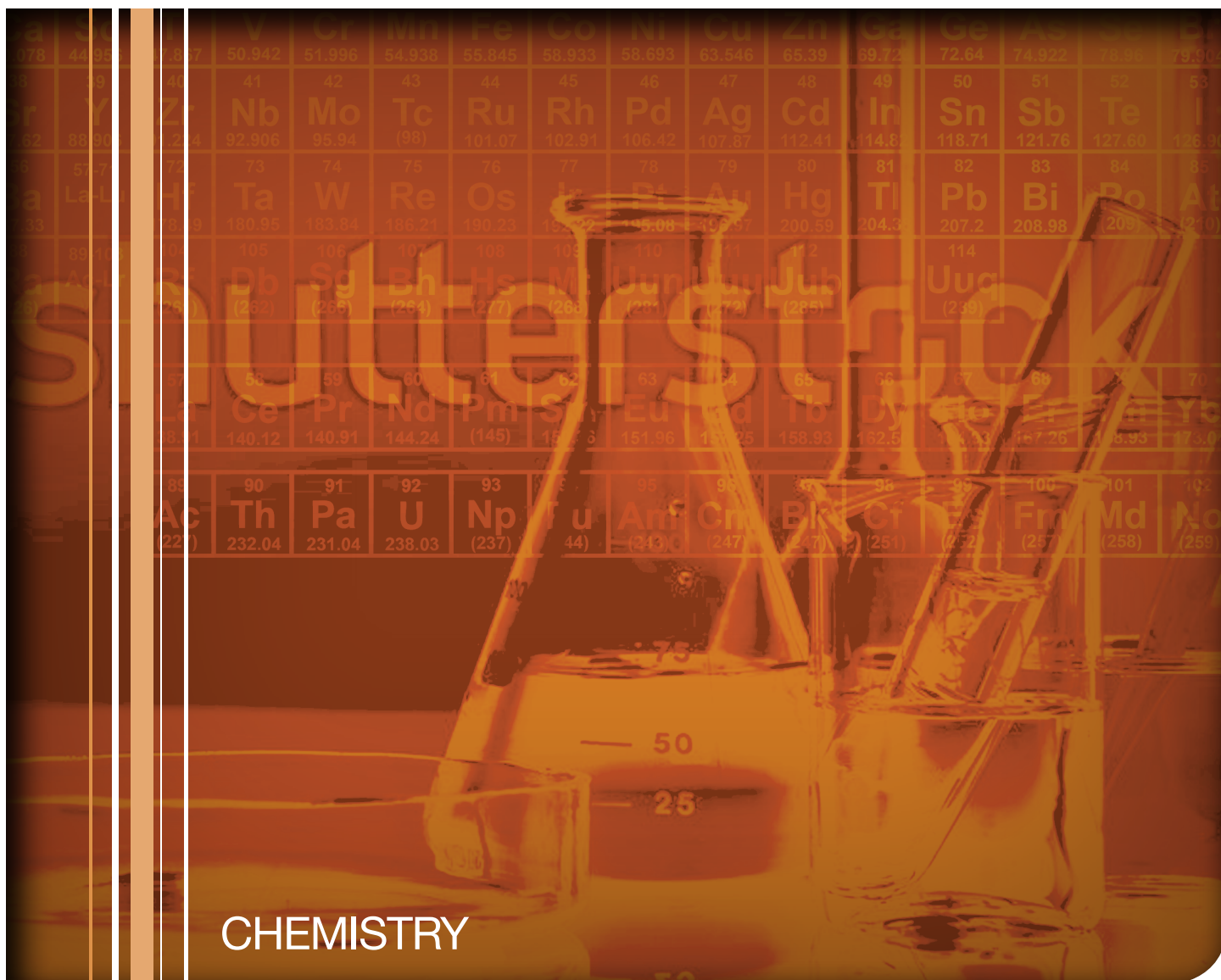
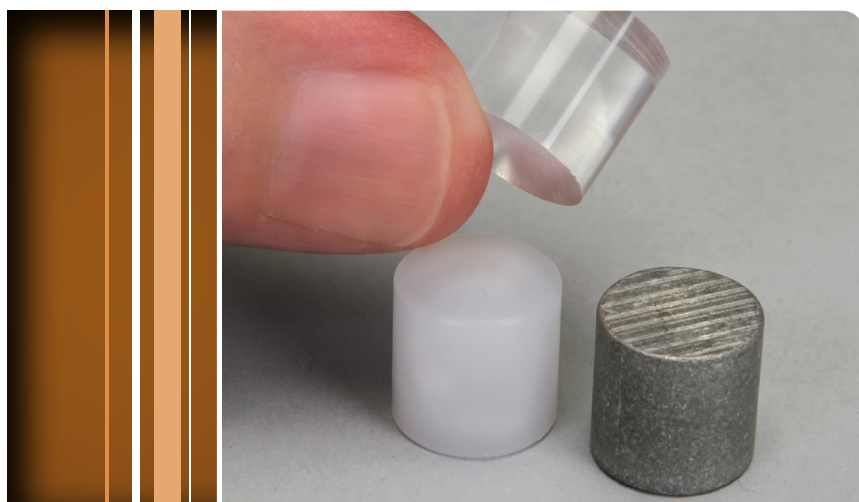




Exploring Density



Investigation
Manual

EXPLORING DENSITY

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Overview

Explore the concept of density through four activities. In the first activity, the densities of three regular solids will be determined. In the second activity, the densities of water and sucrose solutions will be determined from graphs of mass versus volume. Using the information collected in the first two activities, you will predict and test if the solids sink or float in the sucrose solutions. In the final activity, the density of a beverage will be used to calculate the concentration of sucrose.

Objectives

- Calculate the densities of regular solids.
- Determine the densities of solutions by plotting mass versus volume.
- Predict whether objects will sink or float in different solutions based on the densities of the solutions and objects.
- Determine the concentration of sucrose in a beverage based on a graph of known sucrose concentration densities.

Time Requirements

Preparation	30 minutes
Activity 1	15 minutes
Activity 2	60 minutes
Activity 3	15 minutes
Activity 4	30 minutes

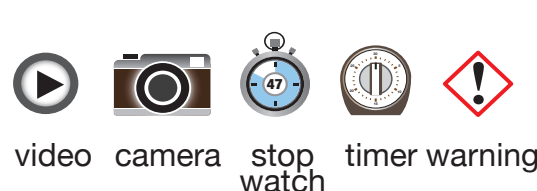
The lab may be paused at any time and continued later. If the lab is paused prior to completion, ensure that all liquids are sealed to prevent evaporation.

Key

Personal protective equipment (PPE)



gloves goggles apron



video camera stop watch timer warning

Background

Density

Density is a physical property of matter that is based on mass and volume of the substance. Mass and volume are extensive properties, meaning that they are dependent on the quantity of matter. However, density is an intensive property and does not change with quantity. Density is a derived unit, meaning that it is composed of two basic units. Density can be defined as mass per unit of volume. The mathematical expression for density is $D = M/V$, in which mass (M) is expressed in grams (g), and volume (V) is expressed in cubic centimeters (cm³). Milliliter (mL) units may replace cm³ when describing liquids, because the two units are fundamentally equivalent.

Density and weight are not the same value. For instance, some people might say that steel weighs more than sand. However, a huge mound of sand obviously weighs more than one steel marble. It would be more accurate to compare masses of steel and sand that have equal volumes. In doing so, they would find that 1 cm³ of steel has a greater mass than that of 1 cm³ of sand. In other words, steel does not weigh more than sand; rather, steel is more denser than sand.

Best-Fit Line

A best-fit line (or regression line) is a line within a scatter plot that shows the linear relationship

of data. A best-fit line allows data points that were not collected during an experiment to be predicted. Most experiments have some experimental error. A best-fit line helps average out these errors. These lines can be calculated with statistical formulas for regression lines; however, most spreadsheet applications, such as Microsoft Excel®, are able to perform these calculations.

Best-Fit Line and Density

The equation of a line is typically represented as $y = mx + b$, in which y represents a data point on the y-axis; x represents a data point on the x-axis; m represents the slope of the line, and b represents the y-intercept (i.e., where the line crosses the y-axis). When a graph of mass versus volume is created in this experiment, the y-intercept must be set to zero. This is because when there is no mass, there is no volume, and vice versa. The equation is then $y = mx$. Because the mass is graphed on the y-axis, and the volume is graphed on the x-axis, this equation actually shows that mass = (m)volume. Rearrangement of the equation to isolate m (the slope) results in the equation: mass/volume = m. Mass/volume is the mathematical formula for density. Thus, in a graph of mass versus volume, the slope (m) represents the density of the substance.

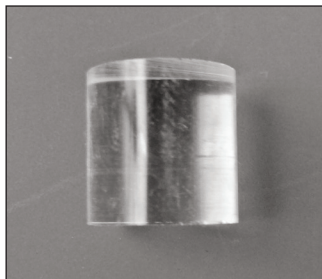
EXPLORING DENSITY

Materials

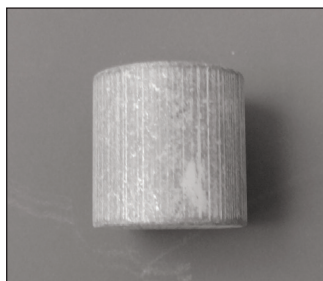
Included in the materials kit:



Polyethylene cylinder
(white)



Acrylic cylinder (clear)



Aluminum cylinder
(silver)

Included in the materials kit:

- Polyethylene cylinder (white)
- Acrylic cylinder (clear)
- Aluminum cylinder (silver)

Needed from the equipment kit:



Graduated
cylinder
50-mL



Electronic
balance



Pipets



Spoons



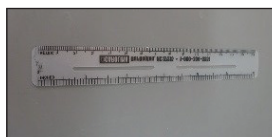
Weighing boats



Plastic cups



Wax
pencil



Ruler

Needed from the equipment kit:

- Graduated cylinder 50-mL
- Electronic balance
- Ruler
- Pipets
- Weighing boats
- Spoons
- Plastic cups
- Wax pencil

Needed but not supplied:

- Sugar (sucrose, $C_{12}H_{22}O_{12}$), 250 g
- Water (bottled or purified), 1 L
- Non-diet beverage containing natural sugar, 100 mL
- Graphing program (such as Microsoft Excel®)

Bottled or purified water should be used because they lack most of the solids found in tap water. Water that has been filtered through a water purifier (e.g., Brita® or PUR®) works well.

Safety

Safety goggles should be worn during this investigation. There are no additional safety concerns.



Read all of the instructions for this laboratory activity before beginning. Follow the instructions closely. Observe established laboratory safety practices, including the use of appropriate personal protective equipment (PPE) as described in the Safety and Procedure sections.

Do not eat, drink, or chew gum during this activity. Wash your hands with soap and water before and after the activity. Clean the work area with soap and water after completing the investigation. Keep pets and children away from lab materials and equipment.

EXPLORING DENSITY

Preparation

1. Read the procedure.
2. Obtain all materials.
3. Clean and sanitize the work area.
4. Label each of seven cups with “0%”, “10%”, “20%”, “30%”, “40%”, “50%”, and “60%” sucrose.
5. Label one cup “beverage.”
6. If a carbonated beverage will be used in Activity 4, open the beverage to allow the soda to flatten (degas) for about 24 hours. Prepare the following sucrose solutions (reported in mass by mass percentage) by mixing the indicated mass of sucrose in 50 mL (50 g) purified water in the appropriately labeled cup. Use the electronic balance to measure the sugar. Use the graduated cylinder to measure the water. Stir the solutions thoroughly with a spoon until all of the sucrose has dissolved.

There must be no carbonation in the beverage when Activity 4 is being performed.

Percentage of Sucrose (w/w%)	Sucrose (g)	Water (g)
0%	0.0	50
10%	5.5	50
20%	12.5	50
30%	21.5	50
40%	33.4	50
50%	50.0	50
60%	75.0	50

The sucrose in the 50% and 60% solutions will not dissolve easily. It may help to warm the solutions slightly in the microwave. Then stir and allow the solutions to cool to room temperature.

As the concentrations of sucrose increase, the solutions will become slightly yellow. However, the solutions will remain transparent when the sucrose has fully dissolved.

7. If the solutions will not be used immediately, cover them with plastic wrap and store them for later use. Solutions should be used within 48 hours of preparation.

ACTIVITY

ACTIVITY 1

A Determining the Densities of Regular Solids

- 1. Using a balance, measure the mass of each cylinder in grams. Record the results in the Activity 1 Data Sheet.
- 2. Using a ruler, measure the height (h) and diameter (d) of each cylinder in centimeters. Record these measurements in Table 1.
- 3. The diameter of a circle is equal to twice its radius

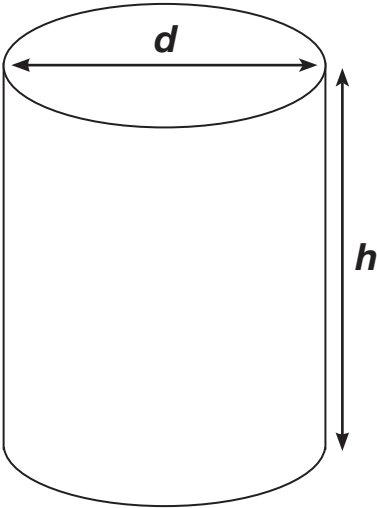


Figure 1. Dimensions of a cylinder

- ($d = 2r$ or $r = d/2$). Find the radius of each cylinder by dividing the diameter of the circle by 2.
- 4. Record these dimensions in Table 1.
 - 5. Calculate the volume of each cylinder using the equation $V = \pi r^2 h$. The approximate value of π is 3.14.
 - 6. Calculate the density of each cylinder by dividing its measured mass by its calculated volume ($D = M/V$).
 - 7. Record the results in Table 1.

Table 1: Activity 1 Data Table

Cylinder Type	Mass (g)	Height (cm)	Diameter (cm)	Radius (cm)	Calculated Volume (cm³)	Density (g/cm³)
Aluminum (silver)						
Acrylic (clear)						
Polyethylene (white)						

ACTIVITY

ACTIVITY 2

B Determining the Densities of Solutions

1. Weigh an empty 50-mL graduated cylinder. Record the mass in Table 2.
2. Add 5 mL of water (0% sucrose) to the 50-mL graduated cylinder. Use the pipet to add or remove small quantities of liquid so that the water is exactly at the 5-mL mark.
3. Record the total mass of the liquid and graduated cylinder and liquid in Table 2.
4. Add more water until the cylinder contains 10 mL volume. Use the appropriate pipet to adjust the volume.
5. Record the total mass in Table 2.
6. Continue adding water in increments of 5 mL, and determine the mass of 15 mL, 20 mL, and 25 mL water. Record all of the data in Table 2.
7. Calculate the corresponding mass for each volume of water and record this information in Table 3.
8. Use a graphing program to create a scatter-plot graph with the mass of the solution on the y-axis and the volume of the solution on the x-axis.
9. On the graph, create a best-fit line (linear trend line) based on the data points. Ensure that the y-intercept of the best-fit line is set to 0. Record the equation for the best-fit line in Table 3.
10. Determine the slope from the equation of the best-fit line, and record the value. This is the density of the solution. The units will be in g/mL. Record the slope (average density) for water in Table 3.
11. Return the solution to the appropriately labeled cup.
12. Rinse the graduated cylinder with purified water, and shake out any remaining water droplets.
13. Shake any solution out of the pipet so that it is dry.
14. Repeat steps 1–13 for each of the sucrose solutions (10%, 20%, 30%, 40%, 50%, and 60%).
15. Plot all of the data on the same graph. At the end of Activity 2, there should be seven sets of data with seven best-fit lines on one graph.

Table 2: Density Data Table

Percentage of Sucrose in Solution	Volume (mL)	Mass of Solution + Graduated Cylinder (g)	Mass of Cylinder (g)	Mass of Solution (g)
0%	5			
	10			
	15			
	20			
	25			
10%	5			
	10			
	15			
	20			
	25			
20%	5			
	10			
	15			
	20			
	25			
30%	5			
	10			
	15			
	20			
	25			
40%	5			
	10			
	15			
	20			
	25			
50%	5			
	10			
	15			
	20			
	25			

ACTIVITY

ACTIVITY 2: continued

Table 2: Density Data Table (continued)

Percentage of Sucrose in Solution	Volume (mL)	Mass of Solution + Graduated Cylinder (g)	Mass of Cylinder (g)	Mass of Solution (g)
60%	5			
	10			
	15			
	20			
	25			

Table 3: Density Results Table

Percentage of Sucrose in Solution	Equation of the Best-Fit Line (with y-intercept = 0)	Density (slope) (in g/mL)
0%		
10%		
20%		
30%		
40%		
50%		
60%		

ACTIVITY 3

C Will It Sink or Float?

1. Based on the calculated densities of the cylinders and solutions, predict whether each cylinder will float or sink in each of the sucrose solutions and water. Record the predictions in Table 4.
2. Test the predictions by placing the aluminum (silver-colored) cylinder in at least the following two solutions: the solution in which you predict the aluminum is most likely to sink, and the one in which you predict the aluminum is most likely to float.
3. Record the results in Table 4.
4. If the predictions were incorrect, test the aluminum cylinders in other solutions.
5. Repeat steps 1–4 for the acrylic (colorless) and polyethylene (white) cylinders.
6. After testing the cylinders, rinse them with fresh water and dry them.

Remove excess solution from the cylinder before you place it in the next solution.

Table 4: Will It Sink or Float Activity

Sucrose Solution	Predictions			Observations		
	Aluminum Cylinder	Acrylic Cylinder	Polyethylene Cylinder	Aluminum Cylinder	Acrylic Cylinder	Polyethylene Cylinder
0%						
10%						
20%						
30%						
40%						
50%						
60%						

ACTIVITY

Activity 4

D Determination of the Sugar Content in a Beverage

The beverage must be completely flat or decarbonated to accurately determine the concentration of sucrose.

1. Use a graphing program and the data from Activity 2 to create a scatter-plot of Sucrose Percentage versus Density.
2. Use the same procedure as that of Activity 2 to determine the mass of 5 mL, 10 mL, 15 mL, 20 mL, and 25 mL of the beverage.
3. Record all of the data in Table 5.
4. Use a graphing program to plot the mass of the solution on the y-axis and the volume of the solution on the x-axis.
5. On the graph, draw a best-fit line through all of the points.
6. Determine the slope of the best-fit line and read the value. This is an average of all five data points with units in g/mL.
7. Record the slope (average density) below the data table.
8. Use the graph created in step 1 to determine the percentage of sucrose in the beverage.
 - Determine the density of the beverage from the y-axis.
 - Draw a horizontal line from this point across the graph until it intercepts the best-fit line.
 - Draw a vertical line from the intersection of the horizontal line and best-fit line to the x-axis.
 - Record the percentage of sucrose from the intersection of the vertical line and the x-axis. This is the percentage of sucrose in the beverage.

Table 5: Determination of Sugar in a Beverage Data

Volume (mL)	Mass of Beverage and Graduated Cylinder (g)	Mass of Cylinder (g)	Mass of Beverage (g)
5%			
10%			
15%			
20%			
25%			

Density (slope) of Beverage: _____

Percentage of Sucrose in Beverage: _____

Disposal and Cleanup

1. Dispose of the sucrose solutions in the sink.
2. Clean and dry all of the equipment; return items to the equipment kit.
3. Sanitize the workspace.

NOTES

CHEMISTRY
Exploring Density
Investigation Manual

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