy used in different ways.

1.32 Use the web to determine how the Btu was initially established. For the engineering applications where this unit is still used today, why is it a sensible unit?

The amount of energy required to raise one pound of liquid water 1 degree Fahrenheit at its maximum density (occurs at 39.1 °F). It is sensible because of the associated temperature change that can be sensed or measured.

1.33 How many micrograms are equal to one gram?

The prefix micro− represents the power 10^{-6}. One microgram (μg) is therefore equal to $\frac{1}{1{,}000{,}000}$ gram. There are one million micrograms in one gram.

1.34 Convert the value 0.120 ppb into ppm.

1.20×10^{-4} ppm

1.35 How was the Fahrenheit temperature scale calibrated? Describe how this calibration process reflects measurement errors that were evident when the temperature scale was devised.

The upper temperature, 100 degrees, was set by body temperature. The lower temperature was determined by the coldest temperature that could be achieved by adding salt to water and set at 0 degrees. This shows limitations of the measurement in that the accepted temperature of a human body is 98.6 °F (although this can vary from individual).

1.36 Superconductors are materials that have no resistance to the flow of electricity, and they hold great promise in many engineering applications. But to date, superconductivity has only been observed under cryogenic conditions. As of 2016, the highest temperature at which superconductivity has been observed is 203 K. Convert this temperature to both °C and °F.

°C = 203 K – 273.15 = –70°C; $°F = \frac{9}{5}(-70.15°C) + 32 = -94°F$

1.37 Express each of the following temperatures in kelvins:

(a) −10. °C **kelvins = −10. °C + 273 = 263 K**
(b) 0.00 °C **kelvins = 0.00 °C + 273.15 = 273.15 K**

(c) 280. °C **kelvins = 280 °C + 273 = 553 K**
(d) 1.4×10^3 °C **kelvins = 1400 °C + 273 = 1700 K**

To convert from the Celsius scale to kelvins, we add 273. The unit size is the same, making this conversion easier. Note: we do not write the degree symbol with kelvins.

1.38 Express **(a)** 275°C in K, **(b)** 25.55 K in °C, **(c)** –47.0°C in °F, and **(d)** 100.0°F in K

(a) 548 K, (b) –247.60°C, (c) –52.6°F, (d) 310.9 K

1.39 Express each of the following numbers in scientific notation:

(a) 62.13 **6.213×10^1**
(b) 0.000414 **4.14×10^{-4}**
(c) 0.0000051 **5.1×10^{-6}**
(d) 871,000,000 **8.71×10^8**
(e) 9100 **9.1×10^3**

Scientific notation expresses a number factoring out all powers of ten and writing a number between 1 and 10 multiplied by some power of 10. It makes writing very small or very large numbers much easier.

1.40 How many significant figures are there in each of the following? **(a)** 0.136 m, **(b)** 0.0001050 g, **(c)** 2.700×10^{-3} nm, **(d)** 6×10^{-4} L, **(e)** 56003 cm^3

(a) three, (b) four (c) four, (d) one, (e) five

1.41 How many significant figures are present in these measured quantities?

(a) 1374 kg **4 significant figures**
(b) 0.00348 s **3 significant figures (leading zeros only locate decimal point)**
(c) 5.619 mm **4 significant figures**
(d) 2.475×10^{-3} cm **4 significant figures**
(e) 33.1 mL **3 significant figures**

1.42 Perform these calculations and express the result with the proper number of significant figures.

(a) (4.850 g – 2.34 g)/1.3 mL
(b) $V = \pi r^3$, where $r = 4.112$ cm
(c) $(4.66 \times 10^{-3}) \times 4.666$
(d) 0.003400/65.2

(a) 1.9 g/mL, (b) 218.4 cm^3, (c) 2.17×10^{-2}, (d) 5.21×10^{-5}

1.43 Calculate the following to the correct number of significant figures. Assume that all these numbers are measurements.

(a) $x = 17.2 + 65.18 - 2.4$ **= 80.0 (round to tenths place)**
(b) $x = 13.0217/17.10$ **= 0.7615 (round to four significant digits)**
(c) $x = (0.0061020)(2.0092)(1200.0)$ **= 14.712 (round to five significant digits)**
(d) $x = 0.0034 + \dfrac{\sqrt{(0.0034)^2 + 4(1.000)(6.3\times10^{-4})}}{(2)(1.000)}$ **= 0.029 (The 2 and the 4 in the quadratic formula are exact numbers, so they do not limit the significant figures in the result.)**

In addition and subtraction, the number that has a doubtful digit in the largest decimal place determines the number of significant digits retained.
When multiplying and dividing, the number of significant digits retained is determined by whichever factor has the fewest significant digits.

1.44 In an attempt to determine the velocity of a person on a bicycle, an observer uses a stopwatch and times the length of time it takes to cover 25 "squares" on a sidewalk. The bicycle takes 4.82 seconds to travel this far. A measurement of one of the squares shows that it is 1.13 m long. What velocity, in m/s, should the observer report?

5.86 m/s

1.45 A student finds that the mass of an object is 4.131 g and its volume is 7.1 mL. What density should be reported in g/mL?

Density is the ratio of mass per unit volume.
$$\textbf{density} = \frac{\textbf{mass}}{\textbf{volume}} = \frac{\textbf{4.131 g}}{\textbf{7.1 mL}} = \textbf{0.58 g/mL} \quad \textbf{(rounded to two significant digits)}$$

1.46 Measurements indicate that 23.6% of the residents of a city with a population of 531,314 are college graduates. Considering significant figures, how many college graduates are estimated to reside in this city?

1.25×10^5

1.47 A student weighs 10 quarters and finds their total mass is 56.63 grams. What should she report as the average mass of a quarter based on her data?

The average mass of a quarter would be found by dividing the total mass by ten quarters.

$$\textbf{Average mass of a quarter} = \frac{\textbf{56.63 g}}{\textbf{10 quarters}} = \textbf{5.663 g}$$

The answer should retain all four significant digits because the ten quarters is an *exact* number.

1.48 A rock is placed on a balance and its mass is determined to be 12.1 g. When the rock is then placed in a graduated cylinder that originally contains 11.3 mL of water, the new volume is roughly 17 mL. How should the density of the rock be reported?

2 g/mL

Problem Solving in Chemistry and Engineering

1.49 A package of eight apples has a mass of 1.00 kg. What is the average mass of one apple in grams?

1.00 kg = 1.00 × 10^3 g

The average mass of an apple would be found by dividing the total mass by eight apples.

Average mass of an apple = $\frac{1.00 \times 10^3 \text{ g}}{8 \text{ apples}}$ **= 1.25 × 10^2 g per apple**

The answer should retain three significant digits because the eight apples is an *exact* number.

1.50 If a 1.00-kg bag containing eight apples costs $1.48, how much does one apple cost? What mass of apples costs $1.00?

(a) $0.185 per apple
(b) 0.676 kg

1.51 A person measures 173 cm in height. What is this height in meters? feet and inches?

173 cm × $\frac{1 \text{ m}}{100 \text{ cm}}$ **= 1.73 m**

173 cm × $\frac{1 \text{ in}}{2.54 \text{ cm}}$ **= 68.1 inches**

68.1 inches - 5 feet (60 inches) = 8.1 inches

The height is 1.73 m or 5 feet 8.1 inches

1.52 The distance between two atoms in a molecule is 148 pm. What is this distance in meters?

1.48 × 10^{-10} m

1.53 Carry out the following unit conversions:

(a) 3.47×10^{-6} g to μg $\quad$ $\mathbf{3.47 \times 10^{-6}\ g \times \frac{1\times10^{6}\ \mu g}{1\ g} = 3.47\ \mu g}$

(b) 2.73×10^{-4} L to mL $\quad$ $\mathbf{2.73 \times 10^{-4}\ L \times \frac{1000\ mL}{1\ L} = 2.73 \times 10^{-1}\ mL}$

(c) 725 ns to s $\quad$ $\mathbf{725\ ns \times \frac{10^{-9}\ s}{1\ ns} = 7.25 \times 10^{-7}\ s}$

(d) 1.3 m to km $\quad$ $\mathbf{1.3\ m \times \frac{1\ km}{1000\ m} = 1.3 \times 10^{-3}\ km}$

1.54 Carry out each of the following conversions: **(a)** 25.5 m to km, **(b)** 36.3 km to m, **(c)** 487 kg to g, **(d)** 1.32 L to mL, **(e)** 55.9 dL to L, **(f)** 6251 L to cm^3

(a) 2.55×10^{-2} km
(b) 3.63×10^{4} m
(c) 4.87×10^{5} g
(d) 1.32×10^{3} mL
(e) 5.59 L
(f) 6.251×10^{6} cm^3

1.55 Convert 22.3 mL to

(a) liters $\quad$ $\mathbf{22.3\ mL \times \frac{1\ L}{1000\ mL} = 0.0223\ L}$

(b) in^3 $\quad$ $\mathbf{22.3\ mL \times \frac{1\ cm^3}{1\ mL} \times \frac{(1\ in)^3}{(2.54\ cm)^3} = 13.524\ g/L6\ in^3}$

(c) quarts $\quad$ $\mathbf{22.3\ mL \times \frac{1\ L}{1000\ mL} \times \frac{1.057\ qt}{1\ L} = 0.0236\ qt}$

1.56 If a vehicle is traveling 92 m/s what is its velocity in miles per hour? (0.62 miles = 1.00 km)

$$\mathbf{\frac{92\ m}{s} = \frac{60\ s}{1\ min} = \frac{60\ min}{1\ h} = \frac{1\ km}{10^3\ m} = \frac{0.62\ mi}{1\ km} \cong 210}$$

1.57 A load of asphalt weighs 254 lbs and occupies a volume of 220.0 L. What is the density of this asphalt in g/L?

Density is the ratio of mass per unit volume. The mass = 254 lbs × $\frac{454\ g}{1\ lb}$ = 1.15 × 10^5 g

density = $\frac{mass}{volume} = \frac{1.15 \times 10^5\ g}{220.0\ L}$ **= 524 g/L**

(The answer is rounded to 3 significant figures)

1.58 One square mile contains exactly 640 acres. How many square meters are in one acre?

4 × 10^3 m

1.59 A sample of crude oil has a density of 0.87 g/mL. What volume in liters does a 3.6-kg sample of this oil occupy?

Mass = 3.6 kg = 3600 g

Density is the ratio of mass per unit volume, density = $\frac{mass}{volume}$.

Rearranging, **volume =** $\frac{mass}{density} = \frac{3600\ g}{\frac{0.87\ g}{mL}}$ **= 4100 mL or 4.1 L**

1.60 Mercury has a density of 13.6 g/mL. What is the mass of 4.72 L of mercury?

6.42 × 10^4 g

1.61 The area of the 48 contiguous states is 3.02 × 10^6 mi^2. Assume that these states are completely flat (no mountains and no valleys). What volume of water, in liters, would cover these states with a rainfall of two inches?

The volume of water would be the area of the contiguous states multiplied by the depth of water.

Area:

$$3.02 \times 10^6\ mi^2 \times \frac{(1.609\ km)^2}{(1\ mi)^2} \times \frac{(1000\ m)^2}{(1\ km)^2} \times \frac{(100\ cm)^2}{(1\ m)^2} = 7.82 \times 10^{16}\ cm^2$$

Depth:

$$2\ in \times \frac{2.54\ cm}{1\ in} = 5.08\ cm$$

Volume:

$$7.82 \times 10^{16}\ cm^2 \times 5.08\ cm = 3.97 \times 10^{17}\ cm^3 \times \frac{1\ L}{1000\ cm^3} = 3.97 \times 10^{14}\ L$$

1.62 The dimensions of aluminum foil in a box for sale in supermarkets are yards by 12 inches. The mass of the foil is 0.83 kg. If its density is 2.70 g/cm^3, then what is the thickness of the foil in inches?

Area: 66.66667 yards $\times \dfrac{\textbf{3 feet}}{\textbf{1 yard}} \times \dfrac{\textbf{12 inches}}{\textbf{1 foot}}$ **× 12 inches wide = 28,800 inches**

Volume: 830 g $\times \dfrac{\textbf{1 cm}^3}{\textbf{2.7 g}} \times \dfrac{(\textbf{1 in})^3}{(\textbf{2.54 cm})^3}$ **= 18.76 in^3**

Thickness: $\dfrac{\textbf{Volume}}{\textbf{Area}}$ **= 6.5 × 10^{-4} inches**

1.63 Titanium is used in airplane bodies because it is strong and light. It has a density of 4.55 g/cm^3. If a cylinder of titanium is 7.75 cm long and has a mass of 153.2 g, calculate the diameter of the cylinder. ($V = \pi r^2 h$, where V is the volume of the cylinder, r is its radius, and h is the height.)

Using the density, the volume can be calculated: volume = $\dfrac{\text{mass}}{\text{density}} = \dfrac{153.2\text{ g}}{\frac{4.55\text{ g}}{\text{cm}^3}}$ **= 33.7 cm^3**

The radius may now be calculated by using the height of the cylinder and the formula for its volume: $r = \sqrt{V/\pi h} = \sqrt{(33.7\text{ cm}^3)/(3.1416)(7.75\text{ cm})}$ **= 1.176 cm**

Finally, the diameter is two × *r* = 2 × 1.176 cm = 2.35 cm

1.64 Wire is often sold in pound spools according to the wire gauge number. That number refers to the diameter of the wire. How many meters are in a 10-lb. spool of 12-gauge aluminum wire? A 12-gauge wire has a diameter of 0.0808 in. and aluminum has a density of 2.70 g/cm^3. ($V = \pi r^2 \ell$)

510 m

1.65 An industrial engineer is designing a process to manufacture bullets. The mass of each bullet must be within 0.25 % of 150 grains. What range of bullet masses, in mg, will meet this tolerance? 1 gr = 64.79891 mg

First, calculate 0.25% of 150 grains. (Recall percentage is parts per 100 parts.)

$$\frac{0.25}{100} \times 150\text{ gr} = 0.375\text{ gr}$$

Next, calculate this mass in milligrams:

$$0.375\text{ gr} \times \frac{64.79891\text{ mg}}{1\text{ gr}} = 24.3\text{ mg}$$

The bullets must be manufactured with a tolerance of ± 24.3 mg

Next, convert bullet mass to mg:

$$\mathbf{150\ gr \times \frac{64.79891\ mg}{1\ gr} = 9720\ mg \simeq 9700\ mg\ (two\ significant\ figures)}$$

Each bullet should have a mass of 9700 mg. (Calculation gives a range of 9696–9744 mg, but the data given have just two significant figures, and therefore both ends of the range round to 9700 mg.

Note: It is extremely important that bullets be manufactured with tight tolerances in mass and shape to produce precise shooting results.

1.66 An engineer is working with archeologists to create a realistic Roman village in a museum. The plan for a balance in a marketplace calls for 100 granite stones, each weighing 10 denarium. (The denarium was a Roman unit of mass: 1 denarium = 3.396 g). The manufacturing process for making the stones will remove 20% of the material. If the granite to be used has a density of 2.75 g/cm^3, what is the minimum volume of granite that the engineer should order?

1.5×10^3 cm^3 (Recall the question is asking for a minimum volume to order, not just the mathematical answer to the calculation.)

1.67 On average, Earth's crust contains about 8.1% aluminum by mass. If a standard 12-ounce soft drink can contains approximately 15.0 g of aluminum, how many cans could be made from one ton of the Earth's crust?

There are 2000 pounds in one ton.
First, calculate the mass of aluminum in one ton of the Earth's crust. (Recall percentage is parts per 100 parts.)

2000 lbs Earth × $\frac{8.1\ \text{lbs Al}}{100\ \text{lbs Earth}} \times \frac{454\ \text{g}}{1\ \text{lb}}$ = 73548 g of aluminum. Next, divide by the mass of one can to find the number of cans that could be made.

73548 g Al ÷ 15.0 g Al per can = 4.9×10^3 cans (rounded to two significant figures)

1.68 As computer processor speeds increase, it is necessary for engineers to increase the number of circuit elements packed into a given area. Individual circuit elements are often connected using very small copper "wires" deposited directly onto the surface of the chip. In some current generation processors, these copper interconnects are about 32 nm wide. What mass of copper would be in a 1-mm length of such an interconnect, assuming a square cross section. The density of copper is 8.96 g/cm^3.

9.2 pg

1.69 The "Western Stone" in Jerusalem is one of the largest stone building blocks ever to have been used. It has a mass of 517 metric tons, and measures 13.6 m long, 3.00 m high and 3.30 m wide. What is the density of this rock in g/cm^3? (1 metric ton = 1000 kg)

Assuming the "Western Stone" is rectangular, the volume is calculated by multiplying length × height × width: 13.6 m × 3.00 m × 3.30 m = 134.64 m^3.

Converting to centimeters: $134.64\ \mathrm{m}^3 \times \dfrac{(100\ \mathrm{cm})^3}{1\ \mathrm{m}^3} = 1.3464 \times 10^8\ \mathrm{cm}^3$

The mass is $517\ \text{metric tons} \times \dfrac{1000\ \mathrm{kg}}{1\ \text{metric ton}} \times \dfrac{1000\ \mathrm{g}}{1\ \mathrm{kg}} = 5.17 \times 10^8\ \mathrm{g}$

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{5.17 \times 10^8\ \mathrm{g}}{1.3464 \times 10^8\ \mathrm{cm}^3} = 3.84\ \mathrm{g/cm}^3$$

1.70 A load of bauxite has a density of 3.15 g/cm^3. If the mass of the load is 115 metric tons, how many dump trucks, each with a capacity of 12 cubic yards, will be needed to haul the whole load?

Four trucks are required to haul the load.

INSIGHT Touchscreen Technology

1.71 Is touchscreen technology better described as a simple design or as a more complex system? Explain your answer.

The technology would be better described as a complex system. There are multiple components involving a variety of materials and several different chemical and physical principles involved to make the technology work.

1.72 What does ITO stand for in the ITO films in touchscreens?

ITO stands for indium tin oxide, a transparent thin film conductor.

1.73 Why are two separate ITO layers required in a touchscreen display?

The two layers allow an *x*-direction and *y*-direction to be separately located. This creates a two dimensional map on the screen which can respond to touch in any direction.

1.74 What are the two properties of ITO that make it serve its function in touchscreen applications?

First, ITO is a doped semi-conductor material which means it has a specific conductivity, needed for the current to be detectable. Second, they are optically transparent, critical for the display screen beneath it to be seen.

1.75 What does it mean that ITO films are made by deposition? In what phase do materials begin, and in what phase do they end up?

ITO thin layers are created by condensing indium oxide and tin oxide layers on a surface. The deposition is carefully controlled to create a checkerboard design necessary for position to be detectable. So, the materials begin as a vapor and end up as a solid.

1.76 How does Gorilla Glass differ from more commonly found alumina silicate glass?

Gorilla glass is harder, thinner, and very scratch resistant. It is also less likely to break on impact. The primary reason for this enhanced toughness is the replacement of some sodium ions in the silicate with potassium ions. This ion exchange increases the residual compressive stress of the glass, which leads to the superior properties of Gorilla Glass.

Conceptual Problems

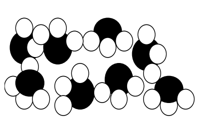
1.77 How can a liquid be distinguished from a fine powder? What type of experiment or observation might be undertaken?

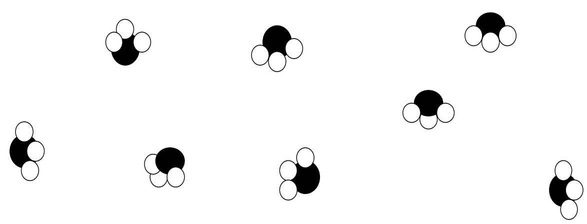
A fine powder and a liquid have some similarities, such as the fact that both take on the shape of a container. One difference is that a powder is likely to be compressible because there is space between the grains. So pressing or tamping down on the powder will reduce its volume. Another test could be to pour some of each substance onto a flat surface. A powder will be able to form a pile, with angled sides, whereas a liquid will not.

1.78 Some farmers use ammonia, NH_3, as a fertilizer. This ammonia is stored in liquid form. Use the particulate perspective to show the transition from liquid ammonia to gaseous ammonia.

Ammonia, NH_3, in the liquid form will have the molecules very close together, in random orientation. As a gas, the molecules will be far apart.

Liquid: **Gas:**





1.79 Use a molecular level description to explain why gases are less dense than liquids or solids.

See Problem 1.78. There is a large amount of empty space between the molecules when a substance is in the gaseous state. Fewer molecules in a given volume means less mass per volume, meaning the density decreases. Solids and liquids have little space between the molecules, giving a relatively high mass per volume and much larger density.

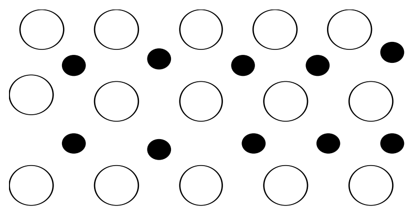
1.80 All molecules attract each other to some extent, and the attraction decreases as the distance between particles increases. Based on this idea, which state of matter would you expect has the strongest interactions between particles, solids, liquids or gases?

Intermolecular forces of attraction are greatest in solids, as we will learn in further detail in Chapter 8.

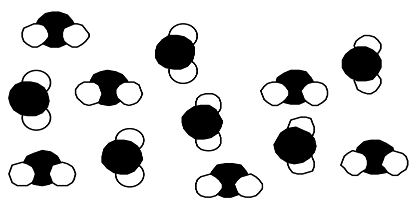
1.81 Draw a molecular-scale picture to show how a crystal differs from a liquid.

A crystalline solid has a regular repeating arrangement of the particles that make up the solid. A liquid has particles randomly arranged.

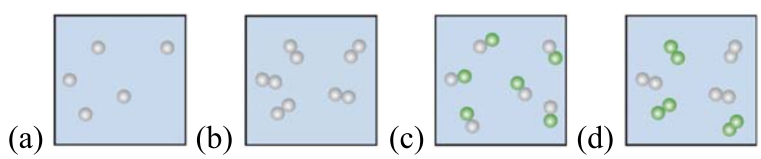
Alumina (Al_2O_3, crystal)



Water (H_2O, liquid)

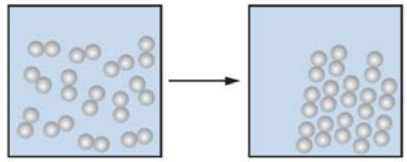


1.82 Which of the following molecular-scale diagrams best represents a pure compound? Explain your answer.



A compound is composed of two or more different types of atoms. Images (a) and (b) contain only one type. Image (d) involves two types of atom but they are not together in the form of a compound; they are in separate molecules. Therefore (d) is a mixture. Image (c) shows two types of atoms bonded together in a compound.

1.83 What type of transition is represented in the following molecular-scale illustration?



The images most likely show a liquid transitioning to a solid. In the liquid state, molecules are moving randomly but relatively close together. Molecules are moving little, very close, and usually organized in a repeating pattern in the solid state.

FOCUS ON PROBLEM SOLVING EXERCISES

1.84 A student was given two metal cubes that looked similar. One was 1.05 cm on an edge and had a mass of 14.32 grams; the other was 2.66 cm on a side and had a mass of 215.3 grams. How can the student determine if these two cubes of metal are the same material using only the data given?

Determine the density of each cube. If the densities vary significantly, the cubes are not the same material. If the densities are similar, the student can suggest that the materials "appear" to be similar but can not say that they are the same without doubt. In this particular case, the first cube has a density of 12.4 g/cm^3 and the second has a density of 11.4 g/cm^3. This difference suggests that the two materials are not the same.

1.85 Battery acid has a density of 1.285 g/mL and contains 38.0% sulfuric acid by mass. Describe how you would determine the mass of pure sulfuric acid in a car battery, noting which items(s) you would have to measure or look up.

First you would measure the volume of battery acid and then using the density provided, calculate the mass of the acid solution: $\mathbf{V\ (mL) \times \dfrac{1.285\ g}{mL} = mass\ (g)}$

Next, using the percent sulfuric acid would allow the mass of pure sulfuric acid to be determined: $\mathbf{mass\ battery\ acid\ (g) \times \dfrac{38.0\ g\ sulfuric\ acid}{100\ g\ battery\ acid} = mass\ pure\ sulfuric\ acid\ (g)}$

1.86 Unfermented grape juice used to make wine is sometimes called a "must." The sugar content of the must determines whether the wine will be dry or sweet. The sugar content is found by measuring the density of the must. If the density is lower than 1.070 g/mL, then sugar syrup is added until the density reaches 1.075 g/mL. Suppose that you have a sample taken from a must whose mass is 47.28 g and whose volume is 44.60 mL. Describe how you would determine whether or not sugar syrup needs to be added and if so, how would you estimate how much sugar syrup to add?

$$\textbf{density} = \frac{\text{grams}}{\text{volume}} = \frac{47.28\ \text{g}}{44.60\ \text{mL}} = \mathbf{1.06\ g/mL}$$

This result is less than the target of 1.07 g/mL, suggesting that sugar syrup must be added. We would need to look up the density of the sugar syrup so we could calculate how much mass is added per volume of syrup added, so a new density could be calculated.

1.87 A solution of ethanol in water has a volume of 54.2 mL and a mass of 49.6 g What information would you need to look up and how would you determine the percentage of ethanol?

We could estimate the percentage of ethanol if we knew the densities of both water and ethanol. The information given allows us to find the density of the solution, and then we can set that equal to a weighted average of the densities of the two components. If we let x equal the fraction of ethanol, then we would have:

$$\rho_{\text{solution}} = x(\rho_{\text{ethanol}}) + (1 - x)(\rho_{\text{water}})$$

Note that such a calculation assumes that the volume of the solution is the sum of the volumes of the individual liquids, but this is not necessarily true.

1.88 Legend has it that Archimedes, a famous scientist of Ancient Greece, was once commanded by the king to determine if a crown he received was pure gold or a gold-silver alloy. He was not allowed, however, to damage the crown (by slicing off a piece, for example). If you were assigned this same task, what would you need to know about both gold and silver, and how would you make a measurement that would tell you if the crown was pure gold?

Whatever tests we perform would have to be nondestructive, so as to not damage the valuable crown. Mass and volume are two nondestructive measurements that could tell us something about the composition of the crown. The density of silver and gold are different. By measuring the mass and volume of the crown, we could calculate the density. We would need to look up the density of both gold and silver; then if the measured density of the crown lies between those densities, it is an alloy.

1.89 Imagine you place a cork measuring 1.30 cm × 4.50 cm × 3.00 cm in a pan of water. On top of this cork you place a small cube of lead measuring 1.15 cm on a side. Describe how you would determine if the combination of the cork and the lead cube would still float in the water. Note any information you would need to look up to answer the question.

An object will float in water if its mass is less than the mass of water that would be displaced if the entire object were submerged. We are given dimensions for the cork and the lead cube but not masses. So we might start by looking up densities for cork and for lead. (Because the lead will be much heavier, we might neglect the mass of the cork.) If the combined mass of the cork and the lead is less than the mass of water that would occupy the combined volume of the cork and the lead, then they should float.

1.90 A calibrated flask was filled to the 25.00-mL mark with ethyl alcohol and was found to have a mass of 19.7325 g. In a second experiment, 25.0920 g of metal beads were put into the container and the flask was again filled to the 25.00-mL mark. The total mass of the metal plus the alcohol was 43.0725 g. Describe how to determine the density of the metal sample.

The first step, with only the alcohol, allows us to determine the alcohol density. In the next step of the experiment, we can find the mass of alcohol added by subtracting the mass of the beads from the combined mass: 43.0725 g – 25.0920 g. With this difference, we can calculate the volume of alcohol added using the density calculated in step one. Now we can find the volume of the metal beads by subtracting the volume of alcohol added from the total volume, 25.00 mL. Finally, using the mass of the metal beads and the volume, we can calculate the density of the metal.