Density Determinations for Solutions

Introduction:
The density of a sample of matter represents the mass contained within a unit volume of space in the sample. For most samples, a unit volume means 1.0 mL. The units of density, therefore, are quoted in terms of grams per milliliter (g/mL) or grams per cubic centimeter (g/cm^3) for most solid and liquid samples of matter. Because the density does in fact represent a *ratio*, the mass of any size sample divided by the volume of that sample, gives the mass that 1.0 mL of the same sample would possess.

Densities are usually determined and reported at 20°C (around room temperature) because the volume of a sample, and hence the density, will often vary with temperature. This is especially true for gases, with smaller (but still often significant) changes for liquids and solids. References (such as the various chemical handbooks) always specify the temperature at which a density was measured.

Density can also be used to determine the concentration of solutions in certain instances. When a solute is dissolved in a solvent, the density of the solution will be different from that of the pure solvent itself. Handbooks list detailed information about the densities of solutions as a function of their composition (typically, in terms of percent solute in the solution). If a sample is known to contain only a single solute, the density of the solution could be measured experimentally, and then the handbook cold be consulted to determine what concentration of the solute gives rise to the measured solution density.

The determination of the density of certain physiological liquids is often an important screening tool in medical diagnosis. For example, if the density of urine differs from normal values, this may indicate a problem with the kidneys secreting substances that should not be lost from the body. The determination of density (specific gravity) is almost always performed during urinalysis.

For liquids, very precise values of density may be determined by pipeting an exact volume of liquid into sealable weighing bottle (this is especially useful for highly volatile liquids) and then determining the mass of liquid that was pipeted. A more convenient method for routine density determinations for liquids is to weigh a particular volume of liquid as contained in a graduated cylinder. It is this second technique that will be used in this lab.

The concentration of solutions is often expressed in terms of the solution's *percentage composition* on a weight basis. For example, a 5% sodium chloride solution contains 5 g of sodium chloride in every 100 grams of solution (which corresponds to 5 g of NaCl in every 95 g of water present).

Materials:

10.00 mL Graduated cylinder	NaCl solutions: 5%, 10%, 15%, 20%, 25%, 2 unknowns
Analytical balance	Transfer pipets

Procedure:

Goggles and aprons must be worn at all times in the lab!

A) Determination of the density of solutions of known and unknown concentration
   1) Your instructor has prepared NaCl solutions of the following percentages by weight: 5%, 10%, 15%, 20%, and 25%. Make a mass determination for 10.00 mL of each solution, using the analytical balance and your graduated cylinder. Be certain to record the temperature for each solution as you test its density.
   2) Make a mass determination for 10.00 mL of each of the two unknown solutions, again recording the temperature for each solution as you test the density.

B) Organization of data
   1) Your density data should be organized in a table (see later in this lab) in your lab report. Using this data, construct a graph of the density of your solutions of known concentration versus the percentage of NaCl the solution contains. What is your independent variable (x-axis)? What is your dependent variable (y-axis)? What sort or relationship exists between the density and composition?
   2) Use the graph to determine the concentration of NaCl in the solutions of unknown concentration. What is the concentration of Unknown solution "A"? What is the concentration of Unknown solution "B"?

C) Using the graphing calculator.

1) As a class, we will use the TI-83+ graphing calculator to do an analysis of the data.

<u>Step 1: Enter the data in a list</u>

STAT → "EDIT" → 1:Edit → ENTER This opens the list window. If there are contents in the lists, then use the "up" cursor to move into the uppermost field – the list header (L_1, L_2, L_3…). Once there, press CLEAR and then the "down" cursor. This clears the list field.

Now enter the values for concentration in L_1 and density in L_2.

<u>Step 2: Turn on Diagnostics</u>

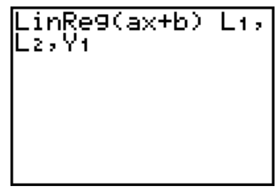
In order to analyze the linearity of our data, we need to turn on the statistical diagnostics. This will provide us with correlation coefficients when we perform a linear regression.

Open the Catalog function: 2nd → 0 and then scroll down to "DiagnosticOn" and press ENTER, and then ENTER a second time. The diagnostic functions are now on.

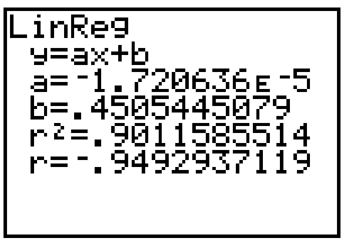
<u>Step 3: Perform Linear Regressions</u>

Press STAT > CALC, press ENTER. Scroll down to **4:LinReg(ax+b)** and press ENTER

We will now perform a linear regression on the contents of L_1 and L_2. We would also like to store the resulting linear equation for later use. We will store it in under the Y= function. The homescreen should now say "**LinReg(ax+b)**". Press 2nd 1 , 2^{nd} 2 , VARS > (Y-VARS, 1:Function) ENTER and Select "**1:Y_1**". Press ENTER. The screen should now appear as it does to the right.



Press ENTER once again, the screen should look (somewhat) like it does below:



The values of $\mathbf{r^2}$ and **r** give us a sense of how closely our data correlates to a linear equation. The closer these values are to 1, the better the correlation. In this case, the correlation is not very close. This indicates that there is not a linear relationship between our variables, or that our data is inaccurate. How does your data correspond to the expected linear relationship between concentration and density? Copy the results of your regression analysis into your write up and compare the slope and y-intercept of your hand-drawn (or Excel) graph with the results from the TI-83+.

<u>Step 4: Analyze the Graph</u>

You should now be able to press σ and see a graph of the line yielded by your analysis. Use the ρ key and the cursors to move along the line until you come to the densities of your unknown solutions. Record the value of the concentration (x-axis) that corresponds to each density. In your write-up discuss any differences between the results of your hand-graph (or Excel) and the TI-83+ graph.

<u>Suggested Data Table</u>

	Solutions						
	5%	10%	15%	20%	25%	Unknown #1	Unknown #2
Temperature (°C)							
Mass (g)							
Volume (mL)							
Density (g/mL)							

	Conc. of Unknown #1	Conc. of Unknown #2	Slope of line	Y-intercept	r	r^2
Hand Graph						
TI-83+						