Lab 2. Density of a Liquid Mixture

Prelab Assignment

Before coming to lab:

- Use the handout "Lab Notebook Policy" as a guide to complete the following sections of your report for this lab exercise *before* attending lab: Title and Date of Lab, Introduction, Materials/Methods *and Data Tables*. Ensure that the table of contents of your lab notebook is current.
- Complete the Prelab questions on the last page and hand in on the instructor's table at the start of lab.

Purpose

In this laboratory you will determine the density of liquid mixtures and use graphical techniques to determine the composition of an unknown mixture. You will learn to use MS Excel to graph data and determine the slope, and understand the difference between accuracy and precision as it applies to experimental data.

Introduction

When two liquids are mixed, how does the density of the solution compare to the density of the pure liquids? How does this density change as the percentage of each liquid changes? In this laboratory you will investigate these questions by determining how the density of an isopropanol/water mixture varies as the fraction of isopropanol increases.

You will begin by using the known density of pure water to determine the volume of a pycnometer, and then determine the densities of pure isopropanol and several isopropanol/water solutions. The results will be graphed, and a relationship between the density of the solution and percent isopropanol will be found. This graph can then be used to find the percent composition of an unknown mixture.

For this experiment you are to ***work in pairs***. The first task will be to determine the volume of the ***pycnometer***. This is accomplished by weighing the pycnometer empty, filling it with deionized water of known temperature and re-weighing. From this data, the mass of water can be calculated. Then, using the known density of water at the temperature used (available in published tables) the volume of the water, and thus the volume of the flask, can be determined.

Figure 1. Pycnometers come in a variety of sizes. A 25 mL pycnometer will be used in this lab activity.

Figure 2. A sketch of a pycnometer and a one filled with a blue solution.

The densities of all remaining solutions are to be determined in a similar way. Once the volume of the pycnometer is accurately known, it can be filled with the desired solutions and weighed. Using the mass and volume of the unknown solutions, each density can be calculated.

Each pair of students will be assigned one of the following isopropanol/water mixtures to prepare and determine the density of: 10.0, 20.0, 40.0, 60.0, 80.0 or 90.0% isopropanol by volume. The assigned solution will be prepared by mixing the appropriate amounts of isopropanol and water. You will also be given a solution with an unknown percentage of isopropanol, and are to determine its density, and from that, its composition. Lastly, every pair of students will determine the density of pure isopropanol.

A graph of density vs percent isopropanol will be prepared from the class data and linear regression will be used to determine the slope and intercept. This can then be used to determine the composition of the unknown solution.

Finally, we will judge the accuracy and precision of our methods by pooling the class results for the density of pure isopropanol.

Using a Pycnometer. Here are some things to keep in mind when using your pycnometer.

- The pycnometer is delicate and expensive; exercise care when handling it.
- Since the mass of each pycnometer and stopper vary slightly in mass, be sure that you do not inadvertently switch stoppers or pycnometers with someone else. If your pycnometer and/or stopper have a number engraved on it, record each of them for easy identification.
- The pycnometer and stopper must be clean and DRY before the initial weighing.
- To fill the pycnometer with liquid, fill the pycnometer to about halfway up the neck, and then slowly insert the capillary stopper.
- When full, there should be NO air bubbles in the bulb or capillary of the pycnometer, and no air space at the top of the capillary.
- Before weighing the full pycnometer, the outside should be perfectly dry.
- A small amount of acetone (use under the lab fume hood) is handy for drying both the inside and outside of the pycnometer.

Procedure

1. **Determination of the Volume a Pycnometer.** Obtain a pycnometer. If it is clean and dry, proceed to step 2. If not, wash it carefully with soap and water and rinse it with deionized water. To dry, squirt a small amount of ***acetone*** inside, swirl to coat the sides, and discard the liquid in the waste container under the hood. Blowing air into the flask using the compressed air supply under the hood will speed up the drying process.
2. Weigh the clean, dry pycnometer with its glass lid inserted, and record the result.
3. Obtain a beaker of deionized water and record the temperature. Look up the density of water at this temperature in the *CRC Handbook of Chemistry and Physics* and record the density in your data table in your notebook.
4. Fill the pycnometer with the deionized water. This requires a little care. First fill to just above the cap stem, tap gently to dislodge bubbles, and insert the glass lid. Water should squeeze out the hole in the lid and *no air bubbles should remain*.
5. Dry the outsides of the flask, weigh, and record the result. Calculate the volume of the pycnometer. Repeat the procedure a second time to ensure that you are achieving consistent results.
6. **Preparation of a solution of Isopropanol and water.** Record the solution you have been assigned to prepare here and in your lab notebook: _____ Figure out the amount of water and isopropanol to mix in order to prepare ***100.0 mL of this solution***. Mix the liquids in a graduated cylinder, and cap with a rubber stopper when you are done to minimize evaporation.

7. **Determination of the Density of Isopropanol Solution.** Fill the dry pycnometer completely with this solution and weigh. Use the known volume of the flask to calculate the density of your solution. Repeat the procedure a second time and record both results on the whiteboard.
8. **Determination of the Density of an Unknown Isopropanol solution**. Obtain one of the unknown mixtures of Isopropanol and water and record its number in your lab notebook. Rinse your pycnometer twice with small amounts of your assigned unknown, and then fill it with the mixture. Weigh the flask and contents, record the result, and calculate the density of the unknown mixture.
9. **Determination of the density of pure Isopropanol**. Rinse the pycnometer twice with small amounts of pure isopropanol, and then fill with pure isopropanol. Weigh the flask and contents, and record the result. Calculate the density of pure isopropanol, and record your result on the whiteboard.

Analysis of Results

1. ***Make a graph of the class data by Hand***: Use a *full page* in your lab notebook to construct a graph of density *vs* percent isopropanol for all ***class data*** obtained. For guidelines in constructing your graph see #4 of the "Lab Report Checklist" on page 5. You must complete a graph by hand and have it approved by your instructor prior to using a computer to generate a graph.
    - Calculate the ***slope*** of the hand-drawn graph. Clearly show *on the graph* your calculation of the slope and the *two points* used to calculate the slope.
    - Calculate the ***y-intercept*** of the hand-drawn graph. Clearly show *on the graph* your calculation the y-intercept.
2. ***Make a graph of the class with Excel***: Each student is to use *MS Excel* to build a spreadsheet containing the same data as the hand-drawn graph, being sure to arrange the data in columns, with clear labels and proper units included at the top of the columns. Use the "Format Cells" command to format the data so that the correct number of significant figures is displayed. While constructing your spreadsheet pay attention to appearance as well as substance. *Be sure to include you name in the title at the top of the spreadsheet, and print a copy for inclusion in your report*.
    - Use the "Chart" feature to prepare a graph of the data, and use the ***trendline*** feature to determine the slope of the line. Print a copy of the graph to include in your lab report. Since the graphs will appear very similar it is essential that you **place your name on the graph before printing**.
    - Using the equation for a line, y = mx + b, the slope and y-intercept (each obtained from the graph made with *MS Excel*), determine the composition of your unknown isopropanol solution.
3. ***Use Excel to statistically analyze the class data for the density of 100% Isopropanol***: Use *Excel* to create a table (use formatting as in #2, above) of the class data for the density of the pure isopropanol. Then use the formulas in *MS Excel* to compute the ***average density***, ***standard deviation*** and ***percent error*** for the density of pure isopropanol. Include the class results in your calculation. Print a copy of this data table for inclusion in your report.
    - ***Error Analysis*:** Use the *CRC Handbook of Chemistry and Physics* to look up the accepted value for the density of isopropanol at 20^{o}C (more correctly named 2-propanol and commonly called "rubbing alcohol." Calculate the ***percent error*** and comment on the ***accuracy*** and the ***precision*** of the class data. Discuss the most likely source(s) of error that may be responsible for the class results being either too high or too low. Use specific numerical data to support your analysis (e.g. theoretical density, class average, % error, standard deviation, etc.)

Error Analysis Questions

Consider the following questions when analyzing the results of this lab for sources of experimental error, but record your answers to these questions after the conclusion section of your report. Title this section of your report "***Error Analysis Questions***" and number your responses as the questions are numbered below. It should be clear from each answer what the question is you are answering—hence, "*incorporate the question into each answer*."

1. What effect would a partially filled pycnometer (e.g. due to the presence of air bubbles, etc.) have on the determination of its volume? How would this error impact the density calculations? Explain your reasoning.
2. What effect would water (i.e. during step 5 of the procedure) on the outside of the pycnometer have on the density determinations? Explain your reasoning.
3. A student failed to dry the inside of the pycnometer completely during step 7 of the procedure. What effect would this error have on the density determinations? Explain your reasoning.

Laboratory Write-up Guidelines

Write your lab report in your lab notebook by following the guidelines outlined in the handout "Lab Notebook Policy." Your report should include:

1. Tables of all data collected, with correct units and significant figures.
2. Two graphs of density *vs.* percent isopropanol, the first prepared by hand and the other using MS Excel. Be sure to label the axes fully and give each graph an informative/proper title.
3. A section showing all calculations, including the calculation for the slope of the graph. All values should contain the correct units and significant figures.
4. Your calculation of the density of the unknown solution, and determination of its composition.
5. The class average for the density of pure isopropanol, the accepted value, the percent error and standard deviation of the class results.
6. Your analysis/discussion of the accuracy and precision of the class results, and discussion of possible sources of error.
7. See the next page for a detailed summary of what should be included in your report.

Lab Report Guidelines

As indicated previously, be sure to include all your lab data and calculations in your report, according to the guidelines in "*Lab Notebook Policy*" handout. Below is a checklist of what should appear in each of the 5 sections of your lab report.

Lab 2 Report Checklist

1. Introduction

- Goal/purpose of the lab is stated clearly?
- Includes summary of background information

2. Materials and Methods

- Procedure is brief, but detailed enough that a competent student could use it to replicate the experiment?
- Uses your own words—doesn't plagiarize the procedure from the handout?

3. Results

- Ruled and easy to read data table(s)
- All or most data summarized in **one table**? → makes for easy comparison of data
  - Includes accepted values & %Error?
- Correct use of Sig figs?
- Correct use of Units?

4. Analysis of Results

- **Graphs by hand**
  1. Informative title?
  2. Axes are labeled clearly and have numbers with correct sig figs?
  3. Graph has scales so that the graph occupies most of the page?
  4. Correctly draws line of best fit (L.O.B.F.)?
  5. Slope – shows work with units on the graph?
     - Uses two points on the line of best fit?
  6. y-intercept – includes work with units on the graph?
- **Graph with Excel**
  1. Informative title?
  2. Axes are labeled clearly and numbers have correct sig figs?
  3. Slope – includes units
  4. y-intercept – includes units?
  5. Equation for line
  6. Correctly determines composition of unknown using the *equation of the trend line*?
- **Spreadsheet for Pure Isopropanol**
  1. Average density for class
  2. Standard Deviation
  3. Calculation of %Error
- **Discussion of Accuracy and Precision**
  1. Discusses sources of error? → are there any systematic errors and/or just random errors?
  2. Quotes specific data:
     - % Error when discussing accuracy
     - Std deviation when discussing precision?

5. Conclusion

- Uses "*bullets*" to state major conclusions: density of 100% Isopropanol , Isopropanol Soln, % Composition of Unknown
- Uses specific numerical data to support conclusions
- Includes %error whenever possible
- Summarizes sources of error?

6. Error Analysis Questions

Gives in-depth explanations to error analysis questions 1 – 3?

"It's not that I'm afraid to die, I just don't want to be there when it happens."
Woody Allen

"Electricity is actually made up of extremely tiny particles called electrons, which you cannot see with the naked eye unless you have been drinking."
Dave Barry

"You can only be young once but you can be immature forever."
Dave Barry

Lab 2 Prelab Questions Name_____
Density of a Liquid Mixture Team ___Date _____Section ___

Instructions: Complete the following questions and hand in at the start of your lab period or when instructed by your instructor. Show your work with units and correct significant figures for all questions that involve a calculation. Circle your numerical answers.

1. Suppose that when determining the volume of a pycnometer a student did not completely dry the outside of the pycnometer after adding the DI water. What effect would this have on the determination of the pycnometer's volume? (Circle the correct choice below and explain your reasoning!)

   (a.) too high. (b.) too low (c.) Unaffected

   Explanation:

2. In this lab activity each pair of students will be assigned one of the following isopropanol/water mixtures to prepare and determine the density of: 10.0, 20.0, 40.0, 60.0, 80.0 or 90.0% isopropanol by volume. Look up the accepted value for the density of isopropanol (commonly called rubbing alcohol, but its correct chemical name is ***2-propanol***) and predict how the density of each solution will change as the concentration of isopropanol increases. As the concentration of isopropanol increases the density of the solution will….

   (a.) increase. (b.) decrease. (c.) remain unchanged. (Circle one)

   Density of Isopropanol: _____

   Explanation for your choice, above: