Fifth Edition

YOU BE THE CHEMIST™

ACTIVITY GUIDES

Hands-on Science
for Grade K-8 Students

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Properties of Matter: Density

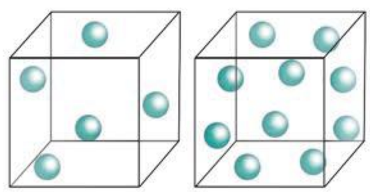
Background

Activity Guides:

DENSITY TOTEM | DANCING RAISINS | LIQUID RAINBOW | BUOYANT BUTTER

Introduction to Density

Density is a measure of how compact matter is within a substance. As matter in a substance becomes more compact, its density increases. As the matter in a substance spreads out more, its density decreases.



The box on the left has a lower density than the box on the right.

Think of a large, empty room that is filling with people. When there are only three people in the room, density is low because there is a lot of space between those people, giving them ample room to move. As more people fill the room, density increases and each person has less space to move around.

Similarly, if we start with the same three people but put them in a smaller room, there is also a relatively high density because they have less space to move and there is less space between each person.

Even if we can't see density by simply looking at an object, we observe it all around us. Think of a **fluid** (a liquid or gas), such as water in a swimming pool or a bathtub. You might have noticed that some objects sink, others float, and still others hover within these fluids. In a bathtub, a person, soap, and certain toys sit on the bottom of the tub because they are more dense than water. (Their matter is more compact than matter in water.) Other objects, like rubber ducks, toy boats, and bubbles float to the top of the water because they are less dense than water. Different substances naturally have different densities, causing them to have distinct positions in fluids.

Different types of substances and objects have characteristic densities. Because density is relatively easy to measure, it is often used to figure out the identity of a substance. For example, in a mystery sample we can calculate density to get a better idea of what the sample might be. In an experiment, there are also times where we can manipulate the density of samples or mixtures to learn more about their properties. First, let's see how density is measured.

Measuring Density

Density is the amount of matter in a given amount of space, so to calculate density of a substance you need to know two measurements: mass and volume.

Mass is a measurement of how much matter is present in something. To calculate mass, we can use a variety of instruments, the most common of which is a **scale** or **balance**. The units used to measure mass are **milligrams (mg)**, **grams (g)**, or **kilograms (kg)**.

A scale or balance is the most common instrument used to calculate mass.

A fish tank at home will have a smaller volume than a shark tank in an aquarium.

You have likely determined your own mass on a bathroom scale, or measured the mass of your luggage before boarding a flight. Increasing the amount of matter in a sample will increase its mass. For example, if you add a heavy pair of shoes to a suitcase its mass will increase, and if you put it on a scale you will see the value increase.

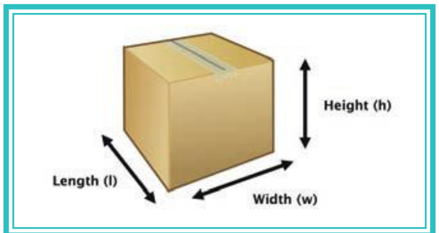
The second measurement we need to calculate density is volume. **Volume** is a measurement of how much space a substance takes up. For example, a deflated balloon or beach ball has a smaller volume than when it is inflated and takes up more space. A mini water bottle has a smaller volume than a large water bottle. And a fish tank at home will have a smaller volume than a shark tank in an aquarium.

There are a few ways to calculate the volume of an object. If you are measuring a liquid, you can use a **graduated cylinder** or a **beaker**. A more precise tool—such as a **graduated pipette**—can also be used to measure volume.

These instruments come in a variety of shapes and sizes, and have volume measurements along the side. When a liquid is poured into one of them, you can tell the volume by where the top of the liquid is and what number it is touching. After pouring a liquid into a graduated cylinder or beaker, position yourself so your eyes are at the level of the surface of the liquid. This is the most accurate way to read volume. Imagine reading the measurement while standing above the glass or far below it; it would be difficult to read the measurement accurately.

When looking at the top of the liquid, you will notice a slight downward curve at the surface. This curve is called the **meniscus**. Read the measurement from the bottom of the meniscus. A way to remember this is to "read the tip of the dip," meaning you should take the measurement from the lowest point of the liquid's surface. Notice that the **units** used to measure the volume in a liquid are **milliliters (mL)** or **liters (L)**.

How do you calculate volume if the substance is not a liquid and cannot be poured into one of these instruments? If you have a solid that is a regular shape (like a **cube** or a **rectangular prism**), you can calculate the volume using a formula. For example, a rectangular prism is essentially a 3-dimensional rectangle with six faces, like a pack of cards or a box of pasta. You can find the volume of a rectangular prism by multiplying the length, width, and height as shown in the formula below.

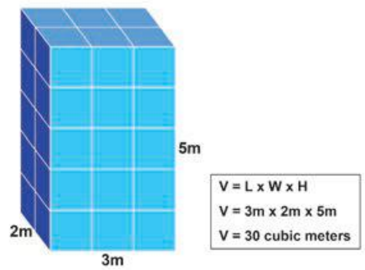


Volume (V) = length (l) x width (w) x height (h)
V = l x w x h

Length, width, and height can be found by using any tool that measures distance. **Meter sticks**, **tape measures**, and **rulers** are some examples.

The **meter (m)** unit of a meter stick is divided into **centimeter (cm)** and **millimeter (mm)** units. To get the volume of a rectangular prism, measure each side using the same units (all mm, all cm, or all m). Then multiply the side lengths together to get the volume. Since the units are multiplied together three times, the units for volume in a solid will end up being a **cubic millimeter (mm^3), cubic centimeter (cm^3), or cubic meter (m^3)**.

Length (l) x width (w) x height (h) = mm x mm x mm = mm^3



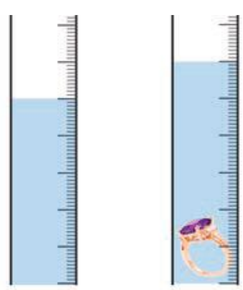
In the example above, the volume of the solid is measured in cubic meter (m3).

Note that one cubic centimeter is equal to one milliliter (cm3 = mL), which is the same unit used to measure the volume of a liquid in a beaker or a graduated cylinder.

If you have an object that is a different three-dimensional shape—such as a triangular prism, cone, sphere, or cylinder—you can also calculate the volume with other formulas that involve a bit more computation. These are great extension activities for students who are ready for more advanced math and measurement!

If you have an object that has an irregular shape, a trick for how to measure the volume is to completely submerge it in water and measure the change in volume—or **displacement**—of the water, which is equal to the object's volume. Think about when you get into a full bathtub, or when you pour a box of pasta into boiling water. The water level rises when objects are added. To measure volume using displacement, first measure the volume of the water without the object. Then completely submerge the object in the water and measure the volume of the water again. The volume should be higher this time. Subtract the original measurement from the final one and you will have the volume of the object. You can try this in the classroom by dropping small rocks, marbles, or small plastic toys into a graduated cylinder to watch the water rise.

BEFORE RING ADDED:
Volume of water = 50.0 mL



AFTER RING ADDED:
Volume of water = 60.0 mL

Volume of ring = 60.0 mL - 50 mL = 10.0 mL

Now that we know how to measure mass and calculate volume, we can determine the density of a substance. Mass is a measurement of how much matter, or stuff, is in something. Volume shows how much space it takes up. To get the amount of matter per amount of space, we can divide mass by volume. The formula for density is

Density (D) = Mass (m) ÷ Volume (V)

Remember the units for mass and volume? Mass is typically measured in grams, and volume is measured in cubic centimeters (for solids) or milliliters (for liquids). This means that density is typically in **grams per milliliter (g/mL)** or **grams per centimeter cubed (g/cm^3)**.

$$D = \frac{m}{V}$$

A trick to remember this formula is that the m/V looks like a heart cut in half!

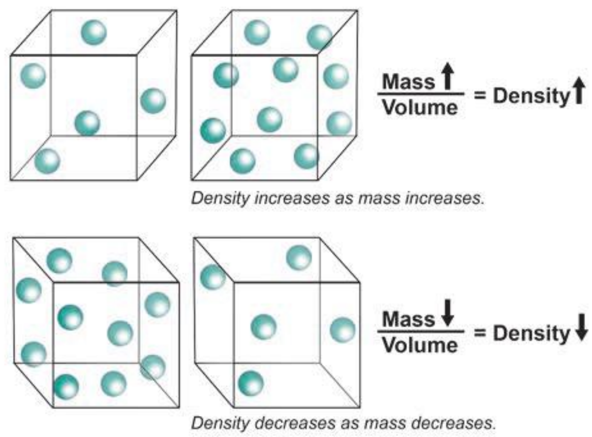
Density as a Physical Property of Matter

Density is part of the identity of any pure substance. At the same temperature and pressure, a cup of distilled (pure) water in your kitchen has the same density as a cup of pure water in a scientist's laboratory, which has the same density as pure water at school, and so on. A stick of butter in the supermarket and a stick of the same type of butter at a restaurant will have the same density.

The density of any specific pure substance (like pure water) can't change, but the density of an object or a sample of that substance can change. Look at the density formula – can you think of any ways to change density of a sample?

Factors Affecting the Density of a Sample

One way to increase density is by increasing the mass of a substance. Think back to the example of the suitcase. In this example, the volume (size of the suitcase) stays the same, but we can increase the mass by adding more items into the suitcase. Similarly, if you have a container with a few marshmallows and add more, you are increasing the mass. This means that in the container there is more matter packed into the same amount of space, so density increases. In our density formula the numerator (mass, the number on top) increases, which means the density will also increase. Conversely, if the mass is decreased and the volume remains the same, the density of the sample will also decrease.



Another way to increase density is to reduce the volume. Think of a large room with a group of 20 people in it. What happens if the whole group is moved to a room of half the size? The number of people (mass) does not change, but they are now in less space (lower volume). With lower volume the density increases because the people are more tightly packed together. In this case, we are making the denominator (volume, the number on bottom) in the formula smaller, so density will increase.

Conversely, think of moving those 20 people to a larger room instead. The mass has not changed, but they have more space to move around. If we increase the volume but the mass remains the same, the density of the sample will decrease.

Two other factors that can affect density of gases are pressure and temperature, though we will not go into this in detail at this level.

Applications of Density

Density determines if a solid, liquid, or gas will sink or float in a **fluid** (liquid or gas). If a substance is denser than a fluid it will sink, and if it is less dense it will float.

Think about learning to swim. A person is more dense than water, so they should sink. Children often learn to swim with floatation devices, such pool noodles, rafts, or tubes. These devices are usually filled with air or foam, so they have a low mass (very light) and high volume (take up a lot of space). This means they float in water. The density of a person is more than the density of water, but the density of a person plus a pool noodle together is less than the density of water. A person on their own may sink, but a person with a pool noodle will float.

Similarly, the items used to make a boat and all of the items on the boat have a very high mass. Engineers and architects have to make sure that the volume of the boat is large enough that it floats on the water despite its high mass.

We can also see density in nature. When a freshwater stream meets the salty ocean, the fresh water will rest on top of the ocean water before mixing because it has a lower density.

As the weather changes, humid (water-filled) air blows in that is more dense than dry air, so humid air stays lower to the Earth than the less-dense, drier air.

You can see density in your kitchen, too! Think about a pitcher of ice and tea, a container of pulpy orange juice, a mixture of chocolate syrup and milk, or an oil and vinegar salad dressing. The reason each substance separates out into different locations is due to differences in density.

Raw milk naturally separates into layers: creamy milk fat on top and watery milk on the bottom. If you drink skim milk, you are consuming milk where the less dense cream has been skimmed off the top to lower the fat content.

Another example is inflating a balloon. As more gas—air or helium—is pushed into the balloon, the volume increases. If you use helium you will find that the balloon rises and floats in the air. This is because the helium-filled balloon has a lower density than the air around it. Helium atoms are smaller and have a much lower mass than most particles in the air. The low mass leads to a smaller density and the balloon rises.

Let's try some activities so you can experience density in action!

ENGAGE YOUR STUDENTS

Before beginning any of these activities, use the following ideas to engage your students about density:

- To show how mass and density can change in a given volume, use tape to draw a square on the floor. First, have just two students walk around randomly in the square. Then add another student, and then another until there is no more room to move within the square. You can try this again but this time move the tape to adjust the volume. How does this change how much space each student has? Provide the definition for mass, volume, and density, and ask the students to define each in terms of this exercise. Ask them to explain when and how mass, volume, and density change in each scenario.
- Create a "pop aquarium!" Fill a large, transparent tub or fish tank with water and ask students to make predictions about whether a variety of closed, full cans of soda pop will sink or float. Be sure to use some regular and some diet sodas for this example. After students have made their predictions, drop the soda pop cans into the water and ask them to share their observations and predictions as to why they behaved differently.
- Create a setup like the pop aquarium, but instead of soda pop use two similarly-sized oranges. Peel one and leave the peel on the other. Ask students to predict whether the peeled orange will sink or float, then drop it into the water. Based on their observations, ask them to make a prediction for the unpeeled orange. Drop it in and observe.
- Provide learners with a variety of candies and water (in a cup, pitcher, or tank depending on group sizes). Ask them to predict whether each candy will sink or float and why, then test their predictions. Are there any patterns they notice?
- Show a variety of examples of large objects floating (e.g., boats, giant rubber ducks), and small objects sinking (e.g., pebbles, pennies). Ask students to explain how this is possible.
- Show students a container with a mixture of olive oil and vinegar. Shake the container, and watch the substances separate again so that that vinegar is on the bottom and olive oil is on top. Ask students to explain why the two liquids always layer this way.

Density Totem

Section **PROPERTIES OF MATTER** *Topic* **DENSITY**

Estimated Time Setup: 5 minutes; Procedure: 10-15 minutes

OVERVIEW

Students will layer a variety of liquids to understand how density can be observed and how relative densities of different substances can be predicted through a series of tests.

We can use the physical property of density to explain why liquids settle in different layers when put together. In this activity, students mix the following samples together two at a time: vegetable oil, light corn syrup, and water. Based on their observations they predict how to make a "density totem," where the liquids are stacked in a container in order of increasing density from top to bottom.

INQUIRY QUESTIONS

Getting Started:

- Do different liquids have different properties?

Learning More:

- What properties of liquids can be used to distinguish different samples from one another?

Diving Deeper:

- How can we predict and calculate density of a liquid?

CONTENT TOPICS

This activity covers the following content topics: measurement, density, properties of matter, physical properties of liquids, mixtures, miscibility and immiscibility, heterogeneous and homogeneous mixtures, emulsions, polarity

This activity can be extended to discuss the following: environmental science (weather, oceans), separation techniques, ideal gas laws, particulate nature of matter, intermolecular forces, physical versus chemical changes

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:

- **2-PS1-1:** Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.
- **5-PS1-3:** Make observations and measurements to identify materials based on their properties.
- **MS-PS1-2:** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MATERIALS

For one setup:

- 16-oz plastic or glass container with lid
- 7 clear plastic cups
- 3 spoons
- Measuring cup – 1/3 cup
- Food coloring – blue and red
- Vegetable oil
- Light corn syrup
- Water

ACTIVITY NOTES

This activity is good for:

- Pairs
- Small groups
- Project or take-home assignment
- Concept introduction

Safety Tips & Reminders:

- Oil should be disposed of in the trash, not down a sink or drain.
- Review the Safety First section in the Resource Guide for additional information.

ENGAGE

Use the following ideas to engage your students in learning about density:

- Present students with the three samples from phase 3 of the procedure. Ask students to observe and record the physical properties of the three liquids and to brainstorm ways to test if the samples are the same or different. Have a student close their eyes and place one cup in each hand. Which one feels heavier? Which sample do they think it is?
- Provide students with two liquids with different densities (e.g., water and oil, or oil and vinegar) and challenge them to mix the two together. Have students discuss what is happening and why. Can the two liquids be mixed? Do they always settle in the same part of the cup?
- Present students with a variety of liquids that separate into layers (e.g., salad dressings, juices, lemonade, and tea – anything you can find!). Ask students to mix them, then watch for a few minutes to see if and how they separate. What is in each layer and why do they separate? Leave them out overnight to see if a more defined separation can be seen the following day.

See more ideas for engagement in the Density Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

EXPLORE

Procedure:

PHASE 1

1. Add 1/3 cup of water to each of two clear plastic cups. Add two drops of blue food coloring to each cup and stir.
2. Add 1/3 cup of light corn syrup to the first cup of water and 1/3 cup of vegetable oil to the second cup of water. Record your observations.
3. Write a prediction about what will happen if the contents of both cups were combined.

PHASE 2

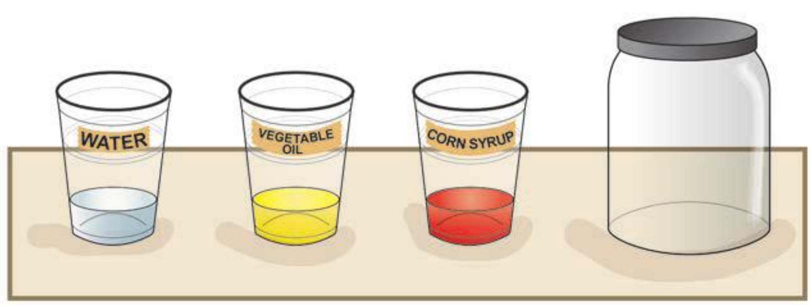
4. Add 1/3 cup vegetable oil to a third cup.
5. In a fourth cup, add 1/3 cup of light corn syrup and two drops of red food coloring, then stir until combined.
6. Add the corn syrup mixture to the oil. Observe and record the results.

PHASE 3

7. Obtain three new cups. Pour 1/3 cup of vegetable oil into one, 1/3 cup of light corn syrup into the second, and 1/3 cup of water into the third.
8. Add two drops of red food coloring to the cup of corn syrup and stir until combined.
9. Add two drops of blue food coloring to the cup of water and stir until combined.
10. Based on the results from phase 1 and 2, predict which liquid will be on the bottom, in the middle, and on top if all three liquids are put together.
11. In a 16-oz container, first pour the sample that you think will be on the bottom. Second, carefully add the sample that you think will remain in the middle. (If you are having trouble getting the liquids to layer, try pouring the sample over the back of a spoon as it goes into the cup. This will slow the speed of the liquid.) Next, pour in the liquid that you think will rest on top of the other samples. Observe and record results. Did you layer them correctly?

PHASE 4

12. Make a prediction: what will happen if you mix the three liquids in the container? Secure the lid on the 16-oz container and shake. What do you notice as the liquids mix and settle?



DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Record your observations and draw and label your "density totems" from each phase.
- Which substance is the most dense in each phase?
- Which substance is the most dense overall? Which is the least dense?

Fun Fact #1

Floating in water that has a higher salt content is easier than floating in fresh water. The addition of salt increases the density of the water, and the higher the density the easier it is to stay afloat. Check out the Liquid Rainbow activity to learn more about this!

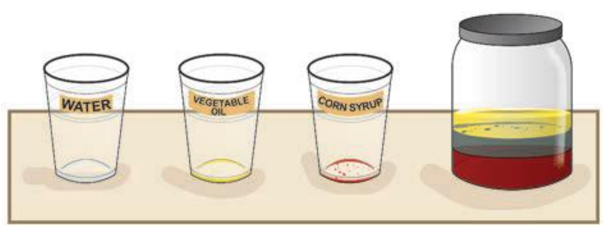
EXPLAIN

What's happening in this Activity?

First review the Density Background section to gain a deeper understanding of the scientific principles behind this activity.

Density is a property of matter that describes the compactness of a substance. In simple terms, it is how spread out or how closely packed together the matter is in a given amount of space, or mass per unit of volume. Density is dependent on the **volume**—the space a substance takes up—and **mass**—the amount of matter present—and can be calculated using the formula **D=m/V**, where the density is equal to the mass divided by the volume. If there are two substances that take up the same volume, but one has more matter in that space, then that one will be more dense. If two substances have the same mass, but in one sample the mass is more compact and in a smaller space, then it will be more dense. Samples may have different densities based on their **chemical makeup** i.e., what atoms and molecules they are made of and in what arrangement) and their conditions (i.e., temperature and pressure). When liquids and gases with different densities are put together they form layers based on density, with the densest substance on the bottom and least dense substance on top.

In this activity, there are three liquid samples: water, light corn syrup, and vegetable oil. When they are put together they make distinct layers based on differences in density. The density of each substance differs because each has a different chemical makeup—each is made up of different molecules with varying sizes, atomic weights, and molecular arrangements. If you calculate or research the density of each liquid sample, you will find that the light corn syrup has the greatest density, followed by water, then vegetable oil. This aligns with what you saw: the light corn syrup forms the bottom layer, with water in the middle, and vegetable oil on top.



Sample	Density (g/mL)
Vegetable oil	0.92
Water	1.00
Light corn syrup	1.33

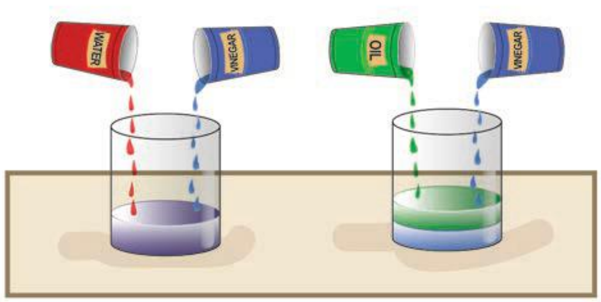
But why do the liquids form layers instead of mixing together? And why do the samples separate out again after they are mixed together? This happens because of a property of matter called **miscibility**. If two substances are **miscible** (think of "mixable") it means that they easily mix together to form a **homogenous mixture**, where there is a uniform appearance and composition throughout. Think of juice and water, vinegar and water, coffee and milk—these all make homogenous mixtures.

Conversely, a **heterogeneous mixture** is not uniform, and a sample from any area within the mixture could yield different results. Examples include oil and vinegar, oil and water, or sand and water.

Whether or not two substances are miscible depends on their chemical makeups. In this example, water, light corn syrup, and vegetable oil are **immiscible** (not miscible) so they form layers when poured together.

EXPLAIN continued

Water and vinegar and miscible and mix evenly to form a homogenous mixture. Oil and vinegar are immiscible and do not mix. Instead, they form distinct layers when put together.



Water and vinegar are miscible and mix evenly to form a homogenous mixture. Oil and vinegar are immiscible and do not mix. Instead, they form distinct layers when put together.

Diving a bit deeper into atomic structure, miscibility is dependent on the **polarity** in a molecule. Polarity means that the molecule has partial negative and positive charges. These slight charges are caused by varying electron density throughout the molecule, which means that charge is unequally distributed. The rule with polarity and miscibility is that "like dissolves like," which means

- polar liquid + polar liquid = miscible
- nonpolar liquid + nonpolar liquid = miscible
- polar + nonpolar liquid = immiscible

Water is a polar substance and oil is nonpolar. In this example, you see that water and oil are not miscible. As a result, they don't mix and instead they form layers based on their densities.

When the three samples are forced together through shaking or mixing the container, you might have noticed that they briefly seem to mix. This unstable mixture is called an **emulsion**. An emulsion is when substances that are immiscible are forced together, and one substance forms droplets within the other. It might have looked like there were "bubbles" of light corn syrup, oil, and water in the container. In time, the three substances separate back into layers based on their densities.

Differentiation for Younger or More Advanced Students

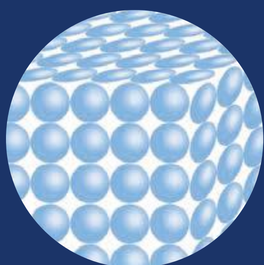
You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED	DIVING DEEPER
For younger students, emphasize the following concepts: • Introduction to density • Physical properties of liquids	**For more advanced students, emphasize the following concepts:** • Density formulas, calculations and predictions • Converting between units • Miscibility and emulsions • Polarity and types of bonds, and how they affect which substances can mix

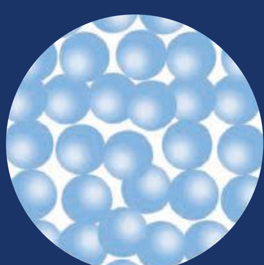
Notes

Fun Fact #2

The density of ice is 0.92 g/mL which is less than that of water, 1.00 g/mL. This is why ice cubes float in glass of water. Most solids are denser than their liquid form, but water's unique molecular structure causes particles to be more spaced apart as a solid, and closer together as a liquid:



Solid



Liquid

Gas

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Students can make predictions about a variety of solids and what their densities might be. These can include things like candies, buttons, rocks, or paper clips—anything you don't mind dropping into the samples! After making predictions they can drop each sample into the "density totem" and record their observations. Or, drop different candies into a glass of water and see if they settle in different locations.
- Students can calculate the mass and volume of the samples with a scale and a graduated cylinder. What do they notice about the mass and volume of each sample? Does this explain the order in which they were layered? Now change the volume of each liquid: make one less, one greater, and keep one the same. Have students record whether the mass or volume changed for each sample—or if both changed! Ask students if this will this change how they layer (their densities). Try it! Introduce the density formula and see if that provides a reliable way to make predictions in this situation. Although the volume will be changed, students will find that the density remains the same.
- Have a completed density totem "rainbow" at the front of the class at the beginning. After students have done part of the activity, ask them to guess which color you put in which liquid.
- Set up a lava lamp in the room and ask learners to speculate as to how it works and why the substances inside are moving around: what makes them fall and rise? Lava lamps are made up of two immiscible liquids with very similar densities. The heavier liquid settles at the bottom, but when it is heated it rises to the top of the lamp. The liquids never mix because they are immiscible and therefore never dissolve in one another.

EVALUATE

- As a take-home assignment, challenge students to a competition of who can make the "density totem" with the most different substances. They can draw a diagram with labels for each sample in the totem. To verify their results ask them to research or calculate the density of each sample and add that to their diagram.
- Provide three new samples of liquids that were not used in the original activity, or have students find examples at home. Ask them how they would make measurements to correctly predict the relative densities and what units they would use. You can provide scales and graduated cylinders to assist with making accurate measurements, or they can make estimates based on the liquids being filled to the same height in a cup and feeling which one seems heavier than the others. Ask them to write or draw a prediction, explain their thought process, get it checked by their educator, and then test their prediction.
- We see density all around us! A notable example is in the ocean, where animals, plants, debris, boats, ice, and even the sea water will settle at different heights based on density. Ask students to find a photo online that shows this, and to write a description of what is happening in the photo in terms of density.

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

Oil is less dense than water. When an oil spill happens in water, part of the cleanup process involves skimming the less dense oil off the surface of the water.

Helium-filled balloons rise and float in the air because helium gas is less dense than air (a mixture of nitrogen, oxygen, argon, carbon dioxide, and more).

Different types of milk—such as whole milk, 2% milk, and skim milk—are made by separating liquids based on density. The fat in milk has a lower density than the rest of the milk, so fat molecules will eventually rise to the surface. To lower the fat content, this layer of milk fat is skimmed off of the surface. This is why lower-fat milk is called "skim milk."

Careers in Chemistry

- Environmental chemists that study icecaps are interested in water displacement and the impact of melting snow and icebergs. There is a common misconception that when the icecaps melt sea levels will rise, but we know that water has already been displaced by the ice floating in the water, so whether they are solid or liquid the water levels will not change. But the melting ice and snow that is on land could change the water levels and the salinity of the water, since more water in the oceans means changing concentrations of salt in the water.
- One option for astronauts to return to Earth after a mission is a splashdown, which is when the space capsule lands in the water. Scientists must design a space capsule that is strong enough to protect the astronauts, but also able to float in the water.

Picture from NASA's Gemini 11 splashdown and recovery in 1966.

Notes

Buoyant Butter

Section **PROPERTIES OF MATTER** *Topic* **DENSITY**

Estimated Time Setup: 5 minutes; Procedure: 5–10 minutes

OVERVIEW

Students will discover the connection between density and whether an object will sink or float.

How can we determine if an object will sink or float in water? In this activity, students will calculate the density of butter and compare it to the density of water. They will make predictions about whether the butter will float or sink in the water based on their calculations and then test these predictions.

INQUIRY QUESTIONS

Getting Started:
- Do solids float or sink in liquids?

Learning More:
- How can we make predictions as to whether an object will sink or float in a liquid?

Diving Deeper:
- What forces cause an object to sink or float in a liquid?

CONTENT TOPICS

This activity covers the following content topics: instruments, measurement, precision vs. accuracy, density, displacement

This activity can be extended to discuss the following: environmental science (weather, oceans), engineering design, forces, buoyancy

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:
- **2-PS1-1:** Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.
- **5-PS1-3:** Make observations and measurements to identify materials based on their properties.
- **MS-PS1-2:** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Fun Fact #1

The only soap that is known to float on the surface of water is Ivory soap! This is possible for Ivory because they whip air into the soap to decrease its density. Check out the Growing Soap activity to learn more!

MATERIALS

For one setup:
- 1 Stick of butter or margarine, with wrapper
- Metric ruler
- Large bowl or container
- Water

Optional materials:
- Scale

ACTIVITY NOTES

This activity is good for:
- Individuals
- Pairs
- Small groups

Safety Tips & Reminders:
- To reduce the mess, use a frozen stick of butter. Alternatively, you can use any rectangular prism that can be easily cut, such as paraffin wax.
- Only adults should handle the knives if the butter needs to be cut for the activity or modifications.
- There is no eating or drinking in the laboratory—even when we are working with normally edible materials.
- Review the Safety First section in the Resource Guide for additional information.

ENGAGE

Use the following ideas to engage your students in learning about density:

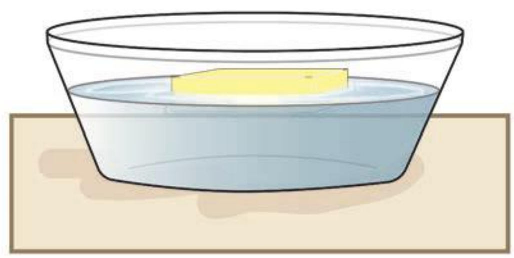
- Explain the concept of density using a visual. For example, use mini-marshmallows in a clear box to show how mass can change in a given volume.
- Collect different objects and ask the students if the objects will sink or float in water. Try to find objects of varying shapes, sizes, and densities. How can one predict floating or sinking accurately? What factors are important to making this determination?
- Ask students whether all rocks sink or float, or if it varies. Collect rock samples that are similar in volume and test it out! Include one rock that is pumice, which will float. This will help the students to understand that a variety of factors play into density.
- Place a piece of aluminum foil on top of the water as a flat sheet. Then crumple it slightly and put it in the water again. What happens? Now ball it up into a tight sphere and ask the students if it will still float. This will illustrate that the same mass but in a smaller space (more dense) will sink rather than float.

See more ideas for engagement in the Density Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

EXPLORE

Procedure:

1. Determine and record the mass of the butter in grams (g). This can be measured on a scale or found on the wrapper label or box.
2. Using a ruler, measure and record the length, width, and height of the stick of butter in centimeters (cm).
3. Calculate the volume of the stick of butter by multiplying the length times the width times the height (V = l x w x h).
   - The answer will be in centimeters cubed (cm^3), which is equal to milliliters (mL). Record the volume in milliliters.
4. Calculate the density of the butter.
   - Density is the mass divided by the volume (D = m/V), so divide your answer from step 1 by your answer from step 3.
5. Determine the density of water. Make a prediction about whether the butter will float, hover in the middle, or sink in the water. Draw a model, and explain your thinking.
6. Fill the large bowl or container with water and place the butter in the bowl to determine whether your prediction was correct. Record your observations.



Fun Fact #2

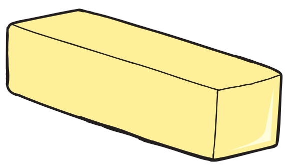
Over 2,000 years ago, ancient Greek mathematician Archimedes made a very useful measurement observation. As legend has it, Archimedes was tasked with determining whether a gold crown was a fake or not. It was known that sometimes goldsmiths would swindle their clients by mixing gold with a less expensive metal, like silver, to save money while still selling it at an exorbitant rate, but there was no known way to determine the amount of gold in a sample. On a trip to the public baths, Archimedes realized that the more he sank into the water, the more the water level rose and was displaced. He realized that different substances displace water different amounts, uncovering the forces of buoyancy and different densities of gold and silver! Realizing this discovery, the story goes that Archimedes leapt out of the bath and ran through the streets naked crying "Eureka!" ("I've found it!"), though the authenticity of this part of the story is up for debate!

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Label this diagram (representative of the stick of butter) with your measurements and show the density calculation:

V = l x w x h



- What is the density of water? (This can be looked up online or in a textbook, or calculated by measuring the volume and mass.)
- We know that the density of water is 1 g/mL. Is the density of the butter less than, equal to, or greater than the density of water? Does this mean that the butter will float, hover in the middle, or sink if we put it in the bowl of water?
- Draw a model of where the butter will go when added to the water. Was your prediction correct?

Notes

EXPLAIN

What's happening in this Activity?

First review the Density Background section to gain a deeper understanding of the scientific principles behind this activity.

In this activity, we calculate the **density** of a sample and predict whether it will sink or float in water. Because density equals **mass** divided by **volume**, to calculate density the mass and volume of a substance need to be determined. The mass is calculated with a scale or by using the provided mass of the butter. The volume is calculated using the length, width, and height of the stick of butter. After calculating and recording these measurements, we determine that the density of butter is lower than that of water, indicating that the butter will float in the water.

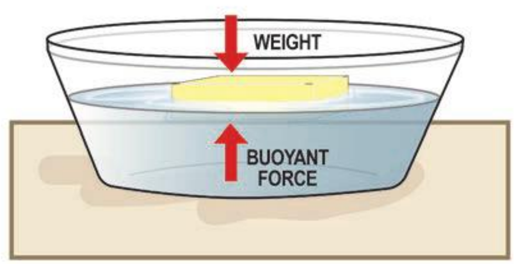
If many students are measuring the dimensions of the butter, you'll notice that not everyone gets the same measurements or calculations. Scientists are always striving to get measurements that are both **accurate** and **precise**.

- **Accuracy** means how close a measurement is to a known, standard value. In this case, we know that a stick of butter typically has a mass of 110 grams, a volume of 121 mL, and therefore a density of 0.911 g/mL. The closer your numbers are to these standard measurements, the more accurate they are.

- **Precision** is how close a measurement is to others that were taken, or how easy it is to get the same value multiple times. If you measure the length of a stick of butter multiple times and get very close to the same number each time, your answer is precise. It is best practice to repeat measurements until precision is reached. For example, if you measure the length of the butter three times and get the results of 8.1 cm, 9.6 cm, and 6.0 cm, your measurements are not very precise. If you get measurements of 8.2 cm, 8.1 cm, and 8.3 cm, your measurements are more precise. You can take the average of these numbers to use for your calculations. If your measurement is precise, it is less likely the result of experimental error, and more likely to be accurate.

The goal is always to get a measurement that is both accurate (close to the correct value) and precise (consistent in your measurements).

While conducting this experiment you might observe that when a stick of butter is added to water, some of it remains above the water line and some is below. The butter comes to rest in this position due to the force of buoyancy. **Buoyancy** is the upward force that a fluid (liquid or gas) exerts on an object.



The strength of the force of buoyancy of a fluid is dependent on its density: the denser it is, the stronger buoyancy is, too. An example of this is swimming in fresh water versus salt water. The Dead Sea is a body of water with a high salt content, which makes it easier for people to float in the water. The high salt content gives the liquid a greater density because there is more mass per volume in the water. This means a stronger buoyant—or upward—force, making it easier for people to float.

EXPLAIN continued

The force of **gravity**—which is dependent on the mass of an object and therefore on the density of the object—pulls objects to the Earth's center, and buoyancy pushes in the opposite direction. Depending on the strength of these forces, the object may sink, float, or rest at a specific place within the fluid. Ultimately, the force of gravity is directly related to the density of the object and the buoyant force is directly related to the density of the fluid, so both forces determine whether an object will float or sink in a fluid.

If you conducted this experiment in a narrow container, you might have noticed that the water level rose when the butter was added. If you push the butter deeper into the water you see that the water level continues to rise until the butter is fully submerged. This is a demonstration of **displacement**, which is when an object takes up space in a fluid and pushes the fluid that was there out of the way. As the butter moves into the space where the water used to be, the water is forced out of the way—or displaced—and the volume of the system (water and butter) increases.

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED

For younger students, emphasize the following concepts:

- Testing predictions
- Instruments and units of measurement

DIVING DEEPER

For more advanced students, emphasize the following concepts:

- Density of solids and liquids
- Buoyancy: buoyant forces and the force of gravity
- Displacement

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Skip the calculations and ask students to make predictions as to whether a variety of objects will sink or float. Do they notice anything that is similar between all of the objects that float and all of the objects that sink? What factors seem to cause something to sink or float?
- Cut the butter into various sizes so every sample is a different volume. Ask students to first make predictions as to which sample of butter will sink or float based on the size and shape. Use a scale to measure the mass and calculate the volume by calculating the height, width, and length of each sample. After they do some calculations they can make a prediction and test it by dropping their sample into water. Then have each group share the density they found with the whole class.
- Use a variety of objects that have the same volume but different masses (e.g., a cube of cream cheese, hard cheese, soft cheese, butter, margarine, various fruits, etc.; or inedible samples such as wooden and plastic blocks). What makes some of these objects float, and others sink?
- Have students calculate the density of water by measuring the mass and volume of a sample of water. How close are they to 1.00 g/mL? Ask them to brainstorm ways to make their measurements more accurate and precise.
- Use the data collected by the class to plot the mass versus volume of the stick of butter on a graph. Is there a pattern? Now do the same but with sticks of butter of different sizes (and shapes for more complicated volume calculations!). Is there still a pattern? Do you see a constant slope on the graph? What does that mean for the density of each sample? Remember that density is a ratio of mass to volume ($D = m/V$), so for any given sample of butter the density should be the same, which is why you see a constant slope (density) on the graph.
- Conduct the activity in a variety of liquids (e.g., oil, milk, soda water) or try different samples of water with a different amount of salt dissolved in each. Students can calculate the density of each liquid or just observe whether the butter floats or sinks. Ask students to design a method to make the butter sink in a liquid. Hint: If they can't find a liquid that is less dense than butter, is there a way to increase the mass per volume of the butter? Can they add a heavy object to the butter to make it sink? Ask students to calculate the new density.
- Get an air-tight container that can float in water. Have a variety of objects to put inside to change the overall mass. Ask the students to hypothesize which objects will cause the container to sink to the bottom of the water. Can they make a calculation that accurately predicts how much more mass needs to be added for it to sink? You can also have two containers with different surface area but the same internal volume. Ask the students if the shape of the container will affect its ability to remain afloat. How do buoyancy and displacement change as more objects are added?

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

Challenge your students to determine how huge boats made of metal can float. Then, explain that the massive weight of the boat is spread out over a large area, thus it has a large volume, making it possible to float in water. The concepts of density and buoyancy are vital to the development of large ships such as aircraft carriers, cargo ships, and cruise ships.

Life jackets are made in different sizes to accommodate different sized people. As your mass increases you want to have the right jacket on to keep you buoyant in the water.

Single-stream recycling processes rely on different densities to separate each type of material, or different plastics from one another. Machines move objects to different parts of the process based on their densities so they can be recycled and reused in the appropriate way.

Buoys are used in the water as anchored floats to help with navigation or to mark hazards in the water, among other uses. A floating buoy must be designed so that part of it stays below water, and other parts above water. Different shapes, materials, and masses are used to achieve the ideal density and buoyancy.

Careers in Chemistry

- Soap manufacturers use chemistry to figure out if their soap will sink to the bottom of a tub or float on the surface. Some soap has extra air whipped into the formula so it will float in water and it is easier to retrieve dropped soap from a tub!
- Anything that goes in the water is designed by scientists with density and buoyancy in mind: boats, buoys, submarines, floating piers or docks, diving equipment, and more. An example is a "buoyancy compensator," which is a piece of equipment used for professional underwater diving. The device has a bladder that can hold air, and the diver adjusts the bladder to establish the right amount of buoyancy during a dive so they can either descend into the water or float to the top.

EVALUATE

- Provide students with a series of rectangular prisms or cubes. You can use matchboxes with different objects in them, various wood samples, or anything else that can readily be measured for mass and volume. Ask students to conduct their measurements, calculate density, and see if they can accurately predict whether the objects will sink or float in water.
- Challenge students to go home and make a list of objects that sink, float, or hover around the middle of a glass of water. They can draw their answers in a diagram and label the picture, or make it into a matching or fill-in-the-blank game they can play with a partner in class the next day. Were there any that surprised them? Why?
- Design a research project to better understand how engineers create ships that stay afloat in the water. Ask students to research the materials used on ships and the properties of the materials. What are the densities of the metals used? Where can this information be found online? What precautions are taken to ensure that the ship stays afloat in the water? Challenge them to design their own ship that can carry a 1 kg weight without sinking. Who can do this using the cheapest materials? The least amount of materials? With the smallest ship?

Fun Fact #3

Sulfur hexafluoride (SF_6) is a gas that is almost five times as dense as air. It is so dense that a solid sheet of aluminum can float on top of it!

Liquid Rainbow

Section **PROPERTIES OF MATTER** *Topic* **DENSITY**

Estimated Time Setup: 15 minutes; Procedure: 15–20 minutes

OVERVIEW

Students will explore the properties of density and solubility through a challenge to make a liquid rainbow.

How can we determine relative densities of saltwater solutions? In this activity, students will try to layer different colored saltwater solutions in a straw. If they layer the solutions correctly they will create five distinct layers of color to make a liquid rainbow!

INQUIRY QUESTIONS

Getting Started:

- How do properties of a liquid change when it is mixed with other substances?

Learning More:

- How can we determine relative densities of liquids?

Diving Deeper:

- What happens at the molecular level when salt is added to water to create a solution?

CONTENT TOPICS

This activity covers the following content topics: measurements, instruments, density, properties of matter, solubility, miscibility

This activity can be extended to discuss: environmental science (weather, oceans), polarity, properties of solutes and solvents, saturation

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:

- **2-PS1-1:** Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.
- **5-PS1-3:** Make observations and measurements to identify materials based on their properties.
- **MS-PS1-1:** Develop models to describe the atomic composition of simple molecules and extended structures.

MATERIALS

For one setup:

- 6 clear plastic cups
- Food coloring – yellow, green, red, blue
- Measuring cups – ½ cup and 1 cup
- Measuring spoons – ½ teaspoon and 1 teaspoon
- Transparent drinking straws
- Salt

Optional materials:

- 5 pitchers or large containers

ACTIVITY NOTES

This activity is good for:

- Pairs
- Small groups
- Advanced students

Safety Tips & Reminders:

- This activity requires some dexterity and quick hands! It might not be appropriate for young students, but can be done as a demonstration for them instead.
- Be sure to do this activity on a waterproof surface and to have paper towels nearby.
- Review the Safety First section in the Resource Guide for additional information.

ENGAGE

Use the following ideas to engage your students in learning about density:

- See if it is easier for different objects to float in some solutions than in others! Prepare the solutions from the procedure and try out a variety of objects to see which will float or sink in different solutions. Tell students that all solutions are a mixture of salt and water, and ask them to discuss and explain why some objects behave differently in different solutions. A raw egg, for example, will float in the saltwater solution with the highest density, but not in the solution with lowest density.
- Ask students what happens when you drop an ice cube into a glass of water. Explain that the ice cube first will drop into the water due to gravity, but then will rise up to the surface because of the buoyancy of the ice in the water and the differences in density. Ice is less dense than water, so it will float.

See more ideas for engagement in the Density Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

Fun Fact #1

Salt is used to keep sidewalks free of snow and ice in cold climates. The more salt that is added to water, the lower the freezing point. With the maximum amount of salt dissolved in water, the freezing point can be as low as 0 °F or −17.8 °C. That means that even when the temperature outside is below the freezing point of water, the salt on the sidewalk will make the snow and ice into a liquid!

EXPLORE

Procedure:

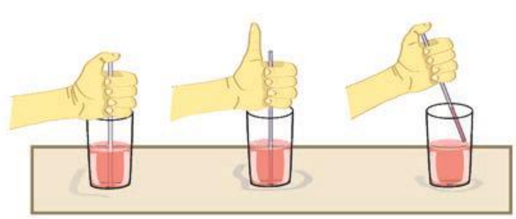
Prepare five salt solutions as described below, choosing an option on the basis of the group size and whether students will perform this activity individually or in teams. If preparing the solutions in large pitchers, fill the clear cups from the pitchers to a depth of at least 5 cm.

OPTION 1			OPTION 2		
Cup # and food coloring (3–5 drops)	**Water (cups)**	**Salt (tsp)**	**Pitcher # and food coloring (25–40 drops)**	**Water (cups)**	**Salt (tsp)**
1 – yellow	1	0	1 – yellow	16	0
2 – green	1	1.5	2 – green	16	1.5
3 – none (clear)	1	3	3 – none (clear)	16	3
4 – red	1	4.5	4 – red	16	4.5
5 – blue	1	6	5 – blue	16	6

Note: 16 cups of water is equal to 1 gallon of water.

Provide each student or group with six cups total, five filled with each of the solutions prepared as outlined above, and one empty as a "waste" cup. Do not indicate to students the amount of salt that is in each cup. Instruct students to layer the different colors inside a straw to create a liquid rainbow using the following steps:

1. Take a straw and press your thumb over the opening on one side.
2. Holding the straw straight down, place it into the first cup so the open end of the straw is close to touching the bottom of the cup.
3. While holding it in place perpendicular to the bottom of the cup, quickly lift your thumb off of the opening and cover it again. This should allow a small amount of the liquid to go into the straw. This might take some practice to get right!
4. With your thumb still over the top of the straw and some of the first solution inside, carefully remove the straw from the cup and place it straight down into the second cup. Again, remove and replace your thumb quickly over the straw opening so a small amount of liquid goes into the straw.
5. Observe what occurs between solutions and record your observations.
   - If the second solution is less dense, it is likely to mix with the first solution as it attempts to move to the top of the first solution.
6. Discard the 2 solutions in the waste cup.
7. Continue this process until you are able to layer all five solutions in a straw. Test 2 or 3 solutions at a time and use those comparisons to determine the order of the solutions from least to most dense.
   - Each layer pulled into the straw will be smaller than the first, because the pressure of the layers already in the straw will only allow a small amount of the next solutions to enter the straw.
   - To layer all five solutions, you should begin layering with the least dense solution and end with the densest solution.

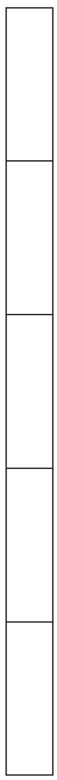


DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Draw your "liquid rainbow" and label each layer.
- Calculate the density of the blue water before and after adding the salt.
- Are the densest solutions at the bottom or the top of the straw? Explain your thinking. Draw a model of what you think the particles look like in each part of the rainbow.

Top



Bottom

EXPLAIN

What's happening in this Activity?

First review the Density Background section to gain a deeper understanding of the scientific principles behind this activity.

In this activity, we layer a series of samples based on their densities. We know that **density** is a measure of how compact a substance is, meaning how much matter is in a certain amount of space. The greater the density, the more matter is present per unit of volume. The smaller the density, the less matter is present per unit of volume. This is also represented with the formula **Density = mass/Volume**, or **D = m/V**.

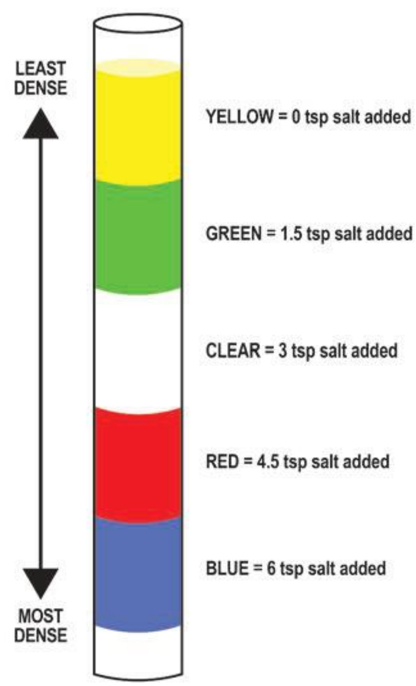
The density of water is 1 g/mL. As we add salt to a sample of water, the mass increases. The mass in the cup is now the mass of the water plus the mass of the salt. It may look like the salt disappears, but it is dissolved in the water, creating a saltwater solution.

A **solution** is a liquid mixture where one substance (called the **solute**) dissolves into a liquid (called the **solvent**). The solute is evenly distributed in the solvent, so the mixture is the same throughout the liquid. A sample taken from the bottom of the cup will be the same as a sample taken from the top. A mixture that is mixed evenly throughout, such as a solution, is a **homogenous mixture**. In this activity, salt is the solute and water is the solvent. When they are put together, we see that salt is **soluble** (able to dissolve) in water, and it makes a homogenous solution of salt water.

As you add salt to the cup, notice that you do not see the volume increase. This is because salt is soluble—it breaks down and dissolves in water. When it is a solid on its own, salt (NaCl) has a crystalline structure. This means that Na^+ and Cl^- ions are arranged in a large network. When salt dissolves, this crystal structure breaks down. The Na^+ and Cl^- ions dissolved in water take up much less space than the Na+ and Cl– in a crystal structure. The amount of space the dissolved ions take up is so small that it can be treated as no change at all.

The mass of the sample increases as salt is added, but the volume does not increase. As more salt is added the density increases because there is more matter (mass) in the same amount of space (volume). The more salt is added to a cup of water, the higher its density.

Notes



EXPLAIN continued

We also know that if we mix **fluids** (liquids, gases) and they have different densities, they will form layers with the highest density sample on the bottom and lowest density sample on the top. In this case (and with some practice!) we can layer the saltwater samples on top of one another from lowest to highest density to make a "liquid rainbow!"

You might notice that after some time your "liquid rainbow" becomes less defined and the colors start to mix together. This is because we are working with solutions of salt water, and they are **miscible** (mixable) with one another. Even though the amount of salt varies, when put together they easily mix to form another homogenous solution.

In the blue solution, there may be some solid salt crystals at the bottom of the cup that did not dissolve. Why does this happen? Even if a substance is soluble in a liquid, only a certain amount can dissolve in a given volume. The maximum amount of solute that can dissolve in a solvent is the **saturation point**. If a solution is **saturated**, that means no more solute can go into the solvent. Any solute added after a solution is saturated will stay an undissolved solid. Luckily, there are ways to increase the saturation point, like increasing the temperature of the solvent. You can try it for yourself: can hot or cold water dissolve more salt?

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED	DIVING DEEPER
For younger students, emphasize the following concepts: • Mixtures—homogeneous and heterogeneous • Measurements and instruments • Density	**For more advanced students, emphasize the following concepts:** • Solubility, miscibility • Saturation • Polarity • Solutes and the properties of their solvent—freezing point depressions, boiling point elevation

Fun Fact #2

The Dead Sea, which is located in the Middle East, has a very high concentration of salt. Its density is so great that anyone can float, almost lie, in the water. The reason it has such a high concentration of salts is because of its extremely low elevation—salts and minerals flow into the Dead Sea, and then remain there when the water evaporates.

Notes

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- This activity can be tricky to perform if you do not have steady hands! A modification for younger students is to make a mini "graduated cylinder" using a few inches of a clear straw stuck in some clay. You can add each sample into the "graduated cylinder" carefully using an eyedropper and see if the solutions layer or mix, which will provide clues to the densities.
- Students can calculate the density of each sample by measuring the mass on a scale and volume in a graduated cylinder, then dividing the mass by the volume. Have them make predictions based on their calculations before trying the experiment.
- Conduct the experiment again but try different solutes dissolved in water, such as sugar, baking soda, or Epsom salt. If you use an equal amount of water and add an equal amount of solute to each sample, what do you notice when you make your rainbow?
- Calculate saturation point by seeing how much salt you can put into a sample of water until no more salt will dissolve. Record this as the grams of salt (mass of solute) that dissolved per liter of water (volume of solvent). Try this out with other solutes (e.g., sugar), with water of different temperatures, or with different volumes of water. What do you notice? How does each factor affect saturation point?
- Which is more soluble: salt or sugar? Ask students to pair up and get two equal cups of water along with samples of salt and sugar. Add the salt to one cup and sugar to the other, teaspoon by teaspoon, keeping track of how much is added and dissolved. Which solute dissolves better? Will the samples have the same or different densities?

EVALUATE

- Relate this experiment to what happens naturally in our oceans. The salinity (salt concentration) of water in the ocean increases with depth. Why does this happen? What does this mean for the plants and animals that live in either shallow or deep water? How have they adapted to this environment? How do ships stay afloat and divers sink down?
- Have students research bodies of water with high salinity (e.g., the Dead Sea, Great Salt Lake). How are they formed? If you went swimming in these bodies of water would you float more or less? Why?
- Have students find foods in their home with salt content listed on the label (soup, canned vegetables, etc.). What foods did they find that have salt as a solute? What are some other solutes in foods and drinks around their house?

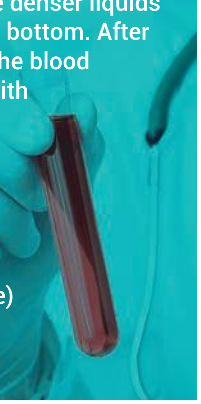
CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

The density of ice is 0.92 g/mL and the density of salt water in the ocean is around 1.025 g/mL. This means than an iceberg in the ocean is slightly less dense than the seawater, so it should float. Typically, 10% of an iceberg is visible above the water, and the other 90% is hidden below the surface!

When someone donates blood, it needs to be separated into its different components: plasma, white blood cells, and red blood cells. Each of these substances has a different medical use, and also a different density. The blood sample is placed in a centrifuge, which spins the sample around very fast so that the denser liquids quickly settle to the bottom. After being centrifuged, the blood sample is layered with red blood cells (most dense) on the bottom, white blood cells (middle density) in the middle, and plasma (least dense) on top.



Careers in Chemistry

- Water chemistry is important in an aquarium. Scientists must achieve the proper salinity of water (salt concentration) so that the marine life will live happily! Different marine organisms can thrive with different amounts of salt in their living space.

Dancing Raisins

Section **PROPERTIES OF MATTER** *Topic* **DENSITY**

Estimated Time Setup: 5 minutes; Procedure: 10 minutes

OVERVIEW

Students will explore the concepts of density and solubility as they watch raisins "dance" in a glass of soda water or pop.

What makes the raisins "dance" or causes them to sink and float? In this activity, students observe as bubbles form in a carbonated liquid. The bubbles cling to each raisin because of its textured surface, lowering the density of the raisin and air bubbles together until the raisin floats to the surface. As the bubbles pop and reform, the raisins "jump" and "dance" in the glass.

INQUIRY QUESTIONS

Getting Started:
- What causes an object to sink or float?

Learning More:
- Where do the bubbles in a carbonated drink come from and where do they go?

Diving Deeper:
- Why are gases released from carbonated liquids at certain sites?

CONTENT TOPICS

This activity covers the following content topics: density, carbonation, solubility, buoyancy

This activity can be extended to discuss: environmental science (weather, oceans), food science, equilibrium

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:
- **2-PS1-1:** Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.
- **5-PS1-3:** Make observations and measurements to identify materials based on their properties.
- **MS-PS1-1:** Develop models to describe the atomic composition of simple molecules and extended structures.

MATERIALS

For one setup:
- Tall, clear glass or plastic cup
- Clear soda (This can be soda water, pop, or any other carbonated beverage; it should be cold for the experiment to work best.)
- Raisins

ACTIVITY NOTES

This activity is good for:
- Demonstrations
- Small groups
- Large groups

Safety Tips & Reminders:
- Be sure to either give the seltzer time to settle or to pour the seltzer into a glass before starting the experiment and adding the raisins in slowly. Otherwise, when you drop the raisins in it will release a lot of gas and you might get sprayed!
- Even though this activity uses edible food, there is no eating or drinking in the lab.
- Review the Safety First section in the Resource Guide for additional information.

Fun Fact **#1**

Most raisins you see are a dark purple color. These are raisins from red grapes. Raisins that are yellow in color are produced from green grapes.

ENGAGE

Use the following ideas to engage your students in learning about density:

- Have the raisin and soda pop mixture ready before class, and ask students to either guess what is in it or explain what is happening.
- Have one glass of water and one glass of soda. Ask your students to predict what will happen when the raisins are dropped into each cup. Then drop the raisins in and observe. Ask students why the raisins behave differently in the water and in the soda.

See more ideas for engagement in the Density Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

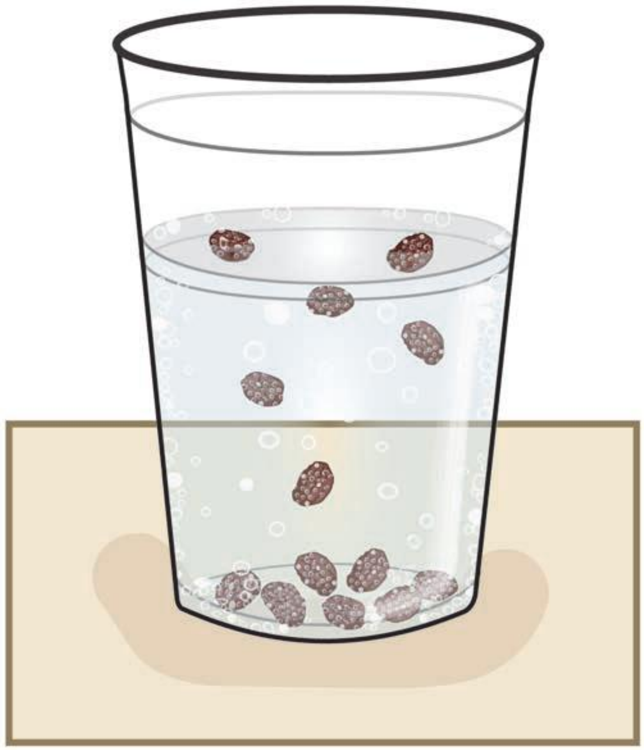
Fun Fact #2

Soda water is often called "seltzer." The word seltzer comes from the German town Selters, which is known for its mineral springs that were originally found in the year 1000 CE! In 2014 the world's oldest bottle of corked Selters water was found in the Baltic Sea. The bottle is believed to be at least 200 years old!

EXPLORE

Procedure:

1. Fill a glass with soda.
2. Drop a few raisins into the glass and turn on the music!
3. Observe what you see and draw or record your observations.



Notes

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Draw a picture of the bottle of soda pop before it is opened and after it is opened. Make note of what sounds you hear and what changes are visible.
- Look closely at each raisin. What do you notice about the ones that are moving?
- Describe the movement of the raisins when they are dropped in the soda pop. What forms on the surface of the raisins? Where it is coming from? Where does it go? Explain using evidence.

Notes

EXPLAIN

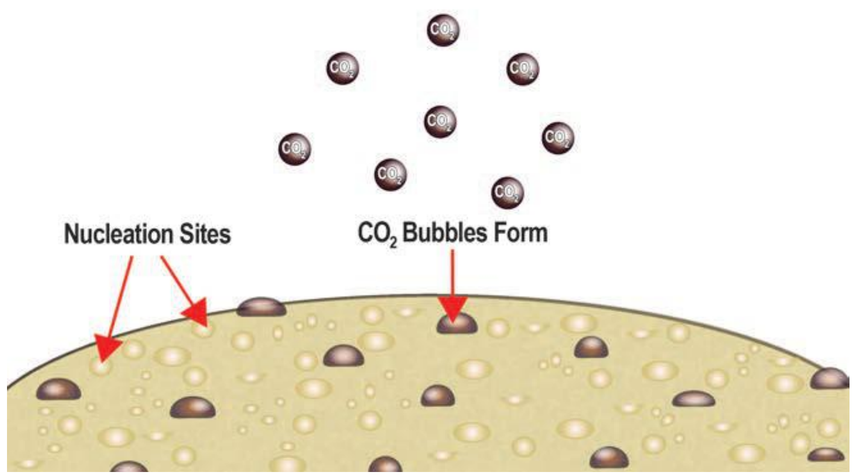
What's happening in this Activity?

First review the Density Background section to gain a deeper understanding of the scientific principles behind this activity.

In this activity, we explain how and why the raisins in the soda water "dance," or move up and down in the container. The moving raisins can be explained by a combination of carbonation and density. **Carbonation** is the process of adding carbon dioxide (CO_2) to water. Carbon dioxide is **soluble** (able to dissolve) in water. Once carbon dioxide is dissolved in water, it is no longer a gas. Instead, it exists as dissolved carbonic acid, or H_2CO_3. However, as we learned in the Liquid Rainbow activity, there is still a limit to how much can dissolve. The amount that can dissolve depends on a number of factors, including pressure.

Increasing the pressure of a liquid increases the amount of gas that can be dissolved in it. The carbon dioxide stays in the water as carbonic acid because it is under high pressure in a sealed bottle, and more gas can dissolve at a higher pressure. Once the bottle is opened, we observe the carbon dioxide released into the air, and hear a familiar hissing sound of gas escaping. The pressure decreases when the bottle is opened, so less gas can stay dissolved in the same amount of liquid. The extra carbonic acid that the liquid can no longer hold forms back into carbon dioxide gas, creating bubbles and floating to the top of the bottle.

Where do these carbon dioxide bubbles form in the liquid? Notice that most of the bubbles form on the raisins and on the inside walls of the container, rather than being spread evenly throughout the liquid. There are strong interactions (known as hydrogen bonds) between water molecules, and forming a bubble is difficult because it requires disrupting those bonds, or interactions. A bubble is not likely to just form in the middle of a liquid, it needs something to build on—think of it like a meeting place for carbon dioxide molecules. The areas where the bubbles form are called nucleation sites. **Nucleation sites** are places where there are microscopic imperfections (tiny flaws) in a material, such as scratches or dirt, which allow gas particles to come together. Every place in the container where bubbles form is a small imperfection, and a raisin's bumpy surface holds tons of ideal nucleation sites! This is why so many bubbles form on the raisins in the soda water. A raisin or an imperfection was already disrupting the interactions between solute water molecules, so it is easier for bubbles to form there.



Density is a measure of how compact a substance is. This means how much matter is in a certain amount of volume, and it is represented by the formula **Density = mass/Volume (or D=m/V)**. When an object is placed in a liquid, it will sink if its density is greater than the density of the liquid, and float if its density is less than the density of the liquid. A raisin drops to the bottom of a glass of soda water because its density is greater than that of the soda.

EXPLAIN continued

The raisins are only able to rise to the top of the liquid once there are many bubbles of carbon dioxide on them. Gases usually have a lower density than liquids or solids because the particles in a gas are more spread out. As the bubbles form on the raisins, the volume is rapidly increasing for each raisin since the bubbles take up space. But the mass is not increasing much because the gas bubbles have low mass. From our formula for density, we know that if the volume increases more than the mass increases, the density will decrease. Eventually, the density decreases enough that the raisin and attached bubbles rise to the top of the liquid. Once the raisin reaches the surface, the carbon dioxide bubbles pop and the gas is released into the air. Without the gas, the raisin once again has its original density and sinks back to the bottom.

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED

For younger students, emphasize the following concepts:

- Density—different substances have different masses and volumes, giving them characteristic properties, like density
- Carbonation and solubility—gases can be dissolved in liquids

DIVING DEEPER

For more advanced students, emphasize the following concepts:

- Solubility
- Buoyancy
- Equilibrium—CO_2 can dissolve in water via the following equilibrium reaction:
  $CO_2(g) + H_2O(l) \leftrightharpoons H_2CO_3(aq)$

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- If you don't have cold carbonated liquids, you can fill a glass halfway with water and then add one tablespoon of baking soda. Stir until it dissolves completely. Add vinegar to fill the cup and add in raisins. This is similar to the reaction in the Exploding Bags activity. As the reaction slows down, add more of the reactants (baking soda and vinegar) to start it back up! Note that the chemistry behind this is slightly different, because the bubbles are being created by a chemical reaction rather than an equilibrium reaction with a dissolved gas.
- Try replacing the soda pop or the raisins with different liquids and solids. What happens when the liquid has a different level of carbonation, or when it has no carbonation? Do you see the same thing happen? What about if you use M&Ms®, pennies, or grapes instead of raisins? Why might they not behave the same way?
- Ask students to make predictions for what would happen if the raisins were flattened, or if many of them were squished together. What predictions can we make? What works better, smaller or larger raisins? Test it out and see!
- Try the experiment again but this time put a lid on the bottle or cup after a few minutes. What effect might this have and why?
- Try the experiment with samples of soda pop at different temperatures: cold, room temperature, and warm. What do you notice? Why might this happen? How does temperature affect the amount of gas dissolved in a liquid? Check out the two Activity Guide experiments Balloon in a Bottle and The Great Escape to better understand what is happening.
- This activity works best with raisins that are old and dried out. Why might that be the case?
- Connect to the Fountain of Soda Pop activity! Explore nucleation sites further by doing this activity with your students.

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

The same concepts of density, displacement, and buoyancy can be observed when young children wear "floaties" in pools. The air in the floaties increases the overall volume of the child, so that the child weighs less than the water displaced. As a result, the child floats more easily in water.

Water contains dissolved oxygen from which fish and other aquatic animals extract the oxygen they need as the water flows past their gills. Humans lack the ability to breathe underwater and have developed oxygen tanks to allow them to stay underwater for long periods. People are able to breathe underwater by using pressurized gas tanks that provide oxygen for divers to breathe.

The ocean naturally absorbs about one-fourth of the atmospheric carbon dioxide humans produce each year, which is converted into carbonic acid when dissolved. The concentration of carbonic acid in the oceans is increasing because of increased atmospheric carbon dioxide in the atmosphere. The increase in ocean acidity has many negative consequences for sea life, such as inhibiting corals from establishing reefs and dissolving animal shells.

Careers in Chemistry

- Food scientists need to understand carbonation of drink products. While mineral water naturally has carbonation, drinks such as tonic water and seltzer water have the carbonation added artificially. Food chemists determine how much carbonic acid to add to the water in order to achieve their desired product.
- Ships and submarines use ballasts filled with air to help them sink or float as needed. Ship captains will order for the ballast to be opened to allow water in when they need to sink below the surface, and open a compressed air valve that pushes air into the ballast (and water out) when they need to reach the surface again.

EVALUATE

- Have students explain the steps in this activity and why the raisins behaved in a certain way at the start, middle, and end of the experiment. See if they can use new vocabulary, such as density, buoyancy, sink, float, volume, mass, and more!
- What connections can students make to the world around them? Ask groups of students to make a drawing or comic strip to show these concepts in the real world. Some examples could be a child using floaties in a pool, or inflating balloons with helium. What other examples can they think of?
- Ask students to try this activity again at home with a variety of different liquids and solids. Create a worksheet where they can write their observations before, during, and after the experiment. Which objects "danced" the fastest? Slowest? Why might that be?