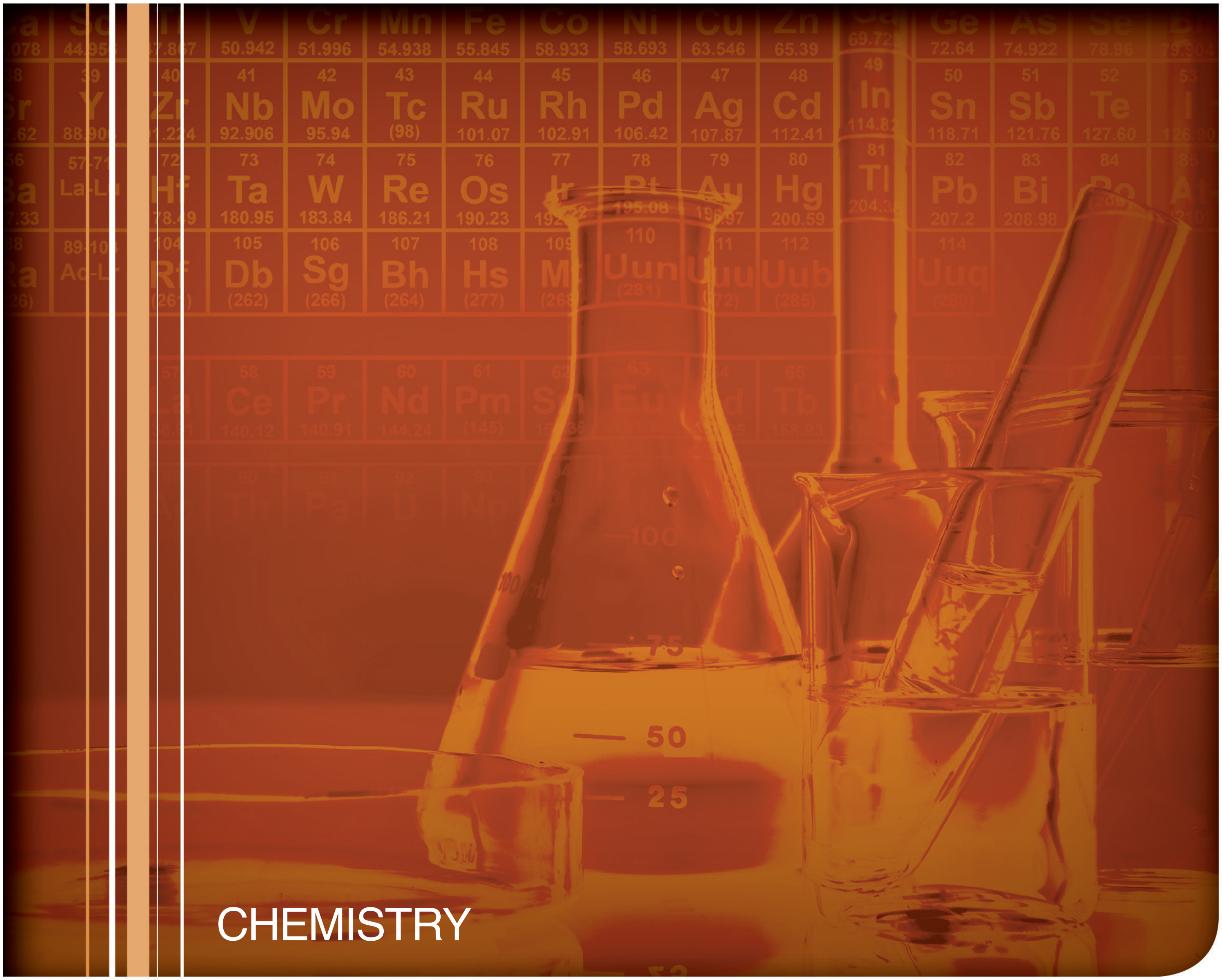
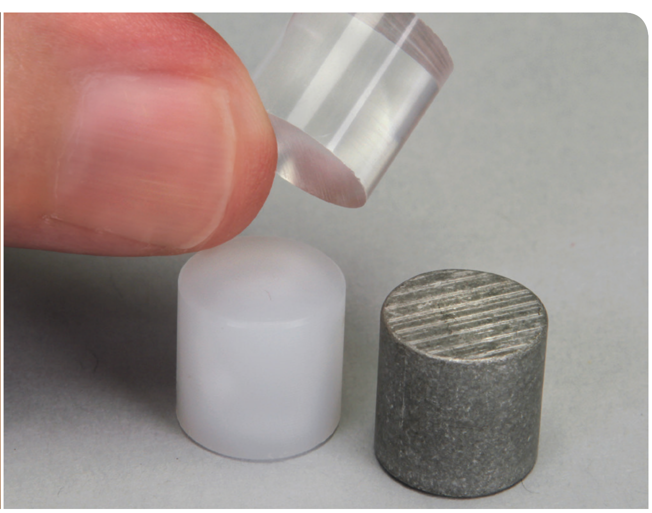


CHEMISTRY

Exploring Density



Investigation Manual

CAROLINA DISTANCE LEARNING

EXPLORING DENSITY

Table of Contents

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.

Outcomes

- 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: Determining the Densities of Regular Solids.. 15 minutes
Activity 2: Determining the Densities of Solutions .... 60 minutes
Activity 3: Will It Sink or Float? .... 15 minutes
Activity 4: Determination of the Sugar Content in a Beverage.. 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)

Made ADA compliant by NetCentric Technologies using the CommonLook® software

CAROLINA®

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. These units are mass and volume. Density can be defined as mass per unit of volume. To calculate the density of an object, the following equation can be used: the mathematical expression for density is **D = M/V**. The mass (M) in this calculation is expressed in grams (g), and volume (V) is expressed in cubic centimeters (cm^3). When describing volumes, milliliter (mL) units may replace cm^3 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. The amount of a substance plays a big role in This case. It would be more accurate to compare masses of steel and sand that have equal volumes. In doing so, it will be determined that 1 cm^3 of steel has a greater mass than that of 1 cm^3 of sand, since the total weight of the steel is higher, yet the volume is the same between the steel and the sand. In other words, steel does not weigh more than sand; rather, steel is denser than sand.

Best-Fit Line

One of the tools to determine unknown values is a best-fit line (or **regression line**), a line within a scatter plot. This will show the linear relationship of data. A best-fit line allows data points that were not collected during an experiment to be predicted. The line created by plotting the known points and connecting them with a linear line allows one value to be determined by reading the other. For instance, if we plot the mass versus volume of known objects, the linear line obtained by connecting the known values can be used to determine the unknown values. If the chart has mass on one axis, we can look at a certain mass, go to the line, and read the corresponding volume from the other axis. Since most experiments have some experimental error, a best-fit line helps average out these errors. To create these lines, they can be calculated with statistical formulas for regression lines. Most spreadsheet applications, such as Microsoft Excel®, are able to perform these calculations.

Best-Fit Line and Density

The equation of a best-fit 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 should also be no volume, and vice versa. The equation used is y = mx. The mass is graphed on the

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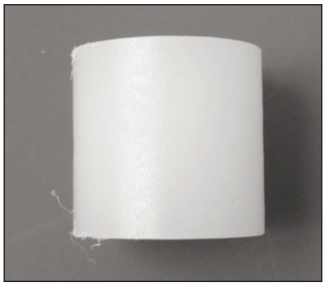
Background continued

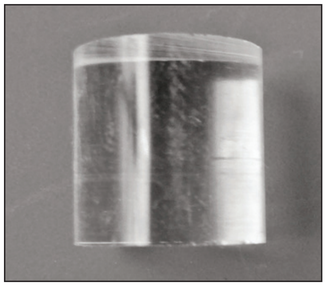
y-axis, and the volume is graphed on the x-axis. This equation actually shows that mass = (m)volume since we determined that the graph needs to go through zero. Rearrangement of the equation to isolate m (the slope) results in the equation: mass/volume = m. Here we divided both sides of the equation by volume. 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. In this investigation, you will be using regular solids. These are solid objects with a regular shape, such as a cube or a cylinder. The regular shape will make it easier to determine the volume of the object compared with an object with an irregular shape.

Materials

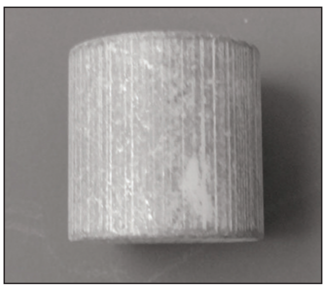
Included in the materials kit:



Polyethylene cylinder (white)



Acrylic cylinder (clear)



Aluminum cylinder (silver)

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®)

Needed from the equipment kit:

Graduated cylinder, 50 mL

Electronic balance

Pipets

Spoons

Weighing boats

Plastic cups

Wax pencil

Ruler

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.

Reorder Information: A replacement kit for Exploring Density (item number 580300) can be ordered from Carolina Biological Supply Company.

Call: 800-334-5551 to order.

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.

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.
7. 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.
8. 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 for short burst of 10 seconds each. 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.

9. 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. **Note:** In order to obtain the best results, check the volume after letting the solution sit for an extended period of time. Adjust the total volume should this be needed.

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 Data Table 1.
2. Using a ruler, measure the height (h) and diameter (d) of each cylinder in centimeters. Record these measurements in Data Table 1.

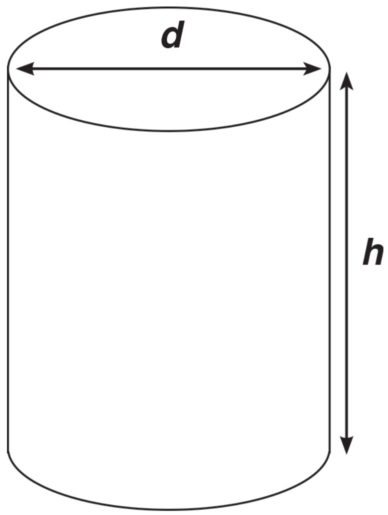


Figure 1.

3. The diameter of a circle is equal to twice its radius ($d = 2r$ or $r = d/2$). Find the radius of each cylinder by dividing the diameter of the circle by 2.
4. Record these dimensions in Data 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 Data Table 1.

Data Table 1: Determining the Densities

Cylinder Type	**Mass** (g)	**Height** (cm)	**Diameter** (cm)	**Radius** (cm)	**Calculated Volume** (cm^3)	**Density** (g/cm^3)
Aluminum (silver)						
Acrylic (clear)						
Polyethylene (white)						

ACTIVITY 2

A Determining the Densities of Solutions

1. Weigh an empty 50-mL graduated cylinder. Record the mass in Data 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 Mass of Solution + Graduated Cylinder in Data Table 2.
4. Add more water until the cylinder contains 10 mL volume. Use the appropriate pipet to adjust the volume.
5. Record the Mass of Solution + Graduated Cylinder in Data 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 Data Table 2.
7. Calculate the corresponding Mass of Solution for each volume of water and record this information in Data Table 2.
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 Data 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 Data 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.

Data Table 2: Density

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			

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Data Table 2: Density (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			

Data Table 3: Density Results

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

A Will It Sink or Float?

1. Based on the calculated densities of the cylinders from Activity 1 and solutions from Activity 2, predict whether each cylinder will float or sink in each of the sucrose solutions and water. Record the predictions in Data 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.

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

3. Record the results in Data Table 4.
4. If the predictions were incorrect, test the aluminum cylinders in other solutions.
5. Repeat steps 1–4 for the acrylic (clear) and polyethylene (white) cylinders.
6. After testing the cylinders, rinse them with fresh water and dry them.

ACTIVITY 4

A 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 Data Table 5.

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Data Table 4: Will It Sink or Float?

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

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.

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.

Table 5: Determination of Sugar in a Beverage

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: ____________________

NOTES

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