

Experiment: Density

Objectives:

- To determine the density of a known liquid
- To identify an unknown liquid by determining its density
- To determine the density of a regular solid and an irregular solid
- To distinguish between accuracy and precision

Materials Needed:

- 10-mL pipette and pump
- 100-mL (or 50 mL) graduated cylinder
- 50-mL beaker
- Eyedropper
- Metric ruler
- Samples of known and unknown liquids
- Samples of regular and irregular solid
- Digital gram scale

Measuring Density:

Much of what is done in the chemistry laboratory involves taking measurements. A measurement is a quantitative observation that has both a numerical value and a unit.

How well a measurement is taken determines both its precision and its accuracy. *Precision* is related to the reproducibility of the measurement. It is a comparison of several measured values obtained in the same way. For example, a student measures the volume of a liquid three times, obtaining in the same way. For example, a student measures the volume of a liquid three times, obtaining the values 3.66 mL, 3.62mL, and 3.64mL. These measurements have high precision; there is only a 0.040 mL difference between the highest and lowest values.

Accuracy is a comparison of a measured value to the accepted, or true, value. Suppose the volume of the liquid had actually been 5.44 mL. Then the accuracy of the three measurements taken would be low because a difference of 1.80 mL between the average measured value and the true value is relatively large.

A good scientist is always trying to achieve both high precision and high accuracy in the laboratory.

In this laboratory, you will practice taking measurements and recording them to the correct degree of uncertainty while determining the density of various samples. Density is defined as mass per unit volume and can be calculated using the equation

$$\text{Density} = \frac{\text{Mass of Sample}}{\text{Volume of Sample}} \left\{ \text{or } D = \frac{m}{V} \right\}$$

Once you determine a density experimentally, you will need to evaluate the precision and accuracy of your results. We shall use a calculation called *percent range* to express precision and a calculation called *percent error* to express accuracy. The necessary formulas are:

$$\text{Precision:} \quad \% \text{ Range} = \left(\frac{\text{highest value} - \text{lowest value}}{\text{average experimental value}} \right) \times 100\%$$

$$\text{Accuracy:} \quad \% \text{ Error} = \left(\frac{\text{average experimental value} - \text{"true" value}}{\text{"true" value}} \right) \times 100\%$$

Procedure

Part A: Density of Liquids (*Pure Water*)

1. Obtain approximately 30 mL of known liquid using a small beaker.
2. Place a clean, dry and empty 50 to 100 mL beaker onto a digital scale. To "Zero" the digital scale with the graduated cylinder on it, press the "Re-Zero" or "Tare" button.
3. Using a 10 mL pipette, obtain approximately 5 mL of the known liquid.
4. Read and record the liquid volume from the marks on the pipette, *using the correct number of significant figures*.
5. Place the liquid into the dry beaker (from step 1). Determine and record the mass of the liquid using the digital scale. Re-zero the scale.
6. Repeat the procedure, this time using approximately 8 mL of the liquid.
7. Repeat the procedure, this time using approximately 10 mL of the liquid.
8. Using your mass and volume measurements, determine the density of the liquid for each liquid sample.
9. Calculate the average density value.
10. Calculate the % Error and % Range for your density values.

(*Different liquid*)

1. Empty and dry the beaker.
2. Record the number (or name) of new liquid.
3. Repeat the above steps using the new liquid.
4. Identify the liquid; compare your density results to those in the table on the last page of this hand-out.

Part B: Density of Solids***Regular Solid***

1. Record the identity of your sample (or sample letter).
2. Determine and record the mass of your sample using a digital scale. (Note: sample must be either cylindrical or rectangular.)
3. If your sample is cylindrical, measure the diameter of the circular face and the height (H). From the diameter, determine the radius (r) for the cylinder. The radius is $\frac{1}{2}$ the diameter of the circular face.
4. Using the formula $V = \pi \times r^2 \times H$ for a cylindrical solid, determine the volume of your sample.
5. Calculate the density of your sample and record this value in the data table.

Irregular Solid

1. Using a 100 mL graduated cylinder, obtain roughly 20 to 30 mL volume of an irregular solid sample.
2. Record your sample number (or substance name).
3. Determine and record the mass of your sample (be sure it's dry).
4. Add approximately 50 mL of water to a 100 mL graduated cylinder (or 30 mL water to a 50 mL graduated cylinder)
5. Read and record the water volume.
6. Carefully place your solid sample in the graduated cylinder with the water. Gently agitate the graduated cylinder to eliminate trapped air bubbles.
7. Read and record the new water volume. This is the volume of the water and the metal sample.
8. Calculate the volume of your sample by subtracting the initial water volume (no metal) from the final water volume (with metal).
9. Calculate the density of your sample.

Taking Measurements Report Sheet

Part A: Density of Liquids

Known Liquid Sample

Show calculations for all items marked with an asterisk (*).

- | | | | |
|--|----------------|----------------|----------------|
| 1. Identity of known sample | _____ | | |
| 2. True value of density of known sample | _____ g/mL | | |
| | Trial 1 | Trial 2 | Trial 3 |
| 3. Mass of liquid | _____ g | _____ g | _____ g |
| 4. Volume of liquid | _____ mL | _____ mL | _____ mL |
| 5. Density of liquid* | _____ g/mL | _____ g/mL | _____ g/mL |
| 6. Average density of liquid* | _____ g/mL | | |
| 7. Percent range* | _____ % | | |
| 8. Percent error* | _____ % | | |

Unknown Liquid Sample

Show calculations for all items marked with an asterisk (*).

- | | | | |
|---|----------------|----------------|----------------|
| 1. Name or number of unknown | _____ | | |
| | Trial 1 | Trial 2 | Trial 3 |
| 2. Mass of liquid | _____ g | _____ g | _____ g |
| 3. Volume of liquid | _____ mL | _____ mL | _____ mL |
| 4. Density of liquid* | _____ g/mL | _____ g/mL | _____ g/mL |
| 5. Average density of liquid* | _____ g/mL | | |
| 6. Percent range* | _____ % | | |
| 7. Identity of unknown (from <i>Table B</i>) | _____ | | |
| 8. Percent error* | _____ % | | |

Part B: Density of Solids***Regular Solid***

Show calculations for all items marked with an asterisk (*).

1. Sample name or number _____
2. Mass of sample _____g
3. Sample dimensions
Cylindrical diameter _____cm radius _____cm height _____cm
4. Volume of Sample* (Note: $1 \text{ cm}^3 = 1 \text{ mL}$.) _____ cm^3 = _____mL
5. Density of sample* _____g/mL
6. Identity of unknown (from *Table A*) _____
7. Percent error* _____ %

Irregular Solid

Show calculations for all items marked with an asterisk (*).

1. Sample number _____
2. Mass of sample _____g
3. Initial water volume _____mL
4. Final water volume _____mL
5. Volume of sample* _____mL
6. Density of sample* _____g/mL
7. Identity of unknown (from *Table A*) _____
8. Percent error* _____ %

Questions

1. Explain why a highly precise measurement does not always mean a highly accurate one.
2. Why is the density of a substance independent of sample size?
3. Identify at least two possible sources of error in the procedure used to determine the density of your unknown liquid.

Appendix 1: Accepted Density Values

The "CRC" (short for Chemical Rubber Company Handbook of Chemistry & Physics) is a commonly used source of physical and chemical data. Among the information compiled in this resource are the density values for all of the solid and liquid elements and numerous compounds. Refer to this data when identifying your unknown substance.

A) Physical Constants of Inorganic Compounds (solids):

Substance	Density (g/cm ³)
lead	11.3
gold	19.3
copper	8.96
aluminum	2.70
iron	7.87
zinc	7.14
tin	7.265
potassium chloride	1.988

B) Physical Constants of Organic Compounds (liquids):

Substance	Density (g/mL)
acetic acid	1.0446
1, 2-ethanediol	1.1135
glycerol	1.2613
2-propanol (isopropyl alcohol)	0.7809
benzene	0.8765
water	0.998