

## Determination of the Densities of Some Liquid and Solid Samples

### INTRODUCTION

In all sciences, *measurements* are essential. The most fundamental properties that can be measured are length, mass, and time. In chemistry, temperature is also treated as a fundamental property. Other properties of matter such as volume, area, and density are ratios or products of the fundamental properties.

For example,

(a) units of area are length x width, or (distance)<sup>2</sup>

(b) units of volume are length x width x height, or (distance)<sup>3</sup>

(c) units of density are mass / volume, or mass / (distance)<sup>3</sup>

The metric system is used almost exclusively in all sciences. The meter, kilogram, and the second are the basic units in the International System of Units (l<sup>e</sup> Système International d'Unités, SI), but the meter and the kilogram are generally too large for convenient use in the chemistry laboratory.

Units in metric system are related to each other as multiples of ten and associated with prefixes such as, **pico** (10<sup>-12</sup>), **nano** (10<sup>-9</sup>), **micro** (10<sup>-6</sup>), **milli** (10<sup>-3</sup>), **centi** (10<sup>-2</sup>), **deci** (10<sup>-1</sup>), **kilo** (10<sup>3</sup>), and **mega** (10<sup>6</sup>).

This experiment has been designed to acquaint you with several types of measurements and measuring devices.

One of the fundamental properties of any sample of matter is its **density**. This property is dependent on the **mass** and the **volume** of the sample. The relationship between density, mass, and volume is:

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \quad \text{units} = \frac{\text{g}}{\text{mL}} \quad \text{or} \quad \frac{\text{g}}{\text{cm}^3}$$

The density of a liquid or of a solution is usually reported in units of grams per milliliter (g/mL). The density of a solid is reported in units of grams per cubic centimeter (g/cm<sup>3</sup>). Because 1 mL is equivalent to 1 cm<sup>3</sup>, these units are interchangeable. The density of water is 1.00000 g/cm<sup>3</sup> at 4°C and is slightly less at room temperature (0.9970 g/cm<sup>3</sup> at 25°C).

For any density determination, two quantities must be determined: the mass and the volume of a given quantity of matter. The mass can easily be determined by weighing a sample of the substance on a balance.

The mass of a sample of liquid in a container can be found by taking the difference between the mass of the container plus the liquid and the mass of the empty container:

$$\text{mass}_{\text{liquid}} = \text{mass}_{\text{liquid+container}} - \text{mass}_{\text{container}}$$

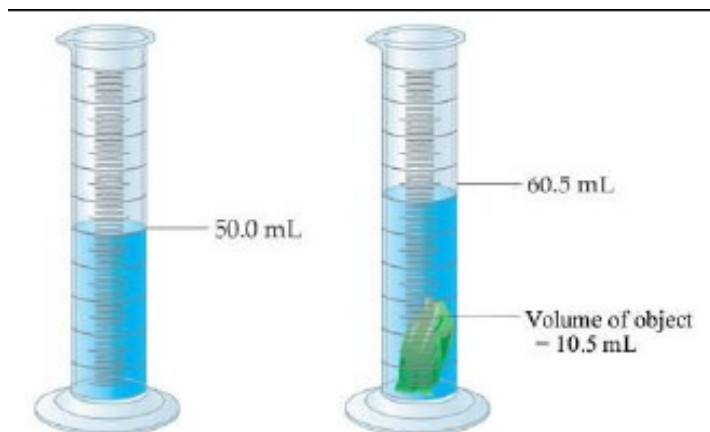
The volume of a liquid can easily be determined by means of “graduated” containers such as graduated cylinders, pipettes, or others for routine measurements. The volume of a solid can be determined by direct measurement if the solid has a regular geometric shape such as a cube, rectangle, or cylinder.

$$V_{\text{cube}} = \ell^3$$
$$V_{\text{rectangle}} = \ell \cdot w \cdot h$$

$$V_{cylinder} = \pi r^2 h$$

A convenient way to determine the volume of a solid (usually irregular-shaped) is to measure accurately the volume of liquid displaced (raised) when an amount of the solid is dropped (immersed) in the liquid. The volume of the solid will equal the volume of liquid which it displaces.

$$V_{solid} = V_{solid+water} - V_{water}$$



### PRE-LAB QUESTIONS

**MUST be completed before an experiment is started. The COPY pages will be collected as you enter the lab.**

*Please answer the following questions and show all work and units. Express all answers to the correct number of significant digits.*

- Q1. Consider MASS, VOLUME, and DENSITY.  
Which are extensive and which are intensive properties?  
Which property is the most useful in helping to identify unknowns and why?
- Q2. A student obtains a silvery metallic unknown. She masses the metal and finds that she has 56.58 g. When she places the metal in a graduated cylinder that contains 25.8 mL of water, the final volume is 32.2 mL.
- A) Calculate the density of the metal.
- B) The Instructor gives her a list of possible unknowns: chromium, cadmium, molybdenum, nickel, or zinc. What is the identity of her sample?
- C) If her identification is correct, what is the percent error of her value?
- D) Was the student accurate? Was she precise? Explain.

## EXPERIMENTAL PROCEDURE

### A. Mass Measurements

- 1) After cleaning the pan and zeroing the balance, take a coin (penny) and measure its mass to  $\pm 0.01$  g.
- 2) Record the mass on the report sheet in grams and milligrams.
- 3) Repeat the measurement for that coin on two other balances.

### B. Volume Measurements

- 1) Read the volume of liquid in the graduated cylinder designated by the instructor.
- 2) Using a dropper, measure the volume of 30 drops of tap water in a 10-mL graduated cylinder.
- 3) Using a 10-mL pipette, transfer 10 mL of tap water to a 50-mL graduated cylinder and read the volume of tap water in the graduated cylinder.

### C. Temperature Measurements

Using a thermometer, determine the temperature of the following:

- 1) 50 mL of tap water in a 150-mL beaker.
- 2) About 100 mL of ice in a 250-mL beaker, with a small amount of water added.
- 3) 100 mL of boiling deionized water in a 250-mL beaker.

### D. Density Measurements

#### Method I for Solids

- 1) Weigh a given solid on a balance to the nearest 0.01g. Make sure you zero the balance before proceeding with each measurement. Record the type of solid used on the report sheet.
- 2) Fill a 50 or 100-mL graduated cylinder about half full with tap water and record the volume as accurately as possible.
- 3) Next, place the solid object in the graduated cylinder and record the water level after the solid is immersed. **NOTE:** When making volume measurements, you should carefully read the lowest point of the water *meniscus* (the concave liquid surface exhibited by water and aqueous solutions when measured in glass containers).
- 4) Calculate the density of the solid.

#### Method II for Solids

- 1) Using a ruler or meter stick, measure the length, width, and height (thickness) of a given wooden block, or the length and diameter of a metal cylinder.
- 2) Calculate the volume of the block.
- 3) Weigh the block on a balance to the nearest 0.01g. Make sure the balance is properly zeroed before weighing.
- 4) From the mass and volume, calculate the density of the solid.

#### Method for Liquids

- 1) Using the provided graduated cylinder, measure 10 mL of rubbing alcohol (isopropyl alcohol). Read and record the correct volume of alcohol in the report sheet.
- 2) Weigh a 50-mL Erlenmeyer flask. Add the alcohol to the flask, and reweigh. *Dispose of the liquid into the waste bottle.*
- 3) Repeat the procedure a second time.
- 4) From your data, calculate the average density of the alcohol.

## Determination of the Densities of Some Liquid and Solid Samples

Name \_\_\_\_\_

Date \_\_\_\_\_

Partner's Name \_\_\_\_\_

### A) Mass Measurement

Balance 1 \_\_\_\_\_ g \_\_\_\_\_ mg

Balance 2 \_\_\_\_\_ g \_\_\_\_\_ mg

Balance 3 \_\_\_\_\_ g \_\_\_\_\_ mg

### B) Volume Measurements

1) Volume of water in graduated cylinder (on the instructor's desk) \_\_\_\_\_ mL

2) Volume of 20 drops of water \_\_\_\_\_ mL

3) Volume of water delivered by pipet in graduated cylinder \_\_\_\_\_ mL

### C) Temperature Measurements

1) Temperature of tap water \_\_\_\_\_ °C \_\_\_\_\_ °F  
(show calculation for conversion of °C to °F)

2) Temperature of tap water + ice \_\_\_\_\_ °C \_\_\_\_\_ °F

3) Temperature of boiling water \_\_\_\_\_ °C \_\_\_\_\_ °F

**D. Density Measurements**

**Solid, Method I**

Type of Solid: \_\_\_\_\_

Mass of solid \_\_\_\_\_ g

Initial volume of water ( $V_1$ ) \_\_\_\_\_ mL

Final volume of water ( $V_2$ ) \_\_\_\_\_ mL

Volume of solid ( $V_2 - V_1$ ) \_\_\_\_\_ mL

Density of solid (show your calculation) \_\_\_\_\_ g/mL

**Solid, Method II**

Type of Solid: Wood Block

Mass of wooden block used in Part A \_\_\_\_\_ g

Dimensions: L = \_\_\_\_\_ cm    W = \_\_\_\_\_ cm    H = \_\_\_\_\_ cm

Volume = \_\_\_\_\_  $\text{cm}^3$

Density of solid (show your calculation) \_\_\_\_\_ g/mL

**Liquid**

**Trial 1**

**Trial 2**

Volume of alcohol \_\_\_\_\_ mL    \_\_\_\_\_ mL

Mass of empty 50-mL flask \_\_\_\_\_ g    \_\_\_\_\_ g

Mass of flask and alcohol \_\_\_\_\_ g    \_\_\_\_\_ g

Mass of alcohol \_\_\_\_\_ g    \_\_\_\_\_ g

Density of alcohol (show your calculation) \_\_\_\_\_ g/mL    \_\_\_\_\_ g/mL

Average density of alcohol (show your calculation) \_\_\_\_\_ g/mL

**Post-Lab QUESTIONS AND EXERCISES**

**(Show all your work. Report to correct number of significant figures and include appropriate units!)**

- Q1. How do you distinguish between the mass and weight of a material?
- Q2. Calculate the density of a rectangular solid, which has a mass of 25.71 g. The dimensions of the solid are 2.30 cm long, 2.01 cm wide, and 1.82 cm high.
- Q3. What is the difference between *specific gravity* and *density*? What is the specific gravity of alcohol having a density of 0.79 g/mL? (Hint: You may need to Google “specific gravity.”)
- Q4. If 15 drops of ethanol from a medicine dropper weigh 0.60 grams, how many drops does it take from a dropper to dispense 1.0 mL of ethanol? The density of ethanol is 0.80 g/mL.
- Q5. A 24.20 g sample of a metal displaces 1.26 mL of water. Calculate the density of the metal.
- Q6. A perfect cube of aluminum metal was found to weigh 20.00 g. The density of aluminum is 2.70g/mL. What are the dimensions of the cube?

Q7. Using appropriate table in Handbook of chemistry and physics, report the density of each of the following substances: a) gold metal b) methyl alcohol (methanol) c) zinc chloride.

Q8. Define the following important terms pertaining to measurements:  
a) Accuracy

b) Precision

Q9. What is the Celsius equivalent of  $-40\text{ }^{\circ}\text{F}$ ?