Mass and Volume Relationships

Objective:

The purpose of this laboratory exercise is to become familiar with some of the basic relationships and units used by scientists. In this experiment you will perform simple measurements of length, volume and mass using the metric system.

Safety Tips:

- No immediate danger is present in this experiment, but because of the importance of laboratory safety visorguards are to be worn at all times.

Background:

Matter is defined as anything that has mass and occupies space. The mass of an object is a measure of the amount of matter it possesses. Mass may be measured by using an electronic balance. The mass is expressed in grams (g). Mass is an extensive property of a substance. Extensive properties depend on the quantity of the substance. Volume, usually measured in units of milliliters (mL), liters (L), or cubic centimeters (cm$^3$) is also an extensive property. Volume is a measure of the amount of space a substance occupies.

If the substance is in a liquid or gaseous state, its occupied space or volume is measured in liters (L) or milliliters (mL). When a substance is a liquid, its volume can be measured directly in a graduated cylinder, which is a piece of calibrated glassware.

If the substance is in a solid state and has a regular shape (i.e., cylinder, rectangle, etc.) its volume can be determined by measuring the dimensions of the solid object and then inserting those measurements into an appropriate formula. For example, a rectangular shaped solid's volume could be determined using the formula: \[ \text{volume} = \text{width} \times \text{length} \times \text{height}. \]

A solid's volume may also be determined by water displacement. This method is frequently used when solid objects do not have regular shapes. This technique is based on the principle that any solid that does not dissolve or react with the liquid it is placed in will displace its own volume when submerged. The weighed solid is added to a known volume of water in a graduated cylinder and the volume of water containing the solid is measured. The difference between these two volumes is the volume of the solid.

A substance, whether solid, liquid or gas, has a number of physical and chemical characteristic properties that can be determined experimentally and used to identify the substance. One physical characteristic of a substance is its density. Density is defined as the mass per unit volume of a substance. Density can be determined experimentally by measuring the mass of the substance and by measuring its volume. Gas and liquid densities are dependent on temperature. Density depends on the state of the substance and is independent of size. Density is thus referred to as an intensive property.

In the metric system the following density units are typically used:

   - For gases: grams per liter (g/L) or grams per milliliter (g/mL)
   - For liquids and solutions: grams per milliliter (g/mL) or grams per cubic centimeter (g/cm$^3$)
   - For solids: grams per cubic centimeter (g/cm$^3$)

NOTE: 1 mL = 1 cc (cubic centimeter = 1 cm$^3$)
Procedure:

Part I: The Density of Wood and Plastic
1. Obtain two wood blocks (different sizes) and two plastic blocks (different sizes).
2. Measure the mass of each block and record this mass to the nearest 0.01 grams.
3. Determine the volume of each block by measuring each of its dimensions (length, width and height) with a ruler. Record the dimensions to the nearest 0.01 centimeters for each block. To determine the block’s volume use the following mathematical relationship.

   \[
   \text{Volume of rectangle} = \text{length} \times \text{width} \times \text{height} = \text{cm}^3
   \]
4. Calculate the density for each block in g/cm³.

Part II: The Density of Aluminum
1. Obtain three aluminum cylinders (different sizes).
2. Measure the mass of each aluminum cylinder and record this mass to the nearest 0.01 grams.
3. Determine the volume of each cylinder by: a) dimensional measurements and b) by water displacement.
   a) Dimensional measurements
      To determine the volume of each aluminum cylinder, use a ruler and measure the following dimensions: height and diameter. Record these values to the nearest 0.01 cm.
      To calculate the volume of each aluminum cylinder use the following mathematical relationship:

      \[
      \text{Volume of cylinder} = \pi (\text{radius}^2) \times \text{height} \quad \text{(remember: radius is 1/2 diameter)}
      \]
   b) Water displacement
      To determine the volume, obtain a 25 or 50 mL graduated cylinder.
      If a 25 mL graduated cylinder is used, pour 15 to 20 mL of water into the graduated cylinder. Record the exact volume to the nearest 0.1 mL.
      If a 50 mL graduated cylinder is used, pour 30 to 35 mL of water into the graduated cylinder. Record the exact volume to the nearest 0.1 mL.
      Carefully place the aluminum cylinder into the graduated cylinder containing the water. Be sure not to splash any of the water out of the graduated cylinder. Record the volume of the water to the nearest 0.1 mL.
      To calculate the volume of the cylinder use the following mathematical relationship:
volume of water + aluminum cylinder, mL
- volume of water without aluminum cylinder, mL

\[
\text{volume of the aluminum cylinder, cm}^3 \quad (\text{Remember 1 mL = 1 cm}^3)
\]

4. Determine the density of each aluminum cylinder in g/cm³.

**Part III: The Density of Water**

1. Place a 50 or 100 mL graduated cylinder on a balance and zero the balance.

2. Carefully add enough water so that the graduated cylinder is approximately 1/2 filled with water. Record the volume to the nearest 0.1 mL and its corresponding mass to the nearest 0.01 grams.

3. Determine the density of water in g/mL.
Mass and Volume Relationships
Post Laboratory Questions

Name ______________________________

Date _______________________________

1. Fill in the data table below with the measurements gathered in this laboratory exercise.

**Part I: The Density of Wood and Plastic**

<table>
<thead>
<tr>
<th></th>
<th>Mass (g)</th>
<th>Length (cm)</th>
<th>Width (cm)</th>
<th>Height (cm)</th>
<th>Volume (cm³)</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood block #1</td>
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<tr>
<td>Wood block #2</td>
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<tr>
<td>Plastic block #1</td>
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<td>Plastic block #2</td>
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</tbody>
</table>

*Calculation workspace:*
### Part IIa: The Density of Aluminum Cylinders by Dimensional Measurements

<table>
<thead>
<tr>
<th></th>
<th>Mass (g)</th>
<th>Height (cm)</th>
<th>Diameter (cm)</th>
<th>Radius (cm)</th>
<th>Volume (cm(^3))</th>
<th>Density (g/cm(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder #1</td>
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<tr>
<td>Cylinder #3</td>
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</tr>
</tbody>
</table>

**Calculation workspace:**

### Part IIb: The Density of Aluminum Cylinders by Water Displacement

<table>
<thead>
<tr>
<th></th>
<th>Mass (g)</th>
<th>Initial Volume (mL)</th>
<th>Final Volume (mL)</th>
<th>Volume (cm(^3))</th>
<th>Density (g/cm(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder #1</td>
<td>______</td>
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<td>______</td>
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<tr>
<td>Cylinder #2</td>
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</tr>
<tr>
<td>Cylinder #3</td>
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</tbody>
</table>

**Calculation workspace:**
Part III: The Density of Water

Mass of water   __________ grams

Volume of water   __________ mL

Density of water   __________ g/mL

Calculation workspace:

2. Will objects of equal size always have the same mass? Briefly explain your answer.

3. Compare the values you calculated for the two methods used to determine the density of aluminum cylinders. Speculate why there are differences. Which method would you predict to be more precise, the water displacement or measured dimensions?

4. Do any of the objects that have different volumes have similar density values? If so, which ones and why would this occur?

5. Do any of the objects that have different masses have similar density values? If so, which ones and why would this occur?
Mass and Volume Relationships
Prelaboratory Questions

Name ______________________________
Date _______________________________

1. What is the numerical relationship between cubic centimeters (cm$^3$) and milliliters (mL)?

2. How does an intensive property differ from an extensive property? Give an example of each.

3. Calculate the density (g/cm$^3$) of a rectangular piece of iron, given the following data: height is 1.42 cm, length is 2.95 cm, width is 0.21 cm and mass is 6.92 grams.

4. Calculate the density (g/cm$^3$) of an aluminum cylinder, given the following data: height is 3.55 cm, diameter is 1.1 cm and mass is 9.1 grams.