

MATHEMATICAL CONVERSIONS IN CHEMISTRY

In science it is often useful to perform conversions from one type of label to another, for example, changing gallons to liters, meters to feet, pounds to grams, milliliters to liters, kilometers to meters, centigrams to grams, and many others. By using the correct labels (grams, meters, liters, miles, gallons, pounds, etc.) these individual conversion factors will be equal to one when they stand alone and are divided out. For example, we know that 1000 milliliters (abbreviated ml) equals 1 liter (abbreviated L). Therefore, if we write $1000 \text{ ml} / 1 \text{ L}$ our answer will be equal to one. Similarly, if we write $1 \text{ L} / 1000 \text{ ml}$ the answer also equals 1, since 1 L equals 1000 milliliters.

These labels are commonly called units and provide us with descriptions of what we are working with. When we use the labels correctly in mathematical problems, we can change from one type of unit to another with relative ease and arrive at the correct numerical values. (This is why it is so important to learn the Greek prefixes and their corresponding numerical and decimal values. See SLAC Natural Science Aid #5.) A conversion factor then, is the step in a mathematical equation that allows us to change from one unit to another.

Let's look at two problems using both of the conversions factors in the first paragraph:

Ex. 1) How many liters are in 460 ml of saline solution?

$$\text{Ans. } 460 \text{ ml} \times \frac{1.00 \text{ L}}{1000 \text{ ml}} = 0.460 \text{ L saline solution}$$

Ex. 2) How many milliliters of saline solution are in 0.460 L?

$$\text{Ans. } .460 \text{ L} \times \frac{1000 \text{ ml}}{1.00 \text{ L}} = 460 \text{ ml saline solution}$$

After looking at our two examples, you may wonder that if the conversion factors are equal to one, how the answers can be anything other than the original number. We all know that any number multiplied by one is that number. Let's look at the steps involved:

Ex. 1) $\frac{460 \text{ ml}}{1} \times \frac{1.00 \text{ L}}{1000 \text{ ml}} = ?$ The first step is to divide the ml labels or units. Note that $A / A = 1$, therefore, $\text{ml} / \text{ml} = 1$

$\frac{460 \cancel{\text{ml}}}{1} \times \frac{1.00 \text{ L}}{1000 \cancel{\text{ml}}} = ?$ Since this is true we have eliminated the ml units and are left with the L units.

$\frac{460 (1)}{1} \times \frac{1.00 \text{ L}}{1000 (1)} = ?$ Now the problem is one of multiplication.

$\frac{460}{1} \times \frac{1.00 \text{ L}}{1000} = \frac{460 \text{ L}}{1000}$ By multiplying straight across the result becomes a simple division problem.

$\frac{460 \text{ L}}{1000} = .460 \text{ L}$ After performing the remaining division problem you have the answer.

Notice that in the original problem we are asked to find out how many liters are equal to 460 ml of solution. This gives you clues as to how to set up the equation. The problem gives you 460 ml and asks for the answer in liters. To change from milliliters to liters we must set up the problem so that liters are the unit we are left with. We set the equation up as fractions on both sides of the multiplication sign and use the conversion factor with ml units as the denominator. By multiplying 460 ml by 1.00 L / 1000 ml we are able to change ml to equal 1 so that 1 times 460 is 460 and 1 times 1000 is 1000. This allows us to drop the ml units and leaves us with the L units, which is what the original question asked us for.

In the second example we are asked to change liters to milliliters. By setting up the equation to multiply the .460 L by the conversion factor 1000 ml / 1.00 L we can change the L units to 1 and leave the ml units, which is what we need.

Ex. 2) $\frac{.460 \text{ L}}{1} \times \frac{1000 \text{ ml}}{1 \text{ L}} = ?$ The first step is to arrange the equation as a multiplication problem with two fractions.

$\frac{.460 \cancel{\text{L}}}{1} \times \frac{1000 \text{ ml}}{1 \cancel{\text{L}}} = ?$ Next, we cross out the L units to leave the ml units.

$\frac{.460 (1)}{1} \times \frac{1000 \text{ ml}}{1 (1)} = ?$ By replacing the L units with 1 we see that only the ml units remain and we simply multiply across.

$\frac{.460}{1} \times \frac{1000 \text{ ml}}{1} = \frac{460 \text{ ml}}{1}$ The answer leaves us with a simple division problem.

$\frac{460 \text{ ml}}{1} = 460 \text{ ml}$ Perform the division and you have the answer complete with the correct units.

Note: Be sure to observe the rules for significant figures and rounding!

In the sample conversion factors from page 1 we showed that 1.00 liter is equal to 1000 milliliters. Another way of stating this is to say .001 liter is equal to 1.00 milliliter. This can be represented in a conversion factor form as: $1.00 \text{ ml} / .001 \text{ L}$ and $.001 \text{ L} / 1.00 \text{ ml}$

$$\frac{1.00 \text{ ml}}{.001 \text{ L}} \quad \text{and} \quad \frac{.001 \text{ L}}{1.00 \text{ ml}}$$

Both of these conversion factors will also equal 1 when they stand alone and the division performed. We can use these the same way we used the first two conversion factors:

$$\begin{array}{l} \frac{460 \text{ ml}}{1} \times \frac{.001 \text{ L}}{1.00 \text{ ml}} = ? \\ \frac{460 \cancel{\text{ml}}}{1} \times \frac{.001 \text{ L}}{1.00 \cancel{\text{ml}}} = ? \\ \frac{460 (1)}{1} \times \frac{.001 \text{ L}}{1.00 (1)} = ? \\ \frac{460}{1} \times \frac{.001 \text{ L}}{1.00} = \frac{.460 \text{ L}}{1.00} \\ \frac{.460 \text{ L}}{1.00} = .460 \text{ L} \end{array} \quad \begin{array}{l} \frac{.460 \text{ L}}{1} \times \frac{1.00 \text{ ml}}{.001 \text{ L}} = ? \\ \frac{.460 \cancel{\text{L}}}{1} \times \frac{1.00 \text{ ml}}{.001 \cancel{\text{L}}} = ? \\ \frac{.460 (1)}{1} \times \frac{1.00 \text{ ml}}{.001 (1)} = ? \\ \frac{.460}{1} \times \frac{1.00 \text{ ml}}{.001} = \frac{.460 \text{ ml}}{.001} \\ \frac{.460 \text{ ml}}{.001} = 460 \text{ ml} \end{array}$$

You may find that your textbook has conversion factors printed inside its front or back covers. If your professor does not require you to use the text, here are some of the more common ones used:

Mass & Weight	Length	Volume
1 kilogram = 1000 grams	1 inch = 2.54 centimeters	1 liter = 0.001 cubic meters
1 gram = 1000 milligrams	1 meter = 100 centimeters	1 liter = 1000 cm ³
1000 grams = 2.205 pounds	100 centimeters = 39.37 inches	1000 cm ³ = 1000 ml
1 pound = 453.59 grams	1 kilometer = 1000 meters	1 liter = 1.056 quarts
1 gram = 6.02 x 10 ²³ amu	1 kilometer = 0.6215 miles	1 quart = 0.9463 liters
1 ton = 2000 pounds	1 mile = 1.609 kilometers	1 milliliter = 0.001 liter

Pressure	Temperature	Energy
1 atmosphere = 760 torr	0 K = -273.15° C	1 calorie = 4.184 joules
1 atmosphere = 760 mm Hg	? K = °C + 273.15°	1 joule = 0.23901 calories
1 atmosphere = 14.70 lbs/in ²	? °F = 1.8(°C) + 32°	1 e ⁻ volt = 1.6022 x 10 ⁻¹⁹ joules
1 torr = 1 mm Hg	? °C = (°F - 32°)/1.8	1 e ⁻ volt = 96.487 kJ/mol

Some problems may require the use of more than one conversion factor in order to solve it.

Ex.) Express 5.67 yards as centimeters.

Notice that the equation is set up to reduce yards to feet, feet to inches and lastly, inches to centimeters.

$$5.67 \text{ yards} \times \frac{3 \text{ feet}}{1 \text{ yard}} \times \frac{12 \text{ inches}}{1 \text{ foot}} \times \frac{2.54 \text{ cm}}{1 \text{ inch}} = ?$$

Eliminating the units leaves us with only the unit we need and changes the rest to 1's, which do not affect our equation

$$5.67 \text{ yards} \times \frac{3 \text{ feet}}{1 \text{ yard}} \times \frac{12 \text{ inches}}{1 \text{ foot}} \times \frac{2.54 \text{ cm}}{1 \text{ inch}} = ?$$

Now that we have eliminated the units we can perform the math.

$$5.67 (1) \times \frac{3 (1)}{1 (1)} \times \frac{12 (1)}{1 (1)} \times \frac{2.54 \text{ cm}}{1 (1)} = ?$$

$$5.67 \times 3 \times 12 \times 2.54 = 518 \text{ cm}$$

In this example it was necessary to change yards to feet, feet to inches and inches to centimeters. To do this you had to know that this series of changes needed to occur before you could reach the units of centimeters. As the student you will need to train yourself to recognize what changes are required for each example when performing conversions.

Although these examples are simple to perform, they demonstrate the procedures and processes you will need to do conversions. Using practice problems from the text or examples furnished by your professor will help you to become familiar with many types of conversions and give you the knowledge and self-confidence to handle any problem encountered, especially at test time. Remember that repetition is the key to understanding and mastering chemistry or any other course. Regular practice will help you gain this understanding.

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