Exercise 1A: Using Common Laboratory Tools to Evaluate Measurements Pre-laboratory
Thinking Questions

Directions

Read over the introduction and protocols for this laboratory exercise and answer the following questions to ensure that you are prepared for the session:

(1) What are the objectives for today’s laboratory (provide a numbered list)?

(2) Why is it important to understand how to convert between metric units in the laboratory?

(3) Why is it important to understand how to use serological pipettes and micropipettes (what will you be using them for in the lab—the more specific, the better)?
Exercise 1B: Using Common Laboratory Tools to Evaluate Measurements

Measurements Introduction

Based upon modifications of worksheets developed by Susan Peckham Petro, DVM.

As scientists, many of the observations we make require that we take and compare measurements. For example, in the experiment you will perform today, you will take several measurements. You will measure different volumes of water using serological pipettes and micropipettes, you will measure the mass of the water using a balance, and you will use the density of water to help you calculate percent error. As we progress throughout the semester, you will continue to realize the importance of measurement taking. We primarily use the metric system to take our measurements. The metric system, developed in France in 1791, is based on units of 10. Fractions or multiples of the standard units of length, volume, and mass have been assigned specific names. The commonly used units of the metric system are highlighted in Table 1.1. Table 1.2 shows the prefixes used to designate fractions and multiples of these commonly used units and provides examples of how they are used.

<table>
<thead>
<tr>
<th>Table 1.1</th>
<th>Commonly used units of the metric system.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement</td>
<td>Unit</td>
</tr>
<tr>
<td>Length</td>
<td>Meter (m)</td>
</tr>
<tr>
<td>Volume</td>
<td>Liter (l)</td>
</tr>
<tr>
<td>Mass</td>
<td>Gram (g)</td>
</tr>
<tr>
<td>Molar</td>
<td>Concentration (M)</td>
</tr>
</tbody>
</table>

Source: Susan Peckham Petro, DVM.
Often, upon taking a measurement, you will be required to convert that measurement to units that are different than the ones you used to initially take the measurement.

**To Convert Smaller Units to Larger Units:** Divide by the appropriate factor of 10 because there are fewer of the larger units.

Example 1: According to Table 1.2, a millimeter (milli = one thousandth) is 10 times smaller than a centimeter (centi = one hundredth). To change 1 millimeter (mm) to centimeters (cm), you must divide 1 by 10. So 1 mm is equivalent to 0.1 cm.

Example 2: According to Table 1.2, a nanogram (nano = billionth) is 1000 times smaller than a microgram (micro = millionth); therefore, to change 1 nanogram (ng) to micrograms (ug), you must divide 1 by 1000. So 1 ng is equivalent to 0.001 ug.

**To Convert Larger Units to Smaller Units:** Multiply by the appropriate factor of 10 because there will be more of the smaller units.

Example 1: According to Table 1.2, a decimeter (deci = one tenth) is 100,000 times bigger than a micrometer (micro = one thousandth).
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millionth); therefore, to convert 1 decimeter (dm) to micrometers (um), you must multiply 1 by 100,000. So 1 dm is equivalent to 100,000 um.

Example 2: According to Table 1.2, a meter is 1000 times larger than a millimeter (milli = thousandth); therefore, to convert 54 meters (m) to millimeters (mm), you must multiply 54 by 1000. So 54 m is equivalent to 54,000 mm.

The Shortcut for Metric Conversions: The shortcut is simple—move the decimal points! When you realize that the units are 1000-fold apart, you can move the decimal over three places (for the three 0’s) and change the units. Make sure that you are moving the decimal point the correct way when you do this:

If you convert from a larger unit to a smaller unit, move the decimal to the right. For example, if you want to convert 2.001 milliliters (ml) to microliters (ul), you must first recognize that there is a 1000-fold \((1 \times 10^3)\) difference between the two units and then move the decimal place three positions to the right (one position for each 0 in 1000) as indicated in the equation below:

Equation 1.1

Metric conversion from larger units to smaller units.

\[
\begin{align*}
2.001 \text{ ml} &= 2001 \text{ ul}
\end{align*}
\]

If you convert from a smaller unit (e.g., ng) to a larger unit (e.g., gram), move the decimal to the left. For example, if you want to convert 51,000 nanograms (ng) to grams (g), you must first recognize
that there is a one billion-fold \((1 \times 10^9)\) difference between the two units and then move the decimal place nine positions to the left (one position for each 0 in one billion; you will have to add 0’s to the left side of the number) as indicated in the equation below:

Equation 1.2

Metric conversion from smaller units to larger units.

\[
\frac{000051,000}{0.000051} \text{ ng} = 1,000,000,000 \text{ g}
\]

Scientific Notation: As you can see from some of the examples above, some of the numbers have many digits. Scientific notation is a method used by scientists to simplify those numbers. Let’s convert the numbers provided in the metric conversion shortcut examples above to scientific notation.

To convert a whole number to scientific notation, place a decimal point to the right of the first digit in the number. To determine the exponent, count the number of digits to the left of the decimal point you just added. For example:

Equation 1.3

Conversion of a whole number into scientific notation.

\[
2001 \text{ ul} = 2.001 \times 10^3 \text{ ul}
\]

To convert a decimal number to scientific notation, place a new decimal point to the right of the first whole digit in the decimal. To determine the exponent, count the number of digits between the old
and new decimal point. The exponent should be a negative number. For example:

Equation 1.4

Conversion of a decimal into scientific notation.

\[0.000051 \text{g} = 5.1 \times 10^{-5} \text{g}\]

*Significant Figures:* Significant figures are the number of digits required to express the result of a measurement so that only the last digit in the number is in question. This means that when you are recording measurements, you should include all of the digits you are sure of plus a rounded estimate of the next smaller digit to the nearest tenth. In practice for the exercises in this laboratory manual, use, at most, three significant figures when reporting measurements. Below, please find some rules for determining the number of significant figures in a measurement:

(1) The number of significant figures does not change when the decimal point is moved.

Example: 625.2 m written as 0.6252 km—both have four significant figures

(2) Zeros between two significant digits are always significant.

Examples: 5.0004 has six significant figures, 94203 has five significant figures, and 650.007 has six significant figures

(3) Trailing zeros to the right of the decimal point are significant in every measurement.
Examples: 5.00 has three significant figures, 27.0 has three significant figures, and 30000.0 has six significant figures (You need to consider rules 2 and 3 for this last example as well, do you know why?).

(4) Leading zeros are not significant in any measurement.

Examples: 0.00007 has one significant figure, 0.708 has three significant figures, and 0.07808 has four significant figures (You need to consider rules 2 and 3 for this last example as well, do you know why?).

(5) Trailing zeros appearing to the left of the decimal point may not be significant.

Examples: 500 has at least one significant figure, 54640 has at least four significant figures, and 87,090,000,000 has at least four significant figures.

(6) Any zeros that disappear when you convert a measurement to scientific notation are not significant.

Examples: 4000 converted to scientific notation (4 × 10^3) has at least one significant figure, 0.00064 converted to scientific notation (6.4 × 10^-4) has two significant figures, 260.00400 converted to scientific notation (2.600400 × 10^2) has eight significant figures, and 0.008090 converted to scientific notation (8.090 × 10^-3) has four significant figures.

Let’s Put This to Practice!
Work independently to perform the following metric conversions. Your answers, where appropriate, should include three significant figures and be written out in scientific notation. After you complete the following problems, work with your laboratory group to come to a consensus for each answer. Be sure everyone in your group
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understands how each answer was determined. Finally, discuss your results with the class.

Convert 100 um to mm.

Convert 251 mg to g.

How many ug are in 354 kg?

How many seconds are in 2.567 ns?

Which is smaller—ul or ml?

Which concentration is higher—M or mM?

Which is larger—nm or mm?

Write 25 ug in g.

Convert 0.075 ml to ul.

Convert 659 nm to um.

Working with Serological Pipettes and Micropipettes

A vast majority of the exercises that you will work on in this laboratory require that you are proficient in using different tools to measure and dispense specific volumes of liquids. These tools include disposable serological pipettes and micropipettes.
There are four types of serological pipettes that you will be using in the laboratory based upon the total volume that they can draw up: 2, 5, 10, and 25 ml. Each of the four serological pipettes is calibrated so that you might be able to ensure that you draw up the appropriate volume of fluid as per the protocol you are working with. In order to draw up fluid, a pipette pump is attached to the top of the appropriate pipette to provide suction. Your laboratory instructor will demonstrate how to attach the pipette pumps and use the serological pipettes. Figure 1.1 provides examples of serological pipettes with attached pipette pumps.

To measure smaller volumes of fluid (<1 ml), micropipettes are used. Most micropipettes are considered adjustable micropipettes—meaning that you can manually adjust the volumes you wish to draw up on the micropipette itself. You will be working with three
different micropipettes in this laboratory based upon the volumes they can draw up: 1000 ul to 100 ul, 100 ul to 10 ul, and 10 ul to 0.5 ul. In order to draw up fluid using the micropipettes, you will need to attach the appropriate disposable plastic pipette tips to the end of the micropipettes. Your laboratory instructor will demonstrate how to attach the tips and use the micropipettes. Figure 1.2 provides an example of micropipettes.

**Figure 1.2** (a) Typical 10, 100, and 1000 ul total volume micropipettes, respectively. (b) 10 ul micropipette volume indicator. The volume indicator on a 10 ul micropipette is read from left to right. Digits to the left of the decimal point indicate uls, and digits to the right of the decimal point indicate tenths of uls. (c) 100 ul micropipette volume indicator. The volume indicator on a 100 ul micropipette is also read from left to right. Digits indicate uls up to 100 ul. (d) 1000 ul micropipette volume indicator. The volume indicator on a 1000 ul micropipette is read from left to right. Digits indicate uls up to 1000 ul. (See insert for color representation of the figure.)
Let’s Put This to Practice!

*Serological Pipettes*: Work in groups of four for this exercise.

(1) Obtain a clean, dry 250ml beaker.

(2) Place the beaker on the electronic balance provided to your group and use the tare control on the balance to adjust the reading to 0. You need to do this to compensate for the mass of the empty beaker so that its mass is not included in your readings. Your instructor will show you how to tare if you have difficulty.

(3) Obtain a flask and add approximately 60ml of tap water to it.

(4) Using the serological pipettes, dispense the water into the beaker on the balance following Table 1.3. When you do this, be sure to use a brand new serological pipette for each volume dispensed. In addition, please make sure that the beaker remains on the balance and that the balance is on when you add the water.

The density of water (0.998g/ml at 23°C) can be used to check the accuracy of your ability to dispense the water into your beaker using

<table>
<thead>
<tr>
<th>Pipette type (ml)</th>
<th>Volume to dispense (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>19</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><em>Total expected volume</em></td>
<td>50</td>
</tr>
</tbody>
</table>

Table 1.3  Volumes to dispense to practice using serological pipettes.
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the serological pipettes. Answer the following questions to determine how accurate your pipetting was:

(1) What was the mass of the water in the beaker upon completion of all of the pipetting? _____

(2) Using the density of water what is the actual volume of water in the beaker?

(Hint: volume of water = mass/density) _____

(3) Finally, to determine how accurate your pipetting was, you can determine your % error. The equation for % error is as follows:

\[
\% \text{ error} = \frac{(\text{dispensed value} - \text{expected value})}{\text{expected value}} \times 100
\]

What is your percent error (keep in mind that you may end up with a negative number if your actual dispensed volume was lower than the expected volume—Why is this?)? _____

*Micropipettes*: Work in groups of four for this exercise. Micropipettes are very expensive and delicate pieces of laboratory equipment. *Never* exceed the upper and lower volume limits of the micropipettes!

(1) Hold the micropipette in one hand. With the other hand, turn the volume adjustment knob to the desired setting (Figure 1.2).

(2) Attach a new disposable tip to the pipette shaft. Be sure the tip is properly attached and has a good seal.
(3) Press the plunger to the first stop (Figure 1.3b) where you feel a slight resistance. This represents the volume displayed on the digital indicator (Figure 1.2).

(4) Holding the micropipette vertically, immerse the tip a few ml into the sample you wish to suck up while holding the plunger at the first stop.

(5) Allow the plunger to slowly return to the UP position (Figure 1.3a). Remember do not let it “snap” to the UP position. Then carefully withdraw the tip from the sample making sure there are no air bubbles.

(6) To dispense the liquid to a new tube, gently touch the tip to the side of the receiving vessel. Press the plunger past the first stop to the second stop (Figure 1.3c). With the plunger fully pressed, withdraw the tip carefully, wiping residual drops against the vessel wall.

(7) Allow the plunger to slowly return to the UP position.

(8) Discard the tip by depressing the tip ejector button.

Practice Pipetting Small Volumes

(1) Pipette and then dispense 10.0ul and 5.0ul samples of water onto a piece of Parafilm using the 0.5–10ul micropipette. Be sure that both water samples end up in the same “bubble” on the Parafilm.

(2) Use the 10–100ul micropipette to draw up the 15.0ul on the Parafilm. Keep practicing this until you can do this without leaving any liquid behind on the Parafilm and until no air is introduced into the tip.
Figure 1.3  (a) Up position of the plunger button on a micropipette. This is the starting position for proper pipetting. (b) The plunger button is depressed to the first stop position to initiate pipetting. While holding the plunger button in this position, insert the micropipette tip into the sample and then slowly release the plunger button to the up position. The desired volume of sample will be drawn up into the tip. (c) When the plunger button is depressed beyond the first stop position to the second stop position, the liquid in the pipettor tip will be completely expelled. (See insert for color representation of the figure.)
(3) Pipette and then dispense 6.2 and 8.8 ul samples of water onto the Parafilm, but, this time, do not combine both water samples into a single “bubble.”

(4) Use the 10–100 ul micropipette to draw up the two bubbles by depressing the plunger on the micropipette to the first stop. While releasing the plunger very slowly, draw up both the 6.2 ul volume and the 8.8 ul volume within one release (stroke) of the plunger. Keep practicing until you can do this without leaving any liquid behind on the wax paper. If air is allowed to be introduced into the micropipette after the 8.8 ul volume, you will not be able to draw up all the remaining liquid.
Exercise 1C: Using Common Laboratory Tools to Evaluate Measurements Post-laboratory Thinking Questions

Based upon modifications of worksheets developed by Susan Peckham Petro, DVM.

Directions

Answer the following questions upon completion of the laboratory exercises:

Complete Table 1.4 by converting the metric linear measurements to their English equivalents (see below). Both should be expressed with no more than three significant figures, if appropriate, and in scientific notation.

Conversion between the English and Metric Systems

1 in. equals 2.5 cm.

1 mile equals 1.6 km.

1 m equals 39 in.

Table 1.4 Conversion of metric to English units of measurements.

<table>
<thead>
<tr>
<th>Metric unit</th>
<th>Definition in meters</th>
<th>English equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.0 kilometers (km)</td>
<td></td>
<td>miles</td>
</tr>
<tr>
<td>0.5 centimeters (cm)</td>
<td></td>
<td>inches</td>
</tr>
<tr>
<td>1.0 decimeter (dm)</td>
<td></td>
<td>inches</td>
</tr>
<tr>
<td>1.0 millimeter (mm)</td>
<td></td>
<td>inches</td>
</tr>
<tr>
<td>1.0 micrometer (um)</td>
<td></td>
<td>inches</td>
</tr>
<tr>
<td>1.0 nanometer (nm)</td>
<td></td>
<td>inches</td>
</tr>
</tbody>
</table>