# 3.6: Converting Units

## Learning Objective

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

For calculations in chemistry, we often need to convert from one unit to another. To demonstrate how to do this, let's look at a familiar type of unit conversion, yards to feet. We know that 1 yard (yd) equals 3 feet (ft). To begin, we write this as an equality:

$$1\,yd = 3\,ft$$

Equalities can be re-written as **conversion factors**. Conversion factors are fractions used to change from one unit to another. For example, the equality

$$1\,yd = 3\,ft$$

can be written as:

$$\frac{3\,ft}{1\,yd} \quad \text{OR} \quad \frac{1\,yd}{3\,ft}$$

These factors can be thought of as stating "3 ft per yd," or "1 yd is 3 ft." Every equality can be written as two different conversion factors. Which one you use depends on the unit of the starting value.

### Converting yards to feet

If you want to know how many feet are in four yards, you may be able to quickly determine the answer in your head. If there are three feet in one yard, there would be 12 feet in four yards. Sometimes a conversion is not easy to do in your head. The following method can be used to solve any type of conversion problem. Because we want to convert yards to feet, we want the unit of yards to go away or cancel. To do this the strategy is to multiply by the conversion factor that will cancel the unit you do not want:

$$4\,yd \times \frac{3\,ft}{1\,yd}$$

We are essentially multiplying fractions where you multiply all the numerators and denominators across. If it helps, you can write or imagine the 3yd term as a fraction with a 1 on the bottom. Remember that if the same thing appears in the numerator and denominator of a fraction, they cancel. In this case, what cancels is the unit *yard*:

$$\frac{4\ \cancel{yd} \times 3\,ft}{1\ \cancel{yd}} = \frac{4 \times 3\,ft}{1} = 12\,ft$$

You can see we get the same answer as before, but in this case, we used a more formal procedure that can be applied to a variety of problems.

### Converting feet to yards

If we had wanted to determine the number of yards in a given number of feet, we would choose the other conversion factor from the equality. For example, to calculate the number of yards in 42 feet, multiply 42 ft by the conversion factor 1yd per 3ft:

$$42\,ft \times \frac{1\,yd}{3\,ft}$$

Which becomes:

$$42\ \cancel{ft} \times \frac{1\,yd}{3\ \cancel{ft}} = 14\,yd$$

The ability to construct and apply proper conversion factors is a very powerful mathematical technique in chemistry. In addition to using it to convert units, it is the foundation of further calculations to determine quantities in chemical reactions.

## Example 3.6.1

a. Convert 35.9 kL to liters.
b. Convert 555 nm to meters.

### Solution

a. 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 1000L/1kL. Applying this conversion factor, we get:

$$35.9\,kL \times \frac{1000\,L}{1\,kL} = 35,900\,L$$

b. 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:

$$\frac{1\,m}{10^9\,nm}$$

Applying this conversion factor, we get:

$$555\,nm \times \frac{1m}{10^9 nm} = 0.000000555\,m = 5.55 \times 10^{-7}\,m$$

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

## Exercise 3.6.2

a. Convert 67.08 μL to liters.
b. Convert 56.8 m to kilometers.

**Answer a**

$6.708 \times 10^{-5}$ L

**Answer b**

$5.68 \times 10^{-2}$ 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:

$$\begin{aligned} 17.6 m^2 &= 17.6 (m \times m) \times \frac{100cm}{1m} \times \frac{100cm}{1m} \\ &= 176000\,cm \times cm \\ &= 1.76 \times 10^5\,cm^2 \end{aligned} \tag{3.6.1}$$

## Example 3.6.3

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:

$$0.883 m^3 \times \frac{100\,cm}{1\,m} \times \frac{100\,cm}{1\,m} \times \frac{100\,cm}{1\,m} = 883000\,cm^3 = 8.83 \times 10^5\,cm^3$$

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

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:

$$\frac{1000\,g}{1\,kg}$$

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:

$$\frac{1000.0000000000\ldots\ g}{1.0000000000\ldots\ kg}$$

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

## 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.
- Unit conversion is a powerful mathematical technique in chemistry that must be mastered.
- Exact numbers do not affect the determination of significant figures.

---