Sample Exercise 1.1 Distinguishing Among Elements, Compounds, and Mixtures

“White gold,” used in jewelry, contains gold and another “white” metal such as palladium. Two different samples of white gold differ in the relative amounts of gold and palladium that they contain. Both samples are uniform in composition throughout. Without knowing any more about the materials, use Figure 1.9 to classify white gold.

Solution

Because the material is uniform throughout, it is homogeneous. Because its composition differs for the two samples, it cannot be a compound. Instead, it must be a homogeneous mixture.

Practice Exercise

Aspirin is composed of 60.0% carbon, 4.5% hydrogen, and 35.5% oxygen by mass, regardless of its source. Use Figure 1.9 to characterize and classify aspirin.

**Answer:** It is a compound because it has constant composition and can be separated into several elements.
Sample Exercise 1.2 Using Metric Prefixes

What is the name given to the unit that equals (a) $10^{-9}$ gram, (b) $10^{-6}$ second, (c) $10^{-3}$ meter?

Solution

In each case we can refer to Table 1.5, finding the prefix related to each of the decimal fractions: (a) nanogram, ng, (b) microsecond, $\mu$s, (c) millimeter, mm.

Practice Exercise

(a) What decimal fraction of a second is a picosecond, ps? (b) Express the measurement $6.0 \times 10^3$ m using a prefix to replace the power of ten. (c) Use exponential notation to express 3.76 mg in grams.

*Answer:* (a) $10^{-12}$ second, (b) 6.0 km, (c) $3.76 \times 10^{-3}$ g
Sample Exercise 1.3 Converting Units of Temperature

If a weather forecaster predicts that the temperature for the day will reach 31 °C, what is the predicted temperature (a) in K, (b) in °F?

Solution

(a) Using Equation 1.1, we have K = 31 + 273 = 304 K

(b) Using Equation 1.2, we have °F = \( \frac{9}{5} \times 31 + 32 = 56 + 32 = 88 \) °F

Practice Exercise

Ethylene glycol, the major ingredient in antifreeze, freezes at –11.5°F. What is the freezing point in (a) K, (b) °F?

Answer: (a) 261.7 K, (b) 11.3 °F
Sample Exercise 1.4 Determining Density and Using Density to Determine Volume or Mass

(a) Calculate the density of mercury if 1.00 × 10² g occupies a volume of 7.36 cm³. (b) Calculate the volume of 65.0 g of the liquid methanol (wood alcohol) if its density is 0.791 g/mL. (c) What is the mass in grams of a cube of gold (density = 19.32 g/cm³) if the length of the cube is 2.00 cm?

Solution

(a) We are given mass and volume, so Equation 1.3 yields

\[ \text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{1.00 \times 10^2 \text{ g}}{7.36 \text{ cm}^3} = 13.6 \text{ g/cm}^3 \]

(b) Solving Equation 1.3 for volume and then using the given mass and density gives

\[ \text{Volume} = \frac{\text{mass}}{\text{density}} = \frac{65.0 \text{ g}}{0.791 \text{ g/mL}} = 82.2 \text{ mL} \]

(c) We can calculate the mass from the volume of the cube and its density. The volume of a cube is given by its length cubed:

\[ \text{Volume} = (2.00 \text{ cm})^3 = (2.00)^3 \text{ cm}^3 = 8.00 \text{ cm}^3 \]

\[ \text{Mass} = \text{volume} \times \text{density} = (8.00 \text{ cm}^3)(19.32 \text{ g/cm}^3) = 155 \text{ g} \]

Practice Exercise

(a) Calculate the density of a 374.5-g sample of copper if it has a volume of 41.8 cm³. (b) A student needs 15.0 g of ethanol for an experiment. If the density of ethanol is 0.789 g/mL, how many milliliters of ethanol are needed? (c) What is the mass, in grams, of 25.0 mL of mercury (density = 13.6 g/mL)?

Answers: (a) 8.96 g/cm³, (b) 19.0 mL, (c) 340 g
Sample Exercise 1.5 Relating Significant Figures to the Uncertainty of a Measurement

What difference exists between the measured values 4.0 g and 4.00 g?

Solution

Many people would say there is no difference, but a scientist would note the difference in the number of significant figures in the two measurements. The value 4.0 has two significant figures, while 4.00 has three. This difference implies that the first measurement has more uncertainty. A mass of 4.0 g indicates that the uncertainty is in the first decimal place of the measurement. Thus, the mass might be anything between 3.9 and 4.1 g, which we can represent as $4.0 \pm 0.1$ g. A measurement of 4.00 g implies that the uncertainty is in the second decimal place. Thus, the mass might be anything between 3.99 and 4.01 g, which we can represent as $4.00 \pm 0.01$ g. Without further information, we cannot be sure whether the difference in uncertainties of the two measurements reflects the precision or accuracy of the measurement.

Practice Exercise

A balance has a precision of $\pm 0.001$ g. A sample that has a mass of about 25 g is placed on this balance. How many significant figures should be reported for this measurement?

Answer: five, as in the measurement 24.995 g, the uncertainty being in the third decimal place
Sample Exercise 1.6 Determining the Number of Significant Figures in a Measurement

How many significant figures are in each of the following numbers (assume that each number is a measured quantity): (a) 4.003, (b) $6.023 \times 10^{23}$, (c) 5000?

Solution

(a) Four; the zeros are significant figures. (b) Four; the exponential term does not add to the number of significant figures. (c) One. We assume that the zeros are not significant when there is no decimal point shown. If the number has more significant figures, a decimal point should be employed or the number written in exponential notation. Thus, 5000. has four significant figures, whereas $5.00 \times 10^3$ has three.

Practice Exercise

How many significant figures are in each of the following measurements:
(a) 3.549 g, (b) $2.3 \times 10^4$ cm, (c) 0.00134 m³?
Answer: (a) four, (b) two, (c) three
Sample Exercise 1.7 Determining the Number of Significant figures in a Calculated Quantity

The width, length, and height of a small box are 15.5 cm, 27.3 cm, and 5.4 cm, respectively. Calculate the volume of the box, using the correct number of significant figures in your answer.

Solution

(The product of the width, length, and height determines the volume of a box. In reporting the product, we can show only as many significant figures as given in the dimension with the fewest significant figures, that for the height (two significant figures):

\[
\text{Volume} = \text{width} \times \text{length} \times \text{height} = (15.5 \text{ cm})(27.3 \text{ cm})(5.4 \text{ cm}) = 2285.01 \text{ cm}^3 \Rightarrow 2.3 \times 10^3 \text{ cm}^3
\]

When we use a calculator to do this calculation, the display shows 2285.01, which we must round off to two significant figures. Because the resulting number is 2300, it is best reported in exponential notation, \(2.3 \times 10^3\), to clearly indicate two significant figures.

Practice Exercise

It takes 10.5 s for a sprinter to run 100.00 m. Calculate the average speed of the sprinter in meters per second, and express the result to the correct number of significant figures.

Answer: 9.52 m/s (three significant figures)
Sample Exercise 1.8 Determining the Number of Significant figures in a Calculated Quantity

A gas at 25 °C fills a container whose volume is $1.05 \times 10^3$ cm$^3$. The container plus gas have a mass of 837.6 g. The container, when emptied of all gas, has a mass of 836.2 g. What is the density of the gas at 25 °C?

Solution

To calculate the density, we must know both the mass and the volume of the gas. The mass of the gas is just the difference in the masses of the full and empty container:

$$(837.6 - 836.2) \text{ g} = 1.4 \text{ g}$$

In subtracting numbers, we determine the number of significant figures in our result by counting decimal places in each quantity. In this case each quantity has one decimal place. Thus, the mass of the gas, 1.4 g, has one decimal place.

Using the volume given in the question, $1.05 \times 10^3$ cm$^3$, and the definition of density, we have

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{1.4 \text{ g}}{1.05 \times 10^3 \text{ cm}^3}$$

$$= 1.3 \times 10^{-3} \text{ g/cm}^3 = 0.0013 \text{ g/cm}^3$$

In dividing numbers, we determine the number of significant figures in our result by counting the number of significant figures in each quantity. There are two significant figures in our answer, corresponding to the smaller number of significant figures in the two numbers that form the ratio. Notice that in this example, following the rules for determining significant figures gives an answer containing only two significant figures, even though each of the measured quantities contained at least three significant figures.
Sample Exercise 1.8 Determining the Number of Significant figures in a Calculated Quantity

Practice Exercise

To how many significant figures should the mass of the container be measured (with and without the gas) in Sample Exercise 1.8 for the density to be calculated to three significant figures?

*Answer:* five (For the difference in the two masses to have three significant figures, there must be two decimal places in the masses of the filled and empty containers. Therefore, each mass must be measured to five significant figures.)
Sample Exercise 1.9 Converting Units

If a woman has a mass of 115 lb, what is her mass in grams? (Use the relationships between units given on the back inside cover of the text.)

Solution

Because we want to change from lb to g, we look for a relationship between these units of mass. From the back inside cover we have 1 lb = 453.6 g. To cancel pounds and leave grams, we write the conversion factor with grams in the numerator and pounds in the denominator:

\[
\text{Mass in grams} = (115 \text{ lb}) \left( \frac{453.6 \text{ g}}{1 \text{ lb}} \right) = 5.22 \times 10^4 \text{ g}
\]

The answer can be given to only three significant figures, the number of significant figures in 115 lb.

Practice Exercise

By using a conversion factor from the back inside cover, determine the length in kilometers of a 500.0-mi automobile race.

*Answer:* 804.7 km
Sample Exercise 1.10 Converting Units Using Two or More Conversion Factors

The average speed of a nitrogen molecule in air at 25 °C is 515 m/s. Convert this speed to miles per hour.

Solution

To go from the given units, m/s, to the desired units, mi/hr, we must convert meters to miles and seconds to hours. From our knowledge of metric prefixes we know that 1 km = 10³ m. From the relationships given on the back inside cover of the book, we find that 1 mi = 1.6093 km. Thus, we can convert m to km and then convert km to mi. From our knowledge of time we know that 60 s = 1 min and 60 min = 1 hr. Thus, we can convert s to min and then convert min to hr. Applying first the conversions for distance and then those for time, we can set up one long equation in which unwanted units are canceled:

\[
\text{Speed in mi/hr} = \left(\frac{515 \text{ m}}{\text{s}}\right)\left(\frac{1 \text{ km}}{10^3 \text{ m}}\right)\left(\frac{1 \text{ mi}}{1.6093 \text{ km}}\right)\left(\frac{60 \text{ s}}{1 \text{ min}}\right)\left(\frac{60 \text{ min}}{1 \text{ hr}}\right)
\]

\[
= 1.15 \times 10^3 \text{ mi/hr}
\]

Our answer has the desired units. We can check our calculation, using the estimating procedure described in the previous “Strategies” box. The given speed is about 500 m/s. Dividing by 1000 converts m to km, giving 0.5 km/s. Because 1 mi is about 1.6 km, this speed corresponds to 0.5/1.6 = 0.3 mi/s. Multiplying by 60 gives about 0.3 \times 60 = 20 mi/min. Multiplying again by 60 gives 20 \times 60 = 1200 mi/hr. The approximate solution and the detailed solution are reasonably close. The answer to the detailed solution has three significant figures, corresponding to the number of significant figures in the given speed in m/s.
Sample Exercise 1.10 Converting Units Using Two or More Conversion Factors

Practice Exercise

A car travels 28 mi per gallon of gasoline. How many kilometers per liter will it go?

*Answer:* 12 km/L
Sample Exercise 1.11 Converting Volume Units

Earth’s oceans contain approximately $1.36 \times 10^9$ km$^3$ of water. Calculate the volume in liters.

Solution

This problem involves conversion of km$^3$ to L. From the back inside cover of the text we find $1$ L = $10^{-3}$ m$^3$, but there is no relationship listed involving km$^3$. From our knowledge of metric prefixes, however, we have $1$ km = $10^3$ m and we can use this relationship between lengths to write the desired conversion factor between volumes:

$$\left( \frac{10^3 \text{ m}}{1 \text{ km}} \right)^3 = \frac{10^9 \text{ m}^3}{1 \text{ km}^3}$$

Thus, converting from km$^3$ to m$^3$ to L, we have

$$\text{Volume in liters} = (1.36 \times 10^9 \text{ km}^3) \left( \frac{10^9 \text{ m}^3}{1 \text{ km}^3} \right) \left( \frac{1 \text{ L}}{10^{-3} \text{ m}^3} \right) = 1.36 \times 10^{21} \text{ L}$$

Practice Exercise

If the volume of an object is reported as $5.0$ ft$^3$, what is the volume in cubic meters?

Answer: $0.14$ m$^3$
Sample Exercise 1.12 Conversions Involving Density

What is the mass in grams of 1.00 gal of water? The density of water is 1.00 g/mL.

Solution

1. We are given 1.00 gal of water (the known, or given, quantity) and asked to calculate its mass in grams (the unknown).
2. We have the following conversion factors either given, commonly known, or available on the back inside cover of the text:

\[
\frac{1.00 \text{ g water}}{1 \text{ mL water}} \quad \frac{1 \text{ L}}{1000 \text{ mL}} \quad \frac{1 \text{ L}}{1.057 \text{ qt}} \quad \frac{1 \text{ gal}}{4 \text{ qt}}
\]

The first of these conversion factors must be used as written (with grams in the numerator) to give the desired result, whereas the last conversion factor must be inverted in order to cancel gallons:

\[
\text{Mass in grams} = (1.00 \text{ gal}) \left( \frac{4 \text{ qt}}{1 \text{ gal}} \right) \left( \frac{1 \text{ L}}{1.057 \text{ qt}} \right) \left( \frac{1000 \text{ mL}}{1 \text{ L}} \right) \left( \frac{1.00 \text{ g}}{1 \text{ mL}} \right)
\]

\[
= 3.78 \times 10^3 \text{ g water}
\]

The units of our final answer are appropriate, and we’ve also taken care of our significant figures. We can further check our calculation by the estimation procedure. We can round 1.057 off to 1. Focusing on the numbers that do not equal 1 then gives merely \(4 \times 1000 = 4000\) g, in agreement with the detailed calculation.
Sample Exercise 1.12 Conversions Involving Density

Solution (continued)

In cases such as this you may also be able to use common sense to assess the reasonableness of your answer. In this case we know that most people can lift a gallon of milk with one hand, although it would be tiring to carry it around all day. Milk is mostly water and will have a density that is not too different than water. Therefore, we might estimate that in familiar units a gallon of water would have mass that was more than 5 lbs but less than 50 lbs. The mass we have calculated is 3.78 kg \times 2.2 \text{ lb/kg} = 8.3 \text{ lbs}—an answer that is reasonable at least as an order of magnitude estimate.

Practice Exercise

The density of benzene is 0.879 g/mL. Calculate the mass in grams of 1.00 qt of benzene.

Answer: 832 g