Pearson

E.7: Converting between Units

Knowing how to work with and manipulate units in calculations is central to solving chemical problems. In calculations, units can help us determine if an answer is correct. Using units as a guide to solving problems is called **dimensional analysis**. Always include units in your calculations; multiply, divide, and cancel them like any other algebraic quantity.

Consider converting 12.5 inches (in) to centimeters (cm). We know from the table in the inside back cover of this book that $1 \text{ in} = 2.54 \text{ cm}$ (exact), so we can use this quantity in the calculation:

$$12.5 \ \cancel{\text{in}} \times \frac{2.54 \text{ cm}}{1 \ \cancel{\text{in}}} = 31.8 \text{ cm}$$

The unit, in, cancels and we are left with cm as our final unit. The quantity $\frac{2.54 \text{ cm}}{1 \text{ in}}$ is a **conversion factor**—a fractional quantity with the units we are *converting from* on the bottom and the units we are *converting to* on the top. Conversion factors are constructed from any two equivalent quantities. In this example, $2.54 \text{ cm} = 1 \text{ in}$, so we construct the conversion factor by dividing both sides of the equality by 1 in and canceling the units:

$$\begin{aligned} 2.54 \text{ cm} &= 1 \text{ in} \\ \frac{2.54 \text{ cm}}{1 \text{ in}} &= \frac{1 \ \cancel{\text{in}}}{1 \ \cancel{\text{in}}} \\ \frac{2.54 \text{ cm}}{1 \text{ in}} &= 1 \end{aligned}$$

Because the quantity $\frac{2.54 \text{ cm}}{1 \text{ in}}$ is equivalent to 1, multiplying by the conversion factor affects only the units, not the actual quantity. To convert the other way, from centimeters to inches, we must—using units as a guide—use a different form of the conversion factor. If we accidentally use the same form, we will get the wrong result, indicated by erroneous units. For example, suppose that we want to convert 31.8 cm to inches:

$$31.8 \text{ cm} \times \frac{2.54 \text{ cm}}{1 \text{ in}} = \frac{80.8 \text{ cm}^2}{\text{in}}$$

The units in the above answer (cm^2/in), as well as the value of the answer, are obviously wrong. We know that an inch is a larger unit than a centimeter; therefore, the conversion of a value from cm to in should give us a smaller number, not a larger one. When we solve a problem, we always look at the final units. Are they the desired units? We always look at the magnitude of the numerical answer as well. Does it make sense? In this case, the mistake was the form of the conversion factor. It should have been inverted so that the units cancel as follows:

$$31.8 \ \cancel{\text{cm}} \times \frac{1 \text{ in}}{2.54 \ \cancel{\text{cm}}} = 12.5 \text{ in}$$

We can invert conversion factors because they are equal to 1 and the inverse of 1 is 1. Therefore,

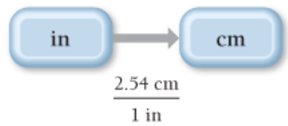
$$\frac{2.54 \text{ cm}}{1 \text{ in}} = 1 = \frac{1 \text{ in}}{2.54 \text{ cm}}$$

Most unit conversion problems take the form:

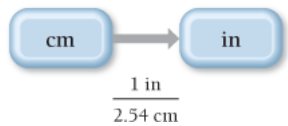
$$\begin{gathered} \text{information given} \times \text{conversion factor (s)} = \text{information sought} \\ \text{given}\ \cancel{\text{unit}} \times \frac{\text{desired unit}}{\text{given}\ \cancel{\text{unit}}} = \text{desired unit} \end{gathered}$$

In this book, we diagram problem solutions using a *conceptual plan*. A conceptual plan is a visual outline that

In this book, we diagram problem solutions using a *conceptual plan*. A conceptual plan is a visual outline that helps us to see the general flow of the problem solution. For unit conversions, the conceptual plan focuses on units and the conversion from one unit to another. The conceptual plan for converting in to cm is:



The conceptual plan for converting the other way, from cm to in, is just the reverse, with the reciprocal conversion factor:



Each arrow in a conceptual plan for a unit conversion has an associated conversion factor with the units of the previous step in the denominator and the units of the following step in the numerator. In Section E.8, we incorporate the idea of a conceptual plan into an overall approach to solving numerical chemical problems.

Conceptual Connection E.4 Unit Conversion

Interactive