Experiment 2 - Metric Measurements and Density

This experiment is an introduction to several kinds of measurements that are commonly made in the laboratory: mass, length, and volume. In addition, the "derived quantity", density, will be studied.

Make each measurement as accurately as you can, within the limitations of the measuring instrument that you are using. Be sure that the way you record and report this measurement correctly shows the degree of accuracy in the measurement. For example, a meter stick is marked off at intervals of 0.1 of a centimeter, so you can make measurements that are accurate "to the nearest tenth centimeter", or, if you interpolate (estimate between the lines), to the nearest 0.01 or 0.02 cm. If an object that you measure with this meter stick seems to have a length of "exactly" 5 cm, the length should be reported as 5.0 cm (or 5.00 cm if you are interpolating). You should not report the length as 5 cm or 5.000 cm.

An answer that is calculated from measurements can be no more accurate than the least accurate measurement that was used in the calculation. Therefore, it is often necessary to round off the numbers we get from calculations. This rounding off must be done according to certain rules of significant figures. (Refer to your textbook.) You should never just round off a number arbitrarily, but always follow these rules.

Safety Precautions:

- All of the materials for this experiment are harmless.

Waste Disposal:

- There is no waste for this experiment.

PROCEDURE

PART 1: MASS OF METAL SAMPLE

To use a digital balance, first turn it on. When the display shows up, press the "tare" bar to zero the balance. Then place an object on the balance, wait for the reading to stabilize, and record the reading and units.

Get an "unknown" piece of metal from the box in the hood. Record the unknown number printed on it, and the type of metal (aluminum or steel). Weigh the piece of metal to the nearest 0.01 g. Check your value against the list posted in the lab, and make sure the mass you obtained for the same piece of metal is within ± 0.01 g of the value on the list. Keep this piece of metal; you will be using it for other parts of the experiment.

PART 2: LINEAR MEASUREMENTS

Use calipers to measure the length, width, and height (to the nearest 0.01centimeter) of the metal sample you used in part 1. Calculate the volume of the metal sample in cubic centimeters (cm^3). The volume of a regular rectangular solid is found by multiplying the length times the width times the height. ($V = l \times w \times h$).

Part 3: Volume by Displacement of Water

Using the same sample of metal, you will measure the volume in a different way. Place about 10-15 mL of water in a 25-mL graduated cylinder. Record the volume of water in the cylinder as accurately as possible. When you read the volume, read the bottom of the curved surface of the water (the meniscus). Make sure to read it at eye level; if you look at the meniscus from slightly below or slightly above, the apparent volume is different. Also, when you measure volumes, it is best to interpolate (estimate) between the lines. The amount of uncertainty in your measurement depends on the number of divisions on the graduated cylinder that you use. For example, if the cylinder has divisions every 1 mL, you can probably estimate to the nearest 0.1 or 0.2 mL, and you should include one decimal place in your data. If the cylinder has divisions every 5 mL, you should probably estimate the volume to the nearest 1 mL.

Once you have read and recorded the volume of water in the cylinder, carefully add the metal sample without letting any water spill out. It helps to tilt the graduated cylinder and let the metal gently slide to the bottom. Be careful when using steel - if you're not careful and you just drop the metal in the graduated cylinder, the cylinder could break. (Note: there must be enough water in the cylinder to completely cover the metal rod when it is submerged. However, you must not put so much water in the cylinder that submerging the rod will cause the water level to rise so high that it cannot be read.) Record the volume reading, again interpolating between the markings on the cylinder.

The volume of the metal sample is the difference between the two liquid level readings. Calculate the volume of the metal. Compare your result with the result you obtained in part 2. (Note: 1 cm^3 = 1 mL by definition.) Which result do you trust more? Why?

Part 4: Density of the Metal Sample

Density is defined as mass per unit volume. To determine the density of a substance, measure its mass and volume, and then divide the mass by the volume. Densities are often expressed in g/cm^3 (for solids) or g/mL (for liquids or solutions).

From the mass of the metal sample (measured in Part 1) and its volume (measured in parts 2 and 3), **calculate** the density of the metal. Do this calculation twice: once using the volume measurement from part 2, and once using the volume from part 3. Express your result to the correct number of significant figures.

Part 5: Density of Water

This will be done by measuring both the volume and the mass of the same sample of water in a graduated cylinder. Obtain a 10-mL graduated cylinder. Make sure that it is dry inside and out. Weigh it on the centigram balance to ± 0.01 g, and record the mass.

Take the graduated cylinder off the balance and carefully add the water, of which you have measured the temperature, until it is just below the 10 mL mark. Wipe off any water that may have spilled on the outside of the graduated cylinder. Read the volume of water to the nearest ± 0.01 mL. You will need to interpolate. Remember to read the bottom of the meniscus at eye level. Record the volume.

Weigh the cylinder with the water. Record the mass. Calculate the mass of just the water in the graduated cylinder.

From the mass and the volume of the water, calculate its density in g/mL. Round your answer to the correct number of significant figures.

The actual density of water at your measured room temperature will help you find the density in the CRC . Calculate the percent error in your density determination:

$$\%\ error = \frac{d_{CRC} - d_{experimental}}{d_{CRC}}$$

Part 6: Predicting a Volume

Obtain a metal sample made of the same kind of metal you used in Parts 1, 2, 3, and 4, but not the same actual piece.

If you know the density of a sample and its mass, you can calculate its volume without measuring it. Density is an intensive property. This means that all pieces of aluminum should have the same density (or close based on experimental values!)

Record the mass of the new piece (second sample) of metal using a centigram balance. From the mass of the second sample of metal, and the density of the sample using water displacement from Part 4, calculate the predicted volume based on density.

If density is intensive, the volume you calculate using the density from the first sample and the mass of the second sample should give a calculated volume close to the actual volume of the second sample of metal. To do the calculation, use the density as a conversion factor.

You have two volumes: a volume based on mass using density (a calculated volume) and a volume measured using a graduated cylinder (a measured volume). Calculate the percent difference between the two volumes.

$$\%\ difference\ of\ volumes = \frac{Vol_{calculated} - Vol_{measured}}{average\ of\ the\ volumes} x100$$

Note: the percent error and the percent difference formulas are very similar. Percent **error** is calculated to compare an experimental value to a known true value of the same quantity. However, many times when experiments are done, the true value is not known. The percent **difference** is calculated to compare experimental values to each other. Percent difference is often calculated when the true value is not known.

Part 7: Relating Metric Volume to Old-Fashioned Volume

A number of household measuring devices are provided, and you are asked to find out the volume of some of them in milliliters (mL). Different sizes of large and small graduated cylinders will also be provided. Choose a household measuring device and a graduated cylinder that is close in size to the household measuring device you chose. Fill the household measuring device to its top marking (if any) with tap water, and then pour the tap water into the graduated cylinder. Read the volume of water in the graduated cylinder, and write it down on the report sheet. Do this for three different measuring devices. If you are using a teaspoon or tablespoon, you may want to use a funnel to transfer the water to the graduated cylinder.

Part 8: Learning to Estimate Volume

In this part of the experiment, you will use a small graduated cylinder to measure out a specific volume of water and then transfer the water to a test tube. Then you will note the height of water in the test tube. You will keep the test tube with the markings on it and you will use it to help you to estimate volumes of water without having to measure them out.

Take one of your regular-sized test tubes from your drawer and attach a piece of white labeling tape so that it extends from one end of the tube to the other (the long way). Measure out 1.0 mL of water in a graduated cylinder. Transfer this water to the test tube, and make a marking on the tape to indicate the water level. Write "1" next to the mark to indicate 1 mL. Dump out the water, and measure out 2.0 mL of water in the graduated cylinder. Transfer this volume of water to the test tube, mark, and label the tube indicating the 2 mL water level. Using a similar procedure, make a marking at 5 mL and at 10 mL.

In many experiments, approximate volumes of liquids will be used. An experiment might read " add about 2 mL of HCl solution to each test tube," meaning that the 2 mL doesn't need to be measured precisely, but can be estimated. You can then put the amount of solution in the tube that matches the height of the 2 mL mark on your labeled test tube. (Estimating the volume is much faster than measuring it out precisely.)

QUESTIONS: SEE PRE-LAB SHEET FOR QUESTIONS