Name: ________________________________ Section: ____________________

Experiment 2 – Measurements

Discussion

Experimental sciences, such as Chemistry, depend on making and using measurements properly. The SI system of units (sometimes called the metric system) is used almost exclusively. This system is very similar to our monetary system: $1 = 10 dimes = 100 cents = 1000 mils. In chemistry, the basic units of length, mass, and volume are the meter, gram, and liter, respectively. They all are divided the same way. For example, 1 meter = 10 decimeters = 100 centimeters = 1000 millimeters. The kilo is also commonly used; it equals 1000 of the basic unit. For example, 1 kilogram = 1000 grams.

Often you will be asked to compare you experimental or calculated value to an "accepted" or theoretical value. The closer you are to the accepted value, the greater the accuracy of your experiment. The accepted value could be located in a reference such as the Handbook of Chemistry and Physics. Percent error is a common method for reporting accuracy, where a smaller percent error represents a more accurate experimental value. Percent error is calculated as:

$$\text{Percent error} = \left|\frac{\text{Experimental} - \text{Accepted}}{\text{Accepted}}\right| \times 100\ \% \qquad (1)$$

In science, an experimenter is allowed to estimate one more digit past what can be measured exactly on an instrument. For example, if the smallest lines on a ruler are centimeters, and an object's length falls between 2 lines, more precision is gained by estimating between the lines. Therefore, the length of an object might be reported as 25.5 cm. The reported numbers are called "significant figures", and the more precise the instrument, the more significant figures it can produce.

A calculation cannot be any more precise than the least precise measurement. For example, density is calculated by dividing the mass of an object by its volume. Therefore, the density of an object might be 23.57 g/ 4.2 mL = 5.61190476 g/mL. But, the least precise measurement (the volume) only has a precision of 2 significant figures. Therefore, the density must be reported as 5.6 g/mL.

Procedure

Record your data on the report form as you complete the measurements.

A. Temperature

   5 beakers with thermometers have been set up for you: (1) room temperature water, (2) boiling water, (3) a mixture of ice and water, (4) a stirred mixture of ice and water, and (5) a stirred mixture of ice, water and salt. Observe and record all temperatures to the nearest 0.1 $^{\circ}$C.

B. Mass

When using any measuring device, never round off your raw data. If the balance fluctuates on the last digit, estimate that value. Weigh a (1) 100-mL beaker, (2) a 250-mL Erlenmeyer flask, (3) a plastic empty weighing boat, and (4) and then add approximately 2 grams of sodium chloride to the weighing boat. Calculate the mass of the sodium chloride added.

C. Length

Using a metric ruler, measure the following in centimeters, remembering to estimate one extra digit: (1) the length of the double arrow on the report sheet, (2) the length of the external height of a 250-mL beaker, and (3) the length of a medium sized test tube.

D. Volume

The graduated cylinder is the most accurate equipment in your locker for measuring volume and can give a precision of 0.1 mL. Water is attracted to the glass sides of the cylinder, causing a curved effect called the meniscus. The cylinder should be read at eye level using the bottom of the meniscus. In theory, a 250-mL Erlenmeyer flask with a marking for 200 mL should have a volume of 200 mL at that mark! However the problem is that volumes marked on beakers and flasks are only approximate values. Therefore, fill a 250-mL Erlenmeyer flask to the 200 mL mark with water, transfer this volume of water to a 250-mL graduated cylinder, and determine the exact volume.

It is often convenient to estimate volumes of 5 and 10 mL simply by observing the height of a liquid in a test tube. Use your graduated cylinder to place 5 and 10 mL of water in a medium-sized test tube and measure the heights in cm.

E. Density

Density measures the "compactness" of material. For example, lead has a high density, and Styrofoam has a low density. Mathematically, this compactness is expressed as mass per unit volume. In chemistry, we use grams and milliliters: d = g/mL. Density is an intrinsic value; it does not depend on the amount of sample taken. We will take advantage of this by measuring the density of various sample sizes and averaging their densities:

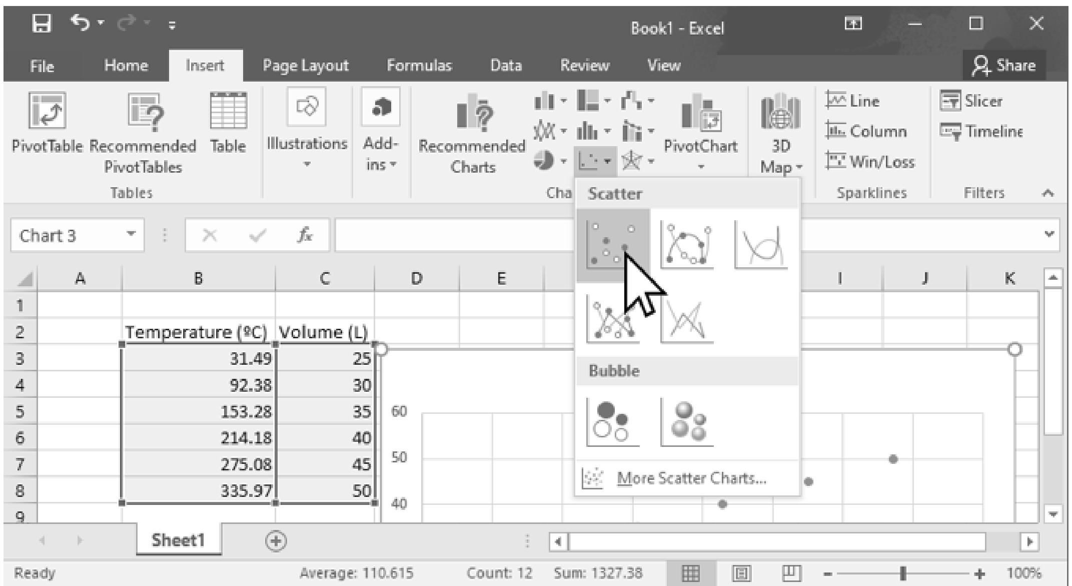
1. Obtain 5 pieces of the same object and record its name on the data sheet.
2. Weigh each object and record the values on the data sheet.
3. Choose the appropriate size graduated cylinder (smallest size that will hold the object plus enough water). Add enough water to the graduated cylinder be able to cover your largest sample. Record the volume to the highest precision (0.1 mL or better).
4. Carefully add the sample to the graduated cylinder. There are two things to watch out for: breaking the cylinder and splashing water out. Tilting the cylinder and gently sliding the object in minimize both of these risks. Record the new volume.
5. Repeat with each sample piece. If the sample pieces are small, the pieces can remain in the graduated cylinder until all sample pieces have been added to the cylinder.
6. Determine the density of each piece and the average density.
7. Using Microsoft Excel®, graph the cumulative data. Use the largest values of mass and volume to determine your x and y scales.

Name: ________________________________ Section: ____________________

Excel® Procedure

Note that various versions of Excel® may function a bit differently from the directions outlined below (which work on department-owned laptop computers):

Put the title for your x-axis (include units) in one Excel® cell (box). In the cell to the right, put the title for your y-axis. Using these boxes as headings, input the numeric data (like a table) in the cells under these titles (each box should contain one number; each row represents one data point in x,y format). Click and drag your mouse to highlight just the numeric boxes. From the "Insert" tab, choose a "Scatter" plot. (See example, below.)



Your graph must include a meaningful Chart Title and Axis Titles (with units). These Chart Elements can be added to your graph by clicking on the "+" icon in the upper right corner of your graph. Your instructor may request additional Chart Elements.

To add a Trendline, right click on any data point on your graph and choose "Display Trendline" from the menu that appears. The format trendline pane will appear on the right side of your screen. Linear should be selected by default. From this pane, you should check the box next to "Display Equation on chart." Your instructor may also ask you to check the box for "Display R-squared value on chart."

Name: ______________________________ Section: ____________________

Data and Calculations for Experiment 2

Measurements

A. Temperature
1. Water at room temperature ______________ °C

2. Boiling point ______________ °C

3. Ice water
   Unstirred ______________ °C

   Stirred ______________ °C

4. Ice water with salt added ______________ °C

B. Mass
1. 100 mL beaker ______________ g

2. 250 mL Erlenmeyer flask ______________ g

3. Weighing boat ______________ g

4. Mass of weighing boat + sodium chloride ______________ g

   Mass of sodium chloride (show calculation setup) ______________ g

C. Length
1. Length of $\longleftrightarrow$ ______________ cm

2. Height of 250 mL beaker ______________ cm

3. Length of test tube ______________ cm

D. Volume

1. 200 mL mark (from Erlenmeyer flask) water transferred to graduated cylinder ______________ mL

2. Height of 5.0 mL of water in test tube ______________ cm

3. Height of 10.0 mL of water in test tube ______________ cm

Name: ____________________ Section: ____________

E. Data Sheet for Density of an Object

Name of Object: ______________________________

Using Microsoft Excel®, graph the following: (last two columns)

Sample #	Object Mass (g)	Initial mL H_2O	mL H_2O w/ Object	Volume object (mL)	Density (g / mL)	Cumulative Sample #s	Cumulative volume (mL) (x-axis)	Cumulative object mass (g) (y-axis)
1	______	______	______	______	______	1	______	______
2	______	______	______	______	______	1 + 2	______	______
3	______	______	______	______	______	1 + 2 + 3	______	______
4	______	______	______	______	______	1 + 2 + 3 + 4	______	______
5	______	______	______	______	______	1 + 2 + 3 + 4 + 5	______	______

Average Density from Table = ______

Average Density from Graph (slope of line) = ______

Be sure to show your properly formatted graph to your instructor to receive credit for this part of the experiment (or print your graph and attach it to this report).

Name: ______________________________ Section: ____________________

Questions

1. Which would work better in this experiment as an unknown solid whose density is to be determined, wood chips or small quartz rocks? Explain your choice.

2. Why is it best to use a smaller graduated cylinder as opposed to a larger graduated cylinder for this experiment?

3. How well does the average density from the table and density from the slope of the graph compare? Which value is closer to the accepted density of your metal? (Refer to the *Handbook of Chemistry and Physics*). Calculate the percent error between your better value and the handbook value.

4. What is the density of a 9.343 gram piece of metal that causes the level of water in a graduated cylinder to rise from 5.1 to 8.1 mL when the metal is submerged in the water? Consider significant figures when doing the calculation.