MiraCosta College
Introductory Chemistry Laboratory
Experiment 2

Measurements and Significant Figures: Measuring Density

EXPERIMENTAL TASK

To measure the density of both water and the rubber used in laboratory stoppers using a number of different methods.

Objectives

After completing this experiment, the student will be able to:

1. Measure both the volume and mass of an object.
2. Use the measured values of volume and mass to calculate the density of the object.
3. Report measurements and results of calculations using standard units and significant figure rules.
4. Calculate the average of a set of measurements.

Additional Reading

- General, Organic and Biological Chemistry, by Timberlake, sections 1.3 – 1.9.
- Laboratory Handbook for General Chemistry, 2nd ed., by Griswold, et al, pp. 9 – 11 & 21 – 22 (top)

Background

Measurements: Experiment 1 introduced measurements as part of the scientific method, including the rules of significant figures for recording measurements. This experiment continues the application of measurements and significant figures, and extends them to making calculations based on original measurements. Therefore, it is vital that each student read and understand the sections covering measurements and significant figures in both Timberlake and Griswold before beginning this experiment. There is no such thing as an exact measurement, because all measurements include some amount of error, and there are two main types of error: *systematic error* and *random error*.

Systematic errors result from errors or defects in the measuring instruments or in the technique of the person making the measurement; a systematic error will repeat itself each time the measurement is made. For example, if the end of a ruler is worn down a little bit so that instead of beginning at “0 cm” it really begins at “0.1 cm,” every time that ruler is used to measure length it will give a result that is 0.1 cm shorter than the value it should give. It is generally possible to identify and fix systematic errors, or to at least allow for them in reporting the measurement. *Calibration* is the process of checking a measuring instrument or technique by using it to measure a known quantity, and then making adjustments to compensate for the systematic error.

Random errors result from carelessness in technique or from many other factors, and the sources of these errors are often unidentifiable. The result of the error is, of course, random—that is, the error in the measurement will be different each time the measurement is made. The best way to reduce random error is by making the same measurement many times and averaging the results (add up all the measurements and divide by the number of measurements in the set).

<u>Derived Units:</u> The International System of Units (“SI” or “metric system”) includes only 7 base units, each of which measures one quantity, or dimension. Some of these are: *meter*, for length; *kilogram*, for mass; *second*, for time; and *kelvin*, for temperature. There are, of course, many more types of quantities to measure in the universe, such as pressure, area, volume, energy, etc. The metric system makes use of *derived* units to measure these other quantities. Derived units are used to measure all other dimensions, and are mathematical combinations of the base units.

For instance, a derived unit for measuring area is the *square meter*, which has the symbol m^2, and is equal to the area of a square that is one meter on each side. The area of a square or rectangle is mathematically equal to the length of one side multiplied by the length of the other, or 1 meter x 1 meter = 1 m^2. Another example is a unit used to measure speed, *meters per second*. The word “per” is the equivalent of “divided by,” so “meters per second” becomes “meters ÷ seconds” or “meters/seconds.” The symbol is just “m/s.”

The density of a sample is defined as the mass of the sample divided by the volume of the sample, and density is therefore a derived quantity. In the metric system there are two main derived units used for density: *kilograms per cubic meter* (kg/m^3) and *grams per milliliter* (g/mL). The first unit generally gives a very large number for most liquids and solids, so chemists prefer to use g/mL for measuring the density of substances (g/mL and g/cm^3 are identical, and are used interchangeably).

Measuring the mass of an object or other sample is usually straightforward, but measuring the volume of an irregular sample, such as a rock, is a little more complicated. The most common method for measuring the volume of such an object is called *displacement*. In this method, some water is put into a graduated cylinder and the volume of the water is measured and recorded. The sample is then added to the water and the combined volume is measured and recorded. The volume of the sample is equal to the combined volume minus the volume of the water alone. The displacement method of measuring volume will be used in this experiment.

The final results of this experiment will be the average density of water, including the percent error in that measurement, and the average density of the rubber used in laboratory stoppers.

Pre-lab Questions

1. What is the main method used to reduce random error? To reduce systematic error?
2. What is a meniscus, and how do you deal with it in making a measurement?
3. A car traveling at a constant speed moves 945 meters in 28 seconds. What the speed of the car, in m/s.
4. What is the average of this set? 47.3 cm, 49.0 cm, 44.9 cm, 48.5 cm, 50.1 cm.

BEFORE STARTING THE EXPERIMENT

Safety

While this experiment involves no hazardous chemicals and uses no flames, etc, you must always keep in mind the rules presented in both the "MCC Laboratory Safety Rules" and the Laboratory Handbook for General Chemistry. It is your responsibility to make sure that you follow all safety rules at all times, and to graciously help everybody else in the laboratory (including the instructor) to do the same.

Equipment

It is a good idea to read through each part of the experiment before starting that section, and determine what glassware and other equipment will be needed. Gather these items and label those that will need labeling first, then carry out the procedure.

Technique

As you carry out these instructions, be sure to watch for sources of error, and try to minimize them. Sloppy technique gives sloppy results. The laboratory period is long enough to allow for careful, thoughtful technique to be used throughout the procedure.

EXPERIMENT PROCEDURE

Measuring the Density of Water

Take the following items from the lab drawer, or obtain them from elsewhere in the lab:

- 100-mL graduated cylinder
- 600-mL beaker
- 100-mL or 150-mL beaker
- Plastic pipet or dropper with bulb
- Digital thermometer and probe

Make a table in your notebook that looks like this:

Trial	Beaker Mass (g)	(Beaker + Water) Mass (g)	Water Mass (g)	Water Volume (mL)
1				
2				
3				
4				
5				

The beakers and graduated cylinder must be completely clean and dry. Label both of the beakers, “water.” Fill the 600-mL beaker with DI water from one of the DI water faucets—DO NOT use regular tap water. Connect the probe to the digital thermometer and turn on the thermometer. Make sure it is displaying °C, then place the probe in the water in the 600-mL beaker so that the tip of the probe is near the bottom of the beaker but not touching the glass. Allow the temperature to stabilize, then record the temperature in your notebook.

Use a top-loading balance to measure the mass of the 100-mL or 150-mL beaker, and record it in the table row labeled “Trial 1.” Pour DI water from the 600-mL beaker into the graduated cylinder until the level is near the 100-mL mark. Use the pipet to add water until the level is right at the 100-mL mark (if too much is added, use the pipet to remove the excess), and record the volume in the last column of the table. Pour this water into the 100-mL or 150-mL beaker, measure the mass of the beaker + water, and record it in the table. Subtract the mass of the beaker from the mass of (beaker + water) to obtain the mass of the water alone, and record this amount in the table.

Repeat this process, including measuring the mass of the empty beaker, until five trials have been completed.

Measuring the Density of the Rubber Used in Laboratory Stoppers

Take the following items from the lab drawer, or obtain them from elsewhere in the lab:

- 100-mL graduated cylinder
- 600-mL beaker
- Plastic pipet or dropper with bulb
- 5 rubber stoppers, each of a different size—make sure the largest one is still small enough so that it will fit in the 100-mL graduated cylinder without getting stuck.

Make a table in your notebook that looks like this:

Trial	Stopper Size	Water Volume (mL)	(Water + Stopper) Volume (mL)	Stopper Volume (mL)	Stopper Mass (g)
1					
2					
3					
4					
5					

Make sure all glassware and the stoppers are clean and dry. Label the 600-mL beaker, "water," and fill it with DI water from one of the DI water faucets in the lab—DO NOT use regular tap water. Select one of the stoppers to begin, record its size in the table row for Trial 1 (the size is a small number located on the larger end of the stopper), and measure its mass using a top-loading balance.

Add about 30 mL of water to the graduated cylinder. Measure the amount of water in the graduated cylinder and record it in the table. Tip the graduated cylinder to the side and GENTLY add the stopper to the water in the graduated cylinder (make sure it does not splash!). Allow any drops of water on the sides of the cylinder to fall back into the bulk of the liquid, then measure and record the volume of the (water + stopper). Subtract the volume of the water from the volume of the (water + stopper) to get the volume of the stopper.

Repeat this process with each stopper.

Clean-up: Dry all stoppers with paper towel before returning them to the cart. Make sure all glassware, etc., that belongs in your drawer gets into your drawer.

RESULTS

Calculations

Follow the instructor's directions concerning where and in what form to record data and calculations—most instructors require that all measurements and results of calculations be recorded in table form in the notebook in a separate "Results" section of the experiment, and that the work needed to perform the calculations be explicitly shown.

Density of Water

Calculate the density of water separately for each trial, then calculate the average density from these five separate values. Remember that density = mass/volume.

The table shown below gives the accepted values of the density of water measured at different temperatures from 12.0 °C to 26.0 °C. Find the accepted value for the temperature of your water sample, then calculate the percent error in your value according to this equation:

$$\%\ \text{error} = \frac{\text{experimental value} - \text{accepted value}}{\text{accepted value}} \times 100\%$$

Temp (°C)	Density (g/mL)	Temp (°C)	Density (g/mL)	Temp (°C)	Density (g/mL)
12.0	0.99950	17.0	0.99877	22.0	0.99777
13.0	0.99938	18.0	0.99860	23.0	0.99754
14.0	0.99924	19.0	0.99841	24.0	0.99730
15.0	0.99910	20.0	0.99820	25.0	0.99704
16.0	0.99894	21.0	0.99799	26.0	0.99678

Density of the Rubber Used in Laboratory Stoppers

Calculate the density of each stopper separately, and then calculate the average density from these five separate values.