Experiment #2. Density and Measurements

Goals

1. To measure and record length, volume and mass accurately with the correct number of significant figures
2. To use significant figures correctly in calculations.

Making Measurements

Measurements are central to science and medicine. Scientists and medical professionals need to read and report measurements accurately and precisely to convey information to others. In this lab you will learn how to read scientific instruments and report the results with the correct number of significant figures. Measurements contain certain and uncertain digits. The final digit of a measurement is assumed to have uncertainty and is usually estimated from the instrument being read. You will be expected to carefully and correctly record measurements using the procedures below for rest of the course.

Units of Length

We will use rulers to measure length. The standard unit of length in the metric system is the meter (m). A meter is divided into 100 centimeters (cm). Each centimeter is divided into 10 millimeters (mm).

Measurements taken with instruments with a scale, such as rulers, should be recorded to the nearest 1/10 of the smallest division. Two examples are below.

![Ruler Image]

Smallest division on the ruler: 0.1 cm
1/10 of smallest division: 0.01 cm
Measurement should be read to the nearest: 0.01 cm

The object lies between the 7.2 and 7.3 cm lines. The space between the lines should be mentally divided into 10 to estimate the last digit of the measurement.
A correct reading of this instrument could be **7.24 cm**.

Units of Volume

Volume is a derived unit based on length. The unit of basic metric unit of volume is the liter (L). 1 liter is equal to 1 cubic decimeter (dm)^3. There are 1000 mL in 1 L. A milliliter is the same volume as 1 cm^3.

\[
1 \text{ liter} = (1 \text{ dm})^3 = (10 \text{ cm})^3 = 1000 \text{ cm}^3 = 1000 \text{ mL}
\]

We will use several types of instruments to measure volume in chemistry class.

**Beakers**
- glass containers with straight sides
- used to hold, mix and heat liquids
- markings give an approximate volume
- **beakers are not used for careful volume measurements**
**Erlenmeyer Flasks**
- glass containers with tapered sides and a narrow opening.
- the shape is useful for swirling liquids without spilling and for limiting evaporation
- markings give an approximate volume
- *Erlenmeyer flasks are not used for careful volume measurements*

**Graduated Cylinders**
- long narrow cylinders with volume markings (also known as graduations)
- used to accurately measure volume
- some have a plastic guard to prevent breaks – it should be at the top of the cylinder.
- *graduated cylinders are not used to heat liquids* – the shape of the base does not transfer heat well
- *graduated cylinders are never used to mix substances or hold solids* – solids get stuck at the bottom of the cylinder and are difficult to mix and clean.
- using graduated cylinders
  - various sizes are available, generally the smallest cylinder that can accommodate the volume is used
  - if two scales are shown, always read the scale that increases up the cylinder
  - read at eye level
  - read the measurement at the lowest point of the *meniscus* (the curved surface of the liquid)
  - read to the nearest 1/10 of the smallest division

Smallest division on the cylinder: 0.2 mL
1/10 of smallest division: 0.02 mL
Measurement should be read to the nearest: 0.02 mL

The lowest part of the meniscus appears to exactly hit the 6.6 mark. Since the measurement must be to nearest 0.02 mL, 6.6 mL would NOT be a correct measurement. The volume should be recorded as **6.60 mL**.

Note that on this instrument, 6.60 and 6.62 are possible readings, but 6.61 is not because it implies more precision than this instrument is capable of.
Burets

- Long narrow tube of glass with a stopcock to release liquid at the bottom.
- Used to measure the volume of liquid that has been dispensed.
- Measuring volume with a buret
  - Read the volume that has been dispensed, not the volume that buret still contains
  - Read at eye level
  - Read the bottom of the meniscus
  - Read to the nearest 1/10 of the smallest division

Smallest division on the buret: 0.1 mL
1/10 of smallest division: 0.01 mL
Measurement should be read to the nearest: 0.01 mL

The lowest part of the meniscus is between the 15.4 mL and 15.5 mL lines. A correct reading of the volume dispensed could be **15.45 mL**.

Units of Mass

A laboratory balance is used to measure mass. Mass is the measure of the amount of material or matter. The metric unit for mass is the gram (g) while the SI unit of mass is kilogram (kg).

The balance has a metal pan to weight materials on. Around the pan, there is a plastic shield and a cover. These protect the balance from fluctuations caused by drafts.

Using a balance

- Press the button labeled “tare” or “zero” until the numbers stabilize at zero.
  - If weighing a chemical, place a weigh boat on the balance before zeroing.
    Never put chemicals directly on the balance.
- Place the material on directly on the pan, or scoop into the weigh boat with a spatula.
- If the last digit fluctuates, you may estimate its value.
- If the value continues to go up or down, use the shield and cover.
- Write every digit on the balance on your data sheet - never round off a mass measurement. The final digit is considered uncertain.
- Weigh boats are single use. Dispose of them once used.
- Use the same balance for all measurements in an experiment
- Only weigh objects that are at room temperature.

Procedures will often say “accurately weigh about 5g of X”, this means that you do need exactly 5.000 grams, but whatever mass you portion out should be recorded accurately. For instance 5.080 g and 4.952 g might be recorded as an accurate mass of approximately 5 g. Trying to hit exactly 5.000 g is unnecessary and a waste of time.
Laboratory Activity

Materials: 1 metal block  Graded cylinders  Buret  sodium chloride  
Ruler  Deionized water (in larger white containers on the lab benches)

Procedure

A. Measuring Mass

1. Practice using an analytical balance by finding the mass of two different weigh boats. (See the discussion on the previous page on how to use the balance)

2. Tare one of the weigh boats before adding sodium chloride. Accurately weigh about 3 g of sodium chloride.

3. Return sodium chloride to the container. Dispose of the used weigh boat in the trash. **Note: We normally do not return used reagents to the bottle to prevent contamination.**

B. Measuring Volume

1. Four types of graduated cylinders (10 mL, 100mL, 250mL, and 500 mL) and a buret with different volumes of water will be placed around the room. Note the value of the smallest division on each piece of glassware and the place the instrument should be read to, then record the volume of the water to the correct number of significant figures.

C. Determining the Density of a Metal Block

1. Obtain a metal block, measure its mass using an analytical balance.

2. Obtain a ruler and record the length (l), width (w) and height (h) of your metal block to the correct number of significant figures.

3. Calculate the volume in cm$^3$ of the metal block. $V = l \times w \times h$, and round to the correct number of significant figures.

4. Calculate the density of the block in g/cm$^3$ to the correct number of significant figures using your data for volume and density. $\text{Density} = \text{mass} / \text{volume}$

5. Determine the likely identity of metal block based on the density table below.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Density (g/cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>2.70</td>
</tr>
<tr>
<td>Brass</td>
<td>8.74</td>
</tr>
<tr>
<td>Copper</td>
<td>8.96</td>
</tr>
<tr>
<td>Iron</td>
<td>7.86</td>
</tr>
<tr>
<td>Lead</td>
<td>11.4</td>
</tr>
<tr>
<td>Steel</td>
<td>7.48</td>
</tr>
</tbody>
</table>
D. Determining the Density of Water

Density using a Beaker

1. Record the mass of a dry 150 mL (or a similar sized) beaker to the correct number of significant figures.

2. Fill the beaker roughly 2/3 full with deionized water and record the mass. *The amount of water is not important – do not try to fill exactly to a line!*

3. Read the volume of the beaker to the correct number of significant figures. Use volume and mass to calculate the density of water.

Density using a Graduated Cylinder

4. Record the mass of a dry 100 mL graduated cylinder to the correct number of significant figures.

5. Fill the graduated cylinder roughly 2/3 full with deionized water and record the mass. *The amount of water is not important – do not try to fill exactly to a line!*

6. Read the volume of the graduated cylinder to the correct number of significant figures. Use volume and mass to calculate the density of water.

7. Find the percent error from the actual density of water (1.00 g/mL) for each of the two measurements.

\[
\text{Percent Error} = \left| \frac{\text{actual value} - \text{your experimental value}}{\text{actual value}} \right| \times 100\%
\]

Waste Disposal

- deionized water – sink
- sodium chloride – return to the jar
- used weigh boat – regular waste
CHM111 Lab - Density and Measurements – Grading Rubric

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Points possible</th>
<th>Points earned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lab Performance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Printed lab handout and rubric was brought to lab</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Safety and proper waste disposal procedures observed</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Followed procedure correctly without depending too much on instructor or lab partner</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Work space and glassware was cleaned up</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Lab Report</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data was recorded with correct units and significant figures</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Calculations are correct; work is shown in detail with units.</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Post Lab: Question 1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Post Lab: Question 2 (0.50 points each)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Post Lab: Question 3 (work shown clearly with units)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

Subject to additional penalties at the discretion of the instructor
Include the **proper units** for all measurements and **show all your work** for any calculations. Report your answer to the correct number of significant digits.

### A. Measuring Mass

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of weigh boat 1</td>
<td></td>
</tr>
<tr>
<td>Mass of weigh boat 2</td>
<td></td>
</tr>
<tr>
<td>Mass of sodium chloride</td>
<td></td>
</tr>
</tbody>
</table>

If you forget to zero a weigh boat, can you just subtract the mass of different weigh boat? ______ Explain below.

### B. Measuring Volume

<table>
<thead>
<tr>
<th>Cylinder type</th>
<th>Volume represented by smallest markings</th>
<th>Instrument should read to the nearest ...</th>
<th>Record the volume of water to the correct sig figs</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mL</td>
<td>0.1 mL</td>
<td>0.01 mL</td>
<td></td>
</tr>
<tr>
<td>100 mL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250 mL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 mL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buret</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### C. Determining the Density of a Metal Block

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of metal block</td>
<td></td>
</tr>
<tr>
<td>Value of smallest markings on ruler</td>
<td></td>
</tr>
<tr>
<td>Ruler should be read to the nearest...</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of block</td>
<td></td>
</tr>
<tr>
<td>Width of block</td>
<td></td>
</tr>
<tr>
<td>Height of block</td>
<td></td>
</tr>
</tbody>
</table>

*Did you remember to indicate units in all data entries?*
Density and Measurements: Data Sheet

1. Calculate the volume of the metal block in cm$^3$.

2. Calculate the density of the metal block.

Did you remember to show work and round to the correct number of significant figures in the questions 1 & 2?

3. Based on the table on in the lab instructions, what metal is your block? _______________________

D. Determining the Density of Water

<table>
<thead>
<tr>
<th></th>
<th>Beaker</th>
<th>Graduated cylinder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of empty glassware</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of glassware with water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume of water (think about sig figs!)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density of water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Error</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Show work below for density and percent error calculations. Always show all work with units.
   Beaker                          | Graduated cylinder
Q1. Which density measurement did you expect to have the smaller percent error, the beaker the graduated cylinder? Explain your reasoning below. Did your results match your prediction?

Q2. Read the following instruments to the correct number of significant figures.

Q3. A cube of Brass (density 8.74 g/cm³) has a mass of 87.321 grams. Determine the height of the cube in inches.