The Metric System, Measurement, and Lab Equipment Review

As you know, the metric system is the unit of measurement (International System of Units, or SI) in most countries and the only system adopted by the international science community. Although we don’t often use the metric system in the United States to quantify things in our daily lives, it is what we use exclusively in science. Interestingly, the U.S. has been moving to convert to the metric system for decades, and many things are labeled with the metric system. Think of a two-liter bottle of soda, a 5K charity run, a 600mg dose of Ibuprofen, etc. In use since it was invented in France in the 1790’s, perhaps one day we will catch up!

Learning Objectives:
After this lab you should be able to:
1. Properly identify and use various types of glassware, pipettes, and other basic lab equipment.
2. Measure weight, length, and volume in the Metric System.
3. Make unit conversions within the Metric System.

Introduction:
In today’s lab you will re-familiarize yourself with basic lab equipment used for measuring. It is important to become proficient with the use of these items and the metric system because it is what scientists use, but equally importantly, it is what you will use during all subsequent lab activities. The metric system is a decimal based system that is very easy to use and convert within, once you get the hang of it. The practice in this lab should help make using the metric system more natural and automatic.

The basic units in the metric system are:

Weight: gram (g)
Length: meter (m)
Volume: liter (L)

Temperature: Celsius (C) (not technically metric, but the system that scientists use)

There are several benchmarks for getting a feel of the metric system. For weight, a dollar bill weighs one gram and a penny weighs 2.5g. So if weigh something out that is 25g, think about the weight of ten pennies in your hand.

For length, the meter is 39.37 inches, so slightly longer than a yard (which is 3 feet). A 100-yard football field is slightly more than 91 meters. On a smaller scale, the length of a centimeter is about the width of a standard paperclip or the average width of the nail on your pinky finger! And a millimeter is about the width of your ATM card.

You are already familiar with one and two liter (2L) volumes due to the packaging of soda and water bottles. An additional point of reference is that 1 cup (8 ounces) is about 237 milliliters. So if you had to measure a volume of 250ml it would be slightly more than one cup.

Finally, think about temperature. Your body temperature is probably about 98.6 °F, which is 37°C. You will notice in our labs that we often set the incubators to 34-35°C, which is a little below body temperature at 37°C. Room temperature, 70°F, is 21°C. Now you know that if you are travelling and the temperature is 25°C, it will be a beautiful day (77°F). Of course 100°C is boiling (212°F).
The good news is that we are not going to ask you to convert from standard U.S. measures to metric very often. Rather we just want you to use the metric system and eventually it will become familiar and easy. The other good news, though it takes awhile to catch on sometimes (as you may know from previous coursework), is that it is very easy to convert within the metric system. You just have to get the hang of it, use it, and it will stick.

These are the prefixes that are most commonly used in basic science labs. The prefixes are the same for gram, meter, and volume:

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Abbreviation</th>
<th>Decimal equivalent</th>
<th>Exponential Equivalent</th>
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</thead>
<tbody>
<tr>
<td>pico</td>
<td>p</td>
<td>0.000000000001</td>
<td>$10^{-12}$</td>
</tr>
<tr>
<td>nano</td>
<td>n</td>
<td>0.000000001</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>micro</td>
<td>u</td>
<td>0.000001</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>milli</td>
<td>m</td>
<td>0.001</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>centi</td>
<td>c</td>
<td>0.01</td>
<td>$10^{-2}$</td>
</tr>
<tr>
<td>none</td>
<td></td>
<td>1.0</td>
<td>$10^0 = 1$</td>
</tr>
<tr>
<td>kilo</td>
<td>k</td>
<td>1000.0</td>
<td>$10^3$</td>
</tr>
<tr>
<td>giga</td>
<td>g</td>
<td>1,000,000,000.0</td>
<td>$10^9$</td>
</tr>
</tbody>
</table>

It should be noted that the common term for a micrometer is “micron” (um).

Equipment:

Glassware
Pipettes

Test tubes and racks

Petri Dishes

**Pre-lab questions:**
1. What is the term for milligram in volume and length?
2. How much larger is a centimeter than a micron?

3. If you were traveling to Germany and the posted temperature was 32°C, what clothing might you need?

4. A typical soft drink may have as much as 39g of sugar. How many teaspoons is this? (Google this!).

**Materials:**
- 500 ml beaker with marked graduations
- 100 ml graduated cylinder
- Digital scale
- Glass slides
- Standard petri dish
- Small petri dish
- Small metric rulers
- Standard test tube
- Durham test tube
- 4 empty standard petri dishes labeled 5 ml, 10ml, 15ml, 20ml
- TSA Plate
- Small squares of Parafilm
- Transfer pipette
- 1 ml serological pipette
- 5 ml serological pipette
- Microfuge tubes and racks
- p20 Micropipette and tips
- p200 Micropipette and tips
- p1000 Micropipette and tips
- Colored water or coloring dye
- Beaker of RT water with thermometer beside the beaker
- Beaker of water in an ice bath with thermometer beside the ice bath
- Beaker of water on a hot plate, boiling with boiling stones, with thermometer beside the hot plate

**Procedures:**

**Weight:**

1. Weigh an empty 500ml beaker and record its weight to the nearest tenth of a gram (remember to tare the scale first). Then measure 50ml of water in a graduated cylinder, add it to the beaker, and weigh the beaker again.

Weight of empty beaker: __________________
Weight of beaker plus water: _______________

Calculate the weight of the water: _________________

How much would 1ml of water weigh? ________________

2. To get some reference points for weight, pick several items to weigh, including your cell phone. Other items could be a pen, a coin, your wallet, etc. Take the weight of the item in grams on the scale and convert to the other values. Give the values below. NOTE: Enjoy having your cell phone out for this, in the future you will never have electronic items out in class.

<table>
<thead>
<tr>
<th>Item</th>
<th>kg</th>
<th>g</th>
<th>mg</th>
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</thead>
<tbody>
<tr>
<td>Cell Phone</td>
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</table>

Length:

1. Measure the l x w x h (mm) of a standard glass slide and give the dimensions below:

_________________mm x __________________mm x __________________mm
   l           w       h

2. Measure the diameter and height of standard and small petri dishes:

Standard petri dish dimensions (d x h) in mm:

Small Petri dish dimensions (d x h) in mm:
3. Measure the height and diameter of a standard test tube and a small “Durham” test tube:

Standard test tube dimensions (d x h) in mm:

Durham tube dimensions (d x h) in mm:

4. View the bacterium *E. coli* via the microscope on display. Bacteria are very small organisms. *E coli* averages about 3um in length. As you look in the microscope, keep in mind that the *E. coli* is magnified 1000x. So it is very small indeed! The average lengths of several bacteria are given in um below. Convert these values to cm and mm.

<table>
<thead>
<tr>
<th>Bacterium</th>
<th>um</th>
<th>mm</th>
<th>cm</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>E. coli</em></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Bacillus cereus</em></td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Streptococcus</em></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Rhodospirillum</em></td>
<td>8</td>
<td></td>
<td></td>
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</tbody>
</table>

**Volume:**

1. Fill a 500ml beaker with 100ml of water using the 100ml marking on the beaker. Pour the water into a 100 ml graduated cylinder. What does the volume of the water read in the graduated cylinder (remember to read at the meniscus)?

Volume in the graduated cylinder: _________________

If the volume is different than 100ml calculate the percent error of the 500ml beaker:

% Error = \( \frac{\text{Exp-Obs}}{\text{Obs}} \times 100 \) (Note: there is no negative % error)

% Error =
2. Fill 3 standard test tubes with the following volumes of water- 5ml, 10ml, 15ml, and 25ml. Pour the water from each test tube into the 4 labeled petri dishes. Compare the volume of water in the 4 petri dishes with the volume of media in a normal TSA plate.

a. What is the probable volume of media in the TSA plate?

TSA Plate volume = ____________ml

b. How many TSA plates could be made from 1L of prepared liquid media?

c. Empty the petri dishes when done.

Pipetting practice:

As you do these exercises think about when and why you should use the different types of pipettes. Also make sure that you know how to measure with the serological pipette—this is a common source of confusion and therefore measurement mistakes.

Place a square of Parafilm on your lab bench. Place about 50 ml of water in a beaker (if colored water is available use it, or add coloring to the water).

1. Transfer pipettes:
Using a transfer pipette transfer 0.5ml from the beaker to the Parafilm (the water should bead up on the Parafilm). Using a 1.0 ml serological pipette withdraw 0.5 ml (read from the bottom up) of water from the beaker and dispense onto the Parafilm a few cm away from the first drop.

a. Do the drops look the same size?

b. Using the 1.0 serological pipette, pipette up the first drop you made with the transfer pipette. What was the actual volume of the water dispensed from the transfer pipette?

____________________ml

c. Is this what you expected? Why or why not do you think?

d. When would it be appropriate to use a transfer pipette vs. a serological pipette?

e. When is it more appropriate to use a serological pipette than a transfer pipette?
2. Serological pipettes:
Dry off the Parafilm square. Then, use a 5 ml pipette to transfer 1 ml of the colored water to the Parafilm. Do the same with a 1 ml serological pipette.

a. The drops should look identical. Do they?

b. Dry off the Parafilm again. Use a 5 ml pipette and a 1 ml pipette each, and transfer the following volumes to the Parafilm in two separate rows as in the pattern below: 1 ml, 0.5 ml, 0.1 ml. Draw a picture of your drops below.

<table>
<thead>
<tr>
<th></th>
<th>1.0 ml</th>
<th>0.5 ml</th>
<th>0.1 ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 ml pipette</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 ml pipette</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

c. When would you use a 5 ml pipette instead of a 1 ml pipette?

d. When would you use a 1 ml pipette instead of a 5 ml pipette?

e. Fill a microfuge tube with the colored water using a transfer pipette, using a 5 ml pipette to withdraw the contents. How much volume will the microfuge tube hold?
3. Micropipettes:
Micropipettes are most often used for very accurately measuring very small volumes. It would be
difficult to measure 0.01ml with a 1.0ml pipette but easy with the appropriate micropipette. Each
pipette uses a different pipette tip that fits snugly, and is calibrated with the pipette to withdraw
and dispense the correct amount. Pipette tips can be ejected from the pipette without touching
them, which can be very important when transferring microbial cultures! Pipette tips are disposed
of in small biohazard buckets provided.

Your instructor will review how to withdraw and dispense liquids and eject the pipette tips. Make
sure that you understand how to do this prior to using a pipette.

The most commonly used micropipettes are the p20, p200, and p1000. The values 20, 200, and
1000 refer to the max volume (in ul) each pipette can deliver. Convert the following:

20ul = ______________ ml

200 ul = ______________ ml

1000ul = ______________ ml

Turning the thumbwheel gauge on the top portion of the pipette sets volumes for each. Be very
careful when adjusting these. Do not attempt to adjust the pipette to higher or lower than the
range for that pipette. Doing so can damage the pipette. The range for each is:

p20 measures 2ul-20ul

p200 measures 20-200ul

p1000 measures 200-1000ul

a. The gauge for each pipette is unique in the range it represents. Note what the gauge looks
like, and what it actually represents:

<p>| | | |</p>
<table>
<thead>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10.0ul</td>
<td>100.0ul</td>
<td>1000.0ul</td>
</tr>
</tbody>
</table>

= _____ml  _____ml  _____ml
b. Make sure your piece of Parafilm is dried off again. With the p20 set the gauge to 100 and withdraw 10.0ul from your beaker of colored water and dispense onto the Parafilm. Set the p200 to 100 and withdraw and dispense 100.0ul of water onto the Parafilm. Set the p1000 to 100 and dispense 1000.0ul onto the Parafilm. Compare the sizes of the drops. Draw below:

![Diagram](image)


c. Micropipette challenge: Each person in your group should do the following. Use a p200 and dispense the following amounts of water (from your beaker of colored water) into a microfuge tube, resetting the thumbwheel as needed:

Transfer 20ul, then an additional 35ul, and finally an additional 65ul. What is the total volume you have dispensed?

Total volume = _____________ ul

Compare your microfuge tubes to your lab partners’. Do all the tubes appear to have the same volume?

Now, exchange microfuge tubes with each other so that no one has their own tube. Using a p200 set the gauge to the total volume you determined above and withdraw the liquid from the microfuge tube.

Were you able to withdraw the entire volume of the tube or is there some left in the tube?

Were there any air bubbles in the tip of the pipette?

What could be some sources of error in transferring these volumes?
Temperature:

Observe and record the temperature in Celsius in the three water samples. Handle the thermometers with care; they are easily broken. Place the thermometer in each beaker without letting the thermometer hit the bottom of the beaker and hold it for one minute, record the T and remove the thermometer and place it gently on the lab bench.

<table>
<thead>
<tr>
<th></th>
<th>Temperature (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT beaker</td>
<td></td>
</tr>
<tr>
<td>Ice bath beaker</td>
<td></td>
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<tr>
<td>Hot plate beaker</td>
<td></td>
</tr>
</tbody>
</table>

Questions:
1. What do the following prefixes mean in relationship to the standard base unit (g, m, L)?

   Pico = __________

   Micro = __________

   Kilo = ___________

   Milli = __________

   Centi = __________

2. Circle the value that is larger than the other?

   5cm or 40mm

   150ml or .200L

   1g or 1kg

   2mg or 3 cg

   100 mm or 10km

   100L or 1000ml
3. Fill in the following table:

<table>
<thead>
<tr>
<th>kg</th>
<th>g</th>
<th>mg</th>
<th>um</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
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<td>2</td>
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<td>2</td>
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</tr>
</tbody>
</table>

4. Determine the equivalents:

\[27 \text{ g/L} = 27 \text{ g/______ ml}\]

\[0.1 \text{ ml} = ______ \text{ ul}\]

\[200 \text{ g} = ______ \text{ ug}\]

\[_______ \text{ mm} = 30 \text{ um}\]

\[_______ \text{ cm} = 6 \text{ m}\]

\[5 \text{ cm} = ______ \text{ mm}\]

5. Interpret the following micropipette displays and give the correct volume in ul:

p20

\[
\begin{array}{c}
1 \\
3 \\
0 \\
\end{array}
\]

_______ ul
6. Draw the following:

Beaker:

Erlenmeyer flask:

Graduated cylinder:

Transfer pipette vs. serological pipette (draw each to compare):
7. When is it appropriate to have electronic devices out in class? Check the correct box:

Never

Conclusion:
1. Metric System-
Reflect on what you have learned, or re-learned about the metric system. Did you remember the prefixes and their values? Did you remember how to convert from cm to mm, or kg to gram for example? How confident do you feel about understanding and using the metric system?

2. Equipment:
Do you feel confident about which measuring tools to use? For example, when might a transfer pipette be appropriate over a micropipette? Do you feel confident measuring 0.3ml with a 1.0ml serological pipette?
3. What do you need more assistance or practice with? What do you need to do to understand the metric or measuring better?

Resources:


Metric Practice: https://www.khanacademy.org/math/pre-algebra/rates-and-ratios/metric-system-tutorial/v/unit-conversion

More than you might want to know about the history of the metric system, but a short read: http://www.us-metric.org/origin-of-the-metric-system/

Micropipettes: https://www.mcdb.ucla.edu/Research/Goldberg/HC70AL_Su14/pdf/How%20to%20Use%20Micropipettor.pdf