

Density Laboratories (2 Weeks)

Introduction to Density:

Density is a property of matter defined as the mass of a substance per unit volume.

$$(1) \text{ Density} = \frac{\text{Mass}}{\text{Volume}} \quad (\text{g/mL})$$

The units of density in the metric system are grams per cubic centimeter (g/cc). Since 1 cubic centimeter is equivalent to 1 mL, convenient units for the density of liquids are grams per milliliter (g/mL).

When the density and the mass of a substance are known, equation (1) may be solved to find the volume occupied by that quantity of the substance.

$$(2) \text{ Volume} = \frac{\text{Mass}}{\text{Density}}$$

Examples are given in the sample exercises.

Volume is the amount of space occupied by matter. To determine the volume of a regularly shaped object, one may either measure its dimensions or determine the volume of water it displaces. To determine the dimensions of a cylinder, one measures the radius and the length and calculates the volume as:

$$\text{Volume (of a cylinder)} = \pi r^2 h$$

Where

π = 3.14159, the ratio of the circumference to the diameter of a circle.

r = the radius of the cylinder

h = the length of the cylinder

An alternate method to determine volume is to place the sample in a graduated cylinder and add a known volume of water, (at 20 °C) to the graduated cylinder. The water volume is then read at the bottom of the meniscus in the graduated cylinder. The volume of the sample is calculated as the difference between the two.

Error is the difference between the measured value of the quantity and its true value.

$$(3) \text{ Error} = \text{True value} - \text{Measured value}$$

Absolute Error is the absolute value of the Error.

$$(4) |\text{Absolute Error}| = |\text{True value} - \text{Measured value}|$$

Relative Error is the quotient of the Absolute Error divided by the true value.

$$(5) \text{ Relative Error} = \frac{|\text{Absolute Error}|}{\text{True value}} = \frac{|\text{True value} - \text{Measured value}|}{\text{True value}}$$

$$(6) \text{ Percent relative error} = \text{Relative Error} \times 100$$

The most common way to specify the *precision* of a set of measurements is the **standard deviation, s**, which for a small number of measurements is:

Where: x_i is the individual result
 x_{avg} is the average
 n is the total number of measurements

"It has become appallingly obvious that our technology has exceeded our humanity."

- Albert Einstein (1879-1955)

A. (week 1) Density of an Aluminum Cylinder

Students work independently.



Educational Objectives

The student will become familiar with:

- the intensive property density and its units.
- simple methods used to determine density.
- the use of the analytical balance, the vernier calipers and the buret.
- the techniques of accurate measurement and the determination of experimental error and standard deviation.
- The student will demonstrate that they are familiar with the techniques of laboratory safety.



Safety

Goggles and proper shoes must be worn.



Pre lab Notebook Content:

Title, date, purpose, procedure, data and observations. Tabulated densities and names for the following metals: Al, Pb, Cu, Sn, Fe, Ni, Zn. (include a reference for the source of data, i.e. CRC, Aldrich chemical web site etc.)

Experimental Notes:

- Students make up to FIVE trials.
- Data is to be recorded in your notebook.** Calculations must be worked out in detail in your notebook. Your instructor must initial this work when you turn in your data sheets.

Additional Materials

Aluminum Cylinder, calipers, 25 mL-Plastic graduated cylinders



E-Lab

Point your web browser to <http://ocw.mit.edu/index.html>. Scroll down and select the link to "Chemistry". Select the link to "5.301 Chemistry Laboratory Techniques, January (IAP) 2004". Select "Study Materials". Watch video number 1, "**Volumetric Techniques**". You must select the bandwidth appropriate for your computer.

Sample Exercises:

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Introduction

The density of matter is the mass per unit volume in the sample. The units of density are grams per cubic centimeter (g/cm^3), used to describe the density of solids and grams per milliliter (g/mL), used to describe the density of liquids.

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

Densities vary with temperature and atmospheric pressure. Most materials expand when heated and thus their densities decrease with increasing temperature. Literature values for density are determined and reported at 20°C . The temperature is always specified when a density is reported.

The density of an element or compound is a characteristic physical property and, therefore, is useful in identifying the substance. Unlike liquids and, especially, gases, the densities of most solids are not greatly influenced by small changes in the temperature or pressure. However, the density of a solid may depend somewhat on the method of sample preparation (i.e., whether it has been rolled, cast, or powdered).

A solid which has a regular shape may be measured and dimensional analysis used to determine its volume as follows:

Cubic solid	Volume =	$(\text{edge})^3$
Rectangular solid	Volume =	Length x width x height
Cylindrical solid	Volume =	$\pi \times (\text{radius})^2 \times \text{height}$
Spherical solid	Volume =	$\frac{4}{3} \pi (\text{radius})^3$

Alternately the volume of any solid may be determined by measuring the volume of water it displaces. This method requires that a known volume of water, at a known temperature be added to a graduated cylinder. The solid is placed in the graduated cylinder and the apparent volume of water in the cylinder is read. The difference in the two volumes is the volume of the solid.

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STUDENT NAME:

DATE:

Daily Grading Metric: Density of Aluminum

	Possible points	Points Earned
Notebook Title, Purpose, Procedure-5 record keeping-5 Observations (color, textures, etc.)-5	20	
Lab technique set up-5 safe handling of chemicals-5 safe handling of equipment-5	15	
Average Density of Aluminum by displacement (instructor must check notebook)	10	
Average Density of Aluminum by dimensional analysis (instructor must check notebook)	10	
Calculation of Percent error in measurements density by displacement show calculations on the back of this page and in your notebook; record data in your notebook	10	
Percent error in measurements density by dimensional analysis show calculations on the back of this page and in your notebook; record data in your notebook	10	
Cleaning up your area; check out.	5	
Safety: goggles, clothes and shoes	5	
Quiz	15	
TOTAL	100	

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STUDENT NAME:

DATE:

Raw data and calculations are made in your notebook. This sheet is completed at the end of lab and given to the instructor.

PROCEDURE 1: Density based on dimensions.

Obtain an aluminum cylinder from the instructor. Determine and record the mass of the cylinder. Measure the radius and length using the Vernier calipers. Record this data in your notebook. Make up to five sets of measurements as directed by your instructor. (Be sure to use the same balance each time and be sure to include your units.)

Summary Report: Density of aluminum
(Show all tables and calculations in your notebook)

Room Temperature: _____

Number on metal bar: _____

Table 1: Density of aluminum based on dimensions

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Mass of aluminum cylinder (g)					
Height of aluminum cylinder (cm)					
Radius of aluminum cylinder (cm)					
Volume of aluminum cylinder (cm ³)					
Density of aluminum cylinder: (based on dimensions) (g/cm ³)					

Average density:

Percent error is:

Standard Deviation (optional):

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STUDENT NAME:

DATE:

Raw data and calculations are made in your notebook. This sheet is completed at the end of lab and given to the instructor.

PROCEDURE 2: Density based on displacement of water.

Record the room temperature. Secure a buret to a buret stand and fill it with distilled water. Open the stopcock and allow water to flow to remove any air bubbles. **Let the buret stand for 2 minutes to allow water to drain down the sides.**

Place the aluminum cylinder in a 25 mL PLASTIC graduated cylinder.

Record the initial volume of the water in the buret. Dispense about 10.00mL of water into the graduated cylinder. Record the final volume of the water in the buret. Calculate the volume of water dispensed from the buret.

Read the volume of water level on graduated cylinder. Calculate the volume aluminum cylinder.

Table 2: Density of aluminum based displacement of water

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Mass of aluminum cylinder: (g)					
Final volume of the water in the buret. (V_f) (mL)					
Initial volume of the water in the buret. (V_0) (mL)					
Volume of water dispensed from the buret: ($V_f - V_0$) (mL)					
Volume of water level in graduated cylinder: (mL)					
Volume of aluminum cylinder: (mL)					
Density of aluminum cylinder: (g/mL)					

Average density:

Percent error is:

Standard Deviation (optional):

turn this page in

STUDENT NAME:

DATE:

Post Lab Questions

1. Account for as many possible sources of error as possible.
2. Which method yielded a more accurate result? Explain why.
3. Which method yielded a more precise result? Explain why.
4. How is density affected by temperature? Briefly explain your reasoning.

Calculations: