

## LAB 2 – The Metric System

### Objectives

1. Employ the metric system of measurement to measure length, mass, volume, concentration and temperature.
2. Convert decimal numbers to scientific notation and vice versa.
3. Convert units within the metric system.

### *Introduction*

How many teaspoons are in a cup? How many inches are in a mile? How many ounces are in a pound? If you know the answers to all of these questions, you are one of the few people in the world who can completely understand the **English System of Measurement**. The United States is one of the few countries that still uses the English System of Measurement (not even England uses it!).

The English System was developed over many centuries by the kings and noblemen of the Roman and British empires. In fact, the foot was literally the length of the actual foot of an English king, which happens to be 12 inches (each inch being the length of three seeds of barley). The following are units used in the English System today:

<u>LENGTH</u>	<b>1 mile</b> = 8 furlongs = 1,760 yards = 5,280 feet = 63,360 inches
<u>VOLUME</u>	<b>1 gallon</b> = 4 quarts = 8 pints = 16 cups = 128 ounces = 256 tablespoons
<u>WEIGHT</u>	<b>1 ton</b> = 2,000 pounds = 32,000 ounces = $2.24 \times 10^8$ grains
<u>TEMPERATURE</u>	<b>Fahrenheit</b> - Water freezes at <b>32° F</b> and boils at <b>212° F</b>

Did you know how to do these conversions already? Probably not. Very few scientists, much less everyday citizens, can remember how to convert units within this system, even though they've used it their entire lives. Basically, the English system is so difficult to work with that most countries in the world, and all scientists, have adopted a much easier system called the **Metric System of Measurement**.

The metric system of measurement has been adopted by most countries in the world and all scientists for two primary reasons: 1) there is a single, basic unit for each type of measurement (meter, liter, gram, °C) and 2) each basic unit can have prefixes that are based on powers of 10 making conversions much easier. Once you learn the basic units and the multiples of 10 associated with each prefix, you will have the entire system mastered.

## Basic Units of the Metric System

LENGTH – The basic unit of length in the metric system is the **meter**, abbreviated by the single letter **m**. A meter was originally calculated to be one ten-millionth of the distance from the north pole to the equator, and is ~3 inches longer than a yard.

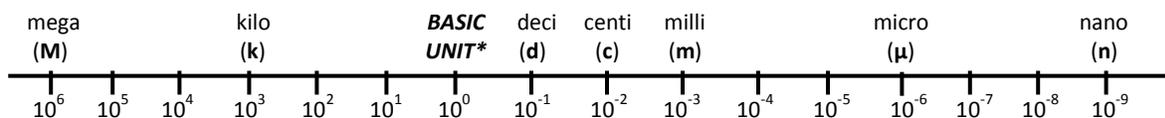
VOLUME – The basic unit of volume in the metric system is the **liter**, abbreviated by the single letter **l** or **L**. A liter is defined as the volume of a box that is 1/10 of a meter on each side. A liter is just a little bit larger than a quart (1 liter = 1.057 quarts)

WEIGHT – The basic unit of mass in the metric system is the **gram**, abbreviated by the single letter **g**. A gram is defined as the weight of a volume of pure water that is 1/1000<sup>th</sup> of a liter. [NOTE: 1/1000<sup>th</sup> of a liter = 1 milliliter = 1 cubic centimeter = 1 cm<sup>3</sup> = 1 cc].

TEMPERATURE – The basic unit of temperature in the metric system is a degree Celsius (°C). Water freezes at 0°C and boils at 100°C.

## Prefixes used in the Metric System

Unlike the English System, the metric system is based on the meter (**m**), liter (**L** or **l**) and gram (**g**), and several prefixes that denote various multiples of these units. Specifically, each basic unit can be modified with a prefix indicating a particular “multiple of 10” of that unit. Here are the more commonly used prefixes and what they mean:



(\*BASIC UNIT = grams, meters or liters without any metric prefix)

Mega ( <b>M</b> )	=	10 <sup>6</sup>	=	1,000,000
kilo ( <b>k</b> )	=	10 <sup>3</sup>	=	1,000
no prefix	=	10 <sup>0</sup>	=	1
deci ( <b>d</b> )	=	10 <sup>-1</sup>	=	0.1 or 1/10 (i.e., <b>tenths</b> of a unit)
centi ( <b>c</b> )	=	10 <sup>-2</sup>	=	0.01 or 1/100 (i.e., <b>hundredths</b> of a unit)
milli ( <b>m</b> )	=	10 <sup>-3</sup>	=	0.001 or 1/1,000 (i.e., <b>thousandths</b> of a unit)
micro ( <b>μ</b> )	=	10 <sup>-6</sup>	=	0.000001 or 1/1,000,000 (i.e., <b>millionths</b> of a unit)
nano ( <b>n</b> )	=	10 <sup>-9</sup>	=	0.000000001 or 1/1,000,000,000 (i.e., <b>billionths</b> of a unit)

Here is how simple the metric system is using the basic units and the prefixes:

What is one thousandth of a meter? a **millimeter (mm)**

What is one millionth of a liter? a **microliter (μl)**

What is 1,000 grams? a **kilogram (kg)**

Let us now examine these units more closely by using them to make actual measurements...

## ***Part 1 – Making Measurements in Metric Units***

### **DISTANCE in the Metric System**

In the United States, when we travel by car, distances are measured in miles. For example, from the Mission College to downtown Los Angeles is about 20 miles. In almost every other country, such distances are measured in **kilometers**. One kilometer is exactly 1,000 meters and approximately 0.6 miles. Thus, 1 km is equal to 0.6 miles.

What are some other real-world examples of metric units of length? One **micrometer ( $\mu\text{m}$ )** is  $1/1,000^{\text{th}}$  the size of a millimeter or  $1/1,000,000^{\text{th}}$  of a meter. When you observe a cheek cell under the microscope in a future lab, it is about  $40\ \mu\text{m}$  in diameter. Typical bacteria are about 5-10  $\mu\text{m}$  in diameter.

One **nanometer (nm)** is  $1/1,000^{\text{th}}$  the size of a micrometer or  $1/1,000,000,000^{\text{th}}$  of a meter. Objects this small are far too tiny to observe even in a light microscope. If you line up five water molecules side-by-side, the length would be about 1 nanometer.

To help you become more familiar with metric units of distance, you will now make a variety of actual measurements.

### **Exercise 1A – Measuring distance**

1. Obtain a wooden meter stick. If you look on the back of the meter stick, one meter is approximately 39 inches or about 3 inches longer than one yard (36 inches). Using the meter stick, measure the distance from the front of the lab to the back window the nearest **meter (m)**.
2. Measure the height and width of one doorway in the lab to the nearest **hundredth of a meter** (e.g., 2.53 m).
3. In the previous measurement you will have noticed that a meter is divided into 100 equal units called centimeters. A centimeter is about the width of a small finger. Use the medical weight and height scale in the lab to measure how tall you are to the nearest **centimeter (cm)**.
4. Using the metric ruler at your table, measure the dimensions of a regular piece of notebook paper to the nearest **tenth of a centimeter**.
5. Observe that each centimeter is divided into 10 smaller units called millimeters. A millimeter is about the thickness of a fingernail. Using the metric ruler to measure the diameter of a hole in your piece of notebook paper to the nearest **millimeter (mm)**.
6. On the back counter there are several microscopes showing a protozoan called *Amoeba* magnified 100 times. The **diameter of the field of view** you see in the microscope (i.e., the circular area that you see) is **1.8 mm**. Visually estimate the length of a single amoeba to the nearest **tenth of a millimeter**. For example, if the amoeba length appears to be one third of the diameter of the field of view, then you would estimate  $1.8\ \text{mm} \times 1/3$  which is 0.6 mm.

## WEIGHT in the Metric System

**Mass** is a measure of the amount of matter in an object whereas **weight** refers to the force exerted by gravity upon an object. Thus the mass of an object is a fixed property, regardless of its location, while the weight of an object will vary depending on the force of gravity it is exposed to. For example, the mass of your body is the same whether you are on earth or in outer space. Your weight, however, will be different on the earth vs outer space (where you can be essentially “weightless”). In the following exercise you will use a metric balance and a digital scale like the ones shown below to become familiar with using both types of instrument to determine the weight of various objects in grams.



balance



digital scale

### Exercise 1B – Measuring weight

1. Place an empty 50 ml graduated cylinder on the balance and determine its weight to the nearest **tenth of a gram**. Repeat the measurement on the digital scale at your table. (*Your instructor will demonstrate how to use each instrument.*)
2. Next, fill the graduated cylinder with 50 ml of water from the “water reserve” (1 gallon container of water at your table) and measure the weight of both the cylinder and the water on the balance and digital scale (be sure to “zero” the digital scale before measuring). Subtract the weight of the cylinder to get the weight of the water. When finished, pour the water back into the water reserve.

**NOTE 1:** Make sure the digital scale is not locked (see switch on the underside of the scale).

**NOTE 2:** By definition, **one gram is the weight of exactly 1.0 ml of pure water**, thus 50 ml of water has a weight of 50.0 grams. How far off was your measured weight from the true weight of 50 ml of water?

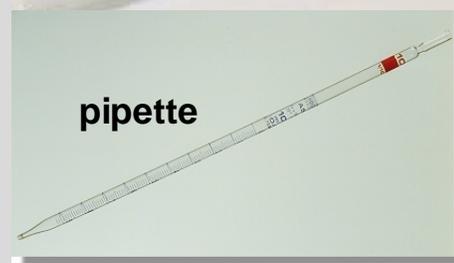
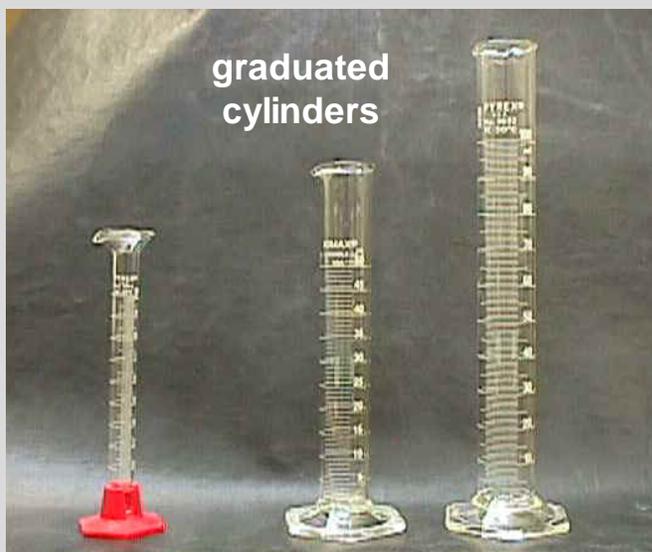
3. Next, measure the weight of a personal item such as your phone or keys to the nearest **tenth of a gram** on the balance and then the digital scale.

## VOLUME in the Metric System

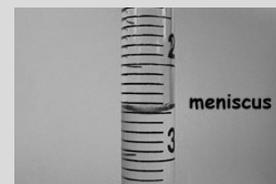
A variety of devices are used to measure volume in the metric system. In the next exercise you will familiarize yourself with measuring volumes greater than 1 ml using beakers, graduated cylinders and various pipettes.

## Exercise 1C – Measuring *volumes larger than 1 ml*

1. Obtain a one **liter (L or l)** beaker. Fill the beaker with one liter of water from the water reserve. To do this, add water until the top level of the water reaches the 1 liter marker on the beaker. Pour the water into a 2 liter soda bottle. Repeat. Once again, fill the beaker with one liter of water. Over the sink, pour the 1 liter of water into the 1 quart container provided. Notice that 1 liter is just a little bit more than 1 quart. In fact, 1 liter = 1.057 quarts. When finished, pour the water back into the water reserve.
2. One way to measure the volume of a fluid in a laboratory is to use a graduated cylinder. Whereas beakers are generally used to *hold* fluids, graduated cylinders are used to accurately *measure* volumes. Obtain a 50 **milliliter (ml)** graduated cylinder. Fill the graduated cylinder with water until the meniscus reaches the 50 ml mark. Add the water to a 1 liter (1,000 ml) beaker. Notice that 50 ml is equal to  $1/20^{\text{th}}$  of a liter. Next, use the graduated cylinder to measure the fluid in the flask labeled "A" to the nearest 0.5 ml. Record this volume on your worksheet.



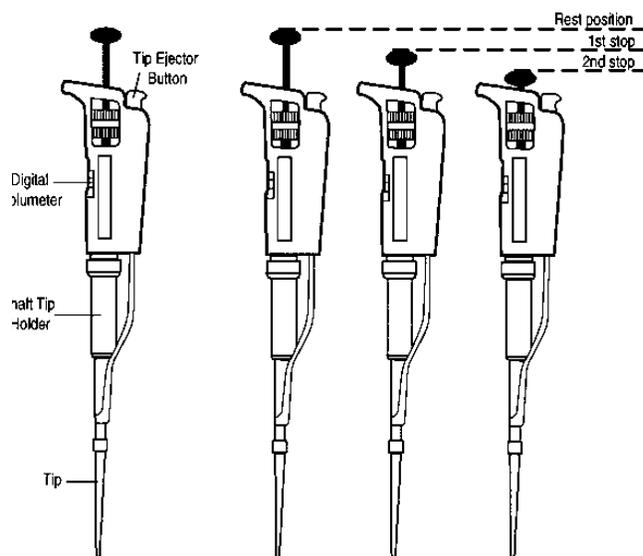
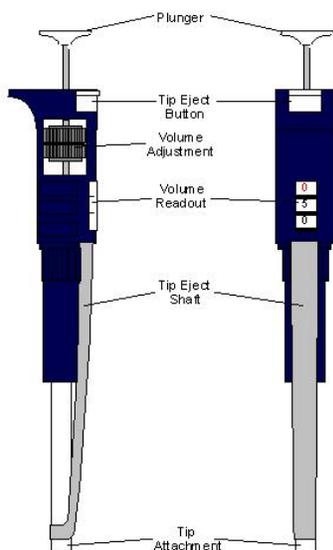
3. Pipettes are used to measure smaller liquid volumes whereas graduated cylinders are used to measure larger volumes. Obtain a 5 ml **glass pipette** and attach it snugly to a **pipette pump**. Using the roller on the pipette pump, gradually suck up some water until the **meniscus** (the base of the curvature at the top of the water column) reaches the 0 ml mark. Measure 5 ml of the water into the sink by moving the roller in the opposite direction. Next, measure the amount of fluid in the test tube labeled B to the nearest 0.1 ml using the 5 ml pipette. Record this volume on your worksheet.
4. Transfer pipettes are commonly used for measuring volumes less than 3 ml and you will frequently use them in future labs. While they are graduated (i.e., contain volume markings), they are not as accurate as a glass pipette. Use the transfer pipette at your table to measure 1 ml of water which you can then dispose of in the sink.



To measure volumes less than 1 ml you will use a **micropipettor** like the one shown below. Micropipettors will allow you to accurately measure volumes at the microliter ( $\mu\text{l}$ ) level. While we don't deal with microliter volumes in everyday life, in the laboratory measurements as little as  $1\ \mu\text{l}$  are used routinely. For this reason micropipettors are essential in any laboratory environment.



You should have two micropipettors at your table, a “P20” which measures from 2-20  $\mu\text{l}$ , and a “P200” which measures from 50-200  $\mu\text{l}$ . Let's first get acquainted with each part of a micropipettor and its corresponding function. Since there are only two micropipettors per table, it would be best if someone reads the next three paragraphs aloud as the micropipettors are passed around your group for each person to see and experience the function of each part:



The end of the micropipettor labeled “**tip attachment**” is where you will attach a disposable plastic tip. The liquid you measure will be contained within the tip and thus will not make contact with the micropipettor itself. When you are finished measuring your liquid, you will discard the tip and use a new tip for the next measurement. This avoids contamination of your sample as well as the micropipettor. The **tip eject button** will move the **tip eject shaft** down to eject the disposable tip.

The **volume readout** shows the number of *microliters* ( $\mu\text{l}$ ) the micropipettor is set to measure. The volume readout is adjusted by turning the **volume adjustment** knob. Each micropipettor has a range of volumes it is designed to measure. ***If you set the micropipettor to a volume outside this range you can damage the instrument's internal mechanism which may destroy its accuracy.*** The P20 and P200 micropipettors you will be using today are designed to measure volumes ranging from 2 to 20  $\mu\text{l}$  and 50 to 200  $\mu\text{l}$ , respectively. Remember, you should ***never*** adjust the volume readout outside the range the micropipettor is designed to measure.

The **plunger** is pressed downward with your thumb and then released to draw liquid into the disposable tip. The measured liquid can then be expelled from the tip by depressing the plunger. If you press down on the plunger you will reach a point of resistance called the “**first stop**” as shown in the illustration. When depressed to the first stop, the plunger will draw in the volume indicated on the volume readout as it is released. To measure 50  $\mu\text{l}$  for example, you will set the volume readout to “050” for the P200, submerge the tip on the end of the micropipettor into the liquid to be measured, and *slowly* release the plunger to its rest position. The liquid can then be expelled from the tip by depressing the plunger to the first stop. If any liquid remains in the tip at this point, the plunger can be depressed beyond the first stop toward the “**second stop**” (see illustration). This will force any remaining liquid out of the tip. *The only time you will concern yourself with the second stop is for this purpose.*

### **Exercise 1D – Measuring volumes less than 1 ml**

*In addition to the P20 and P200 micropipettors, your table should have a rack of disposable micropipettor tips, a small plastic tube of blue liquid, and several empty small plastic tubes in a plastic rack. **Everyone** at your table should practice measuring and transferring the volumes indicated in the exercises below. Before you begin, be sure you are in a comfortable position with everything you will need in front of you or within comfortable reach:*

1. Using the **P200**, transfer **100  $\mu\text{l}$**  of the blue liquid to the tube labeled “100” by following the instructions below:

- adjust the volume of the P200 to 100  $\mu\text{l}$
- place a disposable tip snugly on the end of the micropipettor (tip attachment) by firmly inserting it into a tip in the rack
- open the small tube of blue liquid, depress the plunger to the first stop, immerse the end of the tip into the liquid, and *slowly* release the plunger (*you can hold the tube in your opposite hand while doing this*)
- hold the tube labeled “100” in your opposite hand and insert the tip containing your sample
- *slowly* depress the plunger to the **first stop** to expel the liquid into the tube, **being sure to NOT release the plunger just yet!**

*NOTE: if necessary you can push the plunger toward the second stop to expel any remaining liquid*

- move the tip out of the liquid, and **then** release the plunger (*this is extremely important, you do NOT want to release the plunger before removing the tip from the liquid or else you will pull most of the sample back into the tip!*)
- dispose of your used tip into the small beaker at your table

2. Set the **P20** to “10.0” and transfer **10  $\mu\text{l}$**  of blue liquid to the tube labeled “10”.

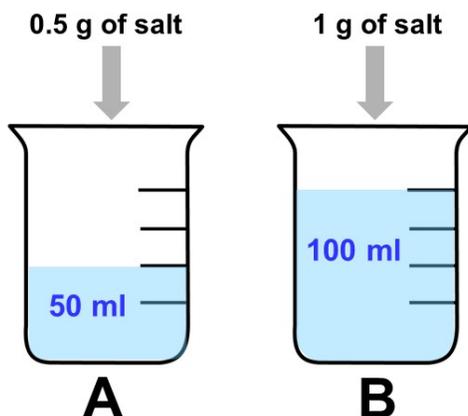
3. Set the **P20** to “02.0” and transfer **2  $\mu\text{l}$**  of blue liquid to the tube labeled “2”.

*NOTE: When finished, please transfer all blue liquid back to the original tube.*

### **CONCENTRATION in the Metric System**

Now that you have experience measuring weight and volume, let’s turn to the concept of **concentration** – **the amount of a substance per unit volume**. In biology, the concept of concentration is most commonly applied to **aqueous solutions** – substances dissolved in water. In an aqueous solution, water is the **solvent** (i.e., the liquid in which something is dissolved) and the substance dissolved in water is the **solute** (e.g., salt or sugar).

To illustrate this let's consider two aqueous solutions in which table salt is the solute:



The concentration of salt in each solution can be calculated by dividing the weight of dissolved salt by the total volume of the solution as shown below:

$$\text{salt concentration in Solution A} = 0.5 \text{ g}/50 \text{ ml} = 0.01 \text{ g/ml}$$

$$\text{salt concentration in Solution B} = 1 \text{ g}/100 \text{ ml} = 0.01 \text{ g/ml}$$

As you can see, each solution has the same concentration of salt despite having different total amounts of salt and different total volumes. This is because the amount of salt per ml in each solution is the same. In these examples the unit of concentration is grams per milliliter (g/ml), however concentration can be expressed using essentially any units of weight and volume. For example, aqueous solutions of DNA in biological research are commonly expressed in ng/ $\mu$ l.

Another common unit of concentration is **percent solution** which by definition is **grams per 100 milliliters**. For example, twenty grams of solute dissolved in a total volume of 100 ml would be a 20% solution. The salt concentrations of solutions A and B above can also be expressed as percent solutions. Solution B is clearly a 1% solution (1 g/100 ml) as is Solution A:

$$\text{Solution A} = 0.5 \text{ g}/50 \text{ ml} = ? \text{ g}/100 \text{ ml} = 1 \text{ g}/100 \text{ ml} = 1\% \text{ solution}$$

To make a percent solution you would do a similar calculation. If you wanted to make 500 ml of a 20% salt solution, for example, you would calculate the amount of salt needed as shown below:

$$20\% \text{ solution} = 20 \text{ g}/100 \text{ ml} = ? \text{ g}/500 \text{ ml} = 100 \text{ g}/500 \text{ ml}$$

### **Exercise 1E – Concentration & percent solutions**

1. Make 30 ml of a 5% salt solution as follows:
  - calculate the amount of salt needed, weigh out the salt and add to a 50 ml conical tube
  - add distilled water up to 30 ml, cap the tube and mix by shaking until the salt is dissolved
2. Answer the questions involving concentration on your worksheet, and be sure to dispose of the salt solution in the sink and rinse the tube with water so it is ready to use for the next class.

## **TEMPERATURE in the Metric System**

Temperature is a measure of the amount of heat a substance contains and can be measured in degrees **Fahrenheit** or degrees **Celsius** (also known as **Centigrade**). The metric unit for temperature is degrees **Celsius** (**°C**), which is based on water freezing at **0° C** and boiling at **100° C**. Notice that this range of temperature is conveniently divided into 100 units. In the Fahrenheit system water freezes at **32° F** and boils at **212° F**, thus dividing the same range of temperature into 180 units.

Here in the United States we are more familiar with temperatures expressed in degrees Fahrenheit, however the scientific community and much of the rest of the world measures temperatures in degrees Celsius. Thus it is especially important here in the United States to be able to convert from one temperature system to the other. There are two simple formulas to do so which are shown below. Instead of simply taking for granted that the formulas will convert temperatures correctly, let's take moment to see how they are derived. In so doing you will not only learn the basis of each formula, but you will never have to remember the formulas since you can derive them yourself!

Recall that for every 100 degrees Celsius there are 180 degrees Fahrenheit. Thus a degree Fahrenheit is smaller than a degree Celsius by a factor of 100/180 or **5/9**. Conversely, a degree Celsius is larger than a degree Fahrenheit by a factor of 180/100 or **9/5**. When converting from Fahrenheit to Celsius or vice versa you must also consider that 0° C is the same temperature as 32° F. Thus the Fahrenheit system has an extra **32 degrees** which must be taken into account. Keeping these facts in mind, let's see how to convert temperatures between the two systems.

### ***Converting Celsius to Fahrenheit***

Since each degree Celsius is equal to 9/5 degrees Fahrenheit, simply multiply the degrees Celsius by 9/5 and then add 32. Note that the extra 32 degrees are added only after you have converted to degrees Fahrenheit, producing the following formula:

$$(9/5 \times ^\circ\text{C}) + 32 = ^\circ\text{F}$$

### ***Converting Fahrenheit to Celsius***

Since each degree Fahrenheit is equal to 5/9 degrees Celsius, simply subtract 32 from the degrees Fahrenheit and then multiply by 5/9. Note that the extra 32 degrees are subtracted while still in degrees Fahrenheit, i.e., *before* you convert to degrees Celsius. This produces the following formula:

$$(^{\circ}\text{F} - 32) \times 5/9 = ^{\circ}\text{C}$$

## **Exercise 1F – Measuring and converting temperature**

3. Use the thermometer at your table to measure the following in degrees Celsius:

- the ambient temperature of the lab
- a bucket of ice water
- a beaker of boiling water

4. Convert the temperatures on your worksheet from Celsius to Fahrenheit or vice versa.



## ***Converting from exponential notation to decimal notation***

To convert from exponential to decimal notation you simply move the decimal a number of places equal to the exponent. If the exponent is negative, the number is less than one and the decimal is moved to the left:

$$1.05 \times 10^{-3} = 0.00105$$

If the exponent is positive, the number is greater than one and the decimal is moved to the right:

$$1.05 \times 10^3 = 1,050$$

### **Exercise 2B – Converting exponential notation to decimal notation**

1. Complete the conversions of exponential numbers to simple numbers on your worksheet.

## ***Converting Units within the Metric System***

### **Method 1:**

Some of you may have learned a more traditional method of converting from one metric unit to another, so let's begin by reviewing how this method works. In a nutshell it involves multiplying the original metric value by a ratio of metric units equal to one that, due to cancellation, leaves you with an equivalent value in the desired units. To illustrate how this works, let's consider the following problem:

$$28 \text{ mg} = \text{ \_\_\_\_\_\_ } \mu\text{g}$$

In this problem you want to convert the units from mg to  $\mu\text{g}$ , so multiply 28 mg by a ratio equal to one that will cancel the mg and leave you with  $\mu\text{g}$ :

$$28 \text{ mg} \times 1000 \mu\text{g}/\text{mg} = \underline{28,000} \mu\text{g}$$

Since 1000  $\mu\text{g}$  equals 1 mg, a ratio of 1000  $\mu\text{g}/\text{mg}$  is equal to one. The key to this method is determining how many of the new units ( $\mu\text{g}$ ) equal one of the original units (mg). Once this is determined simply put the original unit on the bottom (to allow its cancellation) and the equivalent value in the desired units on top.

Let's do one more example to make sure this is clear:

$$3.7 \text{ cm} = \text{ \_\_\_\_\_\_ } \text{ km}$$

$$3.7 \text{ cm} \times 10^{-5} \text{ km}/\text{cm} = \underline{3.7 \times 10^{-5}} \text{ km}$$

If this method works for you, then go ahead and use it. One drawback to this approach, however, is it is easy for students to make mistakes that lead to answers that are way off without realizing it. To avoid this problem we encourage you to consider the next method which forces you to use your common sense and hopefully avoid “way off” answers.

### **Method 2:**

Converting from one metric unit to another is simply a matter of changing a value by the appropriate factor of 10. With decimal numbers that means simply moving the decimal one place for every factor of 10 – to the right to increase the value or to the left to decrease. With exponential numbers you simply increase or decrease the exponent by 1 for every factor of 10. In other words, all you really need to figure out is A) whether the value should increase or decrease and B) by what factor of 10 to do so.

Although this seems fairly straightforward, many students struggle with such conversions and rely on various formulas to do them. This will work just fine, but oftentimes students end up with an answer that is wildly off the mark due to moving a decimal in the wrong direction or changing the exponent in the wrong way. One should immediately realize there is a problem with such errors, however when the process is divorced from intuition and common sense it is easy to make such a mistake and think nothing of it. So instead of focusing on a formula to follow, let’s approach this by appealing to common sense and common experience. Once your common sense has been engaged, converting from one metric unit to another should be easier than it seems.

When dealing with the metric system we usually talk about grams, meters and liters, however the metric system can be just as easily applied to something we are all familiar with and hold dear – money. The basic unit of money in this country is the dollar, with the smallest unit being the penny. We all know that 100 pennies equals a dollar, so a penny is clearly  $1/100^{\text{th}}$  of a dollar, or in metric terms, a **centidollar** ( $10^{-2}$  dollars). We also know that 10 dimes equals 1 dollar, so a dime is actually a **decidollar** ( $10^{-1}$  dollars). And if you’re fortunate enough to have 1000 dollars in the bank, you are the proud owner of a **kilodollar** ( $10^3$  dollars). With this in mind, let’s do some conversions within this system.

If asked, “How many pennies is equal to ten dollars?” you should have little problem figuring this out. Since one dollar is equal to 100 pennies and there are 10 dollars total, it should be clear that 10 dollars is equal to  $100 \times 10$  or 1000 pennies. Now let’s consider the same problem in metric terms:

$$\mathbf{10 \text{ dollars} = \underline{\hspace{2cm}} \text{ centidollars}}$$

Seeing the problem in this form may make the answer less intuitive. Nevertheless it is the same problem to which you can apply the same common sense – there should be 100 times more centidollars (pennies) than dollars. You should also realize that this is true for not only this problem, but for **any** problem involving dollars and centidollars. Let’s now consider the reverse in which you convert pennies (centidollars) to dollars:

$$\mathbf{1483 \text{ centidollars} = \underline{\hspace{2cm}} \text{ dollars}}$$

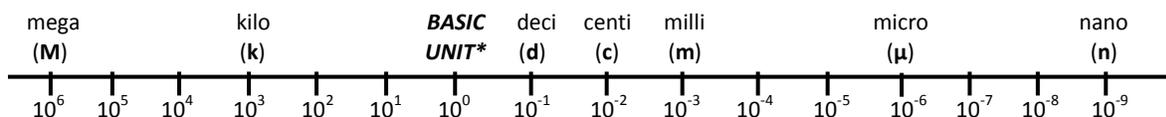
You know the answer immediately, right? The answer is 14.83 dollars since every 100 pennies (centidollars) is equal to one dollar. You intuitively knew to *decrease* 1483 by a factor of 100 to arrive at the correct answer since there should be more of the smaller unit (pennies or centidollars) and less of the larger unit (dollars). This is all there is to metric conversions, realizing if the value should increase or decrease and by what factor of 10 to do so. Hopefully this has shown you that you already know how to do metric conversions intuitively, you just need to think of them in terms that are familiar to you. Let's now try one that's a bit more challenging:

**500 decidollars = \_\_\_\_\_ kilodollars**

In this problem we are actually converting dimes to thousands of dollars. This may take a little more thinking, however you can probably figure out that a decidollar (dime) is 10,000 times smaller than a kilodollar (10 dimes per dollar x 1000 dollars per kilodollar). It should be clear now that 500 decidollars is equal to 10,000 times *less* kilodollars, thus you simply move the decimal 4 places to the left to arrive at the correct answer of 0.05 kilodollars. You can use a calculator if you like, but it really is not necessary since there is essentially no calculating involved.

Next we will do several sample problems involving more traditional metric units to show you how simple and straightforward this can be as long as you are familiar with the metric prefixes which are reproduced for you in the box below. Refer to this as needed and you should have little trouble.

<b>Mega (M)</b>	=	$10^6$	=	<b>1,000,000</b>
<b>kilo (k)</b>	=	$10^3$	=	<b>1,000</b>
<b>no prefix</b>	=	$10^0$	=	<b>1</b>
<b>deci (d)</b>	=	$10^{-1}$	=	<b>0.1</b>
<b>centi (c)</b>	=	$10^{-2}$	=	<b>0.01</b>
<b>milli (m)</b>	=	$10^{-3}$	=	<b>0.001</b>
<b>micro (μ)</b>	=	$10^{-6}$	=	<b>0.000001</b>
<b>nano (n)</b>	=	$10^{-9}$	=	<b>0.000000001</b>



(\*BASIC UNIT = grams, meters or liters without any metric prefix)

Before we do a few more sample problems, it is important to realize that this is really a two step process in which you:

- 1. Identify whether your value should increase or decrease.**
- 2. Determine the factor of 10 by which the value should change.**

Once you have completed these two steps it's simply a matter of adjusting your decimal or exponent accordingly.

As you realize from doing the problems involving money, there should always be a larger number of smaller units (e.g., pennies) and a smaller number of larger units (e.g., dollars). So the first step is easy. Let's now do a problem similar to the ones you'll find on your worksheet:

$$28 \text{ mg} = \underline{\hspace{2cm}} \mu\text{g}$$

You are converting larger mg (0.001 g) to smaller  $\mu\text{g}$  (0.000001 g), so clearly the value of 28 should *increase*. Since a  $\mu\text{g}$  is 1000 times smaller than a mg ( $0.001/0.000001 = 1000$ ), the value of 28 should increase by a factor of 1000. Therefore:

$$28 \text{ mg} = 28 \times 1000 \mu\text{g} = \underline{28,000} \mu\text{g}$$

If you prefer working with exponential numbers then the problem works out this way:

$$28 \text{ mg} = 28 \times 10^3 \mu\text{g} = \underline{2.8 \times 10^4} \mu\text{g}$$

Let's try one more problem which is presented in a slightly different way:

**How many kilometers (km) is 3.7 centimeters (cm)?**

This question can be expressed in the following problem:

$$3.7 \text{ cm} = \underline{\hspace{2cm}} \text{ km}$$

In this problem, km ( $10^3$  m) are clearly larger than cm ( $10^{-2}$  m) so the value of 3.7 should decrease. A km is  $10^5$  times larger than a cm ( $10^3/10^{-2} = 10^5$ ), so the value of 3.7 should decrease by a factor of  $10^5$ . Therefore:

$$3.7 \text{ cm} = 3.7 \times 10^0 \text{ cm} = 3.7 \times 10^{-5} \text{ km}$$

In this problem it is more practical to use exponential notation, however the original value was in decimal form. Converting 3.7 to an exponential number ( $3.7 \times 10^0$ ) makes it easy to *reduce* the value by a factor of  $10^5$  by subtracting 5 from the exponent.

Now that you see how to solve these conversion problems you are ready to complete the final exercise for this lab.

### **Exercise 2C – Metric conversions**

1. Complete the metric conversions on your worksheet.

*Before you leave, please make sure your table is clean, organized, and contains all supplies listed below so that the next lab will be ready to begin. Thank you!*

#### Supply List

- Meter stick
- Small plastic ruler
- Short 50 ml glass graduated cylinder
- Balance
- Digital scale
- Beaker
- Water reserve (1 gallon container with water)
- One 2 liter soda bottle
- 1 quart container
- Pipette pump
- 5 ml glass pipettes
- 1 ml transfer pipette
- 2 empty test tubes in test tube rack
- P200, P20 micropipettors
- Tube of colored water
- Empty microtubes labeled 100, 10, 2 in rack (blue liquid should be restored to original tube)
- One empty, rinsed 50 ml conical tube w/cap in 250 ml beaker
- Small container of salt
- Small scoop
- Small weighing tray
- Unknown "A": flask with stopper containing < 50 ml of colored water
- Unknown "B": test tube with < 5 ml of colored water

*NOTE: Do not throw unknowns away, be sure to return them to original container.*



## **LABORATORY 2 WORKSHEET**

Name/section \_\_\_\_\_/\_\_\_\_\_

### **Exercise 1A – Measurement of distance**

Distance from front to back of lab = \_\_\_\_\_ m Doorway: width = \_\_\_\_\_ m length = \_\_\_\_\_ m

Calculate doorway area: width \_\_\_\_\_ m x length \_\_\_\_\_ m = \_\_\_\_\_ m<sup>2</sup>

Your height: \_\_\_\_\_ cm = \_\_\_\_\_ m Paper: width = \_\_\_\_\_ cm length: \_\_\_\_\_ cm

Calculate area of paper: width \_\_\_\_\_ cm x length \_\_\_\_\_ cm = \_\_\_\_\_ cm<sup>2</sup>

Paper hole diameter: \_\_\_\_\_ mm Estimated length of *Amoeba*: \_\_\_\_\_ mm = \_\_\_\_\_ μm

**Indicate which metric unit of length you would use to measure the following distances:**

length of a fork \_\_\_\_\_

width of a cell nucleus \_\_\_\_\_

width of a pea \_\_\_\_\_

length of your car \_\_\_\_\_

height of a refrigerator \_\_\_\_\_

distance to the beach \_\_\_\_\_

### **Exercise 1B – Measurement of weight**

Weight of Graduated Cylinder \_\_\_\_\_ g (*balance*) \_\_\_\_\_ g (*digital scale*)

Weight of Graduated Cylinder with 50 ml of water \_\_\_\_\_ g (*balance*) \_\_\_\_\_ g (*digital scale*)

Calculated weight of 50 ml of water \_\_\_\_\_ g (*balance*) \_\_\_\_\_ g (*digital scale*)

How far off from 50 g were your water weights? \_\_\_\_\_ g (*balance*) \_\_\_\_\_ g (*digital scale*)

Personal item weighed \_\_\_\_\_ : \_\_\_\_\_ g (*balance*) \_\_\_\_\_ g (*digital scale*)

### **Exercise 1C – Measurement of volumes greater than 1 ml**

Volume of fluid in Flask A = \_\_\_\_\_ ml Volume of fluid in Test Tube B = \_\_\_\_\_ ml

### **Exercise 1D – Measurement of volumes less than 1 ml**

Instructor initials \_\_\_\_\_

*Once you transfer 100 μl, 10 μl and 2 μl to the indicated tubes, show them to your instructor who will verify their accuracy and initial above to confirm completion of the exercise.*

### **Exercise 1E – Concentration & percent solutions**

Weight of salt needed to make 30 ml of 5% salt solution = \_\_\_\_\_ g.

2 g of salt in \_\_\_\_\_ ml of water would produce a 0.9% solution (physiological salt concentration).

15 g of sugar dissolved in 250 ml of water is a \_\_\_\_\_% solution which is equivalent to \_\_\_\_\_ g/ml.

### **Exercise 1F – Measurement of temperature**

Ambient temperature in lab \_\_\_\_\_°C      ice water \_\_\_\_\_°C      boiling water \_\_\_\_\_°C

*Convert the following temperatures using the formulas provided in the lab:*

- 1) Mild temperature: 72° F = \_\_\_\_\_ °C      2) Body temperature 98.6° F = \_\_\_\_\_ °C  
3) Cold day 10° C = \_\_\_\_\_ °F      4) Very hot day 34° C = \_\_\_\_\_ °F

### **Exercise 2A – Converting from decimal notation to exponential notation**

*Convert the following decimal numbers to exponential numbers:*

- 1) 186,000 = \_\_\_\_\_      2) \_\_\_\_\_ = 0.00018  
3) 32.9 = \_\_\_\_\_      4) \_\_\_\_\_ = 0.0369  
5) 700.02 = \_\_\_\_\_      6) \_\_\_\_\_ = 0.00000025

### **Exercise 2B – Converting from exponential notation to decimal notation**

*Convert the following exponential numbers to decimal numbers:*

- 1)  $3.7 \times 10^3 =$  \_\_\_\_\_      2) \_\_\_\_\_ =  $10^6$   
3)  $1.01 \times 10^7 =$  \_\_\_\_\_      4) \_\_\_\_\_ =  $2.818 \times 10^{-3}$   
5)  $4.0103 \times 10^{-1} =$  \_\_\_\_\_      6) \_\_\_\_\_ =  $8 \times 10^5$

### **Exercise 2C – Metric conversions**

*Convert the following measurements to the indicated unit:*

- 1) 335.9 g = \_\_\_\_\_ kg      2) \_\_\_\_\_ m = 0.0886 km  
3) 0.00939  $\mu\text{l}$  = \_\_\_\_\_ ml      4) \_\_\_\_\_ kg = 89 mg  
5) 456.82 ng = \_\_\_\_\_  $\mu\text{g}$       6) \_\_\_\_\_ dl = 900.5 cl  
7) 20 megatons = \_\_\_\_\_ kilotons      8) \_\_\_\_\_  $\mu\text{m}$  = 0.37 mm  
9) 8 milliseconds = \_\_\_\_\_ seconds      10) \_\_\_\_\_ mm = 11.5 nm  
11) 25 mg = \_\_\_\_\_ g      12) \_\_\_\_\_  $\mu\text{l}$  = 0.046 L