EXPERIMENT 1
BASIC LABORATORY TECHNIQUES AND TREATMENT OF DATA

MEASUREMENTS

Introduction

In the following experiment you will be required to use a bunsen burner, balance, a pipet, graduated cylinder, flask, pipet bulb and a buret in order to measure the density of water. You will also prepare a graph from a set of experimental data and interpret that graph using basic mathematical techniques. Your results will depend on your ability to use these instruments and to properly manipulate the data you receive. What follows is a short explanation of the use of significant figures, and the proper use of the instruments that you will need in this lab. Please read the instructions carefully and follow the experimental procedure found at the end.

Reporting the Accuracy of a Measurement

Scientific measurements must be as precise as possible, which often means estimating between the smallest scale divisions on the instrument being used. Suppose we are measuring a piece of wire, using a metric ruler calibrated in tenths of centimeters (millimeters). One end of the wire is placed at exactly zero cm and the other end falls somewhere between 6.3 cm and 6.4 cm. Since the distance between 6.3 and 6.4 cm is very small, it is difficult to determine the next digit exactly. We might estimate the length of the wire as 6.34 cm, though a more precise instrument might show it was 6.36 cm. If the wire had come to exactly 6 cm, reporting the length as 6 cm would be an error, for it would indicate only that the length is closer to 6 cm than to 5 or 7 cm. What we really mean is that, as closely as we can read it, it is exactly 6 cm. But "exactly" implies perfection; that is 6.000... cm. So we must write the number in such a way that it tells how closely we can read it. On this scale we can estimate to 0.01 cm, so our length should be reported as 6.00 cm.

Precise versus Approximate Values

In conducting an experiment it is often unnecessary to measure an exact quantity of material. For instance, directions might state, "Weigh about 2 g of sodium sulfite," This instruction indicates that the measured quantity of salt should be approximately 2 g; for example, somewhere between 1.8 and 2.2 g. To weigh exactly 2.00 g only wastes time, since the directions call for weighing "about 2 g."

Suppose the directions read, "Weigh about 2 g of sodium sulfite to the nearest 0.001 g." This instruction does not imply that the amount is 2.000 g but only about 2 g and that it should be weighed accurately to 0.001 g. Therefore four different students might weigh their samples and obtain 2.141 g, 2.034 g, 1.812 g, and 1.937 g, respectively, and each would have satisfactorily followed the directions.
Significant Figures

The result of multiplication, division, or other mathematical manipulation cannot be more precise than the least precise measurement used in the calculation. For instance, suppose we have as object that weighs 3.62 lb and we want to calculate the mass in grams. If there are 453.6 grams/lb then multiplication by 3.62 lb yields 1,642.032 grams. To report 1,642.032 g as the weight is absurd, for it implies a precision far beyond that of the original measurement. Although the conversion factor has four significant figures, the weight in pounds has only three significant figures. Therefore the answer should have only three significant figures; that is, 1,640 g. In this case the zero cannot be considered significant, it is a place holder. Using scientific notation this value can be expressed as $1.64 \times 10^3$ g.

EXPERIMENTAL TECHNIQUES
The Bunsen Burner

Almost all laboratory burners used today are modifications of a design by the German chemist Robert Bunsen. In Bunsen's fundamental design gas and air are premixed by admitting the gas at relatively high velocity from a jet in the base of the burner. This rapidly moving stream of gas causes air to be drawn into the barrel from side air ports and to mix with the gas before entering the combustion zone at the top of the burner.

The burner is connected to a gas valve by a short length of rubber tubing.

With some burners the gas cock is turned to the fully on position when the burner is in use, and the amount of gas admitted to the burner is controlled by adjusting a needle valve in the base of the burner. In burners that do not have this needle valve, the gas flow is regulated by partly opening or closing the gas cock. With either type of burner the gas should always be turned off at the gas valve when the burner is not in use.

**Figure 1**: A Bunsen burner showing a properly adjusted flame.
OPERATION OF THE BUNSEN BURNER

Examine the construction of your burner and familiarize yourself with its operation. A burner is usually lit with the air ports nearly closed. The ports are closed by rotating the barrel of the burner in a clockwise direction. After the gas has been turned on and lit, the size and the quality of the flame is adjusted by admitting air and regulating the flow of gas. Air is admitted by rotating the barrel; gas is regulated with the needle valve, if present, or the gas valve. Insufficient air will cause a luminous yellow, smoky flame; too much air will cause the flame to blow out. A Bunsen burner flame that is satisfactory for most purposes is shown in Figure 1; such a flame is said to be "nonluminous."

EXPERIMENT: After properly adjusting the flame of a Bunsen burner determine the temperature of the various regions of the flame. This can be done in a qualitative way by placing metals of differing melting points into the flame and noting whether the metal melts. The metals to be used are iron, copper, and aluminum. Using these metals determine the temperature of each region of the flame. The melting points of these metals can be found in the inorganic section of the CRC handbook. Draw the flame of a bunsen burner and indicate the approximate temperature of each portion of the flame.

MASS MEASUREMENTS

General Instructions: The following precautions should be observed when using the balances.

1. Never place chemicals directly on the weighing pan; first place them on a weighing boat or in a container.

2. CLEAN up any materials you spill on or around the balance.

3. Never try to make adjustments on a balance. If it seems out of order, tell your instructor or the instructional assistant.

Balances can vary widely in instructions for use and applications. For specific instructions of the use of the balances in the lab consult your instructor or instructional assistant.

VOLUME MEASUREMENTS

Beakers and flasks are marked to indicate only approximate volumes. You will usually make measurements of volume in a graduated cylinder. When observing a volume in a graduated cylinder, read the point on the graduated scale that coincides with the bottom of the curved surface - called the meniscus - of the liquid (see Figure 2). Volumes measured in your graduated cylinder should be estimated and recorded to the nearest 0.1 mL.
More accurate measurements may be made with burets and pipets. Each of these pieces of glassware are meant to contain very accurate volumes. You may notice that at the top of some containers the initials TC or TD may be found. These initials mean "to contain" and "to deliver" respectively. The difference in these two terms is in the ability of the glassware to accurately deliver a given volume. Containers marked TC may contain an accurately measured volume but that volume cannot be poured out of that container. The reason for this is that a significant amount of liquid may adhere to the sides of the container thus reducing the volume delivered. Containers marked TD account for the volume which adheres to the container and therefore deliver an accurate amount of liquid. Burets and pipets are both TD and should be used when very accurate volumes are required.

THE USE OF PIPETS AND BURETS

Burets and pipets require special mention in order for them to be used properly. There are two types of pipets, volumetric and graduated. On volumetric pipets there is a mark to which the pipet must be filled in order for it to deliver the correct volume. Graduated pipets (Mohr) will deliver almost any volume accurately since it is marked with various volumes. Your mouth should never be used to fill a pipet, pipet pumps are available for your use in the lab. Anyone found mouth pipeting will receive an automatic zero on the lab.

Pipet pumps are placed onto the end of the pipet, and the wheel rotated to fill the pipet. Once the pipet is filled, press the release lever on the side of the pump until the proper amount of liquid has been dispensed. Do not control the pump's delivery of liquid with the plunger on top of the pump.

Burets and pipets should ALWAYS be rinsed with a small amount of the liquid to be pipetted or buretted before the instrument is used. Buret tips are notorious sources of error. These tips hold relatively large amounts of air whose volume cannot be accounted for. It is therefore necessary to rid the tip of air by allowing a portion of liquid to flow from the buret forcing the air out of the
tip of the buret. The buret should be refilled and is now ready for use.

Pipets and burets are both read by measuring the volume at the bottom of the meniscus. This is the bottom of the curved surface formed by the liquid near the top of the pipet or buret.

**EXPERIMENT:** Weigh a 125 mL Erlenmeyer flask to the nearest 0.001 g. Fill the flask to the 50 mL mark and reweigh the flask. Record the mass of the empty flask and the mass of the flask filled with 50 mL of water in the data section of the lab report which is included at the end of this experiment.

Empty the flask and reweigh it (dry the outside of the flask but do not attempt to dry the inside). Record this new mass. Now fill a 25 mL graduated cylinder with 25 mL of water and pour this water into the flask. Reweigh the flask with the water and record their mass. Be sure to include all further weighings in the lab report.

Empty the flask and reweigh it. Now take the 10 mL graduated pipet from your locker and fill the pipet with water to the 10.0 mL point using a pipet pump. Empty the pipet into the flask and reweigh the flask.

Empty the flask and reweigh it. Take a 10 or 25 mL volumetric pipet and fill it with water using a pipet pump. Empty the water from the pipet into the weighed flask and reweigh the flask. Empty the flask and reweigh it. Obtain a 50 mL buret and fill it with water (make sure there are no bubbles in the tip.) Adjust the volume until the buret reads 0.00 mL. Empty exactly 25 mL of
water from the buret into the flask and record the new mass for the flask.

Complete the data table found at the end of this lab. Finish filling in the table by dividing the mass of the water by its volume. The result of this calculation gives the density of the water in grams/mL. The actual density of water is 0.99707 g/mL at 25°C. Do not be concerned if you densities do not match the true density exactly. You will notice that the TD glassware is much more accurate than the TC glassware, it delivers more accurate volumes which produce more accurate densities.

**GRAPHS AND GRAPHING**

Learning how to make proper graphs is an acquired skill that takes a lot of practice. In this section you will obtain data and plot this data on graph paper in an acceptable format. You will also interpret this data by calculating the slope and intercept of your plot. You may not use a computer-generated plot or equation for this experiment.

**EXPERIMENT:** Using a piece of string, measure the circumference of five or six different sizes of beakers. Draw the string snugly around the beaker and mark the overlapped ends of the string with a fine-tipped pen. Measure the distance between the marks on the string to the nearest millimeter using a ruler. Record this value in the data section. Now measure the diameter of the beaker using the ruler or calipers. Fill in the data table. Make a plot of circumference versus diameter (y vs x) using the graph paper provided. Draw the axes in such a way that the data will cover the ENTIRE sheet of paper. Label the axes circumference/cm, and diameter/cm. This method of axis labeling can be understood in the following example. Suppose that one of your data points had an x value of 10 cm. When you plot this point on your graph it would be 10 units along the x axis. The label indicates that,

$$\text{circumference/cm} = 10$$

or by multiplying through by the cm unit,

$$\text{circumference} = 10 \text{ cm}$$

which is what you meant when you plotted your data point.

Now provide your graph with a title which indicates the axes units and the source of the data. The source of the data in this case came from the measurement of beakers. A proper title for this graph would be Circumference vs. Diameter of Various Beakers. The data must be plotted and labeled in ink. Your name and the date must be located in the upper right-hand corner of the graph.
TREATMENT OF GRAPHICAL DATA

After the data are plotted, the slope and the intercept of the plot must be found. The slope is calculated by finding the change in the y coordinate as a function of the change in the x coordinate. Mathematically this is represented by,

\[
\text{slope} = \frac{\text{change in y}}{\text{change in x}}
\]

\[
= \frac{\text{change in circumference}}{\text{change in diameter}}
\]

This is sometimes expressed as,

\[
\text{slope} = \frac{\text{rise}}{\text{run}}
\]

**Experimental data points should NEVER be used to calculate the slope of a graph!!!**

The data obtained in your experiment are only a representation of the true values of the circumference and diameter of a beaker. A line can be drawn which will come close to passing through all of your data points. This line has the benefit of being determined by many points and is a better representation of your data than any two arbitrarily chosen data points. Therefore pick two new points, one at each end of the line and calculate the slope of your plot. Use the equation \( y = mx + b \). Where \( m \) is the slope and \( b \) is the y-intercept. The intercept is the point where your line crosses the y-axis. Report both values in your results.
OBJECTIVE: The purpose of this experiment was to learn the proper use of basic laboratory equipment, to generate some simple data in the laboratory, and to learn how to analyze this data for specific results.

PROCEDURE: Determine approximate temperatures of a Bunsen burner flame by using different metals. Use different types of volumetric glassware to determine the density of water. Graph circumference vs. diameter of several sizes of beakers.

DATA: Bunsen Burner Flame:

<table>
<thead>
<tr>
<th>Melting Point Temperature °C</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outer Cone</td>
</tr>
<tr>
<td>Fe</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td></td>
</tr>
<tr>
<td>Temperature Range</td>
<td></td>
</tr>
</tbody>
</table>

Volumetric Glassware:
Density of water at 25°C (don't forget units- look this up in the CRC Handbook)

<table>
<thead>
<tr>
<th>Glassware</th>
<th>Volume of Water (mLs)</th>
<th>Mass of Empty Flask (grams)</th>
<th>Mass of Flask and Water (g)</th>
<th>Mass of Water (g)</th>
<th>Density of Water (g/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flask</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grad. Cylinder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mohr Pipet</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Vol. Pipet</td>
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<td></td>
</tr>
<tr>
<td>Buret</td>
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</tbody>
</table>

Beaker Measurements:
New points from graph (x,y) (do not use any data points)

Point 1 (______,______)

Point 2 (______,______)

**CALCULATIONS:**

1) Sample Calculation for density of water (flask)

Mass of flask and water - Mass of empty flask = Mass of water

\[\text{Mass of water} \div \text{volume of water} = \text{density of water}\]

\[\begin{align*}
\text{Mass of water} & \div \text{volume of water} = \text{density of water} \\
\end{align*}\]

2) Calculation of slope:

\[\text{slope} = m = \frac{(y_2 - y_1)}{(x_2 - x_1)}\]

\[\text{m} = \frac{(______ - ______)}{(______ - ______)} = \]
RESULTS:

Flame Temperatures

Greater than _____________ and less than _____________

Greater than _____________ and less than _____________

Greater than _____________

Volumetric glassware with most accurate density _____________
(most digits and closest to CRC value)

Slope of Graph _____________
(from calculations)

Y-Intercept _____________

CONCLUSION:

From this lab we can conclude that different regions of a flame have different temperatures, this may be important in further labs if we need to use the cooler or perhaps the hotter region of the flame. That some types of measuring glassware are more accurate than others. We can use this information to determine the most appropriate lab equipment and technique for each lab. It can also be concluded that we can graphically represent our data to gain further information, such as the slope and y-intercept and that these points may provide important information as in this lab where our slope should be pi.

SOURCES OF ERROR:

Stretch in the string prevents an accurate measurement of circumference. In all measurements there is some error due to imprecision of the measuring device.