Learning the techniques of common laboratory measurements is a principle goal of the laboratory experience in Chem 123. When you have completed this course you will have competencies in a number of laboratory techniques. The lab today will introduce you to the techniques of mass and volume measurement and to record experimental results in a laboratory notebook.

The density of a compound, often in units of g/mL, is an important property of a substance. The density, ratio of mass to volume, is an intensive property, which means that the quantity of material does not affect the density. The density of gold (19 g/mL) was used to distinguish pure gold from fake gold that was often of a lower density. Solution density is also used to determine the alcohol content of solutions, this technique is of major importance in the beer and wine industry.

Overview:
The density of Coke will be measured using two different techniques for the measurement of volume. A calibration plot of sugar concentration vs solution density will be constructed in order to determine the approximate sugar content of Coke.

By measuring a sample’s mass and volume, the density can be determined. During this experiment the volume of the sample will be measured in two different ways and the mass will be obtained from a digital balance.

Mass Measurements on the Wofford Digital Balances:

Never add a chemical to a container on a balance. In this course you will ALWAYS mass a sample using the “mass-by-difference” technique. To do this you will make two mass measurements and the difference in these masses is the mass of your sample. Two examples of this technique are given below.

Obtain the mass of the reagent container. Remove the approximate amount of reagent to be used. Remass the reagent container.
The most difficult aspect of these two massing techniques is estimating the amount of sample to be transferred. Usually you will be weighing gram quantities. These are in the ballpark of a half-teaspoon. By the end of the semester will be good at estimating these quantities. Often you do not need exactly 0.500 g of material. You can use 0.626 g of CaCO$_3$ if the procedure calls for half of a gram. You, of course, record that you have obtained 0.626 g of CaCO$_3$ in you notebook. This is sometimes called “weigh exactly about”. If you are doing a laboratory synthesis that requires an exact amount of a substance, use the second example of mass determination, in which case you can add and subtract from the sample dish several times, but never add or remove chemicals while the dish is on the balance.

Procedure:

Density Measurement of Coke: Volume Technique 1:
Obtain the mass of your small graduated cylinder. Fill the graduated cylinder with between 10 mL and 20 mL of decarbonated coke from the beaker at the front of the room. Record the volume in your notebook. Record all measurements in your notebook. Now obtain the mass of your liquid by weighing the filled graduated cylinder. Determine the density of the unknown liquid and report your results on the whiteboard at the front of the room and in your laboratory notebook.

Density Measurement of Coke: Volume Technique 2:
In this measurement of density you will use a more accurate measurement of the coke volume. A buret is a device to deliver an amount of liquid that can be measured to an accuracy of at least a tenth of a milliliter. Use the buret containing Coke to add approximately 30 mL of Coke to a 100 mL beaker of known mass. The volume measurement from a buret is made in a similar fashion to the weigh by difference technique for mass measurements. Make an initial reading of the buret volume (have the TA check your volume reading the first time you use the buret). Open the stopcock at the bottom of the buret. Allow the liquid to flow into a pre-massed 100 mL beaker. After adding about 30 mL (do not make any attempt to deliver exactly 30.0 mL), close the stopcock. Record the mass of the sample dish and add the approximate amount of sample substance to be used. Remove the sample dish and remass the sample dish and sample.
stopcock. Make a reading of the final buret volume. The volume added to your beaker will be \( \Delta V = V_f - V_i \). (Do not let the liquid go below the 50 mL mark on the buret.)

Reading Buret Volumes:
To make a volume reading on a buret, place your eye at the same level as the liquid in the buret. Read from the bottom of the liquid meniscus. In the example below

![Diagram of buret readings](image)

the initial volume would be read as 7.24 mL (The reading of the hundredths place is a little arbitrary) The final volume reading is 8.90 mL. The difference then is 1.66 mL of liquid delivered from the buret.

After determining the volume of Coke added to your beaker, obtain the mass of the Coke and the beaker. Determine the density of coke from this method of volume measurement. Record your density determination on the whiteboard at the front of the lab.

Creating a Calibration Curve to Convert Density to Grams of Sugar in Solution:

In order to determine how much sugar is in Coke, you will make a calibration curve of added sugar vs. solution density. The assumption is that the increased density of Coke is due to the dissolved sugar. This not strictly true, some of the additional mass is due to other components of the Coke formulation, but these are exceedingly small.

You will prepare three sugar solutions of increasing sugar concentration and measure their densities. By determining their densities you will be able to estimate the amount of sugar in Coke. You will prepare each solution in a 100 mL volumetric flask. The volumetric flask is to be obtained from your TA. The volumetric flask has a mark on the
neck of the flask that indicates 100 mL. Prepare a 100 mL solution that contains approximately 8 grams of sugar. As you follow the procedure for preparing solutions of known concentration, consider the steps that must be accomplished carefully verses the steps that are not significantly sensitive to laboratory skill. Recognizing where care is required will help increase your efficiency and accuracy in future experiments.

- Weigh the empty volumetric flask.
- At your desk add the contents of two packages of sugar to the volumetric flask. No sugar is to be added at the balances. Through away the empty sugar packets.
- Weigh the flask with sugar to obtain the mass of sugar added.
- Rinse and fill your squirt bottle with deionized (DI) water (from the plastic faucet). Gently tighten the DI faucet as you turn it off, as the plastic threads strip easily!
- From the top of your water bottle add DI water to the volumetric flask so that it is about 70 to 80 percent full.
- Obtain a piece of parafilm from your TA. Use the parafilm to cover the volumetric flask so that you can invert it without spilling the solution. Be sure your thumb remains over the parafilm while you invert the flask.
- Invert the flask several times allowing the sugar to dissolve.
- Squirt from the bottle (you must replace the cap) enough DI water into the flask to take the bottom of the water meniscus to the 100 mL mark.
- Cover with parafilm and invert the flask several more times so that all of the sugar is dissolved and the solution is thoroughly mixed.

Now that you have a solution of known sugar concentration, measure the density of the sugar solution using a buret to deliver about 30 mL of the sugar solution to a 100 mL beaker of known mass. A few points about preparing the buret should be observed.

- Obtain a buret, ring stand, and buret clamp from your TA.
- Set-up your buret in the ring stand in a fashion similar to the buret containing the Coke at the front of the room.
- Always rinse the buret with the solution that you will use in the buret. Add 10 mL to 20 mL of the sugar solution to the buret, using the plastic buret funnel. Be sure that the buret stopcock is closed.
- Use a large (400 mL) beaker as a waste beaker.
- Open the stopcock and drain into the waste beaker about 5 mL of solution from the buret. It is important during this step that the tip of the buret fills and that no air bubbles are present.
- Remove the buret from the clamp and rotate the buret so that solution coats the buret. Dump the remainder of the solution into the waste beaker.
- After rinsing, returning the buret to the rack and fill the buret nearly to the top with the sugar solution.
- Again drain another 3 – 5 mL of solution into the waste beaker.
- Record the initial volume of the buret.
From the buret, add approximately 30 mL of the sugar solution to a 100 mL beaker of known mass.

- Read the final volume of the buret.
- Obtain the mass of the beaker and sugar solution.
- Calculate the density of the solution

Prepare and obtain the density of a 100 mL sugar solution that contains approximately twelve grams of sugar. Now that you are starting with glassware you have previously used there is a little extra work required.

- Empty the remainder of the sugar solution from the volumetric flask.
- Rinse this flask several times with water.
- Completely dry the outside of the flask before you obtain the mass. Obtain the mass of the flask even though it is wet inside.
- Add the sugar of three packets to the flask and record the weight of the flask with the sugar.
- Measure and record the exact mass of sugar added.
- Dissolve the sugar in the flask with DI water in the same manor you did for the eight gram sugar solution.
- Fill the flask to the 100 mL level and invert the solution several times.
- Empty the buret of the old solution (be sure the tip is also drained) and rinse with the new sugar solution as you did previously. Be sure that all the liquid in the buret and tip is the new sugar solution.
- Rinse and completely dry the 100 mL beaker that you will use to collect the new sugar solution from the buret. Obtain the beaker mass; it should be ± 0.005 g of the mass obtained earlier.
- Add approximately 30 mL of the new sugar solution to the dry 100 mL beaker, recording buret volumes as necessary.

In the third sugar solution use four sugar packets to obtain approximately sixteen grams of sugar. Repeat the preparation and measurement steps to obtain the density of the final sugar solution.

After measuring the density of the third sugar solution, rinse your buret and volumetric flask several times with DI water. Leave the buret stopcock in the open position. Return these two pieces of glassware to your TA.

Plotting Linear Relationships and Calibration Curves:

Often experimental results can be presented most effectively in a graphical form. Our brain is wired to see relationships graphically. The scientific community shares some general guidelines for plotting a set of x–y data. In an x–y plot, the x-data is placed on the horizontal axes and the y-data on the vertical axis. We would say a plot of y vs x. Often one of the variables is the measurement you are making, this is called the dependent variable and is most commonly placed on the y-axis (in this experiment
density). The variable that the researcher has more control over is called the independent variable (in this experiment the concentration of the prepared sugar solutions). The independent variable is placed on the x-axis.

Plotting experimental data requires some preparation. Software programs such as Excel are good at plotting x-y data. Plotting data in Excel will be used later in the semester. To plot data in your notebook, you need to look at the range the data covers and then use the graduations on the notebook paper to mark the high and low range that you wish to cover. Label each axis with the quantity to be reported. Always include units. Label an appropriate number of tic marks (approximately five to ten) with their numerical value. Below is a plot appropriate for the following set of experimental data showing the density relationship to alcohol percentage of a solution (this is similar to what you will be performing for a sugar solution):

<table>
<thead>
<tr>
<th>Solution Density (g/mL)</th>
<th>Volume of alcohol in a 100 mL solution (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Independent Variable)</td>
<td>(Dependent variable)</td>
</tr>
<tr>
<td>0.991</td>
<td>10.2</td>
</tr>
<tr>
<td>0.945</td>
<td>37.1</td>
</tr>
<tr>
<td>0.932</td>
<td>46.3</td>
</tr>
<tr>
<td>0.888</td>
<td>58.8</td>
</tr>
</tbody>
</table>
An equation that relates the dependent variable to the independent variable is extremely useful. It can be used to determine new properties of the substance from the relationship. A linear mathematical relationship is common among many experimental variables and has a simple mathematical form, \( Y = m X + b \). You will remember this equation from high school algebra. In this expression, \( m \) is the slope of the line and \( b \) is the y-intercept. Computer programs also fit a straight line to x-y data using a simple formula.

To draw a straight line through a set of x-y data place a straight edge so that there are an equal number of points above and below the straight line. The line you draw will almost certainly not go through each data point. Do not make a dot-to-dot connection through each data point.

In the example above the straight line can be used to determine the alcohol concentration from a measurement of the solution density. If a solution was found to have a density of 0.910 g/mL the alcohol concentration would be 53 Vol % alcohol from the calibration curve above.

Constructing a Calibration Plot to Determine the Sugar Content of Coke:

After obtaining the density of three sugar solutions make a plot of the solution density (y-axis) vs the grams of sugar in a 100 mL solution (x-axis) on a new page of your laboratory notebook. Use nearly the entire page for your graph, and be sure that your plot contains the point for zero grams of sugar. The three calibration points will bracket the sugar concentration of Coke. With a straight edge, draw a best-fit line through the three data points. Do not connect the data points with straight lines. If you are unfamiliar with adding a best-fit line through a set of data, ask your TA for help.

Locate the density of Coke on the y-axis of your calibration plot. With a straight edge draw a line over to the calibration line. From the intersection with the calibration line determine the sugar content in 100 mL of Coke.

Last Calculation.

From your determination of the sugar present in 100 mL of Coke calculate the number of sugar packets found to 20 fl. oz. of Coke (1 mL = 0.03381 fl.oz)

Wipe down your table, cleaning up and sugary spills. Hand in duplicate pages to your teaching assistant.