Lab: Investigating the Density of an Irregular Solid Object

FOR THE TEACHER

Summary
In this lab, students will use common laboratory equipment to devise a method to measure the density of several irregular objects. They will then create a formal laboratory report using both their own data and data from the entire class.

Grade Level
High School

Objectives
By the end of this lab, students should be able to

- Determine a method to measure the mass and volume of an irregular object.
- Accurately use laboratory equipment to gather data.
- Calculate the density of an irregular object using their data.
- Create a graph of mass vs. volume using class data and use the slope of the line to calculate the average density of the objects.
- Calculate the percentage error of their results using both the experimentally determined value and the accepted value for density.
- Create a lab report using tables and graphs, following a provided template.

Chemistry Topics
This lab supports students’ understanding of

- Density
- Measurement
- Data collection
- Significant digits and uncertainty
- Graphing and analyzing data
- Writing to communicate laboratory results.

Time
Teacher Preparation: 15-20 minutes (however allow additional time to create wooden samples. See Teacher Notes below.)
Lesson: 1 hour for lab; 1 hour for lab report instruction and guided practice
Materials

- Several sets of irregular objects of varying materials (we use three different types of wood: Poplar, Plywood and Treated Southern Pine)
- Regularly shaped objects (blocks or cylinders) made from the same materials/wood as the irregular objects for calculation of accepted density values (if desired for extension of lab activity.)
- Rulers
- Graduated cylinders of appropriate size for irregular objects
- Laboratory balances
- Water

Safety

- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.

Teacher Notes

- This lab is recommender for 1st year high school chemistry classes.
- When creating the wood cut-outs for the first time, allow 30-45 minutes to layout and cut samples from each type of wood.
- This lab is designed to be a guided inquiry lab, as well as an introduction to lab report writing, as discussed in the corresponding article, “Tools and Strategies for Lab Report Writing.” We have students create their own lab report, using the provided lab report template while completing this lab.
- **Background:** The density of a substance is an intensive property of matter that can be used to help identify a substance. It is defined as the mass of the sample of substance divided by its volume, and is often measured in g/cm³ or g/ml. Students may have begun studying this in elementary school. By middle school they should have a fairly good understanding that some substances like lead are denser than others like wood. This activity should help them further their understanding by measuring the mass and volume of several objects, each with a different density, and comparing their results with members of their class.
- **Tips:** As much as possible, let the students work directly from the lab protocol, and only answer questions if 1) nobody in the lab group can do so and 2) the answer does not appear in the protocol. There is a big element of “discovery” in this lab. Make certain there is both a straightedge ruler and graduated cylinder available. If they have trouble with the volume of the object, ask them if they ever talked about water displacement in middle school. Ask if it is important whether the objects are dry before measuring the mass or volume. Ask what the ± of the instruments should be, and how many significant digits are in each
measurement. Plastic graduated cylinders may be a better choice than glass if they are available.

- **Management:** The most common problem is students not pushing an object with density less than water's down so the whole object is submerged. Ask them to *show* you how they are measuring the volume before they make their final measurement.

- **Differentiation:** For advanced level classes, provide a block or cylinder of each substance so they can geometrically calculate the volume and, after measuring the mass, calculate an accepted value of density. For all, use this as an opportunity to calculate the percent error. Demonstrate with numbers for a substance they don't have, and then in guided practice watch them do that calculation with their own data.

**FOR THE STUDENT**

**Lesson**

**Investigating the Density of an Irregular, Solid Object**

**Background**
It’s pretty easy to find the density of a cylinder or cube; they are regular geometric objects, the volume of which is determined by measurement and geometry. But can we find the density of an object that is *not* a regular geometric solid? And what are the densities of different sized objects made of the same material? What are the densities of different sized objects made of a different material? Is density an intensive or extensive property?

**Pre-lab Questions**
Remember that density is defined as an object’s mass divided by the object’s volume, \( D = \frac{m}{v} \).

1. What units are customarily used for these quantities?

2. When you make your graph of mass vs. volume, should the line pass through the origin \((0,0)\)? Explain.

**Objective**
You will measure the volume and mass of an object that is not geometrically regular. Find the density of two different substances. Distinguish between
the accuracy and precision of results. Graph data and find the slope of a linear graph, and the meaning of the slope.

**Safety**
- Always wear safety goggles when handling chemicals in the lab.
- Wash your hands thoroughly before leaving the lab.
- Follow the teacher’s instructions for cleanup of materials and disposal of chemicals.

**Procedure**
1. Follow the given Lab Report Template to appropriately document your results during this lab.
2. Design a procedure to accurately measure the mass and volume of the objects without knowing their densities. You will have the following materials to use: two irregular objects of different materials, a graduated cylinder, a ruler, a balance and the customary lab conveniences. Be sure to outline your procedure and collect all appropriate data while following the lab report template as a guideline.
3. Record the class data for all of the objects in a separate data table.
4. Calculate the density for each material using your data in the appropriate section of your lab report.
5. Make a graph of mass vs. volume for each material in the Analysis section of your lab report.
6. Follow the provided instructions to complete a lab report to communicate your results and the class results.

**Data**
1. Record your own data in a table similar to the example below.

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</table>

2. Create a second data table to record the mass and volume for each material as determined by the other lab groups in your class.

**Calculations**
Calculate the density of each material using your data.

**Analysis**
1. Use the volume as the independent variable, graph the mass against volume. Keep the two substances separate on the graph by plotting the points with different symbols or colors.
2. Determine the slope of each line? Write it on the graph.
3. How do these numbers compare with your calculated density? What does this tell you?

4. **Accuracy:** What are the accepted values for the density of the two substances?
   
   Calculate a % error:
   
   
   \[
   \% \text{ error} = \frac{|(\text{accepted value} - \text{your value})|}{\text{(Accepted value)}} \times 100
   \]

5. **Precision:** How close are the individual points on your mass-volume graph to the best-fitting straight line you drew through each set of points?

**Conclusion**

This should be a one sentence summary of what was discovered. It should answer the question posed in the problem section, or cites data to meet the objective.