Experiment 2: Measurements and Density

Prelab:

1. Read the How to Make a Good Graph pages in this lab manual (**pg. 137**). An additional section about graphing is in your text, Appendix A. Define "independent" and "dependent" variable, and on what axis they should be placed.
2. Make a graph, **BY HAND**, on graph paper (in back of this booklet) for the data below, which was determined by finding the mass of a rope that was cut at specific lengths. Identify and place the dependent variable on the proper axis, and follow the examples starting on **pg. 139**.

length (cm)	10.0	15.0	20.0	25.0	30.0	35.0	45.0	55.0
mass (g)	19.1	35.2	39.9	54.4	69.6	78.8	99.7	116.4

3. Using the graph of the data above, determine the quantitative relationship of mass to length (the equation of the best fit line, or slope) and express as a sentence, with measurements and units.
4. Use this information to find the length of a piece of rope which has the mass, in g, of any number known to +/- 0.1 g between 23-97 (for example, 88.9 g)
5. Read the section on density in your text, AND the introduction below. Write a definition for density, and explain why the density of water has a value that is easy to remember.
6. Calculate the density of an object that has a mass of 71.2 g and a volume of 95.2 cm^3. Calculate the volume of a 195.7 g object with the same density.
7. Read the online directions for using Graduated Cylinders, Pipets and Analytical Balances.
   http://academic.cuesta.edu/gbaxley/chem1A/volume/prelab_reading_for_week_2.htm

   What are the proper accuracy levels for graduated cylinders and pipets?

Questions to consider while performing this lab:

- ★ Do all devices record identical values?
- ★ Does each piece of chemistry glassware measure volumes to the same precision?
- ★ Can the density of a solution be determined via a standard calibration curve?

Introduction:

When writing a measurement:

- ✓ always include both the number (eg. 22.3) and the unit (eg. cm)
- ✓ always write down the correct number of digits (digits that you know plus one estimated).

Your instructor will demonstrate how to determine how many digits to include.

What is Density, and How is it Useful?

Were you ever caught by the riddle "what weighs more, a pound of feathers or a pound of lead?" They each weigh the same, of course, but ask the joker which they would prefer to have dropped on their foot! The reason why this riddle is amusing is that even though a pound of one thing weighs the same any other, the *density* of the lead is much different. The density is a ratio of the mass over the volume for a substance. It is an intensive property, meaning that density doesn't depend on how much of the sample is being measured. The mass any block of lead divided by its volume will yield the same ratio, regardless of the size of the block.

Because most substances increase in volume as their temperature increases while their mass stays constant, the ratio of mass to volume (density) decreases. This is why density is also reported with a temperature. Gasoline is sold on a "per volume" basis. Do you get more mass for your dollar when buying gasoline on cold days or hot days?

Density is fairly easy to measure, and is an important indicator for certain biological fluids. Urine density is analyzed as one indicator of a type of diabetes, and also for dehydration, infection, and renal failure. Blood donors typically have their blood tested by the "float test," where a drop of blood is tested for hemoglobin (and therefore iron) content by observing its density compared to a copper sulfate solution.

Density is also used to express the concentration of solutions. A 5.0% weight/weight solution of NaCl means that there are 5.0 g of NaCl in 100 g of solution, or 5.0 g of NaCl in 95 g of water. The 5.0% solution could also be made with 50.0 g of NaCl and 950.0 g of H_2O. We will study other units for concentration later in the year.

In today's lab, you will:

- Analyze student data from different measuring devices to determine if one device is more accurate or precise than the others.
- Determine the density and concentration of a solution by a common analytical method: using a calibration graph made with known volumes and concentrations of solutions.

<u>Safety:</u>

Although the solutions used today are relatively harmless, GOGGLES and APRONS will be worn at all times. All solutions can be disposed of in the sink.

There is a data sheet at the end of this handout for your measurements. Record all data in **<u>INK</u>**.

<u>Part I: Graphing</u> (may be done at any time in lab)

Check out a lap top computer, log on as <u>2105</u> (no password needed) and start Microsoft Excel. Unfamiliar with Excel? There is a step by step Excel guide in the lab manual starting on **pg. 140**.

Using an application like Excel is very helpful for science and engineering majors, so if you are not familiar with how to use Excel make sure that you learn today.

Turn to the Graphing Questions on **pg. 15** and prepare a graph as described. Answer the graphing questions on **pg. 15** **<u>before</u>** leaving lab. Your instructor may ask you to print the graph, or it may be checked off during lab in order to save paper. Check all of the answers from the temperature section with your instructor.

Part II: Determination of the Concentration of a Solution by Density

A. Data collection (in class)

1. Rinse and dry two 100 mL beakers (available on benches) and record their masses to the nearest 0.001 g in Table 1. Mark the beakers with tape for easy identification.
2. Obtain about 50 mL of one of the unknown solutions in a clean, dry 150 mL beaker.
3. Using the pipet bulb, fill the 10 mL volumetric pipet with about 2-3 mL of the unknown solution. Rinse the bulb of the pipet with the wash, and discard. Rinse twice more.
4. Using good pipet techniques fill the pipet with the unknown solution so it's above the etched mark. Wipe the tip of the pipet with paper towel, hold the tip against the beaker, and allow to drain to the mark. This delivers 10.00 mL (± 0.02 mL) of the solution.
5. Holding the tip of the pipet against the weighing beaker, allow the pipet to drain completely, except for the last drop that does not drain by gravity. Repeat to deliver 10.00 mL of the solution to the second beaker.
6. Weigh the beakers separately, recording the masses of the beaker + solution, and calculate the masses of the solutions.

B. Determining the Concentration (Percent by Mass) of an Unknown Solution (in class)

The density of aqueous (dissolved in water) solutions of salts is related to how much of the salt is dissolved in a given amount of water. The densities and concentrations (in percent by mass) of several calcium chloride solutions are provided for you in the table below. The densities were measured after solutions of specific concentrations were prepared.

Concentration (% by mass)	1.00	8.50	14.00	22.00	32.00	40.00
Density (g/mL)	1.008	1.080	1.120	1.198	1.310	1.39

The density of a $CaCl_2$ solution will be measured using a pipet and a balance. Preparing a calibration graph comparing the density to the known concentrations of the known solutions will allow the concentration of the unknown solutions to be determined from the density. **Do not enter the "%" sign after the numbers for Percent by mass in Excel.**

7. Calculate the density of the unknown solution using your data in Table 1.
8. Check out a laptop computer, log on as <u>2105</u> (no password needed) and start Microsoft Excel. Prepare a graph of the density and concentrations of the calibration solutions above using MS Excel. There is a step by step Excel guide in lab manual starting on **pg. 140**. Each student should prepare their own graph from a blank Excel worksheet DURING class.
9. Expand the number of <u>decimal places</u> in the slope to 6 by right clicking the equation of the line, and selecting "Format Trendline Label" then Number.
10. Before finalizing your graph, consider these questions:
    a. What are the independent and dependent variables? Which axes are appropriate?
    b. What sort or relationship exists between the density and concentration?
    c. Use *both* an estimated line on the graph paper *and* the equation for the line to determine the concentration of salt in the solutions of unknown concentration.

Part III: Comparing the Precision and Accuracy of Two Common Measuring Devices

In a previous semester, students collected density data for two types of Snapple drinks, Regular (sweetened with sugar) and Diet (artificially sweetened). Two measuring devices were used to measure the volumes of the liquids, 50 mL graduated cylinders and 10.00 mL volumetric pipets. The goal of the experiment was to determine which device was more precise, and if there was a difference in densities of the two kinds of drinks.

11. Open the Density Comparison Excel file by opening from the desktop:
    My Computer_chemistry on labvol….(Q:)_Baxley_Density Comparison for Accuracy and Precision.xls
    OR online at http://academic.cuesta.edu/gbaxley/chem1A/lab/DensityExp2.xlsx
12. Use Excel to calculate the average and standard deviations for each of the columns of data. Help with formulas is on **pg. 141**.

To Turn In next week:

1. Prelab for Experiment 2
2. Report Sheet pages for Part II and Part III.
3. Calibration graph for the $CaCl_2$ solutions.

Exp 2: Measurement and Density Name ________________________________

Partner ________________________________

Part I: Graphing Questions answer in lab

The temperature of a water sample was measured with 2 thermometers, one in Celsius and the other in Fahrenheit. The design of the experiment was such that the temperature of the water was measured at every 20.0 °C increase, as ice water was heated to boiling. The data are given below:

T °F	32.1	68.2	103.9	139.8	176.1	211.7
T °C	0.00	20.0	40.0	60.0	80.0	100

Prepare a graph for the data above using MS Excel, and answer the following questions about the graph. Make sure to follow the guidelines for using Excel and making good graphs in this lab manual.

Expand the number of decimal places in the slope to 3 by right clicking the equation of the line, and selecting "Format Trendline Label" then Number..

Do NOT print the graph, but have your instructor check the graph and the questions after you have completed G1-G6.

G1. Which is the dependent variable? Why?

G2. Find the linear relationship between °F and °C. Record the equation for the line using y and x, and also translate these variables into °F and °C. Include correct units.

G3. Explain in words the meaning of the slope and y-intercept values determined from your graph.

G4. Using the equation for the line, what value of °F will be equal to 37.0 °C? (show your work)

G5. Using the equation for the line, what value of °C will be equal to 145 °F?
(this is about the threshold temperature of pain for most people)

G6. The equation for calculating the temperature in Kelvin from degrees Celsius is exactly the same as the equation that would describe the best fit line of a graph of temperature in K vs. °C. What is the slope of this line?

Instructor check:

Exp 2: Measurement and Density Report Sheet Name ______________________________

Partner ______________________________

Part II: Determination of the Concentration of a Solution by Density

Scientists record all data in **INK**-no white out!

Table 1: Mass and Volume for Unknown Salt Solution		
Unknown ID: _______________	Trial 1	Trial 2
Mass beaker		
Mass beaker + liquid		
Mass liquid		
Volume		
Density		
Concentration (% by mass) *(calculated from graph, see procedure for data)*		

1. Show **sample** calculations for density **and** concentration of your unknown *(from graph)*:

2. Using the equation of the line from the graph, calculate the density of a 54.0% by mass $CaCl_2$ solution. Show work, including units. (always put a box around your final answer)

3. Using the equation of the line from the graph, what is the concentration as % by mass of a solution with a density of 1.240 g/mL?

Part III: Comparing the Precision and Accuracy: Data, Calculations and Questions

1. Use the class data to compute the mean (average) density for each data set (each beverage, by each measuring device. See **pg. 141** in the lab manual for how to make Excel do this for you! Enter your results in the table below.

	Regular drink		Diet drink	
	Grad. Cyl.	Pipet	Grad. Cyl.	Pipet
Average				
Standard deviation				

2. Evaluate the graph showing the ranges of the density data for each of the two measuring devices. Based on the graph, which device is more precise? Cite examples from the data, and include a definition of precision in your answer.

3. From this data is it possible to determine which device is more accurate? Be specific, and cite data.

4. From the data collected by the class, compare the densities of the diet and regular beverages. Which drink is more dense? (cite data)

5. In terms of the ingredients of drinks sweetened with sugar compared to aspartame (one artificial sweetener), why would the densities be different between regular and diet drinks? This may require some research on your part.

6. Will an object that is 0.312 kg and 42.0 cm^3 float in 10.0 L of liquid with a mass of 7.9×10^3 g? *(show calculations for remaining problems)*

7. A non-standard issue U.S. Federal Reserve gold bar measures 7.00 × 3.625 × 1.75 inches. If gold has a density of 19.3 g/cm^3, what is the mass of a gold bar in kg and pounds?

8. On a ‘Nick at Nite’ rerun of McGyver, the villain is shown pushing a snow sled upon which is a pile of gold bars that is about 1.0 m^3 in size. Calculate the mass (in pounds) that this stack of gold would weigh.

9. Briefly describe the feasibility of the villain pushing the sled full of gold across a field of snow.

10. Gasoline has a density of about 0.680 g/mL at 20 °C. What is the mass, in pounds, of 15.0 gal. of gasoline? (you may have to look up some extra conversions)