Pre-Lab 1: Measurement and Density

Answer the following questions after reading the background information on the next page. Be sure to use the correct number of significant figures in each answer. THIS SHOULD BE COMPLETED BEFORE LAB.

1. The length of a wooden cylinder is measured to be 16.58 centimeters (cm). What is its length in inches (in)?

2. The volume of a 10 milliliter (mL) beaker is measured to be 15.3 mL. What is the volume in liters (L)?

3. The mass of a steel cylinder is 135.317 grams (g). What is its mass in kilograms (kg)?

4. The length of a wooden cylinder is 16.58 cm. The volume of a cylinder is \( \pi r^2 h \). If the length is equal to \( h \) and the radius of the cylinder is measured to be 1.00 cm. What is the volume of the wooden cylinder?

5. If the same wooden cylinder from question 4 has a mass of 65.359 g. What is the density of the wooden cylinder? (Density = mass / volume) (units = g/mL)
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Objective: The objective of this experiment is to work on scientific math and proper use of conversion factors.

Background Information:
The important techniques that are presented in the lab will be understanding the difference between metric units and U.S. system, how to read scales on the measuring equipment, using conversion factors, using the correct number of significant figures in measurement and in calculations, and calculating density.

Metric Units:
The metric system is used in chemistry labs, in medicine, and in most of the world except in the U.S. The metric units for length are shown in the box below.

<table>
<thead>
<tr>
<th>Type of Measurement</th>
<th>Metric Unit</th>
<th>U.S System unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>meter, m</td>
<td>inch, feet, mile, etc.</td>
</tr>
<tr>
<td>Volume</td>
<td>liter, l</td>
<td>cup, quart, gallon, etc.</td>
</tr>
<tr>
<td>Mass</td>
<td>grams, g</td>
<td>ounce, pound</td>
</tr>
<tr>
<td>Time</td>
<td>Seconds, s</td>
<td>seconds</td>
</tr>
<tr>
<td>Temperature</td>
<td>degrees Celsius, °C</td>
<td>degrees Fahrenheit</td>
</tr>
</tbody>
</table>

In order to show smaller or larger values in the metric system, prefixes are used. Some of the more common prefixes are shown in the table below.

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>kilo</td>
<td>k</td>
<td>1000</td>
</tr>
<tr>
<td>deci</td>
<td>d</td>
<td>0.1 (1/10)</td>
</tr>
<tr>
<td>centi</td>
<td>c</td>
<td>0.01 (1/100)</td>
</tr>
<tr>
<td>milli</td>
<td>m</td>
<td>0.001 (1/1000)</td>
</tr>
</tbody>
</table>

The metric system is a decimal system in which measurements of each type are related by factors of 10. This is similar to the U.S. money system, in that you use the decimal system when you change U.S. dollars. 1 dime is the same as 10 cents or 1 cent is 1/10 of a dime. A dime and a cent are related by a factor of ten. If we used prefixes instead of dime and cents, a dime being 1/10 of a dollar or 0.1 dollar would be called a decidollar. A penny being 1/100 of a dollar or 0.01 dollar would be called a centidollar. This could work with larger bills as well. If you had a 1000 dollar bill, which is the same as having a 1000 one dollar bills, it would be called a kilodollar.

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How to read scales on the measuring equipment:

When using any measuring equipment in chemistry, there is always an uncertainty in the measured value. For example, you have the two rulers below in which you are measuring a stick of wood.

In a), there are not as many divisions so you can only read the ones place, so in measuring the object you can say the object is between 5 and 6. You can estimate where the object is between 5 and 6, and you may say that it isn’t quite halfway so maybe 5.4. Another student may see it as halfway, so 5.5, both are acceptable estimates. Both of the measurements have 2 significant figures.

In b), each number has ten divisions between them, giving a measurable tenths place. In measuring the object, you can see that it is still between 5 and 6, but now you can also use the smaller divisions to get a more accurate measure. Now you can see that the object is between 5.4 and 5.5, and you can estimate where between the lines it is. You may say this time that it is halfway, so the measurement will be 5.45. Another student may get 5.44, both are good estimates. Both measurements have 3 significant figures. Make sure when doing your measurements in lab that you include this estimated value, since it affects how many significant figures you get.

Conversion factors:

In lab you will measure a wooden cylinder using a ruler that measures in centimeters (cm). In order to get to the American system unit of inches (in) you will need to use a conversion to change the cm units to in. This is done by first finding equality between inches and centimeters. In our textbook on page 24 in Table 1.11 we can see that under Metric-U.S. 2.54 cm is equal to 1 in. From that we can write two conversions.
Now we can convert cm to in. For example if our wooden cylinder measured 16.55 cm. To convert this measurement to in we would use the second conversion since that would cause the cm to cross out and leave in on the top line.

\[
16.55 \text{ cm} \times \frac{1 \text{ in}}{2.54 \text{ cm}} = 6.516 \text{ cm}
\]

Since the 2.54 and the 1 in the conversion are exact the significant figures are taken only from the 16.55, so the answer will have the same number of significant figures as 16.55. Read the next section for a review of significant figures.

*Significant figures in measurement and in calculations:*

When taking measurements, make sure that you are reading and recording the all the numbers on the scale so that you have the correct number of significant figures. If you are not sure read the section *How to read scales on the measuring equipment:* above. More information will also be included in the pre-lab discussion.

When adding and subtracting numbers, the final answer will have the same number of decimal places as the number with the least amount of decimal places:

\[
23.456 - 2.34 = 21.12
\]

The answer would have been 21.116, but I had to round the 1 up to 2 to make sure the answer only had 2 decimal places.

When multiplying and dividing numbers, the final answer will have the same number of significant figures as the number with the least amount of significant figures.

\[
6.7 \times 2.345 = 16
\]

The answer would have been 15.7115, but the 5 had to be rounded to 6 in order to keep the significant figures at 2.

*Calculating Density:*

Density is calculated by taking the mass of an object or liquid and dividing it by its volume. Each substance has a unique density, which can be used to identify an unknown object or liquid. In this lab you will identify an unknown metal by its density. Below is a list of metals and their densities.

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<table>
<thead>
<tr>
<th>Metal</th>
<th>Density (g/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>2.70</td>
</tr>
<tr>
<td>Iron</td>
<td>7.86</td>
</tr>
<tr>
<td>Steel</td>
<td>7.80</td>
</tr>
<tr>
<td>Lead</td>
<td>11.3</td>
</tr>
<tr>
<td>Gold</td>
<td>19.3</td>
</tr>
</tbody>
</table>

**Equipment List:**
- Ruler
- 50 mL beaker
- 250 mL beaker
- 100 mL graduated cylinder
- Wooden cylinder
- Steel cylinder
- Unknown metal cylinder

**Procedure:**

Have your report sheet handy to add answers as you do the lab.

Obtain one of each of items in the equipment list.

**Measurement:**

1. Length of a Wooden cylinder.
   a. Use the ruler to measure the length of the wooden cylinder in centimeters (cm).
   b. Remember to include the uncertainty or estimated value.
   c. Record that value on the blank line. Include units.
   d. Record this value on your report sheet also.
   e. How many significant figures are in the measurement?
   f. Use the space below to convert your measurement from cm to inches (in). (Show all work)
      Record the final value on your report sheet.
      Include any observations you may have.
2. Volume of a 50 mL beaker.
   a. Take the 50 mL beaker and 100 mL graduated cylinder to a sink.
   b. Fill the 50 mL beaker all the way up with tap water.
   c. Quickly but carefully pour the water from the beaker into the graduated cylinder.
   d. Return to your table.
   e. With the cylinder on your table, bend down eye-level to the meniscus.
   f. Measure the volume of water in the graduated cylinder, Remember to include the uncertainty or estimated value.
   g. Record that value on the blank line. Include units.
   h. Record this value on your report sheet also.
   i. How many significant figures are in this measurement?
   j. Use the space below to convert your measurement from mL to liters (L). (Show all work)
      Record the final value on your report sheet.
      Include any observations you may have.

   a. Take the steel cylinder to the balance area.
   b. Make sure to tare the balance before weighing the steel cylinder.
   c. When the balance reads zero, place the steel cylinder on the balance plate.
   d. Record the mass on the blank line. Include units.
   e. Record this value on your report sheet also.
   f. How many significant figures are in this measurement?
g. Use the space below to convert the mass from grams to kilograms (kg). (Show all work)
   Record the final value on your report sheet.
   Include any observations you may have.

Density:

1. Wooden cylinder.
   a. Use the balance to get the mass of the wooden cylinder.
   b. Record the mass on the blank line. Include units. __________________
   c. Record this value on your report sheet also.
   d. Rewrite the length of the wooden cylinder from procedure 1c above on the blank line. __________________
   e. No need to rewrite this on the report sheet.
   f. This value for length will be the height in the volume calculation in the next step.
   g. Using the ruler, measure the diameter of the wooden cylinder in cm.
   h. Record this value on the blank line. Include units. __________________
   i. Use the space below to calculate the volume of the wooden cylinder. (Show all work) Volume = πr²h
      Record the final value on the report sheet.
j. Use the space below to calculate the density of the wooden cylinder. (Show all work)
   Record the final value on the report sheet.
   Include any observations you may have.

2. Steel cylinder.
   a. Rewrite the mass of the steel cylinder from procedure 3d above on the blank line.
   __________________
   b. Measure the length of the steel cylinder, in cm.
   c. Record this value on the blank line. Include units.
   __________________
   d. Record this value on the report sheet also.
   e. Using the ruler, measure the diameter of the steel cylinder in cm.
   f. Record this value on the blank line. Include units.
   __________________
   g. Use the space below to calculate the volume of the steel cylinder. (Show all work)
      Record the final value on the report sheet.

   h. Use the space below to calculate the density of the steel cylinder. (Show all work)
      Record the final value on the report sheet.
      Include any observations you may have.
3. **Water**
   a. Using a balance, weigh a dry 100 mL graduated cylinder.
   b. Record the value on the blank line. Include units.
   c. Place about 75-80 mL of water in the graduated cylinder.
   d. Weigh the graduated cylinder and water.
   e. Record the mass on the blank line. Include units.
   f. To get the mass of the water. Take the mass of the graduated cylinder (3e) and water and subtract the mass of the dry graduated cylinder (3b).
   g. Record this value on the blank line. Include units.
   h. Record this value on the report sheet also.
   i. Place the graduated cylinder with water back on the table and measure the exact volume of water.
   j. Record this value on the blank line. Include units.
   k. Use the space below to calculate the density of water. (Show all work).
      Record the final value on the report sheet.
      Include any observations you may have.

4. **Density of an Unknown metal.**
   a. Use the balance to get the mass of the metal cylinder.
   b. Record the mass on the blank line. Include units.
   c. Record this value on your report sheet also.
   d. Measure the length of the metal cylinder in cm.
   e. Record the length on the blank line. Include units.
   f. Record this value on your report sheet also.
   g. Measure the diameter of the metal cylinder in cm.
   h. Record this value on the blank line. Include units.
   i. Use the space below to calculate the volume of the metal cylinder. (Show all work)
      Record the final value on the report sheet.
j. Use the space below to calculate the density of the metal cylinder. (Show all work)
   Record the final value on the report sheet.
   Record which metal the unknown is here and on your report sheet.
   Include any observations you may have.
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Measurement and Density Report Sheet

Measurement:

1. Length of Wooden cylinder (h): a)_____________________
   
b) length (in): __________________
   
   Show the calculation for b) here:

2. Volume of 50 ml beaker: a)__________________________
   
b) volume (L): ______________________

   
a. mass (Kg): ______________________

Density:

1. Wooden cylinder  a) mass:__________________________
   
b) volume: ______________________
   
   Show the calculation for b) here:

   c) density: ______________________
   
   Show the Calculation for c) here:
2. Steel cylinder  
   a) mass:__________________________  
      b) volume:__________________________  
      c) density:__________________________  

3. Water  
   a) mass:__________________________  
      b) volume:__________________________  
      c) density:__________________________  

4. Unknown metal cylinder  
   a) mass:__________________________  
      b) volume:__________________________  
      c) density:__________________________  
      d) unknown metal:__________________________