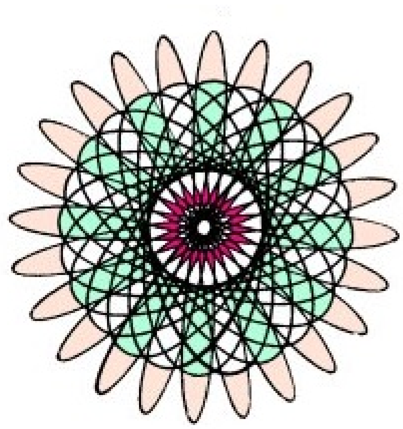


2.4 Converting Units

LEARNING OBJECTIVE

1. Convert from one unit to another unit of the same type.

In Section 2.2 "Expressing Units", we showed some examples of how to replace initial units with other units of the same type to get a numerical value that is easier to comprehend. In this section, we will formalize the process.

Consider a simple example: how many feet are there in 4 yards? Most people will almost automatically answer that there are 12 feet in 4 yards. How did you make this determination? Well, if there are 3 feet in 1 yard and there are 4 yards, then there are 4 × 3 = 12 feet in 4 yards.

This is correct, of course, but it is informal. Let us formalize it in a way that can be applied more generally. We know that 1 yard (yd) equals 3 feet (ft):

1 yd = 3 ft

In math, this expression is called an *equality*. The rules of algebra say that you can change (i.e., multiply or divide or add or subtract) the equality (as long as you don't divide by zero) and the new expression will still be an equality. For example, if we divide both sides by 2, we get

12 yd=32 ft

We see that one-half of a yard equals 3/2, or one and a half, feet—something we also know to be true, so the above equation is still an equality. Going back to the original equality, suppose we divide both sides of the equation by 1 yard (number *and* unit):

1 yd

The expression is still an equality, by the rules of algebra. The left fraction equals 1. It has the same quantity in the numerator and the denominator, so it must equal 1. The quantities in the numerator and denominator cancel, both the number *and* the unit:

1 yd

When everything cancels in a fraction, the fraction reduces to 1:

1=3 ft

We have an expression, 3 ft, that equals 1. This is a strange way to write 1, but it makes sense: 3 ft equal 1 yd, so the quantities in the numerator and denominator are the same quantity, just expressed with different units. The expression 3 ft is called aconversion factor, and it is used to formally change the unit of a quantity into another unit. (The process of converting units in such a formal fashion is sometimes called *dimensional analysis* or the *factor label method*.)

To see how this happens, let us start with the original quantity:

4 yd

Now let us multiply this quantity by 1. When you multiply anything by 1, you don't change the value of the quantity. Rather than multiplying by just 1, let us write 1 as 3 ft:

$$4\ \text{yd} \times 3\ \text{ft}$$

The 4 yd term can be thought of as 4 yd; that is, it can be thought of as a fraction with 1 in the denominator. We are essentially multiplying fractions. If the same thing appears in the numerator and denominator of a fraction, they cancel. In this case, what cancels is the unit *yard*:

$$4\ \text{yd}$$

That is all that we can cancel. Now, multiply and divide all the numbers to get the final answer:

$$4 \times 3\ \text{ft}$$

Again, we get an answer of 12 ft, just as we did originally. But in this case, we used a more formal procedure that is applicable to a variety of problems.

How many millimeters are in 14.66 m? To answer this, we need to construct a conversion factor between millimeters and meters and apply it correctly to the original quantity. We start with the definition of a millimeter, which is

1 mm = 1/1,000 m

The 1/1,000 is what the prefix *milli*- means. Most people are more comfortable working without fractions, so we will rewrite this equation by bringing the 1,000 into the numerator of the other side of the equation:

1,000 mm = 1 m

Now we construct a conversion factor by dividing one quantity into both sides. But now a question arises: which quantity do we divide by? It turns out that we have two choices, and the two choices will give us different conversion factors, both of which equal 1:

1,000 mm

1=1 m

Which conversion factor do we use? The answer is based on *what unit you want to get rid of in your initial quantity*. The original unit of our quantity is meters, which we want to convert to millimeters. Because the original unit is assumed to be in the numerator, to get rid of it, we want the meter unit in the *denominator*; then they will cancel. Therefore, we will use the second conversion factor. Canceling units and performing the mathematics, we get

14.66 m × 1,000 mm

Note how m cancels, leaving mm, which is the unit of interest.

The ability to construct and apply proper conversion factors is a very powerful mathematical technique in chemistry. You need to master this technique if you are going to be successful in this and future courses.

EXAMPLE 7

1. Convert 35.9 kL to liters.

2. Convert 555 nm to meters.

Solution

1. We will use the fact that 1 kL = 1,000 L. Of the two conversion factors that can be defined, the one that will work is 1,000 L. Applying this conversion factor, we get

35.9 kL

2. We will use the fact that 1 nm = 1/1,000,000,000 m, which we will rewrite as 1,000,000,000 nm = 1 m, or 10^9 nm = 1 m. Of the two possible conversion factors, the appropriate one has the nm unit in the denominator: 1 m. Applying this conversion factor, we get

555 nm

In the final step, we expressed the answer in scientific notation.

Test Yourself

1. Convert 67.08 µL to liters.
2. Convert 56.8 m to kilometers.

Answers

1. 6.708×10^{-5} L
2. 5.68×10^{-2} km

What if we have a derived unit that is the product of more than one unit, such as m^2? Suppose we want to convert square meters to square centimeters? The key is to remember that m^2 means m × m, which means we have *two* meter units in our derived unit. That means we have to include *two* conversion factors, one for each unit. For example, to convert 17.6 m^2 to square centimeters, we perform the conversion as follows:

17.6 m

EXAMPLE 8

How many cubic centimeters are in 0.883 m^3?

Solution

With an exponent of 3, we have three length units, so by extension we need to use three conversion factors between meters and centimeters. Thus, we have

0.883 m^3

You should demonstrate to yourself that the three meter units do indeed cancel.

Test Yourself

How many cubic millimeters are present in 0.0923 m^3?

Answer

9.23×10^7 mm^3

Suppose the unit you want to convert is in the denominator of a derived unit; what then? Then, in the conversion factor, the unit you want to remove must be in the *numerator*. This will cancel with the original unit in the denominator and introduce a new unit in the denominator. The following example illustrates this situation.

EXAMPLE 9

Convert 88.4 m/min to meters/second.

Solution

We want to change the unit in the denominator from minutes to seconds. Because there are 60 seconds in 1 minute (60 s = 1 min), we construct a conversion factor so that the unit we want to remove, minutes, is in the numerator: 1 min. Apply and perform the math:

88.4 m

Notice how the 88.4 automatically goes in the numerator. That's because any number can be thought of as being in the numerator of a fraction divided by 1.

Test Yourself

Convert 0.203 m/min to meters/second.

Answer

0.00338 m/s or 3.38×10^{-3} m/s

Sometimes there will be a need to convert from one unit with one numerical prefix to another unit with a different numerical prefix. How do we handle those conversions? Well, you could memorize the conversion factors that interrelate all numerical prefixes. Or you can go the easier route: first convert the quantity to the base unit, the unit with no numerical prefix, using the definition of the original prefix. Then convert the quantity in the base unit to the desired unit using the definition of the second prefix. You can do the conversion in two separate steps or as one long algebraic step. For example, to convert 2.77 kg to milligrams:

$$2.77 \text{ kg} \times 1{,}000 \text{ g}$$

$$2{,}770 \text{ g} \times 1{,}000 \text{ mg}1 \text{ g}$$

Alternatively, it can be done in a single multistep process:

$$2.77 \text{ kg}$$

You get the same answer either way.

EXAMPLE 10

How many nanoseconds are in 368.09 μs?

Solution

You can either do this as a one-step conversion from microseconds to nanoseconds or convert to the base unit first and then to the final desired unit. We will use the second method here, showing the two steps in a single line. Using the definitions of the prefixes *micro-* and *nano-*,

$$368.09\ \mu\text{s}$$

Test Yourself

How many milliliters are in 607.8 kL?

Answer

6.078×10^8 mL

When considering the significant figures of a final numerical answer in a conversion, there is one important case where a number does not impact the number of significant figures in a final answer—the so-called exact number. An exact number is a number from a defined relationship, not a measured one. For example, the prefix *kilo-* means 1,000—*exactly* 1,000, no more or no less. Thus, in constructing the conversion factor

1,000 g

neither the 1,000 nor the 1 enter into our consideration of significant figures. The numbers in the numerator and denominator are defined exactly by what the prefix *kilo*-means. Another way of thinking about it is that these numbers can be thought of as having an infinite number of significant figures, such as

1,000.0000000000… g

The other numbers in the calculation will determine the number of significant figures in the final answer.

EXAMPLE 11

A rectangular plot in a garden has the dimensions 36.7 cm by 128.8 cm. What is the area of the garden plot in square meters? Express your answer in the proper number of significant figures.

Solution

Area is defined as the product of the two dimensions, which we then have to convert to square meters and express our final answer to the correct number of significant figures, which in this case will be three.

36.7 cm

The 1 and 100 in the conversion factors do not affect the determination of significant figures because they are exact numbers, defined by the centi- prefix.

Test Yourself

What is the volume of a block in cubic meters whose dimensions are 2.1 cm × 34.0 cm × 118 cm?

Answer

0.0084 m^3

Chemistry Is Everywhere: The Gimli Glider

On July 23, 1983, an Air Canada Boeing 767 jet had to glide to an emergency landing at Gimli Industrial Park Airport in Gimli, Manitoba, because it unexpectedly ran out of fuel during flight. There was no loss of life in the course of the emergency landing, only some minor injuries associated in part with the evacuation of the craft after landing. For the remainder of its operational life (the plane was retired in 2008), the aircraft was nicknamed “the Gimli Glider.”

The Gimli Glider is the Boeing 767 that ran out of fuel and glided to safety at Gimli Airport. The aircraft ran out of fuel because of confusion over the units used to express the amount of fuel.

Source: Photo courtesy of Will F.,http://commons.wikimedia.org/wiki/File:Gimli_Glider_today.jpg.

The 767 took off from Montreal on its way to Ottawa, ultimately heading for Edmonton, Canada. About halfway through the flight, all the engines on the plane began to shut down because of a lack of fuel. When the final engine cut off, all electricity (which was generated by the engines) was lost; the plane became, essentially, a powerless glider. Captain Robert Pearson was an experienced glider pilot, although he had never flown a glider the size of a 767. First Officer Maurice Quintal quickly determined that the aircraft would not be able make it to Winnipeg, the next large airport. He suggested his old Royal Air Force base at Gimli Station, one of whose runways was still being used as a community airport. Between the efforts of the pilots and the flight crew, they managed to get the airplane safely on the ground (although with buckled landing gear) and all passengers off safely.

What happened? At the time, Canada was transitioning from the older English system to the metric system. The Boeing 767s were the first aircraft whose gauges were calibrated in the metric system of units (liters and kilograms) rather than the English system of units (gallons and pounds). Thus, when the fuel gauge read 22,300, the gauge meant kilograms, but the ground crew mistakenly fueled the plane with 22,300 *pounds* of fuel. This ended up being just less than half of the fuel needed to make the trip, causing the engines to quit about halfway to Ottawa. Quick thinking and extraordinary skill saved the lives of 61 passengers and 8 crew members—an incident that would not have occurred if people were watching their units.

KEY TAKEAWAYS

- Units can be converted to other units using the proper conversion factors.
- Conversion factors are constructed from equalities that relate two different units.
- Conversions can be a single step or multistep.
- Unit conversion is a powerful mathematical technique in chemistry that must be mastered.
- Exact numbers do not affect the determination of significant figures.

EXERCISES

1. Write the two conversion factors that exist between the two given units.

   a. milliliters and liters
   b. microseconds and seconds
   c. kilometers and meters

2. Write the two conversion factors that exist between the two given units.

a. kilograms and grams

b. milliseconds and seconds

c. centimeters and meters

3. Perform the following conversions.

a. 5.4 km to meters

b. 0.665 m to millimeters

c. 0.665 m to kilometers

4. Perform the following conversions.

a. 90.6 mL to liters

b. 0.00066 ML to liters

c. 750 L to kiloliters

5. Perform the following conversions.

a. 17.8 μg to grams

b. 7.22×10^{2} kg to grams

c. 0.00118 g to nanograms

6. Perform the following conversions.

a. 833 ns to seconds

b. 5.809 s to milliseconds

c. 2.77×10^{6} s to megaseconds

7. Perform the following conversions.

a. 9.44 m^2 to square centimeters
b. 3.44 × 10^8 mm^3 to cubic meters

8. Perform the following conversions.

a. 0.00444 cm^3 to cubic meters
b. 8.11 × 10^2 m^2 to square nanometers

9. Why would it be inappropriate to convert square centimeters to cubic meters?

10. Why would it be inappropriate to convert from cubic meters to cubic seconds?

11. Perform the following conversions.

a. 45.0 m/min to meters/second
b. 0.000444 m/s to micrometers/second
c. 60.0 km/h to kilometers/second

`12. Perform the following conversions.

a. 3.4 × 10^2 cm/s to centimeters/minute
b. 26.6 mm/s to millimeters/hour
c. 13.7 kg/L to kilograms/milliliters

13. Perform the following conversions.

a. 0.674 kL to milliliters

b. 2.81×10^{12} mm to kilometers

c. 94.5 kg to milligrams

14. Perform the following conversions.

a. 6.79×10^{-6} kg to micrograms

b. 1.22 mL to kiloliters

c. 9.508×10^{-9} ks to milliseconds

15. Perform the following conversions.

a. 6.77×10^{14} ms to kiloseconds

b. 34,550,000 cm to kilometers

16. Perform the following conversions.

a. 4.701×10^{15} mL to kiloliters

b. 8.022×10^{-11} ks to microseconds

17. Perform the following conversions. Note that you will have to convert units in both the numerator and the denominator.

a. 88 ft/s to miles/hour (Hint: use 5,280 ft = 1 mi.)

b. 0.00667 km/h to meters/second

18. Perform the following conversions. Note that you will have to convert units in both the numerator and the denominator.

    a. 3.88×10^2 mm/s to kilometers/hour
    b. 1.004 kg/L to grams/milliliter

19. What is the area in square millimeters of a rectangle whose sides are 2.44 cm × 6.077 cm? Express the answer to the proper number of significant figures.

20. What is the volume in cubic centimeters of a cube with sides of 0.774 m? Express the answer to the proper number of significant figures.

21. The formula for the area of a triangle is 1/2 × base × height. What is the area of a triangle in square centimeters if its base is 1.007 m and its height is 0.665 m? Express the answer to the proper number of significant figures.

22. The formula for the area of a triangle is 1/2 × base × height. What is the area of a triangle in square meters if its base is 166 mm and its height is 930.0 mm? Express the answer to the proper number of significant figures.

ANSWERS

1. a. $1{,}000\ \text{mL}$ and $1\ \text{L}$
   b. $1{,}000{,}000\ \mu\text{s}$ and $1\ \text{s}$
   c. $1{,}000\ \text{m}$ and $1\ \text{km}$

d. 5,400 m

e. 665 mm

f. 6.65×10^{-4} km

3. a. 1.78×10^{-5} g

   b. 7.22×10^{5} g

   c. 1.18×10^{6} ng

5. a. 94,400 cm^2

   b. 0.344 m^3

7. One is a unit of area, and the other is a unit of volume.

9. a. 0.75 m/s

   b. 444 µm/s

   c. 1.666×10^{-2} km/s

11. a. 674,000 mL

    b. 2.81×10^{6} km

    c. 9.45×10^{7} mg

13. a. 6.77×10^{8} ks

    b. 345.5 km

15. a. 6.0×10^{1} mi/h

    b. 0.00185 m/s

17. a. 1.48×10^{3} mm^2

b. 3.35×10^3 cm^2

2.5 Other Units: Temperature and Density

LEARNING OBJECTIVES

1. Learn about the various temperature scales that are commonly used in chemistry.
2. Define density and use it as a conversion factor.

There are other units in chemistry that are important, and we will cover others in the course of the entire book. One of the fundamental quantities in science is temperature. **Temperature** is a measure of the average amount of energy of motion, or *kinetic energy*, a system contains. Temperatures are expressed using scales that use units called **degrees**, and there are several temperature scales in use. In the United States, the commonly used temperature scale is the *Fahrenheit scale* (symbolized by °F and spoken as “degrees Fahrenheit”). On this scale, the freezing point of liquid water (the temperature at which liquid water turns to solid ice) is 32°F, and the boiling point of water (the temperature at which liquid water turns to steam) is 212°F.

Science also uses other scales to express temperature. The Celsius scale (symbolized by °C and spoken as “degrees Celsius”) is a temperature scale where 0°C is the freezing point of water and 100°C is the boiling point of water; the scale is divided into 100 divisions between these two landmarks and extended higher and lower. By comparing the Fahrenheit and Celsius scales, a conversion between the two scales can be determined:

$$^{\circ}C=(^{\circ}F-32) \times 59^{\circ}$$

$$F=(°C \times 95)+32$$

Using these formulas, we can convert from one temperature scale to another. The number 32 in the formulas is exact and does not count in significant figure determination.

EXAMPLE 12

1. What is 98.6°F in degrees Celsius?
2. What is 25.0°C in degrees Fahrenheit?

Solution

1. Using the first formula from above, we have

$$°C=(98.6–32)$$

2. Using the second formula from above, we have

$$°F=(25.0 \times 95)$$

Test Yourself

1. Convert 0°F to degrees Celsius.
2. Convert 212°C to degrees Fahrenheit.

Answers

1. −17.8°C
2. 414°F

The fundamental unit of temperature (another fundamental unit of science, bringing us to four) in SI is the **kelvin** (K). The Kelvin temperature scale (note that the name of the scale capitalizes the word *Kelvin*, but the unit itself is lowercase) uses degrees that are the same size as the Celsius degree, but the numerical scale is shifted up by 273.15 units. That is, the conversion between the Kelvin and Celsius scales is as follows:

K = °C + 273.15°

C = K − 273.15

For most purposes, it is acceptable to use 273 instead of 273.15. Note that the Kelvin scale does not use the word *degrees*; a temperature of 295 K is spoken of as "two hundred ninety-five kelvins" and not "two hundred ninety-five degrees Kelvin."

The reason that the Kelvin scale is defined this way is because there exists a minimum possible temperature called absolute zero. The Kelvin temperature scale is set so that 0 K is absolute zero, and temperature is counted upward from there. Normal room temperature is about 295 K, as seen in the following example.

EXAMPLE 13

If normal room temperature is 72.0°F, what is room temperature in degrees Celsius and kelvins?

Solution

First, we use the formula to determine the temperature in degrees Celsius:

$$°C=(72.0–32)$$

Then we use the appropriate formula above to determine the temperature in the Kelvin scale:

K = 22.2°C + 273.15 = 295.4 K

So, room temperature is about 295 K.

Test Yourself

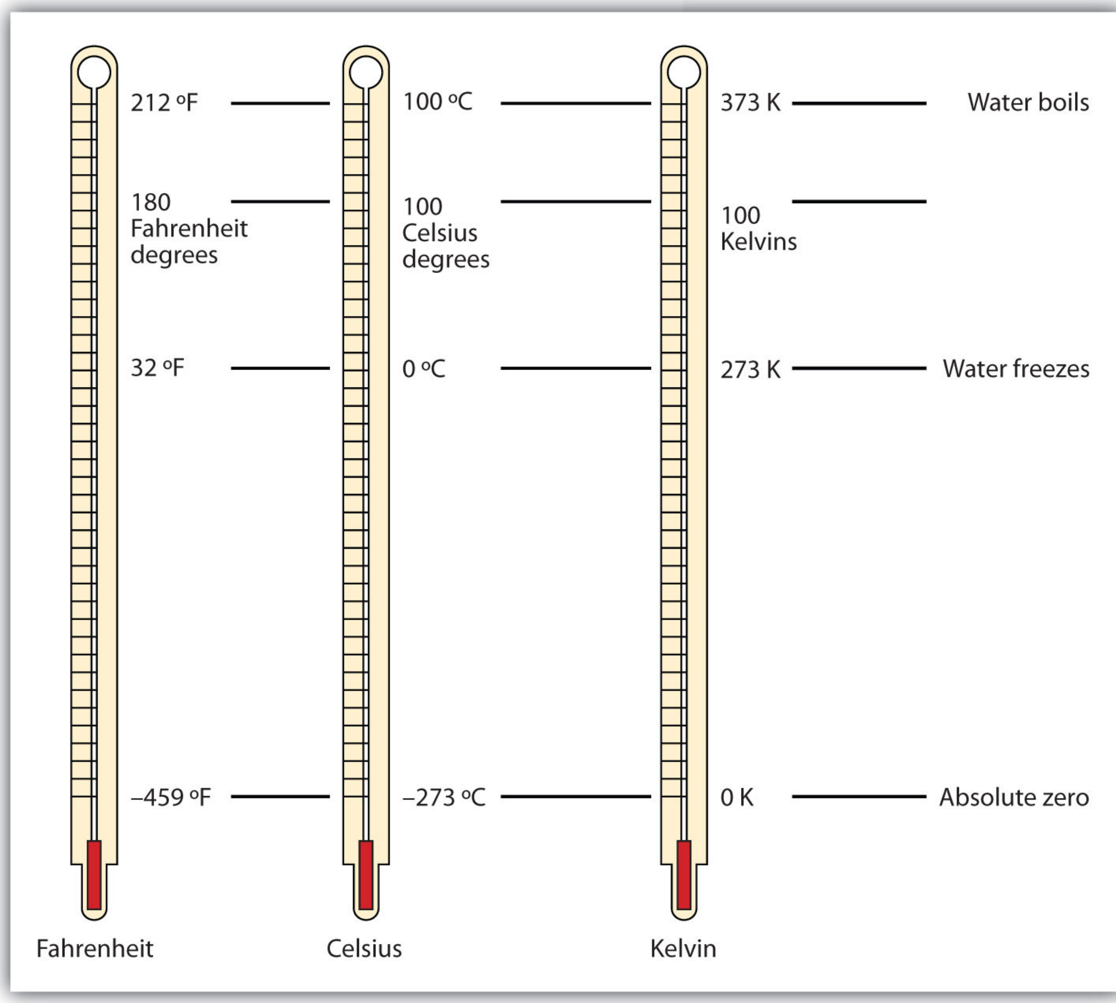
What is 98.6°F on the Kelvin scale?

Answer

310.2 K

Figure 2.9 "Fahrenheit, Celsius, and Kelvin Temperatures" compares the three temperature scales. Note that science uses the Celsius and Kelvin scales almost exclusively; virtually no practicing chemist expresses laboratory-measured temperatures with the Fahrenheit scale. (In fact, the United States is one of the few countries in the world that still uses the Fahrenheit scale on a daily basis. The other two countries are Liberia and Myanmar [formerly Burma]. People driving near the borders of Canada or Mexico may pick up local radio stations on the other side of the border that express the daily weather in degrees Celsius, so don't get confused by their weather reports.)

Figure 2.9 Fahrenheit, Celsius, and Kelvin Temperatures



A comparison of the three temperature scales.

Density is a physical property that is defined as a substance's mass divided by its volume:

density= mass

Density is usually a measured property of a substance, so its numerical value affects the significant figures in a calculation. Notice that density is defined in terms of two dissimilar units, mass and volume. That means that density overall has derived units, just like velocity. Common units for density include g/mL, g/cm^3, g/L, kg/L, and even kg/m^3.

Densities for some common substances are listed in Table 2.2 "Densities of Some Common Substances".

Table 2.2 Densities of Some Common Substances

Substance	**Density (g/mL or g/cm^3)**
water	1.0
gold	19.3
mercury	13.6
air	0.0012
cork	0.22–0.26
aluminum	2.7
iron	7.87

Because of how it is defined, density can act as a conversion factor for switching between units of mass and volume. For example, suppose you have a sample of aluminum that has a volume of 7.88 cm^3. How can you determine what mass of aluminum you have without measuring it? You can use the volume to calculate it. If you multiply the given volume by the known density (from Table 2.2 "Densities of Some Common Substances"), the volume units will cancel and leave you with mass units, telling you the mass of the sample:

$$7.88\ \cancel{\text{cm3}}$$

where we have limited our answer to two significant figures.

EXAMPLE 14

What is the mass of 44.6 mL of mercury?

Solution

Use the density from Table 2.2 "Densities of Some Common Substances" as a conversion factor to go from volume to mass:

$$44.6\ \cancel{\text{mL}}$$

The mass of the mercury is 607 g.

Test Yourself

What is the mass of 25.0 cm^3 of iron?

Answer

197 g

Density can also be used as a conversion factor to convert mass to volume—but care must be taken. We have already demonstrated that the number that goes with density normally goes in the numerator when density is written as a fraction. Take the density of gold, for example:

$$d = 19.3\ \text{g/mL} = 19.3\ \text{g}$$

Although this was not previously pointed out, it can be assumed that there is a 1 in the denominator:

$$d = 19.3\ \text{g/mL} = 19.3\ \text{g}$$

That is, the density value tells us that we have 19.3 grams for every 1 milliliter of volume, and the 1 is an exact number. When we want to use density to convert from mass to volume, the numerator and denominator of density need to be switched—that is, we must take the *reciprocal* of the density. In so doing, we move not only the units but also the numbers:

$$1d=1\ \text{mL}$$

This reciprocal density is still a useful conversion factor, but now the mass unit will cancel and the volume unit will be introduced. Thus, if we want to know the volume of 45.9 g of gold, we would set up the conversion as follows:

$$45.9\ \text{g} \times 1\ \text{mL}$$

Note how the mass units cancel, leaving the volume unit, which is what we're looking for.

EXAMPLE 15

A cork stopper from a bottle of wine has a mass of 3.78 g. If the density of cork is 0.22 g/cm^3, what is the volume of the cork?

Solution

To use density as a conversion factor, we need to take the reciprocal so that the mass unit of density is in the denominator. Taking the reciprocal, we find

$$1d=1\ \text{cm3}$$

We can use this expression as the conversion factor. So

$$3.78\ \cancel{g} \times \frac{1\ \text{cm}}{3}$$

Test Yourself

What is the volume of 3.78 g of gold?

Answer

0.196 cm^3

Care must be used with density as a conversion factor. Make sure the mass units are the same, or the volume units are the same, before using density to convert to a different unit. Often, the unit of the given quantity must be first converted to the appropriate unit before applying density as a conversion factor.

Food and Drink App: Cooking Temperatures

Because degrees Fahrenheit is the common temperature scale in the United States, kitchen appliances, such as ovens, are calibrated in that scale. A cool oven may be only 150°F, while a cake may be baked at 350°F and a chicken roasted at 400°F. The broil setting on many ovens is 500°F, which is typically the highest temperature setting on a household oven.

People who live at high altitudes, typically 2,000 ft above sea level or higher, are sometimes urged to use slightly different cooking instructions on some products, such as cakes and bread, because water boils at a lower temperature the higher in altitude you go, meaning that foods cook slower. For example, in Cleveland water typically boils at 212°F (100°C), but in Denver, the Mile-High City, water boils at about

200°F (93.3°C), which can significantly lengthen cooking times. Good cooks need to be aware of this.

At the other end is pressure cooking. A pressure cooker is a closed vessel that allows steam to build up additional pressure, which increases the temperature at which water boils. A good pressure cooker can get to temperatures as high as 252°F (122°C); at these temperatures, food cooks much faster than it normally would. Great care must be used with pressure cookers because of the high pressure and high temperature. (When a pressure cooker is used to sterilize medical instruments, it is called an *autoclave*.)

Other countries use the Celsius scale for everyday purposes. Therefore, oven dials in their kitchens are marked in degrees Celsius. It can be confusing for US cooks to use ovens abroad—a 425°F oven in the United States is equivalent to a 220°C oven in other countries. These days, many oven thermometers are marked with both temperature scales.

KEY TAKEAWAYS

- Chemistry uses the Celsius and Kelvin scales to express temperatures.
- A temperature on the Kelvin scale is the Celsius temperature plus 273.15.
- The minimum possible temperature is absolute zero and is assigned 0 K on the Kelvin scale.
- Density relates a substance's mass and volume.
- Density can be used to calculate volume from a given mass or mass from a given volume.

EXERCISES

1. Perform the following conversions.

    a. 255°F to degrees Celsius

    b. −255°F to degrees Celsius

    c. 50.0°C to degrees Fahrenheit

    d. −50.0°C to degrees Fahrenheit

2. Perform the following conversions.

    a. 1,065°C to degrees Fahrenheit

    b. −222°C to degrees Fahrenheit

    c. 400.0°F to degrees Celsius

    d. 200.0°F to degrees Celsius

3. Perform the following conversions.

    a. 100.0°C to kelvins

    b. −100.0°C to kelvins

    c. 100 K to degrees Celsius

    d. 300 K to degrees Celsius

4. Perform the following conversions.

    a. 1,000.0 K to degrees Celsius

    b. 50.0 K to degrees Celsius

    c. 37.0°C to kelvins

    d. −37.0°C to kelvins

5. Convert 0 K to degrees Celsius. What is the significance of the temperature in degrees Celsius?

6. Convert 0 K to degrees Fahrenheit. What is the significance of the temperature in degrees Fahrenheit?

7. The hottest temperature ever recorded on the surface of the earth was 136°F in Libya in 1922. What is the temperature in degrees Celsius and in kelvins?

8. The coldest temperature ever recorded on the surface of the earth was −128.6°F in Vostok, Antarctica, in 1983. What is the temperature in degrees Celsius and in kelvins?

9. Give at least three possible units for density.

10. What are the units when density is inverted? Give three examples.

11. A sample of iron has a volume of 48.2 cm^3. What is its mass?

12. A sample of air has a volume of 1,015 mL. What is its mass?

13. The volume of hydrogen used by the *Hindenburg*, the German airship that exploded in New Jersey in 1937, was 2.000×10^8 L. If hydrogen gas has a density of 0.0899 g/L, what mass of hydrogen was used by the airship?

14. The volume of an Olympic-sized swimming pool is 2.50×10^9 cm^3. If the pool is filled with alcohol (d = 0.789 g/cm^3), what mass of alcohol is in the pool?

15. A typical engagement ring has 0.77 cm^3 of gold. What mass of gold is present?

16. A typical mercury thermometer has 0.039 mL of mercury in it. What mass of mercury is in the thermometer?

17. What is the volume of 100.0 g of lead if lead has a density of 11.34 g/cm^3?

18. What is the volume of 255.0 g of uranium if uranium has a density of 19.05 g/cm^3?

19. What is the volume in liters of 222 g of neon if neon has a density of 0.900 g/L?

20. What is the volume in liters of 20.5 g of sulfur hexafluoride if sulfur hexafluoride has a density of 6.164 g/L?

21. Which has the greater volume, 100.0 g of iron (d = 7.87 g/cm^3) or 75.0 g of gold (d = 19.3 g/cm^3)?

22. Which has the greater volume, 100.0 g of hydrogen gas (d = 0.0000899 g/cm^3) or 25.0 g of argon gas (d = 0.00178 g/cm^3)?

ANSWERS

1. a. 124°C

   b.−159°C

   c. 122°F

d. −58°F

3. a. 373 K
   b. 173 K
   c. −173°C
   d. 27°C

5. −273°C. This is the lowest possible temperature in degrees Celsius.

7. 57.8°C; 331 K

9. g/mL, g/L, and kg/L (answers will vary)

11. 379 g

13. 1.80×10^7 g

15. 15 g

17. 8.818 cm^3

19. 247 L

20. The 100.0 g of iron has the greater volume.