Determination of the Density of Water and an Unknown Solid Sample

INTRODUCTION

In this experiment, you will measure the density of water and an unknown sample. You will use the density of the unknown and other physical properties to identify it.

In this experiment you will be asked to pay close attention to uncertainty in your measurements and significant figures in your calculations. You will also analyze the accuracy and precision of your results.

BACKGROUND

Density is an *intensive* property of matter. A substance will have a characteristic density at a given temperature and pressure. The quantity of the substance present does not matter. Density is a ratio of the mass and volume of a substance. Mass and volume are both *extensive* properties – the greater the quantity of material, the larger the mass and volume.

$$Density = \frac{mass}{Volume} \qquad D = \frac{m}{V}$$

Proper use of measuring instruments in the Chemistry laboratory is essential. In recording all measurements, you should use the full precision of the measuring device. In using the graduated cylinders to measure volume, be sure to estimate the last significant digit you record. For measuring mass with a digital analytical balance, the computer will estimate and report the last significant digit to you. You should always record all of the digits.

In the determination of the density of water, you will measure the density of three samples of water of different sizes. Because density is an extensive property, the size of the sample should not change the measured density.

In the determination of the unknown, your unknown will be one from the following list, or from other options indicated by your instructor.

Unknown Metals	Unknown Minerals
Aluminum	Agate
Copper	Garnet
Iron (Steel)	Hematite
Lead	Jasper
Zinc	
Lead-tin solder (alloy of two metals)	

In addition to the densities of the unknowns, you can use the physical properties of metals and minerals, as well as the color(s) of the samples to help identify them by comparison to the literature reports of these properties.

Analyzing Errors is an important part of any experiment. In this experiment, you will want to consider both the accuracy and precision of your data. Accuracy is how close your measured values are to the accepted values for the density of the material. Accuracy is measured as percent error.

$$\%\ \text{error} = \frac{|\text{experimental} - \text{accepted}|}{\text{accepted}} \times 100\%$$

Precision is how close your measurements are to one another. Precision can be measured in a variety of ways. Standard and average deviation calculations work well for a large number of measurements. For a smaller number of measurements, a relative range can be calculated.

$$\text{relative range} = \frac{\text{high value} - \text{low value}}{\text{average value}} \times 100\%$$

PROCEDURE

PART A. *Measuring the density of water*.

1. Record room temperature using your thermometer.
2. Mass a clean, dry 100-mL graduated cylinder. Record the mass in grams to the full precision given by the balance.
3. Fill the graduated cylinder with *approximately* 95 mL of deionized water. It is not necessary to get the volume precisely on the 95.0 line. However, do record the volume in ***mL*** to the appropriate number of significant digits in your notebook.
4. Mass the cylinder with the water. Record the mass in grams.
5. Calculate the mass of the water.
6. Calculate the density of water for this trial.
7. Repeat the process for volumes of approximately 75 mL and 50 mL (record volume to the correct number of significant figures), and calculate the density of water for each of those trials
8. Calculate the average value for the density of water.
9. Calculate the relative range of your results. ***NOTE:*** If the relative range is greater than 5%, repeat the experiment until you have three density readings with relative range less than 5%. Consult with your instructor.
10. Obtain the density of water at the room temperature you measured from the *Handbook of Chemistry and Physics* or another reliable source.
11. Calculate the percent error.
12. *Consider:* Are your measurements accurate? *Explain in the ERROR ANALYSIS section.*
13. *Consider:* Are your measurements precise? *Explain in the ERROR ANALYSIS section.*
14. *Consider:* How could you obtain better accuracy and precision? *Explain in the ERROR ANALYSIS section.*

PART B. *Measuring the density of an irregular object by water displacement*.

15. Obtain approximately 15 - 20 cm^3 of the unknown sample assigned by your instructor.
16. Record the unknown number.
17. Record the physical appearance of your unknown.
18. Mass the DRY unknown.
19. Fill the graduated cylinder about half full of water. Record the precise volume. *Be sure to estimate the last digit.*
20. GENTLY add the sample to the graduated cylinder and record the new volume. ***BE CAREFUL! If you drop it into the graduated cylinder you can break the cylinder.***
21. Calculate the volume of the unknown.
22. Calculate the density.
23. Repeat the above procedure for a second and third sample of the same unknown.
24. Calculate the average of your good trials.
25. Calculate a relative range.
26. If your sample densities vary significantly (relative range > 5%), you may need to obtain additional samples of this unknown and conduct 2 or more additional trials. Consult your instructor if you are unsure.
27. Research and record in your discussion section the densities and physical appearances of the possible unknowns.
28. Identify the unknown sample based on its density and physical appearance.
29. Based on your assignment of the identity of the unknown, calculate the % error for your experimental density.

Repeat the procedure for a second unknown, if assigned by your instructor.

Sample DATA Table

Copy into your notebook before LAB – DO NOT Record data on this sheet! Record ALL data directly in your notebook. This is a REQUIREMENT of the experiment.

Part A.	Trial #1	Trial #2	Trial #3			
Volume of Water						
Mass of graduated cylinder						
mass, cylinder + water						
mass water						
density water						
Average density of water						

Temperature of Water	
Literature value - density water	
Relative Range	
Percent Error	

Part B. Unknown # _____	Trial #1	Trial #2	Trial #3			
Mass unknown						
Volume water						
Volume water + sample						
Volume sample						
Density sample						
Average density sample						

Sample Identity	
Literature value - density of material	
Relative Range	
Percent Error	

Density Experiment • Assignment & Report Guidelines

READING Experiment – Lab Manual Pages / Handout

Laboratory Handbook:
- Section III - Weighing
  - Introduction
  - "Using a top-loading balance"
  - "Weighing by Subtraction"
- Section IV - Measuring Liquid Volumes
  - Introduction
  - "Graduated Cylinders"

Chemistry, 5th ed. by Silberberg: Chapter 1

PRE-LAB Begin the prelab on a new page of your laboratory notebook. **ALL elements of the pre-lab MUST be completed before an experiment is started.** The COPY page from your notebook will be collected as you enter the lab. The original pages must stay in your notebook.

Heading

- Title of experiment and number, your name, the dates of the experiment.

Purpose

- Briefly, but specifically explain the purpose of parts A & B of this experiment.

General Strategy

- Separately, for parts A & B, **summarize** the steps of the experiment, and **explain** how you will use the information to determine the density.

Answers to Pre-Lab Questions

- Answer the questions on the PRE-LAB Questions Handout. Write all answers on that handout and turn in with the COPY pages of the pre-lab information in your notebook. Show ALL units and work.

LAB REPORT *Begin the lab report section on a new page of the lab notebook.* The lab report section includes work recorded during the lab, your analysis and discussion of data and results, and your conclusions. ***The discussion and conclusion sections should be word-processed.*** Other parts of the report - calculations, etc. may be typed.

Heading

- Title of experiment and number, your name, the dates of the experiment.

Data / Observations / Results

- Prepare a data table using the table in the lab manual pages as an example.
- ORIGINAL QUANTITATIVE DATA (signed data pages from your lab notebook).
- Qualitative data (observations) –describe the unknown appearance in your lab notebook. It may help in identification.
- Results - The density of the water, the unknown samples, the identity of the samples, % error, and relative range. These items are incorporated into the suggested results/data table.

Calculations/ Results

- Show all of your calculations! Include units. Report your final results with the correct number of significant figures. The format of each calculation should be as follows. This is an example of a final density calculation for a trial:

HEADING:	Calculation of the density of the unknown #126:	
FORMULA:	$D = m / V$	*(If there are multiple rearrangements or steps in the solutions, show them all.)*
SUBSTITUTE:	$D = 29.232\ g / 4.8\ cm^3$	
SOLVE:	$D = 6.09$ (unrounded)	
	$D = 6.1\ g/cm^3$	

Discussion / Theory / Results / Error Analysis

In this section, you will explain the experiment, evaluate and discuss your results, and analyze error.

Part A – Density of water.

- Explain how you determined the density of water and report your average value for the density.
- Report the literature value for the density of water at the temperature you measured it.
- Report your percent error and relative range. Appropriately relate these to the precision and accuracy of the experiment.

Part B – Density and Identification of the Unknown.

- Explain how you determined the density of the unknown and report your average value for the density.
- Explain why density can be used to help identify your unknowns, but mass or volume cannot.
- Provide a list of the densities and physical properties of the possible unknowns.
- Identify the unknown sample. If a definitive identification cannot be made, explain which unknowns are possible and how you made that determination.
- Report your percent error and relative range. Appropriately relate these to the precision and accuracy of the experiment.

Error Analysis (Parts A & B):

Be specific about where errors may have arisen. Focus on how you can you get more precise or accurate results, rather than what you did "wrong".

- Discuss (identify and explain) which measuring device may have limited your precision. What could help to improve the precision of the experiment?
- Discuss any additional error.

Conclusions

- Your conclusions should include the density of water, and the number, experimental density and proposed identity of your unknown(s).

Answers to Post-Lab Questions

- Answer the questions on the POST-LAB Questions Handout. Write all answers on that handout and turn in with the Lab Report. Show ALL units and work.

PRE-LAB QUESTIONS Name: _____

Please answer the following questions to submit with your pre-lab assignment. Show all work and units. Express all answers to the correct number of significant digits.

1. 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?

2. Cordelia obtains a silvery metallic unknown. She masses the metal and finds that she has 56.58g. 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) Cordelia's teacher 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 Cordelia accurate? Was she precise? Explain.

POST-LAB QUESTIONS Name: _____

Please answer the following questions in the spaces provided and submit with your lab report. Show all work and units. Express all answers to the correct number of significant digits.

1. Look up the density of water at 5.0º, 20.0º, 22.0º, 25.0º, and 30.0ºC. Does temperature affect density? Is temperature a significant source of error for our experiment?

2. In attempting to calculate the density of chloroform, $CHCl_3$, Xander determines the following densities: **1.28** g/mL, **1.24** g/mL, **1.19** g/mL, **1.22** g/mL, **0.812** g/mL, and **1.17** g/mL.

   A) Would it be reasonable for Xander to leave out any values in calculating the average? Why or why not? (Consider your answer here in responding to the rest of the question.)

   B) Calculate the average density of chloroform from his data.

   C) What is the relative range?

(continued on back)

D) If the accepted density of chloroform is 1.48 g/mL, what is the percent error?

E) Was Xander's data accurate? Was it precise? Explain.

2. What would be the volume of iron metal equal to 200.0 g of iron? If the metal were a cube, what would be the length of one edge of the cube?

3. What radius (in mm) must a steel (iron) ball bearing have if it is to have a mass of 3.25 g?

$$V_{sphere} = \frac{4}{3}\pi r^3$$