3.5.1: Metric and Imperial Unit Conversions

Learning Objectives

- The skill to convert a quantity into various units is important. **Unit conversion** and **dimensional analysis** are also scientific methods. There are many examples in Chemistry, and you will encounter them later.

In the field of science, the metric system is used in performing measurements. The metric system is actually easier to use than the English system, as you will see shortly. The metric system uses prefixes to indicate the magnitude of a measured quantity. The prefix itself gives the conversion factor. You should memorize some of the common prefixes, as you will be using them on a regular basis. Common prefixes are shown below:

Table 3.5.1.1

Prefix	Symbol	Power	Prefix	Symbol	Power
mega-	M	10^6	centi-	c	10^{-2}
kilo-	k	10^3	milli-	m	10^{-3}
hecto-	h	10^2	micro-		10^{-6}
deca-	D	10^1	nano-	n	10^{-9}
deci-	d	10^{-1}	pico-	p	10^{-12}

Metric - Metric Conversions

Suppose you wanted to convert the mass of a $250\ mg$ aspirin tablet to grams. Start with what you know and let the conversion factor units decide how to set up the problem. If a unit to be converted is in the numerator, that unit must be in the denominator of the conversion factor in order for it to cancel.

Notice how the units cancel to give grams. the conversion factor numerator is shown as 1×10^{-3} because on most calculators, it must be entered in this fashion, not as just 10^{-3}. If you don't know how to use the scientific notation on your calculator, try to find out as soon as possible. Look in your calculator's manual, or ask someone who knows. Also, notice how the unit, mg is assigned the value of 1, and the prefix, milli-, is applied to the gram unit. In other words, $1\ mg$ literally means $1 \times 10^{-3}\ g$.

Next, let's try a more involved conversion. Suppose you wanted to convert 250 mg to kg. You may or may not know a direct, one-step conversion. In fact, the better method (foolproof) to do the conversion would be to go to the base unit first, and then to the final unit you want. In other words, convert the milligrams to grams and then go to kilograms:

Example 3.5.1.1

The world's ocean is estimated to contain $1.4 \times 10^9\ \text{km}^3$ of water.

a. What is the volume in liters?
b. What is the weight if the specific density is 1.1?
c. How many moles of water are present if all the weight is due to water?
d. How many moles of H atoms (not H_2) are there in the ocean?
e. How many H atoms are present in the ocean?

Solution

$$
\begin{aligned}
&1.4e9\left(\frac{1000\text{ m}}{1\text{ km}}\right)^3\left(\frac{10\text{ dm}}{1\text{ m}}\right)^3\\
&=1.4e21\text{ dm}^3\left(\frac{1\text{ L}}{1\text{ dm}^3}\right)\\
&=1.5e21\text{ L}\left(\frac{1.1\text{ kg}}{1\text{ L}}\right)\\
&=1.5e21\text{ kg}\left(\frac{1000\text{ g}}{1\text{ kg}}\right)\left(\frac{1\text{ mol}}{18\text{ g}}\right)\\
&=8.3e22\text{ mol H}_2\text{O}\left(\frac{2\text{ mol H atoms}}{1\text{ mol H}_2\text{O}}\right)\\
&=1.7e23\text{ mol H}\left(\frac{6.02e23\text{ atoms}}{1\text{ mol}}\right)\\
&=5.0e46\text{ H atoms}
\end{aligned}
$$

In this example, a quantity has been converted from a unit for volume into other units of volume, weight, amount in moles, and number of atoms. Every factor used for the unit conversion is a unity. The numerator and denominator represent the same quantity in different ways.

Even in this simple example, several concepts such as the quantity in moles, Avogadro's number, and specific density (or specific gravity) have been applied in the conversion. If you have not learned these concepts, you may have difficulty in understanding some of the conversion processes. Identify what you do not know and find out in your text or from a resource.

✔ Example 3.5.1.2

A typical city speed for automobiles is 50 km/hr. Some years ago, most people believed that 10 seconds to dash a 100 meter race was the lowest limit. Which speed is faster, 50 km/hr or 10 m/s?

Solution

For comparison, the two speeds must be expressed in the same unit. Let's convert 50 km/hr to m/s.

$$50\ \frac{\cancel{\text{km}}}{\cancel{\text{hr}}}\left(\frac{1000\text{ m}}{1\ \cancel{\text{km}}}\right)\left(\frac{1\ \cancel{\text{hr}}}{60\ \cancel{\text{min}}}\right)\left(\frac{1\ \cancel{\text{min}}}{60\text{ s}}\right)=13.89\text{ m/s}$$

Thus, 50 km/hr is faster.

Note: a different unit can be selected for the comparison (e.g., miles/hour) but the result will be the same (test this out if interested).

? Exercise 3.5.1.1

The speed of a typhoon is reported to be 100 m/s. What is the speed in km/hr and in miles per hour?

English - Metric Conversions

These conversions are accomplished in the same way as metric - metric conversions. The only difference is the conversion factor used. It would be a good idea to memorize a few conversion factors involving converting mass, volume, length and temperature. Here are a few useful conversion factors.

- length: 2.54 cm = 1 inch (exact)
- mass: 454 g = 1 lb
- volume: 0.946 L = 1 qt
- temperature: $^oC = (^oF - 32)/1.8$

All of the above conversions are to three significant figures, except length, which is an exact number. As before, let the units help you set up the conversion.

Suppose you wanted to convert mass of my $23\ lb$ cat to kilograms. One can quickly see that this conversion is not achieved in one step. The pound units will be converted to grams, and then from grams to kilograms. Let the units help you set up the problem:

$$\frac{23\ lb}{1} \times \frac{454\ g}{1\ lb} \times \frac{1\ kg}{1 \times 10^3\ g} = 10\ kg$$

Let's try a conversion which looks "intimidating", but actually uses the same basic concepts we have already examined. Suppose you wish to convert pressure of 14 lb/in^2 to g/cm^2. When setting up the conversion, worry about one unit at a time, for example, convert the pound units to gram units, first:

Next, convert in^2 to cm^2. Set up the conversion without the exponent first, using the conversion factor, 1 in = 2.54 cm. Since we need in^2 and cm^2, raise everything to the second power: 

Notice how the units cancel to the units sought. Always check your units because they indicate whether or not the problem has been set up correctly.

Example 3.5.1.2: Convert Quantities into SI units

Mr. Smart is ready for a T-bone steak. He went to market A and found the price to be 4.99 dollars per kilograms. He drove out of town to a roadside market, which sells at 2.29 per pound. Which price is better for Mr. Smart?

Solution

To help Mr. Smart, we have to know that 1.0 kg is equivalent to 2.206531 lb or 1 lb = 453.2 g. By the way, are these the same?

$$4.99\ \frac{\$}{\cancel{\text{kg}}}\left(\frac{1\ \cancel{\text{kg}}}{2.206532\ \text{lb}}\right) = 2.26468\ \frac{\$}{\text{lb}}$$

Of course, with the money system in Canada, there is no point quoting the price as detailed as it is given above. This brings about the significant digit issue, and the quantization. The price is therefore 2.26 $/lb, better for Mr. Smart than the price of 2.29 $/lb.

Exercises

1. 1.2e-4 kg

   Skill -
   Converting a quantity into SI units.

2. $(70 - 32) \times \frac{5}{9}\ ^\circ\text{C}$

   Skill -
   To convert temperature from one scale to another scale.

3. The price is Cdn$0.60 / L

   Skill -
   Converting two quantities.

4. Canada at Cdn$0.55 / L

   Skill -
   Determine the costs per unit common volume.

5. **A marathon race covers a distance of 26 miles and 385 yards. If 1.0 mile = 5280 ft, 1 ft = 12 in, and 1 in = 2.54 cm, express 26 miles in m.**

   6486 m

Skill -
Convert quantities into SI units.

Contributors and Attributions

- Chung (Peter) Chieh (Professor Emeritus, Chemistry @ University of Waterloo)
- Template:ContribLiini
