Experiment 3

Density of Aqueous Sodium Chloride Solutions

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PURPOSE

Determine the concentration of an unknown sodium chloride solution by measuring its density and comparing with a standard curve prepared from solutions of known density. Practice using pipets and balances. Learn to create and use a standard curve.

DENSITY AND MASS PERCENT

The density of a liquid is usually directly related to the solution's concentration. Because the density of a liquid is easy to measure, this provides a convenient method of determining the concentration. For example, the state of charge of an automobile battery can be determined from the density of the aqueous sulfuric acid battery fluid.

$$Density = \frac{mass}{volume}$$

For a liquid, the volume is readily determined using accurately graduated glassware such as pipets, burets, or volumetric flasks.

Since the volume of a substance varies with temperature, it is important to record the temperature of density measurements. When comparing the densities of different samples the temperature should be held constant for all the density measurements.

The concentration of an aqueous solution can be expressed in many different ways, but the simplest is mass percent (also called weight percent):

$$Mass\ \%\ solute = \frac{mass\ solute}{mass\ solute + mass\ H_2O} x100\%$$

STANDARD CURVES

The density of aqueous NaCl solutions is a nearly-linear function of the NaCl concentration (in mass percent). A linear relationship permits a reliable standard curve to be constructed (see Figure 1). A standard curve relates some measurable property (such as density) to the concentration and is an essential feature of any quantitative chemical analysis.

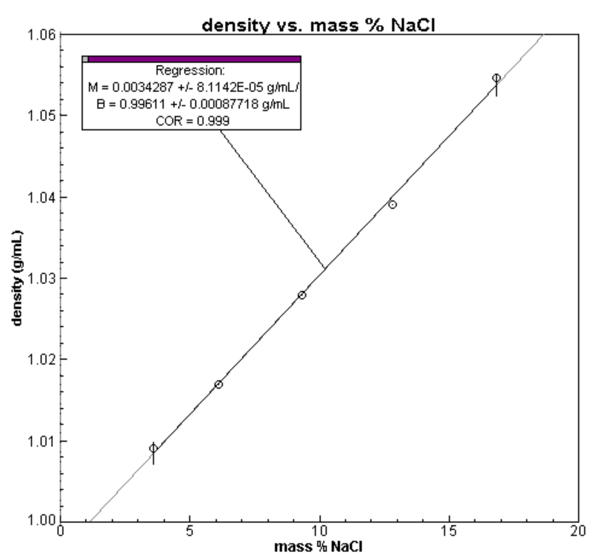

Figure 1. Density vs. mass % NaCl. The best-fit line was added using linear regression.

Usually there is enough random scatter among the data points so that they do not all fall exactly on a line. The best-fit line should go through as many points as possible while having an equal number of the remaining points scattered on either side of it. Generally, this is achieved using **Linear Regression Analysis** (linear least squares) to calculate the equation of the best-fitting line. Outside of lab, this can be accomplished using graphing calculators or computer programs such as EXCEL or LOGGER PRO. In lab, we will use our LabQuest2 to generate and print our standard curves.

Once you have obtained the equation of a line that best fits your five density (y) vs. mass % (x) data pairs, insert your unknown's density for y and the best-fit values for m and b into y = mx + b and solve for the unknown's mass percent x.

IN THIS EXPERIMENT

Five standard solutions of known mass percent will be prepared and their densities determined. A standard curve will be constructed by plotting the density vs. mass % and the best-fit line will be determined via linear regression. The density of an unknown solution will be measured and its mass % will be determined from the best-fit line.

PRE-LABORATORY PREPARATION

1. Read the techniques, procedure and data analysis sections of the experiment.

2. Complete the PRELAB assignment in Canvas. Refer to the procedure and data analysis sections of the experiment as needed. The prelab questions for this experiment exactly replicate the questions in the data analysis section.

EXPERIMENTAL SECTION

WASTE DISPOSAL

All of the chemicals used in this experiment may be safely disposed of by washing down the sink.

PROCEDURE

Unless instructed otherwise, you should work in groups of two or three to reduce the time spent waiting for access to a balance.

PREPARING THE STANDARD CURVE

1. Weigh out the mass of NaCl for solution number 1 (given in Table I – see next page).

Place a clean, dry, 50-mL (or 100 mL) beaker or 50-mL Erlenmeyer flask on a balance, tare (zero) the balance, and then use a spatula to add solid NaCl to the flask.

The mass of solid does not need to be exactly the mass given in the table. But you do need to know exactly how much you measured out, so record the mass to the nearest .001 g.

Do not spill any salt on the balance. The NaCl can corrode the balance, ultimately ruining it. CLEAN UP any salt that you spill.

Additionally, salt spilled on the balance pan will affect the weight and change your results (for the worse). For these reasons it is generally considered to be a bad idea to add large amounts of chemicals to a flask while it is sitting on a balance. It is better to remove the flask, add the chemicals, and replace the flask on the balance. This will not affect the taring done earlier.

Table 1. Approximate Masses of NaCl to use.

Solution Number	Mass of NaCl (g)
1	6
2	4.5
3	3
4	2
5	1

2. Tare the balance again (while the flask containing the salt is still on the balance). Remove the flask from the balance. Then add approximately 30 mL of distilled water to the flask and weigh it.

Use a graduated cylinder to roughly measure the amount of liquid. Again, record the mass to the nearest .001 g.

3. Thoroughly mix the solution by swirling or stirring with a glass stirring rod until all of the solid has dissolved.

4. Measure and record the temperature of the solution (to the nearest 0.1°C).

All five standard solutions must have the same temperature (± 1°C). The temperature of a solution can be adjusted by holding the flask under hot or cold running water (being careful not to splash any water into the flask).

Whenever reading calibrated glassware, always try to estimate one decimal place beyond the closest calibration marks. Since the thermometers are marked every degree, they should be read to the nearest 0.1°C.

5. Measure the mass of a 10.00 mL aliquot (sample) of the standard solution.

Rinse a 10 mL pipet with a small quantity of the solution to be measured. Tare an empty 50 or 100 mL beaker and then remove the beaker from the balance. Use the pipet to add a 10.00 mL aliquot of the standard solution to the beaker. Place the beaker back on the balance and record the mass of the solution.

The mass of each aliquot (10 mL of salt water) should have a mass somewhere between 10 and 12 g. Furthermore, solutions with larger mass percents of NaCl should have larger densities.

6. Repeat the above steps for standard solutions 2-5. For each solution, weigh out a mass of NaCl close to the amount in Table 1.

MEASURING THE UNKNOWN'S DENSITY

Each person must do his/her own unknown.

7. Give the laboratory assistant a clean, <u>dry</u> 50 or 100 mL beaker for your unknown solution.

Record your unknown number on your data sheet.

8. Measure the temperature of the unknown.

If necessary, adjust it to be the same (±1°C) as the temperature of the standard solutions measured earlier.

9. Measure the mass of a 10.00 mL aliquot of the unknown using the procedure described in step 5 above.

Since your grade heavily depends upon the accuracy with which you determine the density of the unknown, *you may want to repeat this measurement several times and then use the average value* when calculating the density.

CLEAN UP ANY CHEMICAL OR LIQUID SPILLED IN THE BALANCE AREA.

Instructors have been known to deduct points from a group's score (or even the entire class) if the balance area is not kept clean. Cleanliness is part of lab safety and that is EVERYBODY'S responsibility.

RINSE YOUR GLASSWARE WITH DISTILLED WATER AND DRY IT BEFORE RETURNING IT TO THE DRAWER.

Name ______________________ Station Used __________ Instructor/Day/Time __________________

Partner __________________ Partner __________________ Station Checked & Approved __________

DATA SHEET

Record measured and calculated values with correct units and the appropriate number of significant figures. Each student should record their unknown data on their own half of the page below.

Standard Solutions:

Solution Number	Mass NaCl	Mass H_2O	Temperature	Mass of 10.00 mL
1				
2				
3				
4				
5				

Unknowns:

Name			
Unknown Number			
Temperature of Unknown (after any adjustment)			
Mass of 10.00 mL of Unknown: Aliquot 1			
Aliquot 2			
Aliquot 3			

DATA ANALYSIS

Your instructor may either require one report per student, or one report per group of students. If this is not announced, ask. In either case, each student must analyze his/her own unknown. *All calculations should be clearly organized, make proper use of significant figures, and include the units.*

1. Calculate the mass % NaCl in each of your five standard solutions. Keep at least 3 places after the decimal for each value. Fill in your results in the table below. Show your sample calculation for solution 1:

2. Calculate the density for each of your five standard solutions. Keep at least 3 places after the decimal for each value. Fill in your results in the table below. Show your sample calculation for solution 1:

Solution Number	Mass % NaCl	Density (g/mL)
1		
2		
3		
4		
5		

3. Generate your standard curve and best-fit line (and print them) using a LabQuest2, as follows:

a. Turn on the LabQuest2 by pressing the red power button on the top. It will take a minute to warm up.
b. Tap on the **Data Table icon** in the upper right. It is the white icon with the X and Y at the top.
c. Tap on the **X** column heading. Change the Name to ***mass % NaCl*** (the % symbol is found by first tapping on 123 and then the arrow key in the bottom left, which toggles between different sets of special characters) and change the Displayed Precision to ***3*** Decimal Places. Then tap ***OK***.
d. Tap on the **Y** column heading. Change the Name to ***density***, the Units to ***g/mL***, and the Displayed Precision to ***3*** Decimal Places. Then tap ***OK***.
e. Enter your results from the table above into the columns. Double-tap on a cell to select it. After you enter a value and tap on the Enter key (↵), it will advance you to the next cell in the table.
f. Tap on ***Done*** when data entry is complete.
g. Tap on the **Graph icon** in the upper left, then tap ***Analyze*** and ***Curve Fit***.
h. Tap on the box saying ***density*** that appears, then tap on the ***Fit Equation*** box and select ***Linear***.
i. Record the slope and y-intercept below (with proper units) and then tap ***OK***.
j. Tap ***File*** from the top menu and then tap ***Print*** and then ***Graph***.
k. Tap on ***Print Graph Title*** and enter the title (e.g., *density vs mass % NaCl*) and then tap ***Print***.
l. Shut down the LabQuest2 by first tapping ***File***, then ***Quit***. Choose to ***Discard*** the data. Next, tap on the ***System*** folder and then ***Shut Down*** and, finally, tap ***OK***.

Slope ____________________ y-intercept ____________________

ANALYSIS OF THE UNKNOWN

Each member of the group must turn in their own individual page with the analysis of their individual unknown. (If the group turns in a single report, staple all of these pages to that report.)

4. Calculate the (average) density of your unknown solution. (a) Show your density calculation below. (b) Record your density in the summary table at the bottom of the page to the proper number of significant figures (given that a pipet has a volume of 10.00 mL).

5. Calculate the concentration (mass %) of your unknown (to the proper number of significant figures) using its density (from question 4) and the slope and y-intercept (from question 3). (a) Show your calculation below. (b) Check your calculation: on the printed graph, draw a horizontal line from the unknown's density on the y-axis to the best-fit line and then a vertical line from this point to the x-axis. If the value you read off the x-axis differs from your calculated value, there must be a mistake that you need to fix. (c) Record your result in the summary table below.

Summary of Results:

Unknown Number	
Density of Unknown	
Mass % of Unknown	
Name	