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 $\mathbf{\frac{1}{1,000,000}}$ 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; $°F = \frac{9}{5}\left(-70.15°C\right) + 32 = -94°F$

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. ºC **kelvins = 280 ºC + 273 = 553 K**
(d) 1.4×10^3 ºC **kelvins = 1400 ºC + 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 × $\dfrac{454\text{ g}}{1\text{ lb}}$ = 1.15 × 10^5 g

density = $\dfrac{\text{mass}}{\text{volume}} = \dfrac{1.15\times10^5\text{ g}}{220.0\text{ L}}$ **= 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 = $\dfrac{\text{mass}}{\text{volume}}$.

Rearranging, **volume =** $\dfrac{\text{mass}}{\text{density}} = \dfrac{3600\text{ g}}{\dfrac{0.87\text{ g}}{\text{mL}}}$ **= 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:

$$3.02\times10^6\text{ mi}^2\times\frac{(1.609\text{ km})^2}{(1\text{ mi})^2}\times\frac{(1000\text{ m})^2}{(1\text{ km})^2}\times\frac{(100\text{ cm})^2}{(1\text{ m})^2}=7.82\times10^{16}\text{ cm}^2$$

Depth:

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

Volume:

$$7.82\times10^{16}\text{ cm}^2\times5.08\text{ cm}=3.97\times10^{17}\text{ cm}^3\times\frac{1\text{ L}}{1000\text{ cm}^3}=3.97\times10^{14}\text{ L}$$

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 = $\dfrac{\textbf{mass}}{\textbf{density}} = \dfrac{\textbf{153.2 g}}{\dfrac{\textbf{4.55 g}}{\textbf{cm}^3}}$ **= 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.)

$2000\ \text{lbs Earth} \times \frac{8.1\ \text{lbs Al}}{100\ \text{lbs Earth}} \times \frac{454\ \text{g}}{1\ \text{lb}} = 73548$ 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)