Experiment 3
Introduction to Density

INTRODUCTION

The purpose of this experiment is to understand the meaning and significance of the density of a substance. Density is a basic physical property of a homogeneous substance; it is an intensive property, which means it depends only on the substance's composition and does not vary with size or amount. The determination of density is a nondestructive physical process for distinguishing one substance from another. Density is the ratio of a substance's mass to its own volume.

$$d = \frac{m}{V} = \frac{mass}{volume}$$

In the metric system the unit of density for a liquid or solid is measured in g/mL or g/cm^3. The cm^3 volume unit used with solids is numerically equal to mL volume unit used with liquids. That is, 1 mL = 1 cm^3. In this experiment you will determine the density of several liquids and compare the physical properties of those liquids.

Which is heavier, a pound of aluminum or a pound of lead? The answer, of course, is neither, but many people confuse the words "heavy" and "dense" "Heavy" refers to mass only. Density is the mass of a substance contained in a unit of volume. Lead is a very dense metal and contains a large quantity of matter in a small volume, while aluminum, being much less dense, contains a smaller quantity of matter in the same volume.

The volume of 20.0 grams of lead is 1.77 mL. The mass of lead contained in each mL is its density.

$$\text{Density of lead} = \frac{mass}{volume} = \frac{20.0g}{1.77mL} = 11.3g/mL$$

The volume of 20.0 g of aluminum is 7.41 mL.

$$\text{Density of aluminum} = \frac{20.0g}{7.41mL} = 2.70g/mL$$

From the definition of the gram and the milliliter, we can see that one mL of water at 4 ^{o}C would have a mass of exactly one gram. The density of water, then, is one g/mL at 4 ^{o}C. Since the volume occupied by one gram of water varies slightly with temperature, the density also varies slightly with changes in temperature.

The mass of any object is determined by comparing its mass with the mass of known object or objects (*i.e.*, it is weighed). The volume of a liquid is measured using a graduated cylinder, a pipet, or some other volumetric apparatus. The volume of a regular solid (e.g. a cube or a sphere) may be determined by measuring its dimensions and then calculating it using the correct mathematical formula. The difficulty in determining the volume of an irregular solid in this manner is obvious. The method commonly used is to measure the change in the volume of water when the object is immersed in the water. The object displaces a volume of water equal to its own volume. If the solid material is soluble in water, another liquid, in which the solid is insoluble, is used (*e.g.* carbon tetrachloride for salt).

PROCEDURE

Part 1: DENSITY OF WATER

In any chemistry experiment, it is always advisable to calibrate your instruments and to practice any new technique. The density of water can be found in the CRC Handbook of Physics and Chemistry. You will learn the technique for measuring the density of any liquid by experimentally determining the density of water then comparing it to the actual value obtained from the CRC Handbook. You will need to pay close attention to the proper use of a graduated cylinder and a balance.

Weigh a clean, dry 25-mL or 50-mL graduated cylinder. Remove it from balance and add 15.0 mL of distilled water and read the volume to the nearest 0.1 mL (carefully observe the bottom of the meniscus). Re-weigh the graduated cylinder now containing water. Calculate the mass of water and the density of the water using the equation, d = m/V.

As with any experiment, you should always check how accurate your experimentally obtained value is compared to the "true" or accurate value. This experimental error is also known as percent error and it describes the percentage the experimental value is off from the actual value.

$$\text{Density of aluminum} = \frac{\text{experimental value - actual value}}{\text{actual value}} \times 100\%$$

If you used the graduated cylinder and balance correctly, you should have an experimental error of less than 1%. If your error is greater that 2% repeat the above experiment until you have a small percent error.

PART 2: DENSITY OF HOUSEHOLD LIQUIDS

1. Obtain some rubbing alcohol (also called isopropyl alcohol). You will probably find the density of rubbing alcohol in the CRC Handbook under isopropyl alcohol. Weigh a dry 25-mL graduated cylinder. Remove it from balance and add 10 mL of rubbing alcohol and read the volume to the nearest 0.1 mL (carefully

observe the bottom of the meniscus). Re-weigh the graduated cylinder now containing alcohol. Record the weight of alcohol then calculate the density of the alcohol using the equation, d = m/V.

2. Obtain either cottonseed oil or corn oil. Look up the actual density in the CRC Handbook. Weigh a dry 25-mL graduated cylinder. Remove it from balance and add 10 mL of oil and read the volume to the nearest 0.1 mL (carefully observe the bottom of the meniscus). Re-weigh the graduated cylinder now containing oil. Record the weight of oil then calculate the density of the oil.

3. Repeat the process with vinegar. Do not look up the density in a reference book because it probably is not reported since vinegar is a mixture and not a pure substance. On the report sheet, record the mass of vinegar then calculate the density of vinegar. Dispose of these test tubes in the sink and wash the test tubes with soap and water. Scrub the oil test tubes well.

Part 3: DETERMINATION OF THE DENSITY OF SOLIDS

Obtain an unknown solid (two sets of pennies) from your instructor and weigh it to the nearest 0.01 g. If an object cannot be weighed directly, weigh a beaker or weighing boat, place the object into the beaker/weighing boat and then re-weigh. Next add about 25-35 mL of water to your graduated cylinder and record the volume to the nearest 0.1-mL. Make sure the object is completely submerged. Place the sample carefully in the filled graduated cylinder, being careful not to lose any water. Record the level of the water after addition of sample, to the nearest 0.1 mL. Calculate the density of the sample. Use the percent error to compare the density you calculate for your sample with the density of the metal found in a reference book.

OPTION 1: Using the Merck Index or CRC Handbook of physics and chemistry, look up the density of the following metals: Al, Cu, Fe, Pb, Sn, Zn, Yellow Brass, Stainless Steel. Your unknown solid may be one of these metals. Report the density and calculate your experimental error.

OPTION 2: The solid unknown may also be copper pennies from different years. Obtain two sets (each set containing about 10 pennies) from two different years. Follow the same directions as above except after placing the pennies into the graduated cylinder, remember to gently tap the sides to free any trapped air bubbles. Share your data with 3 to 4 other groups then make a graph showing the change in the density of pennies over the years.

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Part 1: DENSITY OF WATER

1. Look up the actual density of water: ________________ What are the units? ________________________
2. Mass of a dry 25-mL graduated cylinder = ________________________
3. Volume of water added to graduated cylinder = ________________________
4. Mass of graduated cylinder and water = ________________________
5. Mass of water in the graduated cylinder = ________________________
6. Calculate the density of the water using the equation, d = m/V = ________________________

   Show your work here: density = ________________________
7. Calculate your experimental error = ________________________

Part 2:RUBBING ALCOHOL OR ISOPROPYL ALCOHOL

1. What is the actual density of isopropyl alcohol (look it up!) = ________________________
2. Mass of a dry 25-mL graduated cylinder = ________________________
3. Volume of alcohol added to graduated cylinder = ________________________
4. Mass of graduated cylinder and alcohol = ________________________
5. Mass of alcohol = ________________________
6. Calculate the density of the alcohol using the equation, d = m/V = ________________________

   Show your work here: density = ________________________
7. Calculate your experimental error = ________________________

Cottonseed oil or corn oil

1. Look up the actual density of the oil = ________________________
2. Mass of a dry 25-mL graduated cylinder = ________________________
3. Volume of oil added to graduated cylinder = ________________________
4. Weight of graduated cylinder and oil = ________________________

5. Mass of oil = ______________________

6. Calculate the density of the oil using the equation, d = m/V = ______________________

   Show your work here: density = ______________________

7. Calculate your experimental error = ______________________

Vinegar

1. Mass of a dry 25-mL graduated cylinder = ______________________

2. Volume of vinegar added to graduated cylinder = ______________________

3. Mass of graduated cylinder and vinegar = ______________________

4. Mass of vinegar = ______________________

5. Calculate the density of the vinegar using the equation, d = m/V = ______________________

   Show your work here: density = ______________________

<u>Part 3:DENSITY OF SOLIDS (Options 1 or 2)</u>

Sample # or date of pennies	________________	________________
Mass of container and sample	________________	________________
Mass of container	________________	________________
Mass of sample	________________	________________
Volume of water	________________	________________
Volume of water and sample	________________	________________
Volume of sample	________________	________________
Density of sample	________________	________________
Identity of your metal (*e.g.* copper)	________________	________________
Density of pure metal (from reference book)	________________	________________
% error for your sample	________________	________________

CLASS PROBLEM (Optional Extension)

Within the last 25 years of the 1900s, the composition of the US penny was changed from copper to a copper-coated zinc coin. Your instructor will demonstrate this for a new penny by dissolving the zinc inside the penny with hydrochloric acid, leaving the copper shell. When did this occur? How much of the penny is still copper? Your assignment is to collect (and share) data with your class to answer these questions. You may use the following data table as a guide, but you may choose to draw a graph or do other calculations to answer these questions. Show your work.

Date of pennies	% copper	Date of pennies	% copper
1960's		1985	
1976		1986	
1977		1987	
1978		1988	
1979		1989	
1980		1990	
1981		1991	
1982		1992	
1983		1993	
1984		1994	

What is the density of pure copper?

From table: ________________________________ Your measurement: ______________________________

What is the density of pure zinc?

From table: ________________________________ Your measurement: ______________________________

What year did the composition of pennies change? ___________________

What is the percent copper in the modern penny? ____________________

Show an example of your calculations for % copper: