CHM 130LL: Density

Objectives

In this experiment you will:

- Measure the dimensions of a cylindrical solid "slug" of an unknown metal to calculate its density and identify the metal.
- Measure the mass and volume of an unknown liquid to calculate its density.
- Measure the mass and volume of a rubber stopper to calculate its density.
- Carry out a computer-based exploration on density

Introduction

We commonly use the terms "heavy" and "light" to describe various objects. For example, a thick textbook might be considered "heavy as a rock" while a fine silk camisole might be considered "light as a feather." These terms, "heavy" and "light", actually convey the relative **density** of a substance.

Objects that are heavy have more mass concentrated in a given amount of space; for example, a textbook has hundreds of pages of paper and cardboard concentrated in a given volume. If you were to put a silk camisole in an empty box of the same size as the book, the box with the camisole would be much lighter because it contains the light cardboard in the box, the silk camisole, and air. Even thought they occupy the same volume as the book, the camisole and the box have less solid matter compared to the book, so they have a lower mass and a lower density.

In science, we can compare the densities of different substances to learn more about their masses or the arrangement of atoms in the substance. For example, a cast-iron skillet is heavier than an aluminum skillet of the same size, so assuming the atoms are packed similarly in both solids, we would deduce that iron atoms have a greater mass than aluminum atoms. Looking up their atomic masses on the Periodic Table, we find that iron's atomic mass is 55.85 amu while aluminum's atomic mass is 26.98 amu, confirming our prediction that iron atoms have a higher mass than aluminum atoms. Mathematically, density is defined as a substance's mass-to-volume ratio:

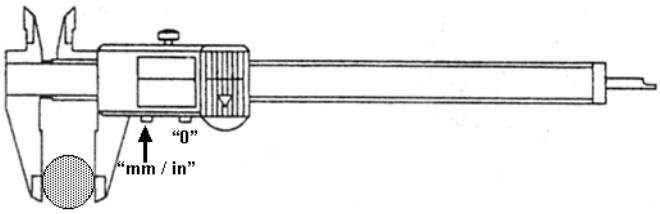
$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

For liquids and solids, mass is reported in grams, and volume is reported in milliliters (mL) or cubic centimeters (cm^3), so density is reported in units of grams per milliliter (g/mL) or grams per cubic centimeter (g/cm^3)—these are equivalent since 1 mL is exactly equal to 1 cm^3.

A substance's density will be the same regardless of the size of a sample. For example, steel has a density of 7.85 g/cm^3 whether you have a tiny steel ball bearing or a large steel beam. Similarly, ice has a density of 0.92 g/ cm^3 whether you have an ice cube or a glacier. Thus, we can use density to identify an unknown substance.

Laboratory Techniques

Calipers are used to obtain a better measurement of length for small objects. They also may be used where a ruler would be awkward (e.g. for inside or outside diameters). Our calipers give readings in mm, so if a cm reading is desired, be sure to convert it. (Example, 14.65 mm = 1.465 cm)

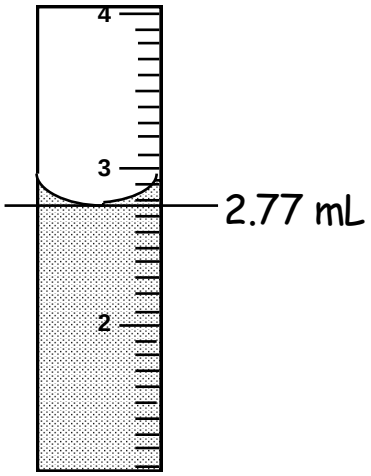


Caliper Directions

1. Adjust the round knob at the top to close the calipers.
2. Turn the calipers on by pressing the **mm/in** button. (If the display does not come on, the battery must be replaced. Bring your calipers to your instructor for a replacement battery.)
3. Press the "0" button to zero the display.
4. Insert the small object in the lower part of the lower opening. Move the round knob to "squeeze" the object, and lock the object and prevent it from moving while the measurement is taken.
5. Record the measurement shown in the digital display in mm.
6. The calipers will turn off automatically.

Graduated cylinders are used to contain and deliver measured amounts of liquid. They are available in many sizes. You will use the 10 mL and 100 mL sizes. Always use the smallest graduated cylinder that will hold the entire volume. The 10-mL graduated cylinders are always read to 2 decimal places (e.g. 5.50 mL) and the 100-mL graduated cylinders are always read to 1 decimal place (e.g. 50.5 mL).

- When water is placed in a glass cylinder, a concave surface forms; this curve is called the ***meniscus***. Glass graduated cylinders are manufactured so that the line at the bottom of the meniscus gives the most accurate reading. In order to read any graduated cylinder accurately, it must be level (sitting on the counter, **NOT** hand-held). Your eye must also be perpendicular to the water level. Note that the graduations on all cylinders read from the bottom up. That is, they indicate the volume **contained** in the cylinder.



- The 10-mL graduated cylinder above is read to two decimal places (to the nearest 0.01 mL). Thus, the volume of liquid is read to be 2.77 mL.
- Note that 100-mL graduated cylinders have markings for each mL, so they are read to one decimal place (to the nearest 0.1 mL).

Procedure

A. Density of a Cylindrical Metal "Slug"

1. Record the unknown number stamped on the end of your slug. Place it upright near the center of the balance pan, and weigh it. Record the mass to ***4 decimal places***, as displayed by the balance. ***NEVER round the mass reported on an electronic balance!***

2. We have calipers for measuring objects accurately, and your instructor will show you how to use them. Always re-zero your calipers before taking a measurement. Carefully measure the diameter and the height of your slug in mm. Record your measurements in mm.
3. Convert your measurements from mm to cm.
4. To calculate the volume in cubic centimeters (cc or cm^3), use the formula for the ***volume of a cylinder***, $\mathbf{V = \pi r^2 h}$, where h = height, π = 3.1416 and r = radius. The radius is one half of the diameter: radius = $\frac{1}{2} \times$ diameter
5. Calculate the density in grams per cubic centimeter (g/cm^3) using the formula for density, $d = \frac{m}{V}$, where d=density, m=mass, and V=volume.

B. Density of an Unknown Liquid

For your unknown liquid, obtain measurements of volume and corresponding mass by following the directions below. **Include the appropriate units for all your measurements.**

1. Weigh an empty, dry 10 mL graduated cylinder, and record the mass.
2. Remove the graduated cylinder from the balance. Use a disposable pipet to transfer about 2 to 3 mL of unknown liquid into the graduated cylinder. (It's not necessary to be exact about the amount added since you will be reading the exact volume directly.) Read and record the volume of liquid in the graduated cylinder (to 2 decimal places) in the table under the Trial 1 column.
3. Reweigh the graduated cylinder with the liquid in it, and record the mass of the graduated cylinder with the liquid under Trial 1.
4. Remove the graduated cylinder from the balance. Add about 2 mL more of the liquid to the amount already present. Read and record the **new** (total) volume of liquid in the graduated cylinder under Trial #2.
5. Reweigh the graduated cylinder with the new level of liquid, and record the mass under Trial 2.
6. Repeat steps 4 and 5 two more times for Trials 3 and 4, making sure that the total volume of liquid stays under 10 mL.
7. Calculate the mass of liquid for each trial using the formula below:

Mass of liquid = "Mass of grad. cylinder + liquid" – "Mass of empty grad. Cylinder"

8. Calculate and record the density for each trial using $\boldsymbol{d = \frac{m}{V}}$. Make sure to give the correct units and the correct number of significant figures for your density values.
9. Calculate and record the average density for your sample with the correct units.

Waste disposal: Your unknown liquid should be poured down the drain in the sink before returning your empty vial to the instructor's desk.

C. Density of a Rubber Stopper using Volume by Displacement

The volume of a solid object with an irregular shape can be determined using the "volume by displacement" method. If a solid object has a density greater than a liquid like water, the object will displace the liquid, causing the level of the liquid to rise by the amount equal to the object's volume. Thus, the volume of the object is equal to the change in level of the liquid.

1. Weigh a dry rubber stopper, and record the mass (to 4 decimal places).
2. Place about 50 mL of deionized water into a 100-mL graduated cylinder. Record the exact volume to 1 decimal place.
3. Tilt the graduated cylinder, and slowly lower the rubber stopper into the liquid, so none of the liquid splashes out. Record the new volume of water to 1 decimal place.
4. Calculate the volume of the rubber stopper.
5. Calculate and record the density (in g/mL) for the stopper using $d = \frac{m}{V}$.

Computer Activity

D. Exploring the Mass, Volume, and Density of Different Objects

- Press ctrl + alt + delete to start up to the computers.
- Use your ***eGCC username and password*** to login and access the network.
- Start **Internet Explorer,**  , by clicking on the icon on the desktop.
- Go to this Address: **http://www.gccaz.edu/chemistry**
- On the menu at the left under **Download Labs here**, click on **CHM130LL**.
- Under **Week 4** click on **Density Computer Activity**.
- When the login window appears, enter your eGCC username and password.
- Use the density computer activity to complete the table and answer the questions in your lab report.

To fill in the table:

1. Set the density of the blue liquid in the pail to **1.0 g/cc**. Place all of the objects in the container with the blue liquid. Record on your report sheet whether each object sinks or floats.
2. Measure and record the mass and volume of each object (include units!).
3. Calculate the density of each object using the formula: $\text{density} = \frac{\text{mass}}{\text{volume}}$. Make sure to use the correct number of significant figures and the correct units for all density values.
4. Answer the remaining questions on the relationship between an object's density and its ability to float.

Note: Be sure to logoff and shut down the computer when you have finished.

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Name: _____

Partner: _____

Section Number: _____

LAB REPORT

A. Density of a Cylindrical Metal "Slug"

Unknown Slug Number: _____

Mass = _____ g

Height = _____ mm = _____ cm

Show the conversion for mm to cm for height:

Diameter = _____ mm = _____ cm

Radius = _____ mm = _____ cm

Show the set-up to calculate the volume of the cylindrical slug using the formula for volume as $V = \pi r^2 h$, where h = height, $\pi = 3.1416$ and r = radius. Give radius and height in cm for this calculation.

Volume of metal slug: _____

Show the set-up to calculate the density below:

Density of metal Slug: _____

Compare the average density of your slug to the densities of common substances below:

Substance	Density (g/cm^3)	Substance	Density (g/cm^3)
Gold	19.3	Titanium	4.51
Lead	11.4	Aluminum	2.70
Silver	10.5	Magnesium	1.74
Steel	7.85	Water (at 4˚C)	1.00
Brass	8.55	Ice (0˚C)	0.92
Copper	8.96	Air	0.0012

The metal used for the unknown slugs can be identified because its density will match one of the densities provided above.

Identify your unknown slug: _____

Explain your choice:

B. Density of an "Unknown" Liquid

Unknown Number: _____

	Trial 1	Trial 2	Trial 3	Trial 4
Mass of grad. cylinder + liquid				
Mass of empty grad. cylinder				
Mass of liquid				
Volume of liquid				
Density of liquid				

Show density calculations for each trial below:

Trial 1: Trial 2:

Trial 3: Trial 4:

Show the calculation for the average density below:

Average density of the unknown liquid: _____

C. Density of a Rubber Stopper using Volume by Displacement

Mass of rubber stopper: _____ g

Volume of water + stopper in graduated cylinder: _____ mL

Volume of water in graduated cylinder: _____ mL

Volume of rubber stopper: _____ mL

Show the calculation for the density of the rubber stopper below:

Density of rubber stopper = _____

D. Exploring the Mass, Volume, and Density of Different Objects

Record the mass, volume and density (with units) for each object, and indicate if it sinks or floats.

Description	Mass	Volume	Density	SINK or FLOAT ?
Red/Black Rectangle				
Orange Rectangle				
Grey Triangle				
Green Triangle				
Purple Oval				
Pink Square				
Red Oval				
Red Square				
Blue Triangle				
Blue Square				

1. Which object has the greatest volume? _____ the least? _____

2. Which object has the greatest mass? _____ the least? _____

3. Which object has the greatest density? _____ the least? _____

4. Is there a correlation (pattern) between the density of an object and its ability to sink or float? Explain how the density of the object determines if it sinks or floats.

5. Use your calculated densities to predict which objects would float if the density of the liquid in the pail was 2.0 g/mL. (Circle all the objects below that would ***float.***)

   Red/Black Rectangle Orange Rectangle Grey Triangle Red Square

   Purple Oval Pink Square Red Oval

   Blue Triangle Blue Square Green Triangle

6. Use the slider to raise the density of the blue liquid in the pail to 2.0 g/cc.

   Were your predictions correct? YES NO

   Explain: