Density: An Intensive Property of Matter

A Carolina Essentials™ Investigation

Overview

This activity has students collect mass and volume data for different samples of the same substance and develop a formula for density based on slope calculations. The procedure fosters the development of a model for density based on the relationship between mass and volume instead of simple formula use. In addition, students assign different substances to groups so they can establish the periodic nature of density through quantitative data.

Physical Science, Chemistry
Grades: 6–8

Essential Question

How can characteristic properties of substances be related to their structure?

Investigation Objectives

1. Analyze and interpret data to develop a mathematical relationship between mass and volume.
2. Using particle diagrams, construct a model for density that represents the relative densities for all substances tested.

Next Generation Science Standards* (NGSS)

PE MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data • Analyze and interpret data to determine similarities and differences in findings.	**PS1.A: Stucture and Properties of Matter** • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.	**Patterns** • Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

Safety Procedures and Precautions

Make certain students are slowly dropping each sample into the cylinder. Tilt the cylinder and let the sample slowly slide down the wall of the cylinder to avoid breakage or water splashing out. Do not force a sample into a graduated cylinder.

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TIME REQUIREMENTS

PREP	ACTIVITY
20 min	45–60 min

Teacher Prep: 20 min
Student Activity: 45–60 min (depending on number of samples)

SAFETY REQUIREMENTS

MATERIALS

Samples of the same element or pure substance (4 or 5)

Ruler with millimeter marks

Graduated cylinder with 1 mL, 0.2 mL, or 0.1 mL graduations

Electronic balance

Weigh boat

HELPFUL LINKS

Density Column Inquiry Challenge

Sweet and Colorful Density Column

Density Cube Set

Specific Gravity Set

Density Rod Set

Density Determination Set, Aluminum

REFERENCE KITS

Exploring Density Kit

Carolina® Introduction to Density Kit

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Teacher Preparation and Disposal

Assign each group a substance for testing. Dry all samples after use. Once samples are dry, they may be reused for subsequent classes. Generate a Class Density Data Table for students to contribute group data.

Class Density Data Table		
Group	**Substance**	**Density (g/mL)**

Student Procedure

1. Obtain 4 or 5 samples of the same element or pure substance.
2. Mass each sample.
3. Find the volume of each sample by displacement of water or calculation. If your samples are regularly shaped geometric solids, like cylinders, spheres, cubes, or rectangular solids, then calculate the volume using the appropriate formula.
4. Record all measurements.
5. Graph the data with volume on the x-axis and mass on the y-axis.
6. Draw the line of best fit.
7. Calculate the slope of the line.
8. Calculate the density of each sample.
9. Calculate the average density of all samples for a substance.

Teacher Preparation and Tips

1. Groupings of metals that tend to give good results include: Fe, Cu, and Al; Fe, Cu, and Pb; or Cu, Al, and Pb.

2. Choose samples of different sizes or shapes. Sample size must be large enough to show a change in volume in the cylinder.

3. Remind students to mass all samples before calculating volume by displacement of water. The mass is not accurate if the sample is wet.

4. Review with students how to calculate volume using displacement of water.

$$Vol_A = Vol_{water2} - Vol_{water1}$$

5. Formulas for regular solids:

Cube or rectangle $= l \times w \times h$
Cylinder $= \pi r^2 \times h$
Sphere $= 4/3\pi r^3$

6. Check students' work to ensure mass is recorded on the y-axis and volume is on the x-axis.

7. Remind students of the slope formula:

$$Slope = \frac{Y_2 - Y_1}{X_2 - X_1}$$

8. Go over how to draw the line of best fit. Students can also use a calculator or computer program to get the line of best fit.

9. Density formula

$D = M(g)/V(mL)$

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Data and Observations

Data will vary by substance and sample size.

Density *(Cu)*

Sample	Mass (g)	Volume by displacement (mL)	Volume by calculation (cm^3) optional	Calculated density (g/mL)
1	*22.8*	*2.6*	*2.59*	*8.8*
2	*4.2*	*0.5*	*.75*	*8.4*
3	*10.9*	*1.2*	*1.20*	*9.1*
4	*30.3*	*3.4*	*3.37*	*8.9*
5	*15.9*	*1.8*	*1.81*	*8.8*

Analysis and Discussion

1. How do the densities of each sample compare?
   There should be a fairly narrow range of densities among the samples.

   Use your data to support or refute the statement that density is an intensive property of matter.
   Density is an intensive property because there is a narrow range of densities across the samples. No matter what the initial mass was, densities were essentially the same. Since intensive properties do not depend on the amount of material, the data indicate that density is an intensive property of matter.

2. How does the average density compare to the slope of the line? Use your data to construct a model for density.
   The average density is 8.8 g/mL and the slope of the line is 9.0 g/mL. The two values are essentially the same so we know that density is a ratio between mass and volume. Density is an intensive property of matter that illustrates how much mass a substance has in a given amount of volume.

3. Translate the slope equation into the density equation. Show the steps with all units. How are the slope and formula for density related?

   $$Slope = \frac{Y_2 - Y_1}{X_2 - X_1}$$

   = [Mass 2 (g) – Mass 1 (g)]/[Vol 2 (mL) – Vol 1(mL)]

   = Mass final (g)/Volume final (mL)

   = Mass (g)/Volume (mL) = Density (g/mL)

   D = Mass (g)/Volume (mL)

   The two formulas are the same.

4. Your teacher will give you the standard value for the density of the metal or other substance you used.

   At 22° C: Al = 2.70 g/mL Cu = 8.96 g/mL Fe = 7.87 g/mL Pb = 11.3 g/mL

   Calculate the percent error using the slope. Calculate the percent error using the average.

   % error = (standard value – experimental value)/standard value

   Compare the two values.

   The two values should be close and percent error should be around 10% or less. Larger values usually indicate poor measurement technique, classroom temperature or water temperature substantially different than 22° C, or flaws in manufacturing. Check the substances yourself before students complete the lab.

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5. Sketch a particle diagram that models the concept of density for each substance.

Remind students that density is recorded as mass per 1 unit of volume. Suggest to them that they use the same size and shape area to represent the same unit of volume. Only the "mass" of the particles will have to change.

TEACHER NOTES