Experiment 1: Measurement and Density

Chemistry 140

Learning Objectives

Become familiar with laboratory equipment and glassware
Begin to see the link between measurement and chemical knowledge
Begin to understand how scientists communicate with significant figures
Engage in proper measurement technique and the data collection process
Begin to make the connection between macroscopic observations and the sub-microscopic level through drawing
Understand the concept of density and explore methods for measuring density in the lab
Begin to see the power of a “class data set”.
Learn how to use EXCEL
Experience the culture of teamwork and individual responsibility to a group.

Purpose

Section 1 — By calculating the density of a known substance (water), determine the relative precision and accuracy of different glassware items.

Section 2 — Determine the density of a salt water solution using the most precise and accurate piece of glassware determined in section 1

Introduction

The ability to make accurate and detailed observations are crucial in science. This lab will focus on quantitative observations, more specifically, measurements. A measurement is defined by a number and a scale or unit. The scale used is often varied. Due to convenience, the metric system is often used in many countries. The universal scale, however, used by scientists is the SI unit. In this lab, we will focus on making accurate and detailed observations in measurements using the metric system while obeying the laws of significant figures.

In addition to quantities defined by a single unit, quantities can also be defined by a combination of units. One such example is density. Density is merely one way to characterize a substance. Density \(d\) is defined as mass \(m\) per unit volume \(V\). Thus, units of both mass (i.e. g) and volume (i.e. mL) are necessary in order to determine density.

\[
d = \frac{m}{V}
\]
**Pre-Lab Questions and Calculations:** *(show your work)*

On a separate sheet of paper complete the following problems before coming to lab.

1. You are given a bottle that contains 4.59 cm\(^3\) of a metallic solid. The total mass of the bottle is 35.66 g. The empty bottle weighs 14.23 g. What is the density of the solid?

2. Mercury is traded by the “flask”, a unit that has a mass of 34.5 kg. What is the volume of a flask of mercury if the density of mercury is 13.6 g/ml?

**Equipment:** 100 mL beaker, 10 mL graduated cylinder, 10 mL pipet with pipet suction device; also, a large beaker to provide a distilled water reservoir

Chemicals: Distilled water, colored saltwater solutions A, B and C

**Part 1: Choosing the most precise and accurate instrument to measure density**

**Procedure:**

1. Weigh a dry 100 mL beaker, a 10 mL graduated cylinder and a 10 mL pipet cylinder (actually, weigh a 150 mL beaker that you will transfer into from the pipet, pipets can’t be weighed effectively) and record the mass for each on the data sheet. Recall that a trailing zero is a significant figure, and should be written down!

2. Obtain a fair amount of distilled water (from the carboy at the front of the classroom) and measure its temperature. Remember to record this number to the tenths of degrees.

3. To the best of your abilities, put 10 mL of water in each glassware item. Record the volume for each one, remembering that you should estimate one place past the markings.

4. Weigh and record the mass for each item. **Be careful not to spill!**

5. Do this three times for each piece of glassware, taking care to dry (as best as your can) the glassware in between trials.

6. Consult a reference book, such as the CRC Handbook to determine the density of water at your observed temperature. Cite your reference properly.

**Data**

Data tables should be created for all original data as well as for calculated results. EXCEL is an excellent computer tool for creating nice data tables! Below are sample data tables to give you an idea of what to do.
Temperature of distilled water ______________ °C

### Beaker:

<table>
<thead>
<tr>
<th>Trial</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry mass (g)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass with water (g)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of water (g)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume of water (mL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density of water (g/mL)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Prepare a similar table for each of the other glassware items.

**Calculations:**

1. Calculate the average (mean) and the standard deviation of the water's density for each of the three pieces of glassware.

2. Calculate the percentage error from the value of the density you looked up in the reference. The formula for % error is:

   \[
   \text{% error} = \left( \frac{\text{measured value} - \text{reference value}}{\text{reference value}} \right) \times 100\%
   \]

3. Report the above in table format similar to the one shown below:

<table>
<thead>
<tr>
<th>Glassware</th>
<th>Beaker</th>
<th>Graduated cylinder</th>
<th>Pipet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean density ± standard deviation (g/mL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent error from the reference value of density</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Part 2 — Determination of saltwater density**

**Procedure:**

1. Obtain one of the colored solutions and record the letter of the solution.

2. Using the most precise and accurate piece of glassware found in section 1, measure the volume of the saltwater. Perform five independent trials, remembering to dry the glassware as much as possible between trials. You may use the taring (zeroing) function of the electronic balance for these measurements.

3. As a qualitative check of your result, obtain a clean dry 100 mL beaker and put about 30 mL of distilled water in it. Using the pipet, carefully trickle 10 mL of the colored saltwater solution down the side of the beaker. Note where the colored solution ends up.
Data

Table 2: Saltwater density determination

Colored saltwater solution letter ______

<table>
<thead>
<tr>
<th>Trial number</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass of solution (g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>volume of solution (mL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>density of solution (mL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculations:

1. Calculate the mean and standard deviation of the density of the saltwater you used. Report your results in a small table.

2. Obtain the raw data for all groups’ saltwater densities, and also the letter of the saltwater solution that each group used. Calculate the mean and standard deviation for each saltwater solution (i.e., Density of saltwater solution A = “1.033 ± 0.034 g/mL” etc.).

3. Qualitative test of the density result: Draw a molecular level picture of the contents of the beaker after the colored saltwater has been added.

Conclusion: In a sentence or two, give the results of your experiment, including error and standard deviation. You are basically answering the questions asked in the purpose. If you got some weird results or poor accuracy or precision, you should include a sentence or two explaining why you think it happened and how to avoid it in the future.

Lab Report:
Prepare duplicates of the appropriate pages of your lab notebook. Answer the following questions on paper (not in your notebook) and include them in your report after the duplicate pages.

1. Though the pipet may be a very precise instrument, what practical limitation does the pipet inherently contain?

2. Was the standard deviation you calculated in section 2 for the saltwater larger, smaller or the same as the standard deviation you calculated for the same piece of glassware in section 1? Assuming you made no significant technique errors, with a larger number of trials, what should happen to the standard deviation for any piece of glassware?

3. What is a data outlier? Looking over the various groups’ data, were there any outliers? Without doing any heavy recalculations, if outliers were removed from the data set, how would the standard deviation be affected?

4. Are saltwater solutions A, B and C clearly distinguishable (in other words, are they different salinities) from each other, according to your calculations (recall that their
ranges must **not** overlap). If not, state which solutions might be the same. Finally, give
the **order**, from least dense to most dense, of A, B and C.

5. Suppose the outside of the glassware is not completely dry when it is weighed with
the water in it, but it *is* dry when weighed at other times. Explain how that error will
affect your density (for instance, will the density be higher or lower than it should be?).
Would this be an example of random or systematic error?