Density

Introduction

In this experiment you will see how to determine the density of various kinds of substances. The **density of a given substance is the amount of matter contained in a specific sized sample of that substance**.

\[
\text{amount of matter in the sample} = \text{mass of the sample} \\
\text{size of the sample} = \text{volume of the sample}
\]

Therefore, density is defined simply as the **mass per unit of volume**.

Suppose you have a sample of lead that is 1 cubic cm in size, and a sample of aluminum of the same size:

- **Lead** cube has mass of **11.3 grams**
- **Aluminum** cube has mass of **2.7 grams**

Since the samples have the same volume, they can be directly compared in order to see which one contains more matter in the sample size (more mass per unit of volume). You can see that lead contains more mass per cubic cm sample. Thus, lead is denser than aluminum.

Density is a basic property of matter—one that distinguishes one kind of matter from another. Thus, **different substances have different densities**. The density of a given substance will always be the same under a specific set of conditions, regardless of the amount of that substance present. For example, a large block of pure lead will have the same density as the 1 cubic cm sample of pure lead under the same conditions. If you were to cut a 1 cubic cm sample out of the large block of lead, you would find that its mass was 11.3 grams. Thus: density of lead will always be 11.3 grams per 1 cubic cm.

How could you determine the density of the large block of lead without actually cutting out a 1 cubic cm sample and determining the mass of that sample? Suppose the entire block of lead has a total mass of 1130 grams and its volume is 100 cubic cm. Its density can be calculated by dividing its mass by its volume, in order to get the mass of 1 cubic cm:

\[
\text{Density of block of lead} = \frac{1130 \text{ grams}}{100 \text{ cubic cm}}
\]

\[
11.3 \text{ grams per 1 cubic cm}
\]

The density of ANY substance (using a sample of ANY size) can be calculated in this manner: **density = mass/volume**
Mass of an object
Mass is the amount of matter contained in a sample of a substance. It is always measured in grams (g) or a derivative of grams, such as milligrams (mg) or kilograms (kg).

Mass is measured in the lab using an analytical balance or scale. You will learn to use an analytical balance in this experiment.

Volume of an object
Volume is the size of a sample of a substance. It is always measured in milliliters (mL), or a derivative of milliliters, such as liters (L).

What size is a milliliter? It is 1 cubic cm.

![This container has a volume of 1 mL]

If you had a container that was exactly 1 cm x 1 cm x 1cm, as shown above, the container would hold exactly 1 mL of liquid. The volume of the container is 1 mL, or 1 cm$^3$.

1 mL is equal to 1 cubic cm
1 mL = 1 cm$^3$

Volume is measured in the lab using a piece of glassware called a graduated cylinder. You will learn to read a graduated cylinder on the prelab below.

Example calculation
The lead block above makes a good example of how to calculate the density of a substance.

density = mass/volume
density = 1130 g / 100 cm$^3$
density = 11.3 g / cm$^3$ or 11.3 g / mL

Note: you can calculate density using volume units of mL OR cm$^3$ since they are equivalent.
1. 50 milliliters (mL) of a certain liquid has a mass of 12.5 grams (g). What is its density? Show your work and show units on EACH number in the calculation for full credit.

2. The volume of a block-shaped object can be calculated using the formula:
   \[
   \text{volume} = \text{length} \times \text{width} \times \text{height}
   \]
   What is the VOLUME of a block of wood with length of 3 cm, width of 2 cm, and height of 4 cm? Show your work and units on EACH number for full credit.

   If the block of wood weighs 20 g, what is the density of the wood? Show your work and show units on EACH number in the calculation for full credit.

3. An irregularly shaped rock is going to be submerged in a beaker that initially contains 50 mL of water. AFTER the rock is put into the beaker, the water level reads 75 mL. What is the VOLUME of the rock? Show your work and show units on each number.

   If the rock weighs 45 g, what is its density? Show your work and units.

4. In problem 3 above, the method used to determine the density of the rock (submerging it in water to figure out its volume) is called “the displacement method” for determining density. Why is it given this name? (Hint: think about what is being displaced during the procedure.)

5. Read the following page on determination of volume using a graduated cylinder. (In today’s lab you will need to measure volumes of liquids using a graduated cylinder.) Then do the questions that follow.

Prelab continued on next page
Determination of Volume

A graduated cylinder is a piece of glassware designed to accurately measure volumes of liquids. When you look at the surface of a liquid in a graduated cylinder you will notice that the surface is curved, rather than flat. This curved surface is called a meniscus.

To take a volume reading in a graduated cylinder, you should place the cylinder on the lab bench and bend down so that your eyes are level with the meniscus. Then use the volume markings on the cylinder to read the volume of the liquid in the cylinder. Always make a reading from the bottom of the meniscus.

Large graduated cylinders are less precise than small graduated cylinders, so your measurements will have fewer digits after the decimal for a large graduated cylinder than for a small one (see example below).

You should always estimate between the lines on a graduated cylinder to get ONE more digit than you can read from the scale. Take a look at the two examples below (for different sized graduated cylinders) and note that in each case the LAST digit was obtained by estimating between the lines.

Now do the questions on the next page.
6. Define the term **meniscus**.

7. Write down a volume reading for each graduated cylinder below. Be sure to determine the last digit by estimating between the lines on the scale.

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--- mL  

--- mL  

--- mL

--- mL  

--- mL
Density Procedure

1. Density of a solid using direct measurement of volume
For regularly shaped objects, we can calculate the volume using geometrical relationships. For example, the volume of a cube is given by: \[ \text{volume} = \text{length} \times \text{width} \times \text{height}. \]

Obtain one of the blocks of wood and determine its volume by measuring each of the three dimensions with a ruler as follows:
- measure to the nearest tenth of a centimeter (cm)—for example, 5.6 cm.
- record the information on the report sheet—be sure to include units when recording data
- after your first measurement, ask the instructor to check the value to be certain you are reading the ruler correctly

When finished measuring, calculate the volume of the wood block on the report sheet.

Measure the mass of the wood block using the balance. If the instructor has not yet demonstrated the proper use of the balance, ask him/her to show you how to use it. Record the mass on the report sheet. Be sure to record ALL digits from the mass readout on the balance and include the units. For example, a readout of 5.000 grams should be recorded as “5.000 g.” Never drop any digits, including final zeros.

Calculate the density of the wood block on the report sheet. Include units.

2. Density of a solid using indirect measurement of volume (displacement method)
The volume of an irregularly shaped object can be measured indirectly by observing the amount of liquid it will displace. This is easily done by partially filling a graduated cylinder with water, noting the water level, immersing the object to be measured, and noting the final level of the water. The change in the volume readings of the cylinder corresponds to the volume of the object.

Obtain a small amount of one type of metal pellets (take enough pellets to fill 2-3 mL in your small graduated cylinder). Record the type of metal on the report sheet. Determine and record the mass of the pellets.

Fill your small graduated cylinder about half full with water and record the exact volume reading (2 digits after the decimal; include units). Ask the instructor to check the value to be certain you are reading the graduated cylinder correctly.

Place the pellets into the cylinder and record the new volume reading. Calculate the volume of the metal pellets and the density of the metal on the report sheet (include units in both cases).
3. **Densities of different liquids**
You will determine and compare the densities of pure water, salt water, and rubbing alcohol (isopropyl alcohol).

Volumes of liquids can be measured quite accurately with a graduated cylinder, but a volumetric pipet will measure volume even more accurately and precisely. A volumetric pipet will measure and deliver only one specific volume—in this experiment you will use a volumetric pipet that delivers 10.00 mL of liquid. If the instructor has not yet demonstrated how to use a volumetric pipet, ask him/her to do so.

**A. Density of purified water**
Measure and record the mass of a small beaker. Obtain a volumetric pipet and rinse it with a little purified water (not tap water) to be sure it is clean and does not contain droplets of any other liquid that may have been left over from the last person who used it. Use the volumetric pipet to deliver 10.00 mL of purified water (not tap water) into the beaker. Then measure and record the mass of the beaker containing the water. Calculate the mass of the water alone, and then calculate the density of the water.

**B. Density of rubbing alcohol (isopropyl alcohol)**
Measure and record the mass of a small beaker—if you're using the same beaker as before, there is no need to measure its mass again, but be sure the beaker is dry before putting the alcohol into it. To get all the water out of the volumetric pipet, rinse it with a little rubbing alcohol (isopropyl alcohol). Then use it to deliver 10.00 mL of alcohol into the beaker. Next measure and record the mass of the beaker containing the alcohol. Calculate the mass of the alcohol alone, and then calculate the density of the alcohol.

**C. Density of salt water**
Follow the same procedure as above to determine the density of salt water. Be sure the beaker is dry before starting, and be sure to rinse the pipet with a little salt water in order to get all the alcohol out of it.
Density Report Sheet

Name __________________

1. Density of a solid using direct measurement of volume

Volume of wood block

   length: ___________ width: ___________ height: ___________

   Calculation of volume:

Mass of wood block: ___________

Calculation of density:

2. Density of a solid using indirect measurement of volume (displacement method)

Type of metal used: ___________

Mass of metal pellets: ___________

Volume of metal pellets

   initial cylinder reading: ___________ final cylinder reading: ___________

   volume of metal pellets:

Calculation of density:

Be certain you have included the proper number of digits after the decimal for all your data above, and include units on each number!
### 3. Densities of different liquids

<table>
<thead>
<tr>
<th></th>
<th>pure water</th>
<th>rubbing alcohol</th>
<th>salt water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of beaker</td>
<td>_______</td>
<td>_______</td>
<td>_______</td>
</tr>
<tr>
<td>Mass of beaker + liquid</td>
<td>_______</td>
<td>_______</td>
<td>_______</td>
</tr>
<tr>
<td>Mass of liquid</td>
<td>_______</td>
<td>_______</td>
<td>_______</td>
</tr>
<tr>
<td>Density of liquid</td>
<td>_______</td>
<td>_______</td>
<td>_______</td>
</tr>
</tbody>
</table>

Show a sample calculation of density below for one of the liquids:

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Be certain you have included the proper number of digits after the decimal for all your data above, and include units on each number!
1. Why would the displacement method (which you used in part 2 to determine the density of metal pellets) not be practical for measuring the density of a piece of a cork or a ping pong ball? (Think about what will happen when you put either of these items in water.)

2. Record volume measurements for the two graduated cylinders shown here. Use the correct number of digits after the decimal.

3. Based on your experimental results (part 3), which is more dense: salt water or pure/distilled water?

   Explain why this is the case.

4. You have a metal cube with a mass of 12 grams and a volume is 6.0 mL. If you obtained another cube of the same metal with a volume of 3.0 mL, what will its mass be?

   Based on your answer above for the mass of the metal cube, what can you conclude about the density of a given material? (In other words, what assumption did you make about the densities of the metal cubes in order to determine the mass?)
5. Assume that you have a gallon of pure water. Its density is 1.00 g/mL. What will be the density of a few drops of this pure water? __________

Explain why you answered as you did.

6. Why did you use a **volumetric pipet**, rather than your small graduated cylinder, to measure the liquids in part 3?

**Applying What You Learned**
You may have heard the story of Archimedes… the king suspected that someone had taken his solid gold crown and replaced it with a counterfeit made of a cheaper metal covered with thin gold plating. Archimedes “saved the day” by figuring out an easy way to determine whether or not the king’s crown was solid gold or just a cheap imitation. (Of course his method did not involve damaging the crown in any way.)

Get the “crown” and some “gold” from the instructor. You may work with your lab partner and/or with other groups of students on this project; you may NOT damage the “crown” in any way!

How did YOU determine whether or not the “crown” is a fake? Explain below; show ALL relevant calculations.