CH 151 Summer 2024: "Density" *(online)* **Lab -** *Instructions*

Step One:

> **Watch the lab video** for the "Density" lab, found here:
>
> **http://mhchem.org/t/j.htm**
>
> **Record** the data found at the ***end*** of the lab video on page Ib-4-5.

Step Two:

> **Complete pages Ib-4-5 through Ib-4-9** using the "Density" video and the actual lab instructions on pages Ib-3-3 through Ib-3-4. Include your name on page Ib-4-5!

Step Three:

> **Submit your lab (**pages Ib-4-5 through Ib-4-9 *only* to avoid a point penalty**) as a *single* PDF file to the instructor via email (mike.russell@mhcc.edu) on Friday, July 5 by 9:00 AM.**   I recommend a free program (ex: CamScanner, https://camscanner.com) or a website (ex: CombinePDF, https://combinepdf.com) to convert your work to a PDF file.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor! Good luck on this assignment!

Density (online) Lab

Introduction

Density, like color, odor, melting point, and boiling point, is a physical property of matter. Therefore, density may be used in identifying matter. Every substance (element, compound, alloy, etc.) has a distinct density. **Density** is defined as **mass per unit volume** and is expressed mathematically as **d = m/V** (d is density, m is mass, and V is volume). Density is essentially a measurement of how tightly matter is packed together.

Density is an important concept in a wide range of fields including chemistry, physics, material science, engineering, geology, meteorology, biology and medicine. For example, a bone density test uses X-rays to determine how much calcium and minerals are packed into a segment of bone. You may also be familiar with different types of plastics, including high-density polyethylene (HDPE, #2, used for milk jugs, hula hoops, and breast implants) and low-density polyethylene (LDPE, #4 used mostly for plastic bags.) The difference between these plastics depends on how tightly the polyethylene molecules are packed together during synthesis.

The **density of water** is 1.00000 g/cm^3 at 4 °C and is slightly less at room temperature. In lab today, you will be using the *Handbook of Chemistry and Physics* to determine the exact density of water at a specific temperature. The density of various materials ranges significantly from less than water (styrofoam's density is about 0.1 g/cm^3) to much greater (Osmium has a density of 22.6 g/cm^3.) For example, aluminum has a density of 2.70 g/cm^3 whereas a sample of lead has a density of 11.2 g/cm^3. The same volume of lead will have a mass over four times that of aluminum! That is why lead is used to shield against X-rays whereas aluminum would be ineffective. Aluminum atoms are not only smaller but also packed so that there is more space between atoms.

The SI unit (International System of Units) for density is kg/m^3 and is typically used by physicists and engineers. Because chemists work with much smaller masses and volumes, traditional metric units of **g/cm³** or **g/mL** are the preferred units of measurement (note that **1 mL = 1 cm³**). Liquids are usually measured in g/mL while solids are measured in g/cm^3. Gases are much less dense, so their density is measured in **g/L**.

Density is often represented as a relative density or ***specific gravity,*** a dimensionless quantity that expresses density as a multiple of a given standard (such as water or a gas.) For example, gasoline has a density of 0.67 g/cm^3. Its specific gravity, relative to water, is 0.67. Specific gravity is used in many fields from chemical engineers studying concrete to food scientists testing the alcohol content of a microbrew.

To determine density, mass and volume must both be determined. The **mass** can easily be found using a balance. Determining the **volume** is more ambiguous. The volume of a liquid can be determined using a calibrated container such as a graduated cylinder or graduated flask. The volume of a solid sample with a regular geometric shape can be determined by direct measurement. However, most solids have an irregular shape. The volume can be determined by immersing the solid in a known volume of liquid and measuring the volume of liquid displaced.

This is similar to the method utilized in the ancient tale of **Archimedes** to prove that King Hiero II's crown was not real gold. Archimedes is alleged to have come upon the liquid displacement method while bathing and noticing the rise in his bath water. He then ran through the streets shouting "Eureka!" (I found it!), so excited

that he forgot his bathrobe. After dressing, he then proved that the king's crown did not displace the same amount of water as a piece of gold of the same mass. This method is called the **"displacement method"** and can be used with a variety of liquids in order to find the density of various materials.

All measurements are approximations. **Significant figures ("sig figs")** are those digits that carry meaning which contributes to precision. The uncertainty is in the last digit and determined by the device. For example, when reading a graduated cylinder, the number of sig figs is estimated one digit beyond the gradations. For the *example pictured on the right,* the bottom of the meniscus is between the 8.4 mL and 8.5 mL markings. You can estimate to the hundredth place or 8.45 mL. Reading a meniscus is subjective and takes practice. In this experiment, you will use the mass and density of water to find the volume of a flask more precisely and reduce human bias.
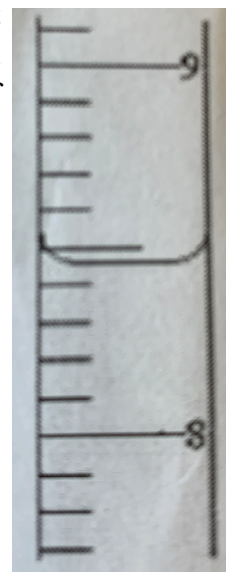
Mass versus Weight: When determining density, you must determine the mass of the sample. The terms *mass* and *weight* are easily confused. The **mass** of a substance is how much matter it is composed of. Units of mass are grams and kilograms. The mass of an object is the same on earth or on the moon. **Weight** is a measure of the force of gravity acting on the object. Pounds (units = lb) is a unit of weight, a force. The weight of an object is variable depending on the location of the object. If Joe weighs 220 Ibs at the North Pole, he would weigh only 219 Ibs at the equator due to the bulge of the earth. He weighs only 37 Ibs on the moon. In outer space, an astronaut is weightless but never massless. A great blue whale is weightless in space, but it would still cause damage to your spaceship if you bumped into it.

Accuracy and Precision: **Accuracy** is how close a measurement, or average of measurements, come to the actual or accepted value. Accuracy is often compared to hitting the bull's eye on a target. In a chemistry lab, accuracy is how close the final calculated answer is to the accepted book value. When working with an unknown, students are graded on their accuracy, how close their answer is to the actual value. Accuracy is determined by calculating the percent error: **percent error = [(|actual value - experimental value|)/actual value] * 100%** (notice the absolute value in the numerator; percent error should be a positive number.) We will use percent error in an upcoming lab. A "good" percent error varies depending on the experiment, the equipment used, and the technician's experience.

Precision is how close multiple measurements of the same quantity come to each other. Precision is a measure of *consistency in lab technique*; is the data reproducible? One method to determine precision is to calculate **parts per thousand** (see the handout in the "Lab Notes" of your Companion, or ask the instructor.) We will calculate parts per thousand in future labs. The term **precision** also refers to the number of significant digits in a measurement. For example, the balances (scales) that will be used in this lab allow measurements to 1 mg (0.001 g). An analytical balance allows mass.to be determined to 0.1 mg (0.0001 g) and so is more precise. The technique used in this lab for determining volume allows for more significant figures and, hence, is more precise than simply using a graduated cylinder.

Random Error and Systematic Error: **Random errors** originate from uncontrollable variables in an experiment. Momentary fluctuations in air currents can affect balance reading. A student who rushes through the lab and follows directions haphazardly will perform many random errors. Random errors affect the precision of measurements and the overall experiment. **Systematic errors** are controllable or repeated errors in

an experiment. A miscalibrated scale will result in all mass measurements being erroneous by the same factor. A student consistently misreading an instrument is a systematic error. Because a systematic error is consistent throughout the experiment, it does not affect the precision but can significantly affect the accuracy.

In this experiment you will determine densities of an unknown liquid and solid by measuring their mass with a balance and their volume. First, you will determine the exact volume of a flask using water. You will determine the density of a solid by displacement of a known quantity of water.

PROCEDURE: (this is what we would have done in the lab room under "normal" circumstances)

Part A: Density of a Liquid *All mass measurements should be recorded to the milligram (0.001 g.)*

1. Clean a 10 mL volumetric flask with soap and water. Dry with a small amount of acetone in the hood and by gently blowing compressed air into it. Determine and record the mass (to the nearest mg) of the *clean* and *dry* 10 mL volumetric flask with a stopper in it.
2. Fill this 10 mL volumetric flask with deionized water. Insert stopper so no air remains in flask. Dry the outside of the volumetric flask. Record the mass to the nearest 0.001 grams.
3. Calculate the mass of the water in the flask. Remember to show all calculation steps in your lab report.
4. Determine the temperature of the water to the tenths place. Use the *Handbook of Chemistry and Physics* to find the density of water at this temperature. Calculate the volume of this volumetric flask. Remember significant digits!
5. Dry the volumetric flask. Obtain an unknown liquid and record the identification number. Fill the volumetric flask with the unknown liquid, stopper and record the mass.
6. Calculate the mass of the unknown liquid added. Calculate the density of the unknown liquid in g/mL to the correct number of significant digits.

Part B: Density of a Solid *All mass measurements should be recorded to the milligram (0.001 g.)*

1. Select an unknown metal and record its identifier.
2. Clean and dry a 50 mL Erlenmeyer flask that will fit your metal sample. Record the mass of the dry flask and stopper. Fill the flask with water. Record the mass.
3. Determine the volume of the Erlenmeyer flask as in part A.
4. Empty and dry the flask thoroughly. Add small chunks of a dry metal sample to the flask until the flask is at least half full. Weigh the flask, with its stopper and the metal, to the nearest milligram. You should have about 50 g of metal in the flask (more is better!)
5. Determine the mass of metal added.
6. Leaving the metal in the flask, fill the flask with water and replace the stopper. Roll the metal around in the flask to make sure that no air is trapped between the metal pieces. Refill the flask if necessary, and then weigh the stoppered flask full of water plus the metal sample.
7. Calculate the mass of water added.
8. Calculate the volume of water added based on its density and mass.
9. Calculate the volume of metal added. Use this value to calculate the density (in g/cm^3) of the metal.
10. Pour the water from the flask. Dry the metal before returning to its container.

Density (online) **Lab**

YOUR NAME: _____

DATA: *Watch the video (***http://mhchem.org/t/j.htm***) to acquire these values using the data at the very end:*

Part A

empty flask (g): _____

flask + water (g): _____

water temperature (°C): _____

density of water (g/mL): _____

flask + unknown (g): _____

Part B

empty flask (g): _____

flask + water (filled) (g): _____

water temperature (°C): _____

density of water (g/mL): _____

flask + metal (g): _____

flask + metal + water (g): _____

Part A Calculations: *Determining the Density of an Unknown Liquid*
Show all work, use significant figures and circle the final answer for full credit.

1. Using the data from the video, calculate the mass (g) of water in the flask for Part A.

2. Using the mass of water in the flask (above) and the given density from the video, calculate the volume (mL) of the water in the flask.

3. Assuming that the water *completely* filled the flask (and it did!), determine the volume (mL) of the flask. Explain your answer.

4. Using the data from the video, calculate the mass (g) of the unknown in the flask.

5. Using the mass of the unknown in the flask (g), and assuming the unknown completely filled the flask (it did!), determine the density (g/mL) of the unknown liquid.

Part B Calculations: *Determining the Density of an Unknown Solid*
Show all work, use significant figures and circle the final answer for full credit.

1. Using the data from the video, calculate the mass (g) of water in the flask for Part B.

2. Using the mass of water in the flask (above) and the given density from the video, calculate the volume (mL) of the water in the flask.

3. Assuming that the water *completely* filled the flask (and it did!), determine the volume (mL) of the flask. Explain your answer.

4. Using the data from the video, calculate the mass (g) of the unknown metal in the flask.

5. Using the data from the video, calculate the mass (g) of water in the flask when the metal was present. *This is a different value from step 1 of part B!*

6. Convert the grams of water in the flask when the metal was present (step 5, above) into the volume of water (mL) present. Use the density from step 2, above.

Part B Calculations: *Continued*

7. Find the volume of the metal (cm³) using the volume of the flask (step 3) and the volume of water present with the metal (step 6.)

8. Using the mass of the metal in the flask (g, step 1) and the volume of the metal (step 7), determine the density (g/cm³) of the unknown metal.

_____

Postlab Questions:
Show all work, use significant figures and circle the final answer for full credit.

1. In the original Indiana Jones movie, our hero is attempting to claim a precious ancient gold relic from a poor third world country. He estimates the size of his prize and carefully adjusts the *volume* of sand in his bag to equal that of the gold relic. With the dexterity that only Indiana Jones possesses, he swiftly but delicately swaps the sand for the gold. After a moment of delight, our hero realizes he has misjudged and the ancient tomb is not fooled. What went wrong? *You do not have to watch the Indiana Jones movie to answer this question!* ☺

2.   Using the techniques covered in this lab, how can the volume of an irregularly shaped object that is less dense than water be found? Assume the object's density is unknown, and "forced submersion" or "weighted submersion" answers will not get credit.

Postlab Questions: *Continued*

3. While panning for gold, you find a nugget that looks like gold. You find its mass to be 1.25g. You know that the density of pure gold is about 20.0 g/cm^3 and that the density of iron pyrite (fool's gold) is 5.0 g/cm^3. Determine if a cubic nugget about 0.40 cm on each side is fool's gold or pure gold. (Show all work)

4. Dennis obtained a clean, dry stoppered flask. He determined the mass of the flask and stopper to be 32.634 g. He then filled the flask with water and determined the mass of the full stoppered flask to be 59.479 g. Based on the temperature of the water, Dennis found the density of water in the *Handbook of Chemistry and Physics* to be 0.998730 g/cm^3. Calculate the volume of the flask.

5. Dennis emptied the flask from question #4, dried it and filled it with an unknown liquid. The mass of the stoppered flask when completely filled with liquid was 50.376 g. Calculate the density of the unknown liquid.

6. Dennis emptied the flask from question #4 and #5 and dried it again. He added an unknown metal to the flask. He determined the mass of the stoppered flask and metal to be 152.047 g. He then filled the flask with water, stoppered it and obtained a total mass of 165.541 g. Calculate the volume of metal added and the density of the unknown metal.

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