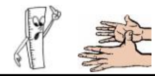


Objectives

- To learn how to make measurements of temperature, length, mass and volume.
- To learn how to calculate the area of a piece of paper and density of liquids.

Discussion

Quantitative measurement is fundamental to chemistry. One must become familiar with the different units of measurement used to quantify ***base quantities*** (such as temperature, length, time, mass, etc.). The main units which will be considered in this lab are the base quantities of temperature, length and mass and the derived quantities of volume and density. The quantity of volume is determined through multiple length measurements. Density is derived from the quantities of mass and volume. We will discuss the base quantities of temperature, length and mass, and the derived quantities of volume and density, individually below.

Increments

The number of decimal places to which any measurement can be read is dependent on the increments in which the tool used is marked. In the figure below, notice that there are 10 subdivisions between the 5 cm and 6 cm marks. If you subtract the difference between the two labeled marks and then divide by the number of spaces or increments, you can find the value of each increment shown on your tool.

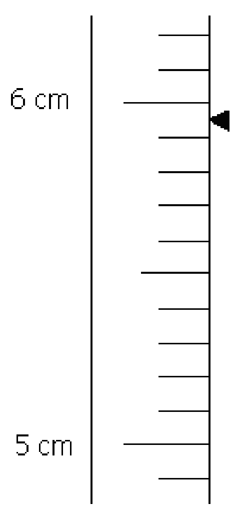
6 cm – 5 cm = 1 cm (There is 1 cm difference between the two marked lines)

1 cm/10 spaces = 0.1 cm
(Each individual space or increment on this measuring stick represents 0.1 cm or a tenth of a centimeter).

Before attempting any measurement you must always first determine the increment.

Determining a Measurement

One must keep in mind that any measurement inherently has an uncertainty associated with it. This means that a measurement is only as certain as the instrument used to take the measurement. The least significant figure that you can claim in a measurement is the digit whose value you estimate. It is in this digit that the uncertainty lies. It is generally accepted that the uncertainty is estimated as ± 1 in that digit, but it is the measurer who actually decides how small the estimate of the uncertainty is. We all agree to assume that measuring devices with electronic displays have uncertainties of ± 1 in the last digit displayed.



Examine the ruler on the left. What can you say for certain about the length of the object being measured (indicated by the arrow)? It is *certainly* at least 5 cm long. In fact, it is *certainly* at least 5.9 cm long.

Make sure that you agree with the previous two statements.

However, the object is not *exactly* 5.9 cm. It is possible to estimate another digit in the hundredths place, which will more accurately describe the length of the object. Try that now:

Your estimation of the object's length: 5.9__ cm

Some of your classmates may estimate a different reading for that last hundredths place digit. That is okay! Since there are no increments on the ruler to indicate hundredths of a cm, there is some error or *uncertainty* associated with the reading. When you report such a reading (in your lab notebook or in a data table), another scientist would recognize that the true length of the object is ± 0.01 cm of the reported value (your reading above).

Rule of Thumb: You will generally estimate one digit beyond the increment digit. Note on the ruler above, the increment is 0.1 cm – your length reading involved estimating to the hundred place (or 0.01cm).

Temperature
A thermometer may be used to measure temperature. Read it while it is in the substance you are measuring. Make sure not to read the thermometer while it is in contact with the substance's container (if the substance was a liquid or powder in a beaker for example).

Why do you think it is important to keep the thermometer from touching the sides or bottom of the container?

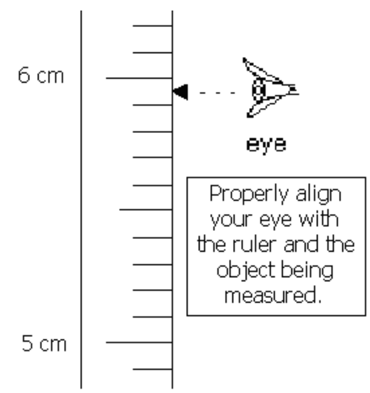
The thermometers used in this lab are quite fragile; if yours breaks, **report it immediately to your instructor** who will provide instructions for proper clean up and disposal of the broken glass.

Length
A meter stick is used to measure length. Meter sticks generally are marked (ruled, graduated or divided are synonyms) in centimeters; and the fine divisions are in millimeters. If you can, grab a meter stick and check this for yourself!

Are there 10 millimeter divisions between the centimeter divisions and are there 100 centimeter divisions for the entire meter stick?

If not, there is a good chance you are using the wrong side of the meter stick—the side marked in inches.

In measuring the lengths of objects, avoid using the end of the meter stick whenever possible since the end may not be accurately cut or may be damaged or worn away. Select a convenient point on the meter stick, such as the 1.00 cm mark, and line it up with the end of the object to be measured. Locate a point on the meter stick that lines up with the other end of the object. The arithmetic difference between the two points is the length of the object. Be sure your eye, the end of the object, and the ruler are properly aligned, so as to minimize error.



Mass
The instrument used in the chemistry laboratory for determining mass is called a ***balance***. The electronic balances used in the chemistry lab are relatively simple to operate. When using the balance, follow these basic steps:

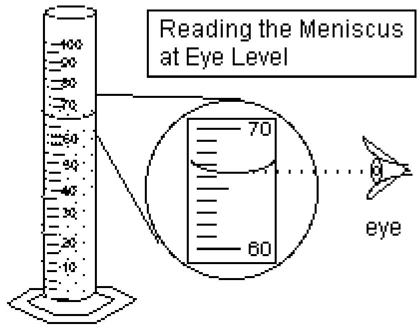
1. Always use the same balance for all your measurements. Record the balance identification number when you use it for measurements.
2. Simply depress the on/off switch to activate the balance.
3. Check that the balance is measuring in the "grams" mode. If not, press and hold the "mode" button down until the letter "g", indicating grams, appears on the balance display.
4. Use weighing paper when measuring out objects. It is always needed even if you have a container.
5. Record <u>every single digit</u> shown in the electronic display. This includes all zeros! The last digit shown on the balance display is the "uncertain" or "estimated" digit.
6. Avoid spilling chemicals on the balance or bench top and always clean up any spills that do occur

Why do you think it is important to consistently use the same balance throughout a lab activity? Why is it important to record the balance identification number?

Volume

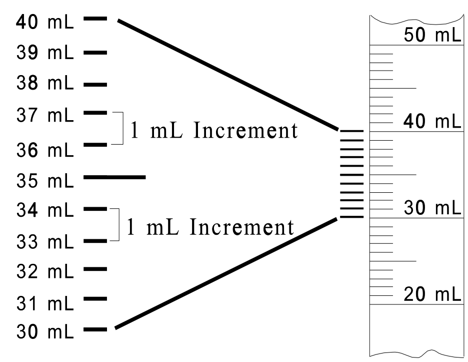
Several different kinds of liquid-measuring devices are common in the laboratory: including ***beakers***, ***graduated cylinders, burettes***, and ***pipettes***. When the surface of water is in contact with the wall of a glass vessel, it curves in a concave fashion. This depression of the surface is called a ***meniscus***. You should always read the volume at the ***lowest*** point of the meniscus!

Measuring devices are calibrated to give the most accurate readings when the bottom of the meniscus is read. Placing a white card below the meniscus on the opposite side of the measuring device betters your ability to see the meniscus. **Always align your eyes so that they are level with the meniscus when reading the volume.**



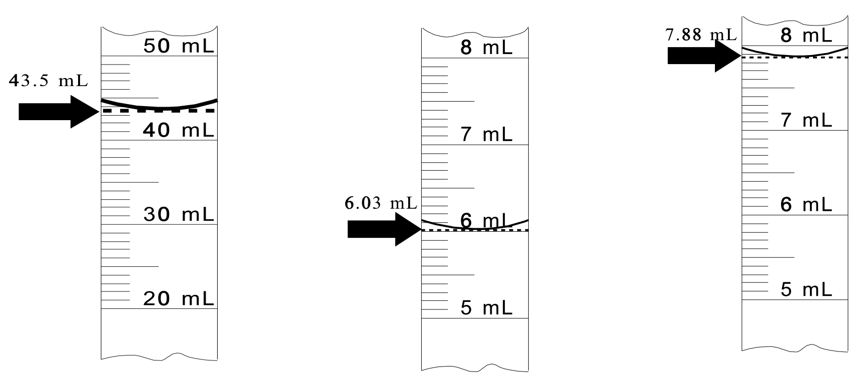
Can you identify the meniscus in the illustration above? At what point on the meniscus would you take a volume reading?

In the diagram at right notice that there are 10 subdivisions between the 30.0 mL and 40.0 mL marks. The value, in milliliters, of each of the subdivision marks is 1 mL; this is the ***volume increment***. Markings on different liquid-measuring devices vary. Before attempting any measurement you must determine the increment (in this case, the amount of liquid necessary to raise the meniscus from one line to the next).

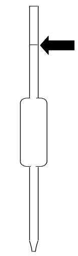


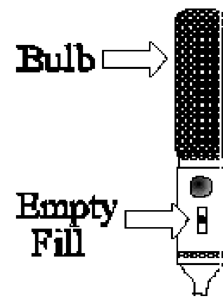
The examples below illustrate several volume measurements using graduated cylinders with different increments. Notice that the arrows indicate the position of the bottom of each meniscus.

*Confirm the value of each measurement and refer to these examples as you complete the pre-laboratory exercise. Remember, it is important to identify the **last significant figure** (the digit of the measurement that is estimated)!*



A ***volumetric pipette*** is used when it is necessary to very precisely dispense a specific volume of liquid. A typical pipette is shown to the right. Notice that the volumetric pipette has only a single line etched on its upper tube. This is because the pipette is capable of dispensing only one particular volume of liquid precisely.





Mouth suction is NEVER used to fill the pipette. Instead, use the ***pipette helper*** shown at right. You will use the pipette helper to pull liquid up and into the pipette. Your instructor will demonstrate the specific techniques for you in lab. When filling the pipette, your goal is to adjust the level of the liquid so that the bottom of the meniscus is aligned with the line etched on the pipette. To dispense liquid, you will simply drain it from the pipette into the proper receptacle container.

The droplet of liquid that remains stuck in the pipette after emptying should not be added to the dispensed liquid.

Density:
Density is the mass of an object divided by its volume and is express by the equation:

$$D = M/V$$
or
$$\text{Density} = \text{Mass}/\text{Volume}$$

In calculations of density, mass is usually expressed in grams and the volume in milliliters or cubic centimeters. Thus, units of density are commonly expressed as g/mL or g/cm^3.

Procedure

Record all measurements: quantity ± measurement uncertainty & units.

(For Example, a volume measurement might be recorded 8.47 ± 0.01 mL)

I. Temperature:

1. Examine the Celsius thermometer. Note the increment of the scale to determine which decimal place you will estimate (which will ultimately determine the number of significant figures in your readings).

2. **Answer these two questions on your data sheet: To what decimal place is the thermometer graduated? What decimal will you be estimating when you make a temperature measurement?**

3. Fill a beaker approximately 2/3 full with tap water (make sure there is enough water to submerge your thermometer up to the appropriate mark).

4. Use your thermometer to measure the temperature of the tap water. Record your measurement.

5. Your instructor will set up one common ice bath for all students in the lab to use. Use the thermometer to measure its temperature and record your measurement.

6. Use the thermometer to measure the temperature of the ice water bath provided by your instructor. Record your measurement.

7. Obtain readings of the ice water bath temperature from two of your classmates (that they measured with THEIR OWN thermometers).

8. Your instructor will set up one common hot water bath for all students in the lab to use. Once it is boiling, measure the temperature of the hot water provided by your instructor. Record your measurement.

II. Length

1. Examine the meter stick designated as "Tool #1". On your data table, record the smallest increment (in meters) marked on this tool.

2. Using Tool #1, measure and record the height of a labmate as precisely as possible in units of meters.

3. Examine the meter stick designated as "Tool #2". On your data table, record the smallest increment (in meters) marked on this tool.

4. Using Tool #2, measure and record the height of the same labmate as precisely as possible in units of meters.

III. Volume of a Liquid

1. Examine the 25 mL graduated cylinder provided to you and determine the smallest increment marked. Record this increment in your data table.

2. Examine the 1000 mL graduated cylinder at its designated station in the lab and determine the smallest increment marked. Record this increment in your data table.

3. Two partially filled graduated cylinders which differ in capacity and increment size are on the instructor's table. Read and record the increment and volume of liquid contained in the:

    a. 10 mL graduated cylinder

    b. 100 mL graduated cylinder

4. Practice with reading volumes from the burettes, another type of glassware used to measure volumes.

IV. Mass

Part One

1. First record in your lab book the balance number that appears on any balance you use. In general, always use the same balance for all of your measurements (in any given experiment) to avoid errors that exist between balances. **Always put a piece of weighing paper underneath the object you are weighing.**

2. Determine and record the mass of the same nickel on **three balances**. This step demonstrates that different balances may give different results for the same object.

Part Two

1. Measure and record the mass of an empty, capped vial.

2. Fill a 50 mL beaker about 2/3 full with tap water.

3. Using a 5.00 mL volumetric pipette, transfer 5.00 mL of water from the beaker to the vial.

4. Reweigh the vial, now capped and containing the 5.00 mL of water.

5. Use the information from steps 1 & 3 to calculate the mass of the 5.00 mL of water by itself (mass by subtraction).

6. Repeat steps 1 through 4 with the same equipment as a second trial of this process. It does not matter if the vial or other glassware is wet for this second trial.

Name_________________________Date___________ Lab Section_________

Record your data to this sheet. **All measurements must have: quantity ± measurement uncertainty & units.**

Temperature

Determine the smallest marked increment of the thermometer: _________________

Determine the decimal place you will estimate, or the uncertainty, when you make a temperature measurement: _________________

Regular tap water temperature _________________________

Ice water temperature _________________________

Classmates' Ice water temperatures Name ______________________ Temp _________________

Name ______________________ Temp _________________

Boiling water temperature _________________________

Length

Meter Stick	Tool #1	Tool #2
Increment (m)		
Uncertainty (m)		
Labmate's Height (m)		

Volume

Graduated Cylinder	10 mL	25 mL	100 mL	1000 mL
Increment (mL)				
Uncertainty (mL)				
Volume of Water (mL)				

Mass

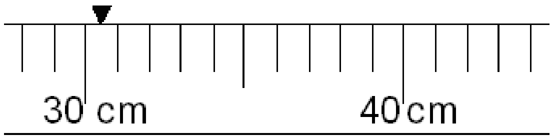
Balance Number			
Mass of Nickel			

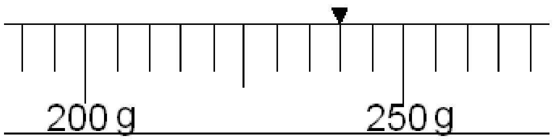
Trial One		Trial Two	
Mass of capped, empty vial		Mass of capped, empty vial	
Mass of capped vial and 5.00 mL water		Mass of capped vial and 5.00 mL water	
Mass of water sample		Mass of water sample	

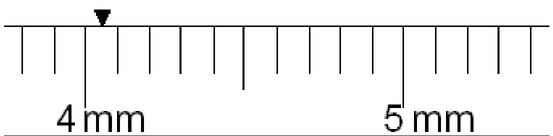
Post-Lab Questions

READING MEASUREMENTS

1. Read the scales below. All measurements must have: quantity ± measurement uncertainty & units.







TEMPERATURE

You should have obtained ice bath temperature measurements from two of your classmates:
How do the three measurements compare with one another? How far off from one another are they?

What reasons might account for any differences you saw among this group of measurements? Assume that each individual followed directions properly and made no mistakes in their reading of their thermometer.
In other words: DO NOT CITE HUMAN ERROR as a reason for observed temperature differences.

LENGTH (and AREA)

For each tool, take the increment that you recorded in meters on your data sheet and now write it as a *whole number* in whatever units are appropriate. For instance, is the smallest increment 1 m, 1 dm, 1 mm, or some other value?

Tool #1 ___________ Tool #2 ___________

For each set of data (from Tool #1 and Tool #2), convert the height of your labmate from meters into yards using the following conversion factor: 1 m = 1.094 yds. (**<u>Show your work</u>** and make sure to follow the rules of using significant figures in calculations).

<u>Tool #1 Conversion</u>

<u>Tool #2 Conversion</u>

VOLUME, MASS, & DENSITY

A student got the following measurements for the same nickel on all three balances: 5.01 g, 4.98 g, and 4.99 g. What might have caused these different measurements?

Based on the masses and volumes you recorded, calculate the density of water for each trial of the lab activity (**Show your work** and make sure to follow the rules of using significant figures in calculations).

Trial One Density ___________________ Trial Two Density ______________________

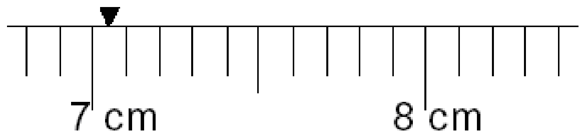
Calculate the average of your two trials: ________________

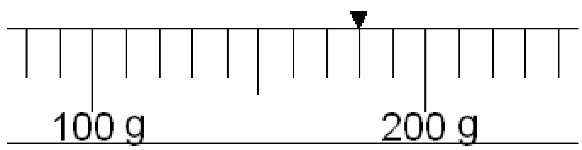
The densities of liquids typically vary, depending on temperature. Select the temperature closest to your measured tap water temperature from Part 1. From this, you should be able to determine a predicted density of the water you used. Circle the temperature and its corresponding density in the following table.

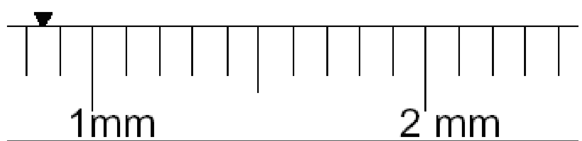
Temperature (ºC)	Density of Tap Water (g/L)
10	999.8
11	999.7
12	999.6
13	999.5
14	999.3
15	999.2
16	999.0
17	998.9
18	998.7
19	998.5
20	998.3
21	998.1
22	997.9
23	997.6
24	997.4
25	997.1
26	996.9
27	996.6
28	996.3

Notice that the values listed in the table above are in units of g/L, while the average density you calculated is in g/mL. In order to compare the two values, you will have to convert the units of one to be the same as the other. Convert your average density from units of g/mL to g/L. (**Show your work** and make sure to follow the rules of using significant figures in calculations)

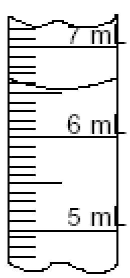
1. Read the scales below. All measurements must have: quantity ± measurement uncertainty & units.

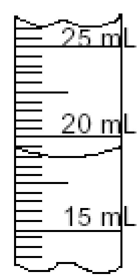






2. On the graduated cylinders below, use an "x" to mark the point on the meniscus where the volume is read. Also, determine the increment (smallest subdivision) for each graduated cylinder.





(Follow the rules of using significant figures in calculations for the following two questions.)

3. Often in lab, you do not directly measure the mass of a sample, and instead you calculate the mass by subtraction. Based on the following data, calculate the mass of sample liquid:

Mass of empty graduated cylinder	_______12.3448 g_________
Mass of grad. cylinder and 5.00 mL sample liquid	_______18.6637 g__________
Mass of 5.00 mL sample liquid	_________________________

4. What is the density of the above liquid sample?