The Metric System

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I. INTRODUCTION

The metric system was devised as a system that would standardize all measurements and facilitate conversions. Although it is somewhat unfamiliar to many Americans, the metric system is arguably easier to understand and use than the American system! Each measurement (i.e., length, mass) has only one base unit (as opposed to the American system of length, which has inches, feet, yards, etc.) and conversions are done using multiples of 10. Due to its ease of use and standardization of units, the various fields of science universally use the Metric system, and *it is therefore vitally important for any student of science to be familiar and comfortable with the metric system.* Incidentally, nearly every country on earth except the United States used the metric system as its primary system of measurement!

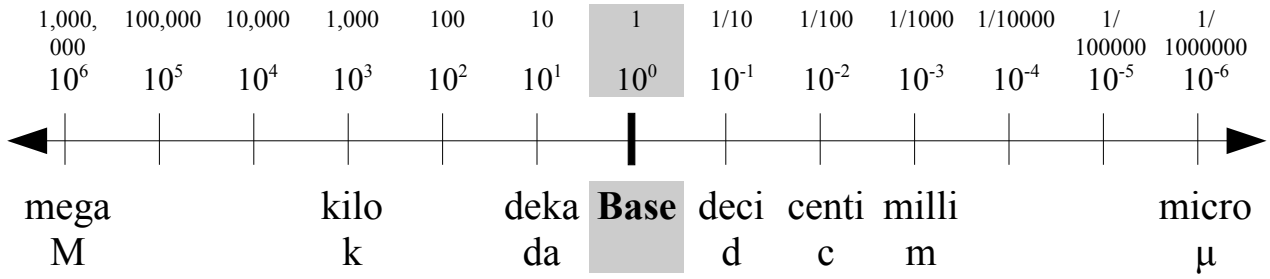
II. BASE UNITS

The metric system provides only one base unit for each type of measurement. Below is a table comparing the base units of length, mass, volume, and temperature for the Metric system versus the American system:

BASE UNITS			
	Metric		American System
Measurement	**Name of Unit**	**Symbol**	**Name of Unit(s)**
Length	meter	m	inch, foot, yard, mile
Mass	gram	g	ounce, pound, ton
Volume	liter	L	ounce, pint, gallon
Temperature	kelvin / Celcius	K, °C	degree Fahrenheit

III. PREFIXES AND POWERS OF TEN

Scientists often need to measure things that are much smaller or much larger than the base unit (for example, the American system uses feet and miles to measure distance). The metric system thus provides a way to multiply or divide the base units by powers of ten. Each power of ten has a name that is a prefix to the base unit. The number line below illustrates this "powers of ten" concept:



To use the number line:

1. Count the number of places on the line from where you are starting to where you are finishing.
2. Move the decimal in the number you are converting that number of places in the same direction.

Example: Convert 0.035 decimeters (dm) to millimeters (mm)

Solution: The prefix “milli” is two places (two powers of ten) to the right of the prefix “deci.” Move the decimal two places to the right.

Answer: 0.035 dm = 3.5 mm

Below is a table of the more common powers of ten and prefixes used in the metric system:

Metric System Prefixes						
	Prefix	**Abbrev.**	**Know?**	**Power of ten**	**Decimal**	**Examples**
Smaller than Base	nano-	n	yes	10^{-9} (one-billionth)	0.000000001	nanometer (nm)
	micro-	μ		10^{-6} (one-millionth)	0.000001	microsecond (μs)
	milli-	m	yes	10^{-3} (one-thousandth)	0.001	millimeter (mm) milliliter (mL)
	centi-	c	yes	10^{-2} (one hundredth)	0.01	centimeter (cm)
	deci-	d		10^{-1}	0.1	deciliter (dL) decibel (dB)
base unit						
Larger than Base	Deca-	dK		10^{1}	10	not widely used
	kilo-	k	yes	10^{3}	1,000	kilogram (kg) kilometer (km)
	Mega-	M		10^{6}	1,000,000	Megawatts (MW) Megabyte (MB)
	Giga-	G		10^{9}	1,000,000,000	Gigawatts (GW)

Knowing the prefixes and the powers of ten associated with them allows you to quickly convert between units. You should become familiar with all of these prefixes, and *you MUST know the four (nano-, milli-, centi-, kilo-) noted in the table*.

To use the prefixes:

- For units larger than the base, use the formula: 1 prefix-unit = power-of-ten base units
  Examples
  1 kilometer = 10^3 meters = 1000 meters (1 km = 1000 m)
  1 Megabyte = 10^6 bytes = 1,000,000 bytes (1 MB = 1,000,000 B)

- For units smaller than the base, use the formula: 1 base unit = inverse power-of-ten prefix-unit
  Examples
  1 liter = 10^3 milliliters = 1000 milliliters (1 L = 1000 mL)
  1 gram = 10^2 centigrams = 100 centigrams (1 g = 100 cg)

Practice (*answers are at the end of the worksheet*)

1. Convert 2.1 grams to milligrams
2. Convert 30.4 microliters to liters
3. What is the symbol for the unit millimeter?
4. How many grams are in one kilogram?
5. How many nanometers are in one meter?

IV ESTIMATING AND USING METRIC UNITS

If I tell you I am 6 feet, 2 inches tall and weigh 220 pounds, you know approximately how large I am simply because you are familiar with these units. However, if I tell you I am 1.9 meters tall and weigh100 kilograms, you are unsure how large I am only because you are not familiar with the units (incidentally, 1.9 m and 100 kg is the same as 6 feet 2 inches and 220 pounds). The best way to become familiar with the metric system is to use it, and the best way to begin is to understand the approximate sizes of the various units. To help you get started, below are some conversions between common American system and Metric system units.

COMMON METRIC UNITS AND AMERICAN EQUIVALENTS		
Length		
American Unit	**Metric Unit**	**Conversion**
Fractions of an inch	millimeter (mm)	1 inch = 25.4 mm
Inch	centimeter (cm)	1 inch = 2.54 cm
Foot / Yard	meter (m)	3 ft = 1 y = 0.914 m (1.1 yd = 1 m)
Mile	kilometer (km)	1 mile = 1.61 km

Mass		
American Unit	**Metric Unit**	**Conversion**
Fractions of an ounce	milligram (mg)	1 oz = 28,350 mg
ounce	gram (g)	1 oz = 28.35 g
pound	kilogram (kg)	1 lb = 0.454 kg (2.2 lb = 1 kg)

Volume		
American Unit	**Metric Unit**	**Conversion**
fluid ounce	milliliter (mL)	1 fl oz = 29.6 mL
pint	milliliter (mL)	1 pint = 473 mL
quart	liter (L)	1 quart = 0.94625 L
gallon	liter (L)	1 gallon = 3.785 L

Examples: For each of the following, what metric unit would be best to use to measure:

1. the distance from Concord to Boston? (km)
2. the volume of soda in a small bottle? (mL)
3. the mass of apples bought in a store? (kg)
4. the width of a sheet of paper? (cm)
5. the thickness of a sheet of paper? (mm)
6. the mass of a few pieces of sand? (mg)

Practice (*answers are at the end of the worksheet*)

For each of the following, what metric unit would be best to use to measure:

6. The volume of a raindrop?
7. The volume of water in an aquarium?
8. The height of an ant?
9. The height of a building?
10. The mass of a small steak?
11. The mass of a cow?

V. COMBINED UNITS

A variety of quantities are measured in units that are a combination of other units. A very common example is speed (or velocity), which is a distance per a time (i.e. miles per hour). You should become familiar with these combined units and the quantities they are used to measure:

COMBINED UNITS		
Quantity	**What is measured?**	**Metric Units**
Speed / Velocity	distance per time	$\frac{m}{s}$, $\frac{km}{hr}$
Density	mass per volume	$\frac{g}{L}$, $\frac{g}{cm^3}$
Concentration	number of things per volume	$M = \frac{moles}{L}$
Energy	mass, distance, and time	$J = kg\frac{m^2}{s^2}$

* note: Often when a unit is on the bottom of the fraction, it will be written as unit^{-1}. Just remember that $x^{-1} = \frac{1}{x}$ so, for example, $m \cdot s^{-1} = \frac{m}{s}$.

VI.. ANSWERS TO **PRACTICE** QUESTIONS

1. 2,100 milligrams
2. 0.0000304 liters
3. mm
4. $10^3 = 1{,}000$
5. $10^9 = 1{,}000{,}000{,}000$
6. milliliters (mL)
7. liters (L)
8. millimeters (mm)
9. meters (m)
10. grams (g)
11. kilograms (kg)

MORE HELP

There are a number of useful sites on the worldwide web that can help you learn the metric system. A few useful sites are:
http://www.austincc.edu/nrgtutor/Units/untut200.htm
http://www.learnchem.net/tutorials/mathb.shtml
http://www.tfhrc.gov/qkref/convtabl.htm

