

# GOALS & OBJECTIVES

**DENSITY, the DYNAMIC DUO: Mass & Volume** incorporates teaching strategies that are designed to:

- involve students in inquiry and discovery activities



- require students to use analysis skills

- welcome curiosity



- encourage questioning

- reward creativity

- promote clear and effective oral and written communication



- integrate mathematics and science.



# SUNSHINE STATE STANDARDS

## Strand: *The Nature of Matter*

### Standard:

- SC.A.1.2.1. Determines that the properties of materials (e.g., density and volume) can be compared and measured (e.g., using rulers, balances, and thermometers).
- SC.A.1.3.1. Identifies various ways in which substances differ (e.g., mass, volume, shape, density, texture, and reaction to temperature and light).
- SC.A.1.3.6. Knows that equal volumes of different substances may have different masses.

## Strand: *The Nature of Science*

Standard: The student uses the scientific processes and habits of mind to solve problems.

- SC.H.1.2.1. Knows that it is important to keep accurate records and descriptions to provide information and clues on causes of discrepancies in repeated experiments.
- SC.H.1.2.2. Knows that a successful method to explore the natural world is to observe and record, and then analyze and communicate the results.
- SC.H.1.2.4. Knows that to compare and contrast observations and results is an essential skill in science.
- SC.H.1.3.4. Knows that accurate record keeping, openness, and replication are essential to maintaining an investigator's credibility with other scientists and society.
- SC.H.1.3.5. Knows that a change in one or more variables may alter the outcome of an investigation.
- SC.H.2.3.1. Recognizes that patterns exist within and across systems.
- SC.H.3.2.2. Knows that data are collected and interpreted in order to explain an event or concept
- SC.H.3.2.4. Knows that through the use of science processes and knowledge, people can solve problems, make decisions, and form new ideas.
- SC.H.1.4.1. Knows that investigations are conducted to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare different theories.

**Strand: Measurement**

**Standard:** The student measures quantities in the real world and uses the measures to solve problems

- MA.B.3.3.1** Solves real-world and mathematical problems involving estimates of measurements including length, time, weight/mass, temperature, money, perimeter, area, and volume, in either customary or metric units.
- MA.B.4.3.1** Selects appropriate units of measurement and determines and applies significant digits in a real-world context. (Significant digits should relate to both instrument precision and to the least precise unit of measurement.)
- MA.B.4.3.2** Selects and uses appropriate instruments, technology, and techniques to measure quantities in order to achieve specified degrees of accuracy in a problem situation.
- MA.B.2.4.2** Solves real-world problems involving rated measures (miles per hour, feet per second).
- MA.B.3.4.1** Solves real-world and mathematical problems involving estimates of measurements, including length, time, weight/mass, temperature, money, perimeter, area, and volume, and estimates the effects of measurement errors on calculations.
- MA.B.4.4.2** Selects and uses appropriate instruments, technology, and techniques to measure quantities in order to achieve specified degrees of accuracy in a problem situation.

**Strand: Algebraic Thinking**

**Standard:** The student uses expressions, equations, inequalities, graphs, and formulas to represent and interpret situations

- MA.D.1.2.1** Describes a wide variety of patterns and relationships through models, such as manipulatives, tables, graphs, rules using algebraic symbols.
- MA.D.1.2.2** Generalizes a pattern, relation, or function to explain how a change in one quantity results in a change in another.
- MA.D.1.3.1** Describes a wide variety of patterns, relationships, and functions through models, such as manipulatives, tables, graphs, expressions, equations, and inequalities.
- MA.D.1.3.2** Creates and interprets tables, graphs, equations, and verbal descriptions to explain cause-and-effect relationships.
- MA.D.2.3.1** Represents and solves real-world problems graphically, with algebraic expressions, equations, and inequalities.

**MA.D.1.4.1** Describes, analyzes, and generalizes relationships, patterns, and functions using words, symbols, variables, tables, and graphs.

**Strand: Data Analysis and Probability**

**Standard:** The student understands and uses the tools of data analysis for managing information.

**MA.E.1.2.1** Solves problems by generating, collecting, organizing, displaying, and analyzing data using histograms, bar graphs, circle graphs, line graphs, pictographs, and charts.

**MA.E.3.2.1** Designs experiments to answer class or personal questions, collects information, and interprets the results using statistics (range, mean, median, and mode) and pictographs, charts, bar graphs, circle graphs, and line graphs.

**MA.E.1.3.1** Collects, organizes, and displays data in a variety of forms, including tables, line graphs, charts, bar graphs, to determine how different ways of presenting data can lead to different interpretations.

**MA.E.2.3.1** Compares experimental results with mathematical expectations of probabilities.

**MA.E.3.3.1** Formulates hypotheses, designs experiments, collects and interprets data, and evaluates hypotheses by making inferences and drawing conclusions based on statistics (range, mean, median, and mode) and tables, graphs, and charts.

**MA.E.1.4.1** Interprets data that has been collected, organized, and displayed in charts, tables, and plots.

**MA.E.1.4.3** Analyzes real-world data and makes predictions of larger populations by applying formulas to calculate measures of central tendency and dispersion using the sample population data, and using appropriate technology, including calculators and computers.

**MA.E.3.4.1** Designs and performs real-world statistical experiments that involve more than one variable, then analyzes results and reports findings.

# BACKGROUND INFORMATION

An ancient story tells about a Greek king, a gold crown... and an amazing scientist named Archimedes. The king had ordered a solid golden crown made. When the court goldsmiths presented it to him, he asked Archimedes to test it...to make sure it was pure gold.



One night, while filling his tub, for a bath, Archimedes accidentally filled it to the very top. As he stepped into it, water spilled out over the top. The idea struck him, that if he collected the water, and measured it, he would know the volume of his body. HE COULD USE THIS TO MEASURE THE CROWN! In other words, the amount of displaced water in the bathtub was the same amount as the volume of his body.



Archimedes was able to obtain the volume of the crown and an equal volume of pure gold, from the King's treasury no doubt. When he placed the two items into separate pans on a two-pan balance..... Well I guess you can figure out the answer if I tell you that the goldsmith was put into jail!

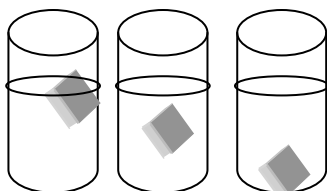


Density is a basic physical property of any sample of matter. It is much more important than other physical properties such as size or shape in that the numerical value of density for a pure substance at a particular temperature and pressure is a constant, and never changes! The density may be determined in the laboratory if the mass and volume of a sample can be determined. Density may be calculated by dividing the mass by the volume ( $d = m / V$ ). It also may be thought of as the ratio of the mass to the volume. The density of water is important to know. It is 1.0 g/mL at 4°C.

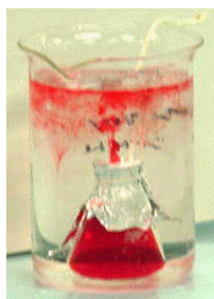


In these experiments, the student will explore the mass and volume of several materials. All three states of matter will be investigated. They will then use their data to explore the relationship between the mass and volume of the materials and calculate their density.

## ACTIVITES THAT MAKE YOU HMMMMMMMM



Underwater Volcano



1. Observing equal volumes.
2. Regular Soda vs. Diet Soda
  - Students will observe that a can of diet soda floats in water, while a can of regular soda sinks
3. Potato Float
  - Students observe that pieces of potato placed into three different beakers of (supposedly the same) liquid will float on the top in one, sink to the bottom in the second, and be suspended mid-way in the liquid in the third
4. Ice floating or is it sinking?
  - Place an ice cube into each of two beakers filled with a clear colorless liquid (supposedly the same).
  - Ice cube floats in one, and sinks in the other
4. Underwater Volcano
  - Hot water rises in a beaker of cold water
5. Density Column
  - A colorful column of different liquids and solids suspended in the liquids is displayed
6. Galileo Thermometer
7. Dancing Raisins
  - Place raisins in water and then in club soda
  - Watch them dance in club soda
8. Floating bubbles
  - Blow bubbles into an aquarium filled with carbon dioxide gas, watch the bubbles float
  - Blow bubbles into the 'air', watch bubbles sink

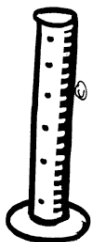
## MASS, VOLUME, DENSITY (SHS)



- Students, measure the mass and volume of several unknown materials. They then use their data to explore the relationship between the mass and volume of the materials and calculate their density.
- Metal Cylinders of the same substance are use.
- The Mass vs. Volume of several cylinders is graphed.
- Students discover that density is a "derived" quantity, not one that is actually measured.

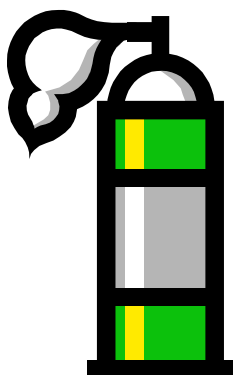
- The slope of the line, which is a ratio, is the density of the metal cylinders.

### MASS, VOLUME, DENSITY (MS)



- Students are shown three different colored solutions.
- They are asked to suggest a way to compare the masses of the three liquids.
- Students are guided towards the realization that in order to compare the masses, equal volumes would have to be massed.
- Using an electronic balance equal volumes of all three liquids are measured and the corresponding mass of each volume is recorded.
- Students discover the concept of density by learning first hand that equal volumes of substances may have different masses.

### FEUDING FOAMS



- Students will have the opportunity to observe, measure, and analyze the density of aerosol shaving creams and foams generated from shampoo and dishwashing liquids or detergents.
- Students will devise a means to determine the mass and volume of 3 different brands of shaving cream.
- The density will be calculated after the measurements are taken.
- An economical analysis can be made by testing several different brands of dishwashing liquids or shampoos at a constant volume.
- Calculate the densities of each product and then calculate the cost/volume (milliliters) as to price of product.

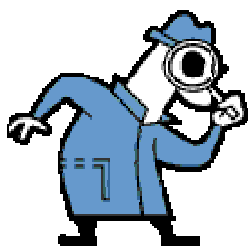


### DASTARDLY DENSITY (from Science and Children, an NSTA publication)

- Three bungling would-be burglars named Agar, Bubba, and Curly decided to relieve a wealthy socialite, Mrs.

Rollinginit, of her most valuable possession, a diamond necklace.

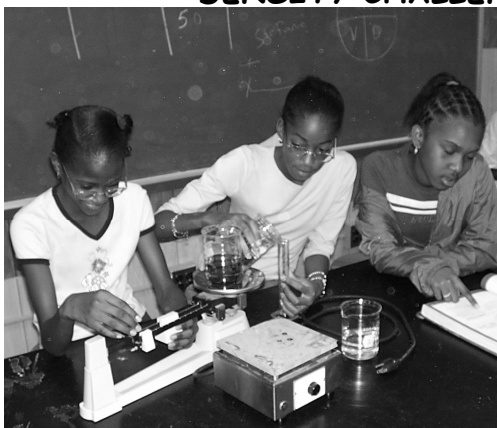
- After a brief stakeout, the trio entered her home while she was out.
- Unknowingly, of course, they tripped a silent alarm upon entry.
- The three located and unlocked the safe, from which they carefully removed a tall, clear canister containing three layers of colorless liquid.
- Peering downward into the vessel, they saw the exquisite necklace sparkling on the bottom.
- The leader of the trio designated the others to reach down and snatch the necklace from its liquid bondage.
- It is now up to the police to determine which thief had actually snatched the necklace from the bottom of the canister.
- Students must discover the "order" of the three liquids in the canister to 'catch' the thief...Of course discovering the densities of the liquids is the key to the solution (no pun intended).



### LIGHTER THAN AIR?

- Determination of the density of various gases including: air, carbon dioxide, helium, and possibly butane and hydrogen.
- Examining the density of warm air and cold air using balloons

### DENSITY CHALLENGE



- Will construct a density column with a minimum of 10 different layers.
- May be used as an alternate assessment.

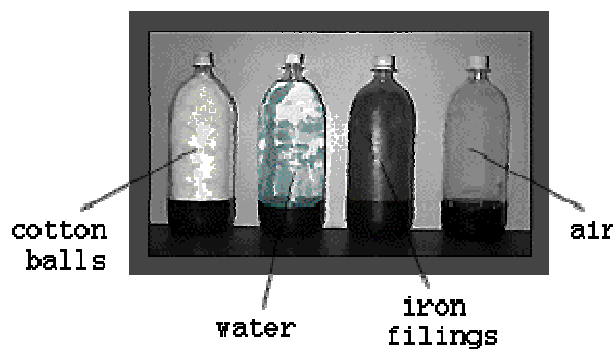


# Equal Volumes; Different Masses



## Density

This is a nice way to introduce density, mass and volume. -Nancy



Q: What is the same?

the kind of bottles, the space the stuff in the bottles takes up (volume), size, shape, etc.

Q: What is different?

the stuff inside the bottles, the weight (mass) of each bottle, color, etc.

To find more helpful tidbits from teachers for understanding scientific concepts, see the [Science Props cluster](#).



*that makes me think* →

What other materials could you fill the bottles with? Is a bottle of diet soda more or less dense than regular soda - how could you find out? Why do they call it a root beer float?

[Science Learning Network](#) / ©1995 Science Museum of Minnesota

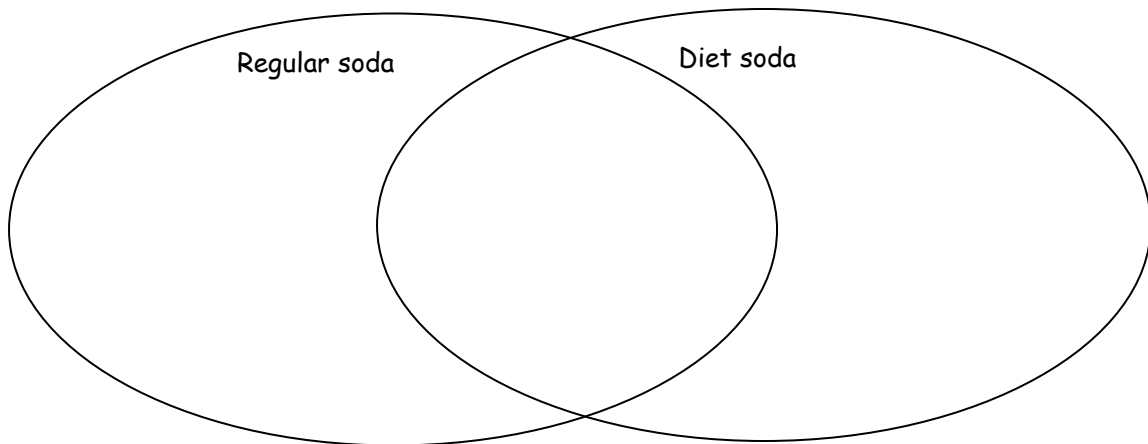
# Equal Volumes; Different Masses: Diet v.s. Regular Soda

## MATERIALS:

- 1 can of diet soda
- 1 can of regular soda, same type as diet, i.e. both same brands of cola
- 1 glass aquarium (or 2 2L beakers)
- water

## PROCEDURE:

1. Fill the aquarium  $\frac{3}{4}$  full of water.
2. Show students both cans of soda.
3. Have students predict what will happen to each can as it is placed into the aquarium water.
4. Place the can of regular soda into the aquarium. (make sure not to trap any air under the bottom depression)
  - Can should sink
5. Have students revisit their predictions, do they want to change or modify them?
6. Place the can of diet soda into the aquarium. (make sure not to trap any air under the bottom depression)
  - Can should float.
7. How can students account for the difference?
  - This should lead into a discussion of density.
    - How are the cans of soda alike; how are they different?



- Allow students to investigate the cans to complete Venn diagram.
- Students should come to the conclusion that the regular soda contains sugar, while the diet soda has an artificial sweetener. It takes a lot more sugar to sweeten the soda than artificial sugar. The regular soda has a greater mass.
- It is a very visual demonstration to place each can of soda on the arm of a two pan balance, and then add sugar to the diet side until the two sides balance.



## Density of Soda - Pepsi vs. Diet Pepsi

### Part 1 - Data Collection

#### Introduction

In this lab we will be measuring density in a variety of ways through a comparison of Pepsi and Diet Pepsi.

#### Part A:

- 1) Work in pairs. Each person should have a copy of the data.
- 2) Put approximately 30ml of regular Pepsi in a 50 ml beaker.
- 3) You will be collecting data on the density of Pepsi by measuring several volumes and masses of those volumes.
- 4) Set up a table with two columns: Volume of Soda, Mass of cylinders and Soda.
- 5) Place two 10 ml graduated cylinders on a scale and measure their mass. Leave them both on the scale.
- 6) Using an eye dropper, add about 2ml of soda to one of the cylinders. Do not spend a lot of time trying to add exactly 2 ml. The important part of this is to precisely read the volume of the soda you actually added.

- 7) Then record your volume and mass.
- 8) Repeat steps 5 and 6, adding about 2ml each time. Until you have 20 ml of soda in your graduates. Be careful not to put more than 10ml in one of the cylinders.
- 9) Repeat this entire process for Diet Pepsi.
- 10) Clean all glassware and eyedroppers.

Part B:

- 1) Record the volume of a Pepsi can. This is printed directly on the can.
- 2) Record the mass of an empty Pepsi can.
- 3) Record the mass of a full Pepsi can.
- 4) Repeat this process for a can of Diet Pepsi
- 5) Calculate the density of Pepsi and Diet Pepsi. Remember to use only the mass of the liquid in your calculation of density.

Part C:

Record your observations of the cans of Pepsi and Diet Pepsi in the bucket of water.

## Part 2 - Problems and Questions

Problems:

- 1) Determine the density of soda from the full can of regular Pepsi. Show work.
- 2) Determine the density of soda from the full can of Diet Pepsi. Show work.
- 3) Construct a separate graph for each set of data: regular and Diet Pepsi.
- 4) Calculate the density by finding the slope of the line on the graph of the regular Pepsi data. Show work.
- 5) Calculate the density by finding the slope of the line on the graph of the Diet Pepsi data. Show work.

Questions:

- 1) The density of pure water is  $1.00 \text{ g/cm}^3$ . Use this information to explain what you saw in Part C of the lab. In your explanation, refer to your calculated densities for regular and diet Pepsi from the problem section of this sheet.
- 2) Compare the densities of soda you determined with the graph and slope method to the full can method. Which method do you think is more accurate? Explain why.

Extension:

Determine if a relationship exists between density and sugar content.

# Potato Float

<http://www.reachoutmichigan.org/funexperiments/agesubject/lessons/whelmer/potato.html>

## Whelmer #49: Potato Float

### Description:

A slice of potato mysteriously floats in the exact center of a glass of water.

### Science process skills:

observation  
space/time relations  
prediction

### Complex reasoning strategies:

comparison  
induction

### Standards:

*K-4:*

Use appropriate tools and techniques to gather, analyze, and interpret data (Standard A.1.3).

Use data to construct a reasonable explanation (Standard A.1.4).

Objects have many observable properties (Standard B.1.1).

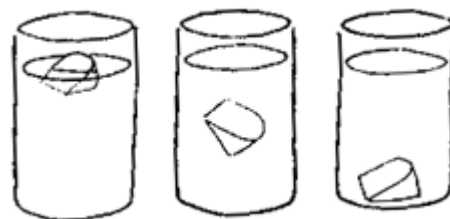
*5-8:*

A substance has characteristic properties, such as density, which are independent of the amount of the sample (Standard B.1.1).

*9-12:*

No standard.

*Above Standards from the National Science Education Standards.*



### Content topics:

solubility  
density

### You will need:

three tall beakers or glass tumblers  
water  
sugar

spoon  
knife  
potato

**Instructions:**

Cut several 1" wedges from the potato. Try to cut the pieces to the same size. This is a density activity. Students might be misled if they see that the pieces are not all the same size.

Make a strong sugar solution by dissolving sugar in water. Dissolve sugar until a piece of potato will float in the solution. If the solution appears cloudy, allow it to stand for a few minutes until it clears.

Fill one glass with the clear sugar solution. Fill a second glass with pure water. Fill the third glass half full of sugar solution. Very carefully and very slowly pour pure water on top of the sugar solution in the second glass. Pour the water down the side of the glass or use a spoon or glass rod to direct the stream against the side of the glass. If you are careful and avoid too much mixing, the less dense water will "float" on the sugar water. The sugar water should be clear enough to prevent any indication that the second glass is filled with anything but water.

Make certain that all three glasses are filled to the same level. Carefully place a wedge of potato in each glass. The potato floats at the top of the liquid in the first glass. The potato sinks to the bottom of the second glass, and it sinks to the middle of the third glass.

**Presentation:**

Before your presentation, fill the three glasses with the proper solutions. Do not allow students to see how you made the sugar solution, or how you created the layered solution in the third glass.

Place a piece of potato in the first glass. The piece of potato floats. Ask students which is more dense; the potato or the liquid? (the liquid)

Place a piece of potato in the second glass. The piece of potato sinks to the bottom. Ask students which is denser, the potato or the liquid? (the potato)

Inform students how you made the solutions in the first two glasses. (The first is sugar-water, the second is pure water.)

Place a piece of potato into the third glass. The potato sinks, stopping at the middle of the glass. Inform them that you used only sugar and water to make the solution in the third glass, but do not tell them how you did it. Ask students to share their thoughts concerning the third glass. How do they think you did it? Challenge them to use sugar and water to create the effect themselves.

**Content:**

The density of water is 1 gram/milliliter. The density of saturated sugar-water (common household sugar) is ~1.83 grams/milliliter. Sugar-water is almost twice as dense as water. Most varieties of potatoes have a density of ~1.6 g/ml.

**Assessment:**

*Type:* class or small group.

*Content/Process:* density.

*Age/Level:* all.

Use [Whelmer #64: Liquid Rainbow](#) as an assessment for this activity. The directions are given following the Whelmer #64 activity.



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## Whelmer #64: Liquid Rainbow

<http://www.reachoutmichigan.org/funexperiments/agesubject/lessons/whelmer/rainbow.html>

### Description:

Students are challenged to layer five liquids of different density in a drinking straw.

### Science process skills:

observation  
classification  
measurement  
space/time relations  
interpreting data

### Complex reasoning strategies:

comparison  
classification  
abstracting  
problem solving

### Standards:

#### *K-4:*

Plan and conduct a simple investigation (Standard A.1.2).

Employ simple equipment and tools to gather data and extend the senses (Standard A.1.3).

Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances (Standard B.1.1).

#### *5-8:*

Design and conduct a scientific investigation (Standard A.1.2).

A substance has characteristic properties, such as density, all of which are independent of the amount of the sample (Standard B.1.1).

#### *9-12:*

Design and conduct scientific investigations (Standard A.1.2).

The physical properties of compounds reflect the nature of the interactions among its molecules (Standard B.2.4).

*Above Standards from the National Science Education Standards.*

### Content topics:

density  
solubility





**You will need:**

five pitchers, milk jugs, or other large containers  
food coloring; 4 colors  
transparent drinking straws  
pickling salt  
6 vials or test tubes for each student or group

**Instructions:**

Prepare five salt solutions, each with a different density. Use the following recipe:  
Pitcher #1: 1 gallon water + 0 cups of salt + bottle of yellow coloring.  
Pitcher #2: 1 gallon water + 1/2 cups of salt + bottle of green coloring.  
Pitcher #3: 1 gallon water + 1 cups of salt + no coloring (clear).  
Pitcher #4: 1 gallon water + 1 1/2 cups of salt + bottle of red food coloring.  
Pitcher #5: 1 gallon water + 2 cups of salt + bottle of blue food coloring.

Mix the solutions thoroughly, until all salt is dissolved. The solutions must be heavily colored. Use the entire contents of one of the small bottles usually sold in sets of four at the grocery store. Pickling salt is preferred for this activity because it does not have any additives and will not make cloudy solutions. Clear or translucent drinking straws must be used so that the colors of the different solutions can be observed when in the straw.

Each student or group of students will need six small vials or test tubes; five to hold the solutions and one to be used as a waste container.

**Presentation:**

Do not allow students to see how much salt is in the solutions. Do not place the five pitchers in order, or in any other manner divulge the relative density of the solutions.

Distribute a sample of each of the five solutions to students. Allow them to practice placing a finger over the end of a straw and "picking up" a sample of a solution.

Direct them to select two of the solutions at random. Draw a small portion of the first solution into the straw. While holding the solution in the straw, lower the end of the straw into the second liquid. Draw a sample of the second solution into the straw. If the first solution floats on the second, the first is less dense. If the

first mixes or falls through the second; the first is more dense.

By making comparisons of all five liquids and making record of each trial, student will establish an order of density for the five liquids. As a extension, challenge students to get all five solutions layered in the straw.

**Content:**

Analytical thinking is a skill which is important to all scientists. While developing their own scheme to order the densities of the five solutions, students will experience analytical thinking; perhaps, without realizing it.

Students will also develop their own technique for drawing a small sample of the solutions into the straw (holding their thumb over the end of the straw, using it as a air valve). They will be challenged to determine a technique to get all five solutions in the straw. They will learn to lower the straw progressively lower into each solution.

**Assessment:**

*Type:* small group.

*Content/Process:* density.

*Age/Level:* all.

This Whelmer is an assessment for [Whelmer #49: Potato Float](#). Follow the directions for the activity. Assess students on their accurate assessment of the relative densities of the solutions. Challenge students to create a patriotic column...red, white, and blue...or one that shows their school colors.

Notes:

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# Ice Floating or is it Sinking?



University of Virginia  
Physics Department

<http://galileo.phys.virginia.edu/education/outreach/8thgradesol/InvestigatDensityFrm.htm>

## *Investigating Density*

A Physical Science Activity

### **Objectives**

Students will:

- use the following skills: measuring, recording data, interpreting data, graphing, and interpreting graphs;
- understand the relationship between mass and volume for a substance;

### **Motivation for Learning**

- Discrepant Event

### **Materials**

Two 500 mL beakers

Two ice cubes (you will need extras)

200 mL of alcohol, isopropyl

200 mL of water

Plastic wrap

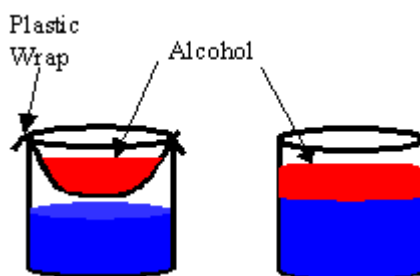
1000 mL beaker

### **Procedure**

1. Show the students a beaker of water and a beaker of alcohol, both filled to the same level. Ask them to make detailed observations of the two beakers and solicit their input on similarities and differences between them. Tell them that they are not allowed to smell or touch the liquids, only look.
2. After observations have been made, show them two ice cubes. Ask for predictions on what will happen if one ice cube is dropped into each beaker.
3. Drop the ice cubes into each beaker, so that the students can observe one float and the other sink. Ask the students if they can explain why the ice floats in one beaker and not the other.
4. Remind the students that they have been actively engaged in the first step of the scientific method, observation, and that they are now ready to hypothesize. If someone argues that the ice cubes are different, you can take

each cube out and put it in the opposite beaker. Someone, sooner or later, will guess that the beakers contain different liquids.

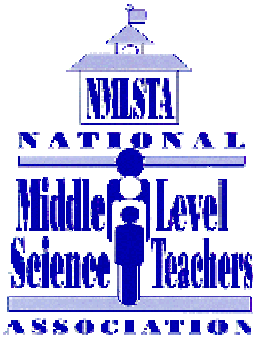
5. Now you can allow them to smell the two beakers. But the question still remains, why did the ice sink in one beaker and not the other?
6. This would be a good time to point out that in the scientific process answering one question often leads to another. Once the discussion has come around to a density or weight difference in the liquid, you can extend your demonstration:
7. Add food coloring to the water and pour it into the larger beaker.
8. Drape a piece of plastic wrap on top of the water inside the beaker so that it looks like a loose fitting cover.
9. Add a different food coloring to the alcohol in the other beaker and gently pour it onto the plastic wrap in the large beaker.
10. Very gently remove the plastic wrap and the alcohol will sit on top of the water.
11. You can drop an ice cube into the mixture again and watch where it floats.



### Background Information

Density is a measure of how much mass per unit volume a certain substance or object has ( $d = m/V$ ). This property is an **intrinsic** property to each particular substance. This means that it is a property of the substance and depends on the type of material as opposed to the amount. **Extrinsic** properties depend on the amount of the material. Some examples of other intrinsic properties include color, melting point, freezing point, and boiling point. Extrinsic properties include volume, mass, and temperature. This activity will help students differentiate between extrinsic properties such as volume or mass alone and intrinsic ones such as density. Because density is intrinsic, as you add more and more of a substance to the sample, the density does not change. The volume and the mass both change as you add more to a sample.

# Convection Currents & DENSITY



*The Level Line*

<http://www.nmlsta.org/coloredwater.htm>

National Middle Level Science Teachers' Association

This article was originally published in the *Level Line*, the NMLSTA newsletter.

## Colored Water Demo by Chris Herald, Manhattan, KS

This demonstration involving colored water has appeared before in *Level Line* but it will be repeated because of an inquiry-based science idea.

Materials: 4 quart canning jars, labeled #1-4, hot and cold water, blue food coloring, index cards, plastic trays or tubs, and paper towels for cleanup (as necessary)



Fill quart canning jars #1 and #3 to the brim with HOT water. Fill jars #2 and #4 with COLD water. Add blue food coloring to jars #1 and #2. Add yellow coloring to jars #3 and #4. Using an index card over the mouth of the jar #2, invert it over jar #3. In the same way, invert jar #1 on top of #4. Have the class predict what will happen when you pull the cards out. Have them write their predictions on paper. Pull the cards out and observe the colored water. This demonstration shows convection currents and density. Hot water is less dense than cold water.

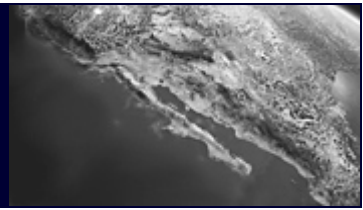
As an extension to this demonstration, one could also use a jar of colored salt water at a room temperature and a jar of tap water at the same temperature. Place the salt water on the top, since it is more dense, so that students can see it

disperse in the tap water. Again, make the students predict before they observe the demonstration.

Editorial Comment: After you do these demonstrations, ask the question, "Will an ice cube melt faster in salt water or tap water?" Let your students hypothesize about this problem. They may have several ideas and explanations. Let them experiment and see what happens. Using uniform sized and COLORED ice cubes is essential. Using salsa cups with lids for stacking in the freezer is one possibility. This experiment was conducted by high school students and written in *the Journal of Chemical Education*, September 1999 by Annis Hapkiezicz, entitled "Authentic Research within the Grasp of High School Students". Middle school students will not get so involved as high school students but they can have a lot of fun with this kind of inquiry-based science. Do you know the answer? Find out with the aid of your students.

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March 7, 2002



<http://www.oceanoasis.org/teachersguide/activity4.html>

## Activity 4

### Convection Currents

#### What causes fluids to circulate?

**In the Film** Convection currents are identified in Earth's mantle. Heated mantle material is shown rising from deep inside the mantle, while cooler mantle material sinks, creating a convection current. It is thought that this type of current is responsible for the movements of the plates of Earth's crust.

In the ocean, warm water is normally found near the surface while the deeper water is usually cold. Deep, cold-water currents play an important role in creating the ocean oasis of the film.

**Concept** Convection currents play a role in the circulation of fluids.

**Objective** To observe convection as a result of differential heating

**Content** Science, language arts

**Background** Convection currents are the result of differential heating. Lighter (less dense), warm material rises while heavier (more dense) cool material sinks. It is this movement that creates circulation patterns known as convection currents in the atmosphere, in water, and in the mantle of Earth.

In the atmosphere, as air warms it rises, allowing cooler air to flow in underneath. Along with the turning of the Earth, this movement of air creates winds. Winds, in turn, create surface waves on the ocean.

Convection also plays a role in the movement of deep ocean waters

and contributes to oceanic currents.

Inside Earth, the convection of mantle material is thought to cause the movement of the overriding crustal plates, resulting in events such as earthquakes and volcanic eruptions.

## Materials

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### Part A Density and Convection

Per student or pair of students: three 8 oz. clear plastic cups, 2 medicine droppers, blue and red food color, small containers for ice water and hot water, ice, hot water, room-temperature water

### Part B Convection Current Class Demonstration

Small aquarium, water immersion heater, blue ice cubes, red food color, medicine dropper, small paper cup, tape

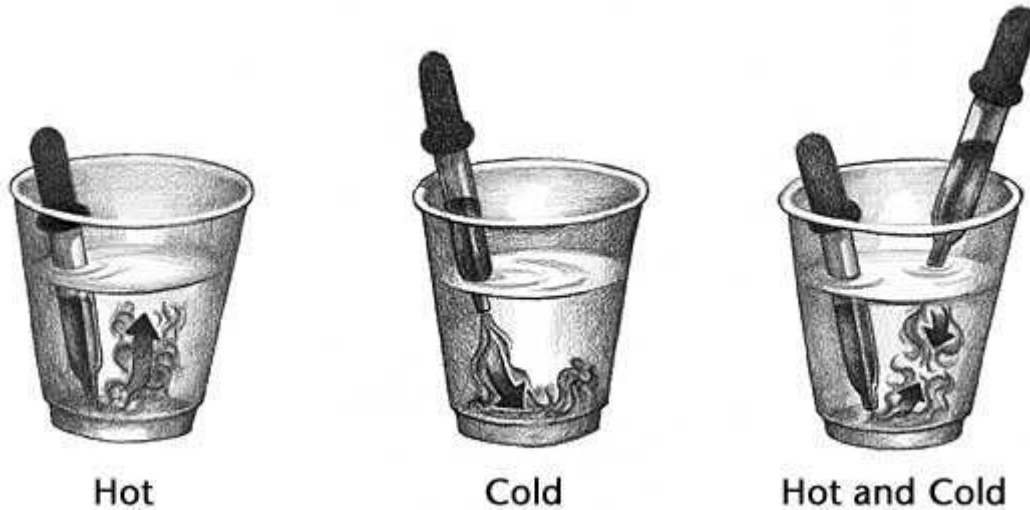
## Procedure

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### Part A Density and Convection (*small groups*)

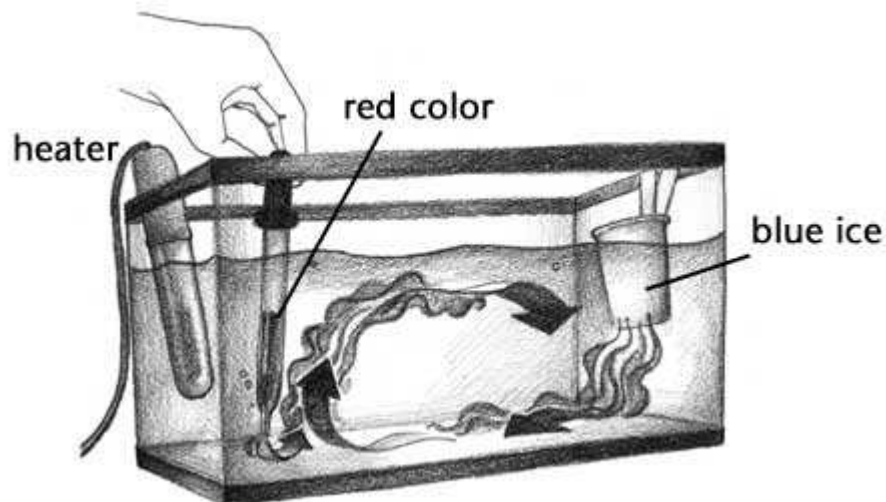
- Discuss or review the concept of density relative to temperature.
- Fill each plastic cup with 6 ounces (200 ml) of water. Allow the water to stand about 5 minutes.
- Fill a small container with very cold water. Add a drop of blue food color.
- Fill another small container with hot water. Add a drop of red food color.
- Use a medicine dropper to release a drop of hot, red water at the bottom of one cup. Observe and record the results. Repeat, releasing the water on the surface. Record the results.
- In the second cup, repeat the process using the cold, blue water. Observe and record the results. What can you determine about warm water? Cold water? Which is more dense?
- In the third cup, simultaneously release hot, red water on the bottom and cold, blue water at the surface. Observe and record the results.





**Part B Convection Current Class Demonstration** (*small groups*)

- Set up the equipment according to the diagram below.
- Poke a few small holes in the paper cup.
- Put the blue ice cubes in the paper cup.
- Tape the cup to the side of the aquarium.
- Turn the heater on.
- Release a few drops of red color at the bottom of the aquarium near the heat.
- Observe by looking through the side of the aquarium. Which is heavier, cold or warm water?
- Record your observations.



### **Local Connection**

Observe local wind patterns. Where is the air warm? Where is the air cold? Which direction does the wind usually blow? Do you live near the ocean or other large body of water? If so, find out about local currents. Do you ever swim or wade in a stream or river? Is the water colder at the surface or near the bottom?

### **Key Words**

convection current



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# A DENSITY COLUMN

<http://www.terrificscience.org/lessonexchange/genchemPDF/LayeringLiquids.pdf>

## Take-Home Challenge

### Layering Liquids

You probably already know that a cork floats in water because it is less dense than water. You can use this principle to make a density column and to determine the relative densities of different objects.

#### Materials

- clear glass bud vase or other slender glass container
- tablespoon measure
- liquids:
  - vegetable oil
  - dark Karo® syrup
  - rubbing alcohol
  - Dawn® or other dishwashing liquid
  - water (addition of 1 or 2 drops of food coloring is optional)
- solids (as many as possible; must be small enough to fit in bud vase or other slender glass container):
  - ball bearing or BB
  - plastic bead
  - rubber stopper
  - cork
  - super ball
  - pine chip (part of a craft stick works)
  - any other solids you wish to test

#### Exploration

Step 1 Place two tablespoons of one of the liquids listed above in the glass bud vase. Then add two tablespoons of one of the other liquids. What happens? How can you tell which one has the greater density?

Step 2 Repeat this experiment several times using different liquids from the list. The densities of the liquids are: 0.87 g/mL, 0.91 g/mL, 1.00 g/mL, 1.26 g/mL, and 1.37 g/mL. Try to match up each density with its respective liquid based upon your results.

Step 3 Now that you know the densities of each of the liquids, slowly pour two tablespoons of each of the liquids into the glass bud vase in order of decreasing density (the highest density liquid on the bottom) to create a density column. How does your density column look?

Step 4 Drop each of the solids into the density column that you created in Step 3. What happens to each of the objects? Explain what the position of each object in the density column means. Can you tell what the density of each object is? Try other objects if you wish.

### **Challenge**

What are the relative densities of various common liquids and solids?

### **Instructor Notes**

22-2

Layering Liquids

### **Concept**

relative density

Expected Student Responses to Exploration

Step 1 (a) Either the second liquid will float on top and there will be little or no mixing; or the second liquid will sink to the bottom, perhaps mixing some with the first as it passes through.

(b) Whichever has the greater density will be on the bottom.

Step 2 Liquid Density (g/mL)

- rubbing alcohol 0.87
- vegetable oil 0.91
- water 1.00
- Dawn 1.26
- Karo syrup 1.37

Step 3 The liquids form layers in the order in which they are placed in the bud vase, with relatively little mixing between them.

Step 4 (a) An object either floats on top of one of the liquid layers or sinks to the bottom.

(b) An object is less dense than the liquid it is floating on and more dense than the one it is in.

(c) Solid Location Density(g/mL)\*

- ball bearing or BB on bottom of the bud vase ball bearing or BB >1.37
- plastic bead floating on the Dawn layer 1.26 > plastic bead >1.00
- rubber stopper floating on the Karo syrup layer 1.37 > rubber stopper >1.26

- cork floating on the alcohol layer 0.87 > cork
- super ball floating on the water layer 1.00 > super ball > 0.91
- pine chip floating on the vegetable oil layer 0.91 > pine chip > 0.87

\*Relative densities may vary slightly depending on specific item used.

### **Expected Student Answer to Challenge**

ball bearing or BB > Karo > rubber stopper > Dawn > plastic bead > water > super ball  
> vegetable oil > pine chip > rubbing alcohol > cork

### Reference

"Household Density Column"; *Fun with Chemistry: A Guidebook of K-12 Activities*, 2nd ed.; Sarquis, M., Sarquis, J., Eds.; Institute for Chemical Education: Madison, WI, 1995; Vol. 1, pp. 115-118.

### Acknowledgment

This activity was developed as a part of the NSF-funded "General Chemistry: Discovery-Based Advances for the Two-Year College Chemistry Curriculum" project, grant #DUE-9354378. Permission to use for educational purposes.

# How a Galileo Thermometer Works!

<http://www.howstuffworks.com/question663.htm>

Based on a thermoscope invented by *Galileo Galilei* in the early 1600s, the thermometer on your co-worker's desk is called a *Galileo thermometer*. A simple, fairly accurate thermometer, today it is mostly used as decoration. The *Galileo thermometer* consists of a sealed glass tube that is filled with water and several floating bubbles. The bubbles are glass spheres filled with a colored liquid mixture. This liquid mixture may contain alcohol, or it might simply be water with food coloring.

Attached to each bubble is a little metal tag that indicates a temperature. A number and degree symbol are engraved in the tag. These metal tags are actually calibrated counterweights. The weight of each tag is slightly different from the others. Since the bubbles are all hand-blown glass, they aren't exactly the same size and shape. The bubbles are calibrated by adding a certain amount of fluid to them so that they have the exact same density. So, after the weighted tags are attached to the bubbles, each differs very slightly in density (the ratio of mass to volume) from the other bubbles, and the density of all of them is very close to the density of the surrounding water.

If you have read this question, then you know that an object immersed in a fluid experiences two major forces: the downward pull of gravity and the upward push of buoyancy. It is the downward force of gravity that makes this thermometer work.

The basic idea is that as the temperature of the air outside the thermometer changes, so does the temperature of the water surrounding the bubbles. As the temperature of the water changes, it either expands or contracts, thereby changing its density. So, at any given density, some of the bubbles will float and others will sink. The bubble that sinks the most indicates the approximate current temperature.

*Consider this example:*

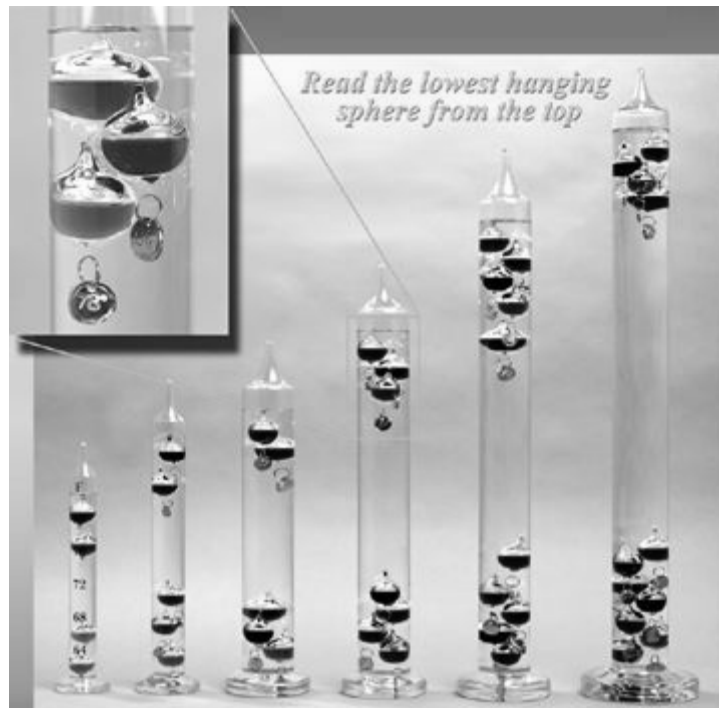
Let's say there are five bubbles in the thermometer:

- A blue bubble that represents 60 degrees
- A yellow bubble that represents 65 degrees
- A green bubble that represents 70 degrees
- A purple bubble that represents 75 degrees
- A red bubble that represents 80 degrees

The blue bubble (60 degrees) is the heaviest (densest) bubble, and each bubble thereafter is slightly lighter, with the red bubble being the lightest. Now, let's say the temperature in the room is 70 degrees. Since the surrounding air is 70 degrees, we know the water inside the thermometer is also about 70 degrees. The blue and yellow bubbles (60 and 65 degrees, respectively) are calibrated so that they have higher densities than the water at this temperature, so they sink.

The purple and red bubbles each have a density that is lower than the surrounding water, so they float at the very top of the thermometer. Since the green bubble is calibrated to represent 70 degrees, the same temperature as the water, it sinks slightly so that it is floating just below the purple and red bubbles - thereby indicating the room's temperature!

<http://science.howstuffworks.com/framed.htm?parent=question663.htm&url=http://www.galileoshop.com/>



# Dancing Raisins

Do you remember the dancing chorus line of raisins? Well now you can have your very own dancing raisins!

## Materials:

6 or more raisins  
unopened bottle of club soda  
tall glass

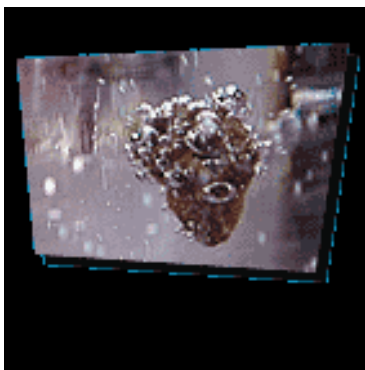


## Procedure:

1. Open a bottle of club soda; it must have lots of bubbles to work!
2. Fill a tall glass almost to the top with the soda.
3. Add 6 raisins to the glass of soda.
4. Watch carefully. What do you observe happening to the raisins?
5. Try and explain what you see.

## Explanation:

The raisins in this experiment sink quickly when the density is greater than the density of the water. The soda in the glass contains carbon dioxide gas ( $CO_2$ ). The  $CO_2$  gas bubbles attach themselves to the raisins, which help make them less dense than water. The raisins are able to float at the surface carried by the carbon dioxide bubbles. After a few seconds, the bubbles break, and the raisins fall back to the bottom. The process repeats itself over and over. These carbon dioxide bubbles are like the water wings you or your little brother or sister wears when you need help swimming. They help you float, just like the carbon dioxide bubbles help the raisins to float. When the bubbles burst at the top, it's like the raisins took off their wings and sunk back down to the bottom.





# Bubbles that Sink



Connecting with Chemistry

Spring/Summer 1998

Incorporating the ICE cycle and Project SERAPHIM News

<http://ice.chem.wisc.edu/CwCsummer98/ideasclass.html>

Ideas for Your Classroom: Aquarium Density1, 2

By Richard Heyard

## Concept

To learn about the physical properties of density.

## Materials

\_\_\_aquarium

\_\_\_matches

\_\_\_baking soda

\_\_\_vinegar

\_\_\_soap bubble solution

\_\_\_4 candles of increasing length

\_\_\_4 jar lids/petri dishes (to be used as candle holders)

\_\_\_4 petri dishes (to hold the baking soda)

\_\_\_4 beakers (for the vinegar)

## Safety and Disposal

Wear safety goggles to protect your eyes. When you are finished with the demonstration, the reaction can be disposed of down the drain.

## Demonstration

1. This step should be completed prior to the start of class. Melt some of the wax from one of the candles. Affix each candle to a candle holder: place a few drops of hot wax onto the holder; place the candle on the hot wax; and let the wax cool. This will help prevent the candle from tipping over.
2. Place the materials in front of the class.
3. Pick four student volunteers. Have each student fill one of the petri dishes with baking soda. Next, they should place the dishes into the aquarium. Make sure a dish is in each corner.
4. Next place the candles in the aquarium, in order of increasing height. Light each candle. Hint: start with the shortest candle and work your

- way up. Otherwise, you might burn yourself. Ouch!
5. Have each student pour vinegar into 1 petri dish containing baking soda. Note: the more baking soda and vinegar, the better! Ask your students for observations.
  6. Once the candles have gone out, blow soap bubbles into the aquarium.
  7. It may take you some practice to acquire this technique. Again, ask your students for observations.

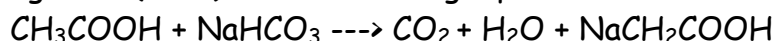
### Questions and Answers

Q. What are the requirements for an object to burn?

A. Oxygen, fuel, and an activation energy source (e.g., spark)

Q. What kind of reaction occurred in the aquarium? How?

A. An acid-base neutralization reaction. The vinegar (acid) reacts with the baking soda (base) in the following equation:



Q. What caused the candles to go out?

A. Carbon dioxide is denser than air. Thus it stays near the bottom of the aquarium, at least for a period of time. Therefore, oxygen is unavailable for the burning process, causing the candle flames to extinguish. The candles should have gone out in order of increasing length. This is because as more carbon dioxide is produced, the "surface" of  $\text{CO}_2$  rises in the aquarium.

Q. Why do the soap bubbles float?

A. The carbon dioxide is denser than the air in the bubble. Therefore, the bubble floats on the carbon dioxide.

### References

1. Idea learned during the 1994 South Dakota Joint Math and Science Consortium.
2. Sarquis, A. M.; Sarquis, J. L. Fun with Chemistry, Vol. 1, 2nd ed.; Activity 5; Institute for Chemical Education: Univ. of Wisconsin, Madison, WI, 1995.
3. "Floating Soap Bubbles"; Hands-On Activities; Institute for Chemical Education: Univ. of Wisconsin, Madison, WI, 1995.

# Determining Density

## MASS, VOLUME, DENSITY

**BACKGROUND:** An ancient story tells about a Greek king, a gold crown... and an amazing scientist named Archimedes. The king had ordered a solid golden crown made. When the court goldsmiths presented it to him, he asked Archimedes to test it...to make sure it was pure gold.

Archimedes knew that pure gold was very soft. He could bite a piece of it, and his teeth would leave a dent in it. (But he also knew that the king would be mad if he returned a dented crown. He couldn't use THAT test.) Archimedes also knew that if he took equal volumes of gold and water, the gold would weigh 23 times more than the water. This was a test he COULD use. (The problem was...measuring the volume of the crown... an irregular object)

One night, while filling his tub, for a bath, Archimedes accidentally filled it to the very top. As he stepped into it, water spilled out over the top. The idea struck him, that if he collected the water, and measured it, he would know the volume of his body. HE COULD USE THIS TO MEASURE THE CROWN! In other words, the amount of **displaced** water in the bathtub was the same amount as the volume of his body.

Archimedes was so excited, that he jumped out of the tub. He ran outside, and down the street, yelling "Eureka! Eureka! (one of the few Greek words I know!) I found the answer!" All this was fine, except...in his excitement, Archimedes had forgotten to put his clothes on. He was running down the street, naked!

Archimedes was able to obtain the volume of the crown and an equal volume of pure gold, from the King's treasury no doubt. When he placed the two items into separate pans on a two-pan balance..... Well I guess you can figure out the answer if I tell you that the goldsmith was beheaded!

The density is a fundamental physical characteristic of any sample of matter. It is considerably more important than other physical properties such as size or shape (incidental physical properties that may be of no help in identification) in that the numerical value of density for a pure substance at a particular temperature is a constant (never changes). The density may be readily and reproducibly determined in the laboratory if the mass and volume of a sample can be determined. Density ( $d = m / v$ ) may be calculated by dividing the mass by the volume.

In this experiment, you will measure the mass and volume of several unknown materials. You will then use your data to explore the relationship between the mass and volume of the materials and calculate their density.

### **MATERIALS (PER PAIR)**

Safety goggles  
1 ruler  
graph paper

centigram balance  
metal samples  
isopropyl alcohol

1 25mL graduated cylinder  
paper towels

### **PROCEDURE**

As you perform the experiment record your data in Data Tables 1, 2, 3

1. Wear safety goggles

#### LIQUID SAMPLES DETERMINATION

2. Determine the mass of a clear, dry 25 mL graduated cylinder to the nearest 0.01 grams, using a centigram balance. Record the mass as 'graduated cylinder alone' in Data Table 1.
3. Fill the graduated cylinder to a volume between 15 and 20 mL. Record the volume in Data Table 1  
NOTE: the volumes should be recorded to the nearest 0.5 mL (for example 10.0, not 10)
4. Place the graduated cylinder + alcohol onto the balance, and record the mass as 'graduated cylinder + alcohol' in Data Table 1
5. Repeat steps 2-4 for another volume of alcohol.
6. You can use the same mass as that determined in #2 as long as you are using the same graduated cylinder.

**METAL SAMPLES DETERMINATION**

7. Determine the mass of two unknown metal samples to the nearest 0.01 grams, using a centigram balance. Record the Masses in Data table 1 and 2
8. Find the volume of each metal sample by water displacement. Fill a 25 mL graduated cylinder about half-full with water, measure the volume, and record as 'volume of water alone' in Data Table 2. Tilt the graduated cylinder and carefully slide one of the metal samples down the side. Make sure that the metal is completely under the water. Measure the volume and record the measurements as 'volume of water + metal' in Data Table 2.
9. Repeat step 8 for the other piece of metal. Dry both samples.

COMPLETE DATA TABLE 3 BY OBTAINING DATA FROM AT LEAST 2 OTHER GROUPS

**OBSERVATIONS**

DATA TABLE 1: INDIVIDUAL DATA AND CALCULATIONS

	Alcohol Sample #1	Alcohol Sample #2
mass of graduated cylinder alone (g)		
mass of graduated cylinder + alcohol (g)		
mass of alcohol alone(g)		
volume of alcohol (mL)		
density of alcohol (g/mL)		
density of alcohol in simplest terms (g/mL)		

DATA TABLE 2 : INDIVIDUAL DATA AND CALCULATIONS

	Metal Sample #1	Metal Sample #2
mass (g)		
volume of water alone (mL)		
volume of water + metal (mL)		
volume of metal alone (mL)		
density of metal (g/mL)		
density of metal in simplest terms (g/mL)		

DATA TABLE 3: CLASS DATA : MASS + VOLUME OF SAMPLES

Lab pair names and symbol used on graph	Alcohol Samples		Metal Samples	
	Mass(g)	Volume(mL)	Mass(g)	Volume(mL)
1.				
2.				
3.				
4.				

ANALYSIS AND CONCLUSIONS

1. Compute the mass of each alcohol sample, using data from Data Table 1. Compute the density of the alcohol samples, showing your work (include units)
2. Compute the volume of each metal sample, using data from Data Table 2. Compute the density of each metal sample, showing your work (include units)
3. Using the class data for alcohol, plot a graph of mass versus volume.... Mass on the y-axis and volume on the x-axis. Represent the plotted points for each sample with a different symbol. Draw a best-fit straight line through each group of plotted points. **(Use your graphing calculator if possible)**
4. Which is considered the independent (manipulated) variable in this experiment?  
\_\_\_\_\_
5. Which is considered the dependent (responding) variable in this experiment?  
\_\_\_\_\_
6. Should the line go through the origin? \_\_\_\_\_ Explain your reasoning.
7. Determine the slope of each of the lines on your graph. Record the slope of each line and your method of calculation in Data Table 4. **Hint:** The general equation of a line is  $y=mx + b$  where m is value for the slope and b is the value for the y-intercept. Pay special attention to the units of the slope.  $m = \frac{y_2 - y_1}{x_2 - x_1}$
8. Repeat step 3 for the metal samples. Place this line on the same piece of graph paper, but use a different color

Data Table 4: Density Calculations from Class Data Using the Slope of the line

Alcohol Calculations	Metal Calculations

9. What is the y-intercept of the line? \_\_\_\_\_
10. What does the slope of the line for the alcohol mean? **Hint:** Look back at Data Table 1
11. Explain density in terms of ratio. Cite examples in your explanation.
12. Show how one would set up a ratio to determine the mass of a substance given that the density was 5.6g/mL with a volume of 3.7 mL.

13. Looking at your graph what does this experiment demonstrate about the density of a metal?
14. Calculate the percent error in the density calculations for the metal sample. Your teacher will provide the accepted density value of the metal. Your density determination (See Table 2) is the experimental value. Show all your work  
 Percent error =  $\frac{\text{accepted value} - \text{experimental value}}{\text{Accepted value}} \times 100\%$
15. Calculate the percent error in the values of density obtained from the slopes of the lines in your graph. Your teacher will provide the accepted density value of the metal. Your density determination (See Table 4) is the experimental value. Show all your work  
 Percent error =  $\frac{\text{accepted value} - \text{experimental value}}{\text{Accepted value}} \times 100\%$
16. Look back at the percent errors calculated in 14 & 15. Generally the slope of the line will give a more accurate value for density than a single sample. Explain why this is true?
17. Is determining the density of a liquid different from determining the density of a solid? \_\_\_\_\_  
 Justify your answer.
18. Based on the results of this lab, develop a hypothesis about how and why unknown substances can be distinguished from one another using their densities.

## THE SAME LAB, BUT JUST A BIT SIMPLER

### MATERIALS (PER PAIR)

Safety goggles	centigram balance	1 50mL graduated cylinder
1 ruler	metal samples	1 100mL graduated cylinder
graph paper	paper towels	

### PROCEDURE

As you perform the experiment record your data in the Data Tables 1& 2

1. Wear safety goggles.

2. Determine the mass of two unknown metal samples to the nearest 0.01 grams, using a centigram or electronic balance. Record the Masses in Data table 1.
3. Find the volume of each metal sample by water displacement. To do this, fill a 50 or 100 mL graduated cylinder about half-full with water, measure the volume, and record as '*volume of water alone*' in **Data Table 1**. Tilt the graduated cylinder and **carefully slide one of the metal samples down the side**. Make sure that the metal is completely under the water. Measure the volume and record the measurements as '*volume of water + metal*' in Data Table 1.
4. Repeat steps 2-3 for the other piece of metal. Dry both samples.

## **ANALYSIS AND CONCLUSIONS**

1. Compute the volume of each metal sample, using data from Data Table 1. Compute the density of each metal sample, showing your work (include units)
2. **COMPLETE DATA TABLE 2 BY OBTAINING DATA FROM AT LEAST 3 OTHER GROUPS.**
3. Using this data for the metal, plot a graph of mass versus volume. Mass on the y-axis and volume on the x-axis. .... (You should have at least 5 points to plot, 2 that you determined and 3 from the other groups).
4. Represent the plotted points for each sample with a different symbol. Make a Scatter plot, do not play connect the dots!!
5. Draw a best-fit straight line through the plotted points. **(Use your graphing calculator if possible)**

## OBSERVATIONS

DATA TABLE 1: INDIVIDUAL DATA AND CALCULATIONS(show all work)

	Metal Sample #1	Metal Sample #2
1. mass (g)		
2. volume of water alone (mL)		
3. volume of water + metal (mL)		
4. volume of metal alone (mL)		
5. density of metal (g/mL)		
6. density of metal in simplest terms (g/mL) do not leave as a fraction		

DATA TABLE 2: CLASS DATA : MASS + VOLUME OF SAMPLES

Lab pair names and symbol used on graph	Metal Samples		
	volume (mL)	mass (g)	Density g/mL
5.			
6.			
7.			
8.			

9. Which is considered the independent (manipulated) variable in this experiment? \_\_\_\_\_

10. Which is considered the dependent (responding) variable in this experiment?

\_\_\_\_\_



11. Should the line go through the origin? \_\_\_\_\_ Explain your reasoning.
12. Determine the slope of the line on your graph. Record the slope of each line and your method of calculation in Data Table 3. **Hint:** The general equation of a line is  $y=mx + b$  where  $m$  is value for the slope and  $b$  is the value for the y-intercept. Pay special attention to the units of the slope.  $m = \frac{y_2 - y_1}{x_2 - x_1}$

Data Table 3: Density Calculations from Class Data Using the Slope of the line

X= the volume from the ordered pair,	Metal Calculations		
	$X_1 =$	$Y_1 =$	$Y_2 - Y_1 =$
	$X_2$	$Y_2 =$	$X_2 - X_1 =$
			$\frac{Y_2 - Y_1}{X_2 - X_1} =$ g/mL

13. Explain density in terms of a ratio. Give examples from the lab in your explanation.
14. If an object floats in water, what can you tell about its density?
15. If an object sinks in water, what can you tell about its density?
16. What is the volume of a sample of water is the mass is 6.7g? Explain why this is soooooo easy to figure out.
17. Show how one would set up a ratio to determine the mass of a substance given that the density was 5.6g/mL with a volume of 3.7 mL. Then solve to determine the mass.
18. Show how one would set up a ratio to determine the volume of a substance given that the density was 2.6 g/mL with a mass of 5.5 g. Then solve to determine the volume.

19. Looking at your graph what does this experiment demonstrate about the density of a metal?

20. Based on the results of this lab, develop a hypothesis about how unknown substances can be distinguished from one another by using their densities.

## MASS, VOLUME, DENSITY

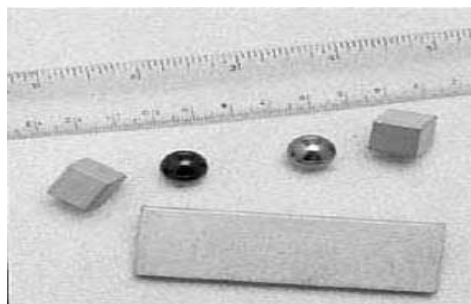
This lesson may be found in the Middle School Science Resource Book providing focus lessons for the annually assessed benchmarks in science.  
<http://mathscience.dadeschools.net/6-8/default.htm>

**Florida Sunshine State Standard Benchmark:** SC.B.1.4.1 - The student identifies various ways in which substances differ (e.g., mass, volume, shape, density, texture, and reaction to temperature and light).

### Teacher Overview:

*Density is a basic physical property of any sample of matter. It is much more important than other physical properties such as size or shape in that the numerical value of density for a pure substance at a particular temperature and pressure is a constant, and never changes! The density may be determined in the laboratory if the mass and volume of a sample can be determined. Density may be calculated by dividing the mass by the volume ( $d = m / V$ ). It also may be thought of as the ratio of the mass to the volume. The density of water is important to know. It is 1.0 g/mL at 4°C.*

In this experiment, the student will measure the mass and volume of several materials. They will then use their data to explore the relationship between the mass and volume of the materials and calculate their density.



[www.rocksandminerals.com/boxed/boxed.htm](http://www.rocksandminerals.com/boxed/boxed.htm)

**Literature Connection:** "Archimedes and the King's Crown"

**Time Frame:** 1 hour

**Materials (per pair):**

Safety goggles

50 mL of isopropyl alcohol (colored red)

50 mL of water (colored blue)

50 mL of salt-water (colored green) Graduated cylinder

Eye dropper

Calculator

Electronic balance or triple beam balance

## Procedure

### Part A-Teacher Pre-Lab Preparation and Presentation

1. Color the isopropyl alcohol red by adding a few drops of red food coloring.
2. Color the water blue by adding a few drops of blue food coloring.
3. Prepare a salt-water solution by mixing four parts water to one part salt by volume. Color the solution green using a few drops of green food coloring.
4. Show the students the three solutions and ask them to suggest a way to compare the masses of the three liquids.
5. Guide the discussion towards the realization that in order to compare the masses, equal volumes would have to be massed.
6. The topic of density, as the relationship between mass and volume could now be introduced.

### Part B: Student Procedure

1. On the electronic balance, mass the graduated cylinder and press "tare" to subtract the mass. If you are using a triple beam balance, mass the graduated cylinder and record this mass to the nearest 0.01g.
2. Pour 10 mL of the red liquid into the graduated cylinder. Use an eyedropper to get an exact amount, 10.0 mL.
3. To get a precise measurement place the cylinder on a flat surface, bring your "eye" down to the level of the liquid, and read the bottom of the meniscus.
4. Determine the mass of the 10.0 mL by reading the electronic balance directly, or if using a triple beam balance record the total mass (cylinder + liquid) and then subtract the mass of the graduated cylinder.
5. Record the mass in the Data Table in the appropriate location, i.e. Red Liquid; 10.0 mL.
6. Calculate the density of the liquid by dividing the mass by the volume.
7. Record the mass in the Data Table in the appropriate location, i.e. Red Liquid; 10.0 mL.
8. Add another 10.0 mL to the cylinder. You should now have a total of 20.0 mL (10 mL + 10 mL).
9. Determine the mass of the 20.0 mL by reading the electronic balance directly, or if using a triple beam balance record the total mass (cylinder + liquid) and then subtract the mass of the graduated cylinder.

10. Find the density again by dividing the mass by 20.0 mL and record it in the Data Table.
11. Keep adding 10.0 mL of the red liquid, recording the mass and calculating the density by dividing the mass by the amount of liquid in the cylinder until a total of 50.0 mL of the red liquid has been used.
12. Repeat the procedure for each liquid, finding mass and density.
13. Graph mass (y-axis) vs. volume (x-axis) for each liquid on the graph paper provided. Use a different color for each solution.
14. Draw a line of "best-fit" for the points of each solution.

### Data Analysis

Mass of empty graduated cylinder = \_\_\_\_\_

#### Data Table for Red Liquid

Volume (mL)	Mass of Liquid (g)	Density (g/mL)
10.0		
20.0		
30.0		
40.0		
50.0		

#### Data Table for Blue Liquid

Volume (mL)	Mass of Liquid (g)	Density (g/mL)
10.0		
20.0		
30.0		
40.0		
50.0		

### Data Table for Green Liquid

Volume (mL)	Mass of Liquid (g)	Density (g/mL)
10.0		
20.0		
30.0		
40.0		
50.0		

#### Analysis Questions:

1. Which variable, mass or volume is considered the independent (manipulated) variable in this experiment?
2. Which variable, mass or volume is considered the dependent (responding) variable in this experiment?
3. Should the line of best-fit travel through the origin of the graph? Explain your reasoning.
4. As the mass increases, what happens to the volume of each sample?
5. As the volume increases, what happens to the mass of each sample?
6. Examine your density calculations for the red liquid. Should the density be the same in each instance? Explain your answer.
7. Explain density in terms of a ratio. Give examples from the lab in your explanation.
8. If an object floats in water, what can you tell about its density?
9. If an object sinks in water, what can you tell about its density?
10. What is the volume of a sample of water if the mass is 6.7g? Explain why this is so easy to figure out.
11. Show how one would set up a ratio to determine the mass of a substance given that the density was 5.6g/mL with a volume of 3.7 mL. Then solve to determine the mass.
12. Show how one would set up a ratio to determine the volume of a substance given that the density was 2.6 g/mL, with a mass of 5.5 g. Then solve to determine the volume.
13. Based on the results of this lab, develop a hypothesis about how unknown substances can be distinguished from one another by using their densities.

## Home Learning:

Students will complete the analysis questions.

## Extensions:

1. Have students explore the density of objects with identical masses, but different volumes. Discover the relationship among mass, volume, and density.
2. Have students explore the density of different liquids and/or solutions, i.e. 5%, 10%, 15% salt water solution. Discover the relationship between density and the solute concentration.

[www.sciencenet.org.uk/.../Chemistry/StructBond/c00195b.html](http://www.sciencenet.org.uk/.../Chemistry/StructBond/c00195b.html)



# Feuding Foams



## *Testing Density of Various Soap Products*

<http://www.rohmhaas.com/company/plabs.dir/htmldocs/testingd.html>

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**Developers:** Joseph J. Leo  
Log College Middle School  
Centennial School District

Allen P. Marks  
Research Scientist  
Rohm and Haas Company  
Spring House, PA

**Grade Level:** 6 to 8

**Discipline:** Physical Science, General Science

**Objectives:** Students will have the opportunity to observe, measure, and analyze the density of aerosol shaving creams and foams generated from shampoo and dishwashing liquids or detergents.

**Background:** The experiment is designed to measure the density (mass per unit volume) generated by the foam(ing) content of each product.

### **Materials:**

1/2 - or 1-gallon plastic jugs  
250- or 300-mL beakers (2 for each product tested)  
25 mL and 50 mL graduated cylinders  
safety goggles or glasses  
shampoo (Head and Shoulders<sup>®</sup>, Prell<sup>®</sup>)  
shaving cream (Barbasol<sup>®</sup>, Gillette<sup>®</sup>)  
liquid soap - (Dawn<sup>®</sup>, Ivory<sup>®</sup>, Palmolive<sup>®</sup>)  
triple beam balance  
spatula or wooden tongue depressors



**Procedure:**

1. Weigh and record the tare weight of each beaker to be used. (Mass)  
(Grams)
2. Fill each beaker with water and find the volume of the beaker by subtracting the tare weight from the beaker and water weight. Since the density of water is 1.0 g/mL, the weight of the water in grams is equal to the volume of the beaker in milliliters. The volume of water within the beaker will be the actual volume of foam that the beaker will hold. (Note that a 250-mL to 300-mL beaker has a volume greater than noted). (Volume) (Milliliters)
3. Prepare a 5% by volume solution of the soap products or shampoo to be used: A 5% solution is made up in a plastic jug by adding 5 milliliters of soap to 95 milliliters of water. Gently swirl the contents to disperse the soap in the water. Then, shake the jug to develop the foam.  
Aerosol shaving cream may be used in place of preparing foam, but it doesn't work as well as soap foam because it does not pack well into the beaker without trapping air pockets.
4. Fill two empty beakers with foam, by inverting the jug and squeezing.
5. Weigh the beakers and subtract the weight of the beaker from the beaker packed with foam. The remainder is the mass of the foam.
6. Remember that 1 gram of water is equal to one milliliter.
7. Calculate the density of the foam in the following manner:

**Example: Density =  $\frac{\text{Mass of foam in beaker}}{\text{Volume of water held by beaker}}$**

**Density =  $\frac{\text{Wt of the beaker and foam minus Wt of beaker}}{\text{Wt of beaker and water minus Wt of beaker}}$**

$$\text{Density} = \frac{\text{Weight of Foam (Grams)}}{\text{Volume of beaker (mL)}}$$

$$\text{Density} = \frac{1379 - 1109}{270 \text{ mL}} = \frac{27\text{g Foam}}{270 \text{ mL water}}$$

$$\text{Density} = 0.10 \text{ gm/mL}$$

#### Problems:

1. What is the density of the foam produced by 2% solution by volume if the container holds 270 mL. and its tare weight is 110 grams? The full container is 130 grams. Calculate the density.
2. Calculate the density of a 5% Dawn® detergent solution using the same container with the full container weighing 148 grams.

#### Extensions:

1. The density of foam generated may be varied by preparing several different solutions of 2%, 10% and 20% by volume. Also, the solution's density will vary by the type of product you use. Soap detergents and shampoo were found to be the best test products.
2. An economical analysis can be made by testing several different brands of dishwashing liquids or shampoos at a constant volume (2%, 5%, etc.). Calculate the densities of each product and then calculate the cost/volume (milliliters or ounces) as to price of product.

## Economic Analysis

(Data made up but you can supply real data.)

### Product A:

#### *Cost:*

\$0.50 for 16 fl. oz. ( a fl. oz. is about 29.6 mL, I think, so 16 fl. oz. - 47.4 mL)

5 % solution makes foam of density 0.10 g/mL (The 5% solution will have a density of about 1.0 before foaming since it's mainly water.)

So 100 g of 5% solution will generate  $\frac{100}{0.07} = 100$  mL of foam

The whole container contains  $\frac{47.4}{0.50} = 95$  aliquots of 5 mL samples

So the bottle will make 95,000 mL or 95 liters of foam for \$.50, or  $\frac{0.50}{95} = 0.0053$  cents/liter

### Product B:

*Cost:* \$ 0.60 for 16 fl. oz.

5 vol % solution makes foam of density 0.07 g/cc

So 100 g of 5% solution will generate  $\frac{100}{0.07} = 1429$  mL of foam

The whole container makes  $1429 \times 95 = 136,000 \text{ m} = 136 \text{ liters}$

So the cost is  $0.60 = 0.0044 \text{ cents/liter}$

$$\frac{\quad}{136}$$

Please note that this experiment works well in cooperative learning groups, with every member having a task to perform.

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# Dastardly Density

## The crime

Three bungling would-be burglars named Agar, Bubba, and Curly decided to relieve a wealthy socialite, Mrs. Rollinginit, of her most valuable possession, a diamond necklace. After a brief stakeout, the trio entered her home while she was out. Unknowingly, of course, they tripped a silent alarm upon entry. The three located and unlocked the safe, from which they carefully removed a tall, clear canister containing three layers of colorless liquid.

Peering downward into the vessel, they saw the exquisite necklace sparkling on the bottom. The leader of the trio designated one of the others to reach down and snatch the necklace from its liquid bondage. The burglar, trembling with fear, managed to reach only into the first level of liquid before rapidly retracting his hand. Furious, the leader screamed for the second burglar to grab the priceless prize. The second would-be thief, shaking like a leaf, reached down as far as the second liquid layer before hastily pulling back his hand. The boldest burglar, giving up on his two timid cohorts, plunged his hand down to the bottom of the container and triumphantly withdrew the necklace.

At this instant, they heard the distant wail of a siren and stampeded from the house. As they were racing across the front lawn, a patrol car rounded the corner, freezing Agar, Bubba, and Curly in their tracks. As the officer approached, they raised their hands in the air and surrendered. The diamond necklace was also recovered on the lawn where one of the thieves had dropped it. It is now up to the police to determine which thief had actually snatched the necklace from the bottom of the canister.

At the station, the three were required to hold their hands under a special light that caused the liquids found in the container to glow different colors. Agar's hand was coated in a liquid that glowed red. Bubba's hand was coated in a liquid that

glowed blue, and Curly's hand was coated in a liquid that glowed yellow. Fortunately, any liquid picked up in a higher layer of the canister was washed off in the next deeper layer, so the crime lab scientists were certain they could determine who reached into the bottom of the canister.

The crime lab separated the liquids from Mrs. Rollinginit's canister and added dye to indicate the color that they glowed under the light, but carelessly forgot to record the order in which the liquids were layered. Your job is to re-layer the liquids in the canister in the proper sequence to determine which thief stuck his hand all the way to the bottom to retrieve the necklace. That person will be charged with first-degree burglary while the remaining two will be charged as primary and secondary accomplices. Submit your evidence to the District Attorney, who will charge the criminals according to their degree of dastardliness.

### **Purpose**

To determine which burglar—Agar, Bubba, or Curly—reached into the bottom of a canister to steal Mrs. Rollinginit's diamond necklace. You will do this by combining three different-colored liquids in the proper sequence so that no mixing occurs.

### **Materials:**

safety goggles  
small plastic cup capable of holding 5 mL of liquid  
balance  
large pipettes (7-10 mL capacity)  
small pipette (1.0-1.5 mL capacity)  
test tubes  
test tube rack

### **Procedure**

1. Insert four small test tubes into the test tube rack, placing them in an upright, vertical position.
2. When your teacher calls your group, bring your test tubes, rack, and pipettes to the station where the three colored liquids are being stored.
3. Using your large pipette, add 5 mL of yellow liquid to the first test tube.

4. Repeat step 3 using a clean pipette to add 5 mL of red liquid to the second test tube.
5. Repeat step 3 using a clean pipette to add 5 mL of blue liquid to the third test tube.
6. Discuss with your group a way to determine the correct order of solutions to see who done it.
7. On a clean sheet of paper write down the experimental procedure you intend to use.
8. Create a data table to test your experiment on the same piece of paper.
9. Record all your trials on your data table.
10. When you determine the correct layering sequence, deduce which of the burglars should be charged with the most serious crime.

### Questions

1. List the correct sequence, beginning with the top layer.
2. Describe the appearance of the contents of the three tubes containing the red, blue, and yellow liquids. Use physical properties such as color, volume, and state, recall that these types of observations are referred to as qualitative. They do not include a \_\_\_\_\_ in their description.
3. Other than color, what are the differences among the contents of the three tubes?
4. Determine the mass of a clean small cup using a pan balance. Then fill it with 5 mL of the yellow liquid and determine the mass of the cup and liquid. Finally, subtract the mass of the cup from the mass of the cup and liquid to determine the mass of the liquid alone. (For example, Mass of cup: 5 grams. Mass of cup and liquid: 9 grams. Mass of liquid:  $(9g - 5g = 4 g)$ ) Repeat these steps for each of the other two liquids and fill out the chart below.

MATERIALS	MASS (g)
Empty cup	
Cup and yellow liquid	
Yellow liquid	
Cup and red liquid	
Red liquid	
Cup and blue liquid	
Blue liquid	

5. You have just determined the \_\_\_\_\_ for each of the three liquids. Are these quantities the same for each liquid?

Did you mass equal volumes for each of the liquids? If the mass of each liquid is different for equal volumes, what is your explanation for the difference?

6. What term describes the relationship between the mass and volume of a substance?

7. Examine your mass-to-volume ratio for the yellow liquid.

8. Fill in the chart below. Be sure to include your density units.

LIQUID	DENSITY (SHOW WORK)
Yellow	
Red	
Blue	

9. Do the liquids used in this investigation have the same or different densities?

10. In your opinion, why does each colored liquid have a different mass for its volume?

11. If you place three liquids of different densities into a test tube, where will they go in relation to one another? Why do the liquids behave in this manner?

Adapted from Science Scope January ,



