Determination of Density

Objective

Density is an important property of matter and may be used as a method of identification. In this experiment, you will determine the densities of regularly and irregularly shaped solids as well as of pure liquids and solutions.

Introduction

The density of a sample of matter represents the mass contained within a unit volume of space in the sample. For most samples, a unit volume means 1.0 ml. The units of density, therefore, are quoted in terms of grams per milliliter (g/ml) or grams per cubic centimeter (g/cm^3) for most solid and liquid samples of matter.

Since we seldom deal with exactly 2.0 ml of substance in the chemistry lab, we usually say that the density of a sample represents the mass of the specific sample divided by its particular volume.

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

Because the density does in fact represent a ratio, the mass of a sample of any size, divided by the volume of that sample, gives the mass of 1.0 ml of the same sample. Densities are usually determined and reported at 20C (around room temperature) because the volume of a sample, and hence the density, often varies with temperature. This is especially true of gases, and there are smaller (but still often significant) changes for liquids and solids. References (such as various chemical handbooks) always specify the temperature at which a density was measured.

Density is often used as a point of identification in the determination of an unknown substance. The density of the unknown might be used to distinguish the unknown from a list of known substances. It is very unlikely for two substances to have the same density, and when coupled with boiling point and melting point it adds even more validity to the identity of the substance.

Density can also be used to determine the concentration of solutions in certain instances. When a substance is dissolved in water, the density of the solution will be different from that of the pure water itself. Handbooks list detailed information about the densities of solutions as a function of their composition (typically, in terms of percent substance in the solution). If a sample is known to contain only a single substance, the density of the solution can be measured experimentally, and then the handbook can be consulted to determine what concentration of the substance gives rise to the measured solution density.

The determination of the density of certain physiological liquids is often an important screening tool in medical diagnosis. For example, if the density of urine differs from normal values, this may indicate a problem with the kidneys secreting substances that should not be lost from the body. The determination of density is almost always performed during a urinalysis.

Several techniques are used form the determination of density. The method used will depend on the type of sample and on the level of precision desired for the measurement. For example, devices have been constructed that permit a quick, reliable, routine determination of the density of urine. In general, a density determination will involve the determination of the mass of the sample with a balance, but the method used to determine the volume of the sample will differ from situation to situation. Several methods of volume determination are explored in this experiment.

For solid samples, different methods may be needed for the determination of the volume, depending on whether or not the solid is regularly shaped. If a solid has a regular shape (cubic, rectangular, cylindrical), the volume of the solid can be determined by geometry

If a solid does not have a regular shape, it may be possible to determine the volume of the solid from Archimedes's principle, which states that an insoluble, nonreactive solid will displace a volume of liquid equal to its own volume. Typically, an irregularly shaped solid is added to a liquid in a volumetric container (such as a graduated cylinder) and the change in the liquid level is determined.

For liquids, very precise values of density may be determined by measuring an accurate volume of liquid in a container that can then be weighed and then determining the mass of the liquid that was measured. A convenient container for determining the volume of a liquid is to weigh a particular volume of liquid in a graduated cylinder.

Procedure:

A. Determination of the Density of Solids

Obtain a regularly shaped solid and describe its appearance in the appropriate spot on the record sheet. Determine the mass of the solid by weighing it with a balance.

Add about 50 ml of water to your graduated cylinder. Record the exact volume of water in the cylinder to the precision permitted by the calibration marks on the cylinder.

Gently place the solid into the cylinder (do not drop the metal because it could break the graduated cylinder). Read the level of the water in the graduated cylinder, again making your determination to the precision permitted by the calibration marks on the cylinder. Assuming the sample does not dissolve in or react with water, the change in the water level represents the volume of the solid.

Use the list of densities of various solids available to determine what solid you obtained. Look up the true density of the material in chemical handbook of data and use it to calculate the percent error in your measurement.

After blotting the sample dry with a paper towel, return the sample to your instructor.

Obtain an irregularly shaped solid and record the identity of the sample. Determine the density of the solid, using the method just described for the regularly shaped object.

Compare the measured density of the object with the value listed in the handbook, and calculate the percent error in your measurement.

B. Density of Pure Liquids

Clean and dry a 50 ml graduated cylinder (a rolled up paper towel should be used). Weigh the dry graduated cylinder as accurately as you can with the balances you have available.

Add water to the cylinder so that the water level is above the 45 ml mark but below the 50 ml mark. Determine the temperature of the water in the cylinder.

Reweigh the cylinder as accurately as the balances available will allow.

Record the exact volume of the water in the cylinder, to the level of precision permitted by the calibration marks on the barrel of the cylinder.

Calculate the density of the water. Compare the measured density of the water with the value listed in the handbook for the temperature at which your experiment was performed. Calculate the percent error.

Clean and dry the graduated cylinder.

Obtain a different type of liquid and record identity. Determine the density of the liquid, using the method just described for water.

Obtain another type of liquid and record identity. Determine the density of the liquid, using the method performed twice.

C. Density of Solutions

The concentration of solutions is often conveniently described in terms of the solutions' percent composition on a weight basis. For example, a 5% sodium chloride solution contains 5 g of sodium chloride in every 100 g of solution (which corresponds to 5 g of sodium chloride for every 95 g of water present)

Prepare solutions of sodium chloride in water consisting of the following percents by weight: 5%, 10%, 15%, 20%, and 25%. Prepare 50 ml of each solution (you do not have to prepare 100 g of each solution to be able to use the percent composition). Make the weight determinations of salt and water to as accurately as possible.

Using the method described earlier for samples of pure liquids, determine the density of each of your sodium chloride solutions. Record the temperature of each solution while determining its density.

Construct a graph of the density of your solutions versus the percent of NaCl the solution contains. What sort of relationship exists between density and composition?

Use a handbook of chemical data to determine the true density of each of the solutions you prepared. Calculate the percent error in each of the densities you determined.

Excerpted from *Experimental Chemistry* 6th edition by James F. Hall

Name ____ Block ____________________________

Lab Instructor ____ Date ______________________________

Determination of Density Record Sheet

RESULTS/OBSERVATIONS

A. Density of Solids

Appearance of regular ____

____

Mass of solid ________________________________

Handbook Density __________________________

Initial Water level ____________________________

Final Water Level ___________________________

Calculated Density ___________________________

Identity of Metal ____________________________

Percent Error ______________________________

Identity of irregular shaped object _________________________

Mass of solid ________________________________

Handbook Density __________________________

Initial Water level ____________________________

Final Water Level ___________________________

Calculated Density ___________________________

Percent Error ______________________________

B. Density of Liquids

Mass of empty graduated cylinder ______________

Mass of cylinder plus water ___________________

Volume of water ____________________________

Density __________________________________

Temperature ______________________________

Handbook Density __________________________

Percent error _____________________________

Identity of second liquid ____

Mass of cylinder plus liquid ___________________

Volume of liquid ____________________________

Density __________________________________

Identity of third liquid ____

Mass of cylinder plus liquid ___________________

Volume of liquid ____________________________

Density __________________________________

C. Density of Solutions

%Nacl	Density measured	Temperature	Handbook Value	%error
5%	______________	___________	_____________	_________
10%	______________	___________	_____________	_________
15%	______________	___________	_____________	_________
20%	______________	___________	_____________	_________
25%	______________	___________	_____________	_________

QUESTIONS

1. Explain density in your own words.

____

____

2. What error would be introduced into the determination of the density of the regularly shaped solid if the solid were hollow? Would the density be too high or too low?

____

____

____

3. An insoluble, nonreactive metal sphere weighing 18.45 g is added to 21.7 ml of water in a graduated cylinder. The water level rises to 26.8 ml. Calculate the density of the metal.

4. An empty beaker weighs 34.4257 g. A 10-ml pipet sample of an unknown liquid is transferred to the beaker. The beaker weighs 40.1825 g when weighed with the liquid in it. Calculate the density of the unknown liquid.

5. Your data for the density of the sodium chloride solutions should have produced a straight line when plotted. How could this plot be used to determine the density of any concentration of sodium chloride solution?

6. Examine your graph and determine the density for each of the following percents of NaCl: 2%, 7%, 12%, 17%, and 30%.

Excerpted from *Experimental Chemistry* 6th edition by James F. Hall