CHM 107LL: 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.
- Perform various density calculations.

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, in the opening sequence of Raiders of the Lost Ark, Indiana Jones tries to replace a gold statue with a bag of sand of about the same volume. Even though the volumes may be the same, gold is much more dense than sand. As Indiana Jones found out, ignoring density and only considering volume can have dire consequences!

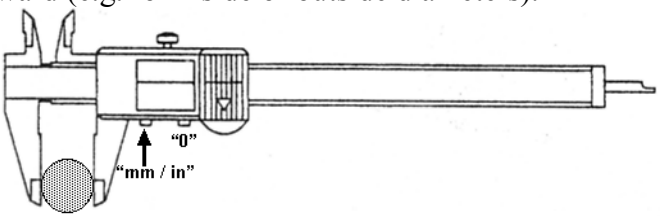
Mathematically, density is defined as a substance's mass-to-volume ratio:

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

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.

Calipers are often 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).



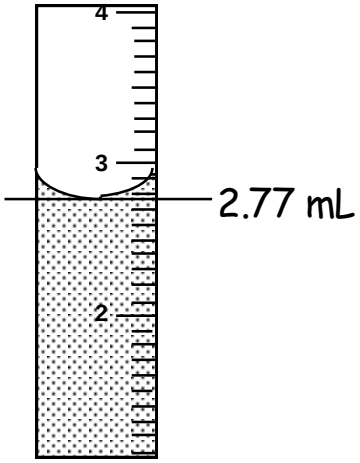
Caliper Directions

1. Make sure the caliper jaws are closed. Roll the wheel on the bottom if needed to close the jaws.
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. The display should now read 0.00 **mm**, not in.
4. Roll the wheel on the bottom to open the caliper jaws and insert the metal slug so that it fits between the ends of the jaws. Move the round knob to lock the object 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. 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.
- 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 for 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! Write down all the numbers always.***
2. Use calipers to measure the metal slug. (Refer to the caliper directions in the introduction.) Always re-zero your calipers before taking a measurement. Carefully measure and record the diameter and the height of your slug in mm.
3. Convert your measurements from mm to cm. (Example, 14.65 mm = 1.465 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.**

Note: Never add liquid to a container while it is on the balance because liquids can damage the balances!

1. Record the unknown number for the unknown liquid at your station.
2. Weigh an empty, dry 10 mL graduated cylinder, and record the mass.
3. Remove the graduated cylinder from the balance. Use the unknown dropper bottle at your station to transfer about 2 mL of your liquid into the graduated cylinder. (It's not necessary to be exact

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.

4. Place the graduated cylinder on the balance, and record the mass of the graduated cylinder with the liquid under Trial 1.
5. 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.
6. Reweigh the graduated cylinder with the new level of liquid, and record the mass under Trial 2.
7. Repeat steps 4 and 5 two more times for Trials 3 and 4.
8. 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"

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

Waste disposal: Pour your unknown liquid down the sink and clean the graduated cylinder.

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 40-50 mL of tap 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.

D. Calculations

Perform the calculations showing all your work, each step. Remember if the density is given, you can use it as a conversion factor to convert between mass and volume. Note that density can be given in units of g/mL or g/cm^3 since they are the same (1 mL = 1 cm^3).

Example: The density of lead is 11.4 g/mL. How much does a 575 mL sample of lead mass in grams?

$$575 \text{ mL} \left(\frac{11.4\ g}{1\ mL}\right) = 6560 \text{ g}$$

Example: The density of lead is 11.4 g/mL. How many mL is a 46.2 g sample of lead?

$$46.2 \text{ g} \left(\frac{1\ mL}{11.4\ g}\right) = 4.05 \text{ mL}$$

CHM 107LL:
Density Lab Report

Name: _____

Partner: _____

Section Number: _____

A. Density of a Cylindrical Metal "Slug"

Unknown Slug Number: _____

Mass = _____ g

Height = _____ mm = _____ cm

Show the conversion for mm to cm for height using 1 cm = 10 mm:

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 the substance of your unknown slug: _____

Explain your choice:

B. Density of an "Unknown" Liquid (include units for ALL measurements)

Unknown Number: _____ Mass of the empty graduated cylinder _____

	Trial 1	Trial 2	Trial 3	Trial 4
Volume of liquid				
Mass of grad. cylinder + liquid				
Mass 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 in graduated cylinder: _____ mL

Volume of water + stopper 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. Calculations. Show your work.

1. Calculate the density of a piece of solid gold if the gold weighs 82.5 g and has a volume of 4.30 mL.

2. Calculate the density of lotion if the contents of a bottle of 650 mL weighs 1170 grams.

3. The density of ethanol is 0.789 g/mL. How much will 1250 mL of ethanol mass in grams?

4. The density of mercury is 13.6 g/mL. What is the volume of 72 grams of mercury?

5. The density of silver is 10.5 g/cm^3. If a pure silver coin has a volume of 45 cm^3, what is its mass?

6. The density of chloroform is 1.483 g/mL. What is the mass of 1.250 L of chloroform?

7. The density of aluminum is 2.70 g/cm^3. What is the volume of 8850 mg of aluminum?

8. The density of copper is 8.96 g/cm^3. What is the volume of a copper ring that masses 103.5428 grams?