Metric System

Many properties of matter are quantitative; that is, they are associated with numbers. When a number represents a measured quantity, the unit of that quantity must always be specified. To say that the length of a pencil is 17.5 is meaningless; however, saying it is 17.5 cm specifies the length. The units used for scientific measurements are those of the **metric system**.

The metric system was developed in France during the late 1700s and is the most common form of measurement in the world. There are a few countries, The United States of America, that do not follow the metric system; we use the English system. Over the years the use of the metric system has become more common; just look at a can of soda, there are indications of the metric system.

Can of Soda showing both English (oz) & Metric (mL) units

Metric Prefixes

Conversions between metric system units are straightforward because the system is based on powers of ten. For example, meters, centimeters, and millimeters are all metric units of length. There are 10 millimeters in 1 centimeter and 100 centimeters in 1 meter. **Metric prefixes** are used to distinguish between units of different size. These prefixes all derive from either Latin or Greek terms.

Prefix	Symbol	Multiplier	
exa	E	10^{18}	1,000,000,000,000,000,000
peta	P	10^{15}	1,000,000,000,000,000
tera	T	10^{12}	1,000,000,000,000
giga	G	10^{9}	1,000,000,000
mega	M	10^{6}	1,000,000
kilo	k	10^{3}	1,000
hecto	h	10^{2}	100
deka	da	10^{1}	10
deci	d	10^{-1}	0.1
centi	c	10^{-2}	0.01
milli	m	10^{-3}	0.001
micro	μ	10^{-6}	0.000,001
nano	n	10^{-9}	0.000,000,001
pico micro micro	p $\mu\mu$	10^{-12}	0.000,000,000,001
femto	f	10^{-15}	0.000,000,000,000,001
atto	a	10^{-18}	0.000,000,000,000,000,001

Prefix	Symbol	Meaning	
kilo-	k	1000	thousand
hecto-	h	100	hundred
deka-	da	10	ten
deci-	d	0.1	tenth
centi-	c	0.01	hundredth
milli-	m	0.001	thousandth

The tables above lists the most common metric prefixes and their relationship to the central unit that has no prefix.

There are a couple of odd little practices with the use of metric abbreviations. Most abbreviations are lower-case. We use “m” for meter and not “M”. However, when it comes to volume, the base unit “liter” is abbreviated as “L” and not “l”. So we would write 3.5 milliliters as 3.5 mL.

As a practical matter, whenever possible you should express the units in a small and manageable number. If you are measuring the weight of a material that weighs 6.5 kg, this is easier than saying it weighs 6500 g or 0.65 dag. All three are correct, but the kg units in this case make for a small and easily managed number. However, if a specific problem needs grams instead of kilograms, go with the grams for consistency.

Metric System

Converting (Dimensional Analysis)

How can a number of track laps be converted to a distance in meters?
You are training for a 10-kilometer run by doing laps on a 400-meter track. You ask yourself "How many times do I need to run around this track in order to cover ten kilometers?" (More than you realize & one of the many reasons I don't run). By using dimensional analysis, you can easily determine the number of laps needed to cover the 10 k distance

Conversion Factors
Many quantities can be expressed in several different ways. The English of system measurement of 4 cups is also equal to 2 pints, 1 quart, and 0.25 of a gallon.

4 cups = 2 pints or 1 quart or 0.25 gallon

Notice that the numerical component of each quantity is different, while the actual amount of material that it represents is the same. That is because the units are different. We can establish the same set of equalities for the metric system:

1 meter = 10 decimeters or 100 centimeters or 1000 millimeters

The metric system's use of powers of 10 for all conversions makes this quite simple.

Whenever two quantities are equal, a ratio can be written that is numerically equal to 1. Using the metric examples above:

$$\frac{1\text{m}}{100\text{cm}} = \frac{100\text{cm}}{1000\text{mm}} = \frac{1\text{m}}{1\text{m}} = 1$$

The 1 m/100 cm is called a **conversion factor**. A conversion factor is a ratio of equivalent measurements. Because both 1 m and 100 cm represent the exact same length, the value of the conversion factor is 1. The conversion factor is read as "1 meter per 100 centimeters". Other conversion factors from the cup measurement example can be:

$$\frac{4\text{ cups}}{2\text{ pints}} = \frac{2\text{ pints}}{1\text{ quart}} = \frac{1\text{ quart}}{\frac{1}{4}\text{ gallon}} = 1$$

Since the numerator and denominator represent equal quantities in each case, all are valid conversion factors.

Scientific Dimensional Analysis

Conversion factors are used in solving problems in which a certain measurement must be expressed with different units. When a given measurement is multiplied by an appropriate conversion factor, the numerical value changes, but the actual size of the quantity measured remains the same. **Dimensional analysis** is a technique that uses the units (dimensions) of the measurement in order to correctly solve problems. Dimensional analysis is best illustrated with an example.

Metric System

Set-Up

unit looking for = $\frac{\text{Given}}{1} \times \frac{\text{Unknown}}{\text{Conversion factor}} =$

The unit you are looking for **MUST** match the unit for your unknown. The unit for your given **MUST** match the unit on the conversion factor

Sample Problem 1:

How many seconds are in a day?

Step 1: List the known quantities and plan the problem.

Known
- 1 day = 24 hours
- 1 hour = 60 minutes
- 1 minute = 60 seconds

Unknown
- 1 day =? seconds

The known quantities above represent the conversion factors that we will use. The first conversion factor will have day in the denominator so that the "day" unit will cancel. The second conversion factor will then have hours in the denominator, while the third conversion factor will have minutes in the denominator. As a result, the unit of the last numerator will be seconds, and that will be the units for the answer.

Step 2: Calculate

$$\# \text{ secs} = 1 \text{ day} \times \frac{24 \text{ hours}}{1 \text{ day}} \times \frac{60 \text{ min}}{1 \text{ hour}} \times \frac{60 \text{ sec}}{1 \text{ min}} = 86{,}400 \text{ sec}$$

Applying the first conversion factor, the "day" unit cancels and 1 x 24 = 24. Applying the second conversion factor, the "hour" unit cancels and 24 x 60 = 1440. Applying the third conversion factor, the "min" unit cancels and 1440 x 60 = 86,400. The unit that remains is "s" for seconds.

Step 3: Think about your result.

Seconds is a much smaller unit of time than a day, so it makes sense that there are a very large number of seconds in one day.

Metric Unit Conversions

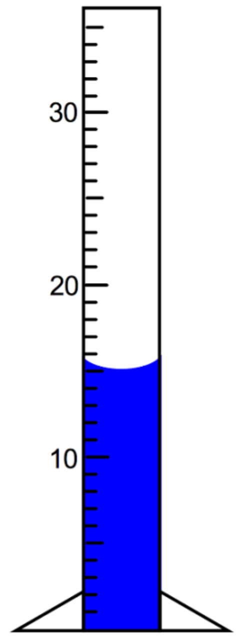
The metric system's many prefixes allow quantities to be expressed in many different units. Dimensional analysis is useful to convert from one metric system unit to another.

Metric System

Sample Problem 2:

A particular experiment requires 120 mL of a solution. The teacher knows that he will need to make enough solution for 40 experiments to be performed throughout the day.

How many liters of solution should he prepare?



Step 1: List the known quantities and plan the problem.

Known

- 1 experiment requires 120 mL
- 1 L = 1000 mL

Unknown

- L of solution for 40 experiment

Since each experiment requires 120 ml of solution and the teacher needs to prepare enough for 40 experiments, multiply 120 by 40 to get 4800 mL of solution needed. Now you must convert ml to L by using a conversion factor.

Step 2: Calculate

$$\# \text{ L} = 4800 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 4.8 \text{ L}$$

Note that conversion factor is arranged so that the mL unit is in the denominator and thus cancels out, leaving L as the remaining unit in the answer.

Step 3: Think about your result.

A liter is much larger than a milliliter, so it makes sense that the number of liters required is less than the number of milliliters.

Two-Step Metric Unit Conversions

Some metric conversion problems are most easily solved by breaking them down into more than one step. When both the given unit and the desired unit have prefixes, one can first convert to the simple (un-prefixed) unit, followed by a conversion to the desired unit. An example will illustrate this method.

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Sample Problem 3: Two-Step Metric Conversion

Convert 4.3 km to cm.

Step 1: List the known quantities and plan the problem.

Known
- 1 m = 100 cm
- 1 km = 1000 m

Unknown
- 4.3 cm =? km

You may need to consult a table for the multiplication factor represented by each metric prefix. First convert cm to m, followed by a conversion of m to km.

Step 2: Calculate

$$\text{\# of cm} = 4.3\text{ km} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{100\text{ cm}}{1\text{ m}} = 430{,}000\text{ cm}$$

Each conversion factor is written so that unit of the denominator cancels with the unit of the numerator of the previous factor.

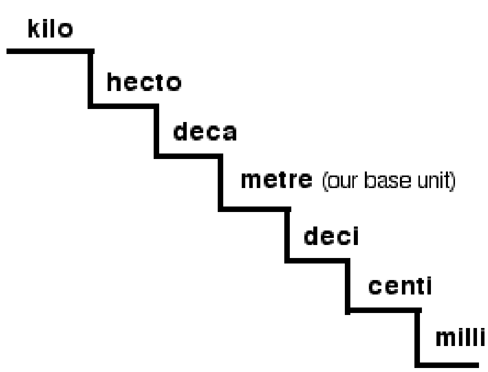
Step 3: Think about your result.
A centimeter is a smaller unit of length than a kilometer, so the answer in centimeters is larger than the number of kilometers given.

The Magic Sentence

There are many tools that can be used to make your life in chemistry easier; one is the magic sentence to learn the metric prefixes and their values. And it goes like this:

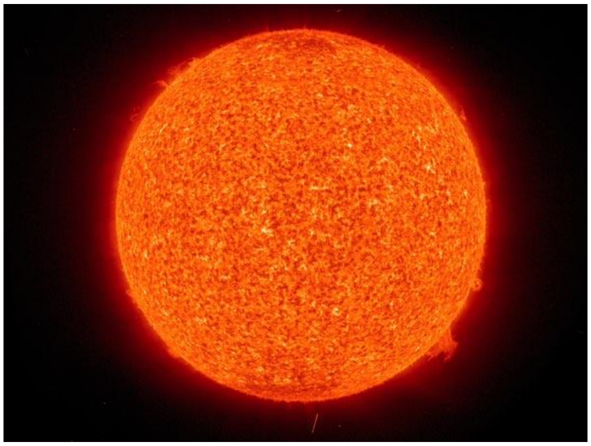
King Hector Died Monday Drinking Chocolate Milk

King *(kilo)* **Hector** *(hector)* **Died** *(deca/deka)* **Monday** *(meter/gram/liter)*
Drinking *(deci)* **Chocolate** *(centi)* **Milk** *(milli)*



Scientific Notation

How far is the Sun from Earth?



Astronomers are used to really big numbers. While the moon is only 406,697 km from earth at its maximum distance, the sun is much further away (150 million km). Proxima Centauri, the star nearest the earth, is 39, 900, 000, 000, 000 km away and we have just started on long distances. On the other end of the scale, some biologists deal with very small numbers: a typical fungus could be as small as 30 µmeters (0.000030 meters) in length and a virus might only be 0.03 µmeters (0.00000003 meters) long.

Scientific Notation

Scientific notation is a way to express numbers as the product of two numbers: a coefficient and the number 10 raised to a power. It is a very useful tool for working with numbers that are either very large or very small. As an example, the distance from Earth to the Sun is about 150,000,000,000 meters –a very large distance indeed. In scientific notation, the distance is written as 1.5×10^{11} m. The coefficient is the 1.5 and must be a number greater than or equal to 1 and less than 10. The power of 10, or exponent, is 11 because you would have to multiply 1.5 by 10^{11} to get the correct number. Scientific notation is sometimes referred to as exponential notation.

When working with small numbers, less than zero, we use a negative exponent. So 0.1 meters is 1×10^{-1} meters. Note the use of the **leading zero** (the zero to the left of the decimal point). That digit is there to help you see the decimal point more clearly. The figure 0.01 is less likely to be misunderstood than .01 where you may not see the decimal. When working with large numbers, greater than zero, we use a positive exponent. So 10 meters is 1.0×10^{1}.

The exponent represents the number of places the decimal point moves, not the number of zeroes in the number. If you move the decimal place to the left you add to the exponent the same number of places you moved; if you are moving the decimal to the right you subtract from the exponent the same number of places you moved. This is often referred to as LARS, (left – add and right – subtract).

<u>Resources</u>

Video: Crash Course #2 - Unit Conversion & Scientific Notation
https://www.youtube.com/watch?v=hQpQ0hxVNTg&list=PL8dPuuaLjXtPHzzYuWy6fYEaX9mQQ8oGr&index=3

- Watch only up to 7:40 (Unit conversion and scientific notation)