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

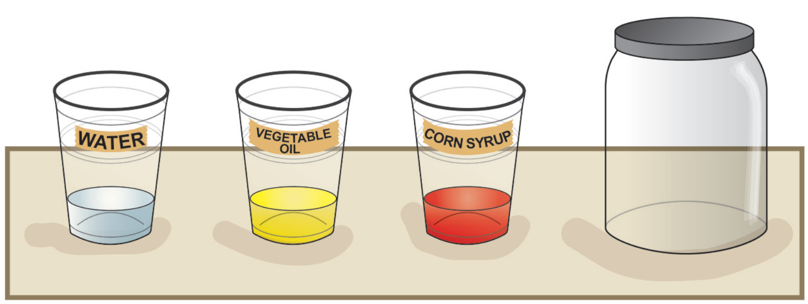
4. Add 1/3 cup vegetable oil to a third cup.
5. In a fourth cup, add 1/3 cup of light corn syrup and two drops of red food coloring, then stir until combined.
6. Add the corn syrup mixture to the oil. Observe and record the results.

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!

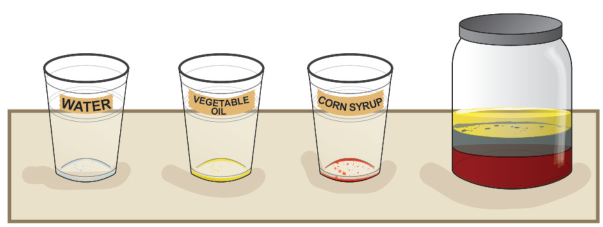
EXPLAIN

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

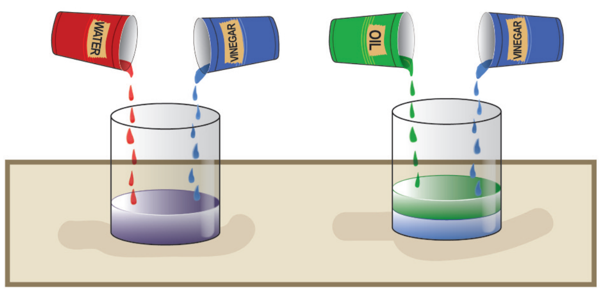
But why do the liquids form layers instead of mixing together? And why do the samples separate out again after they are mixed together? This happens because of a property of matter called **miscibility**. If two substances are **miscible** (think of "mixable") it means that they easily mix together to 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.



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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

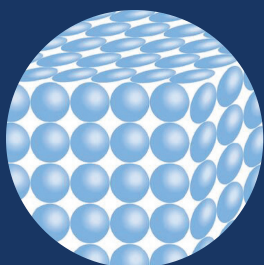
You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

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

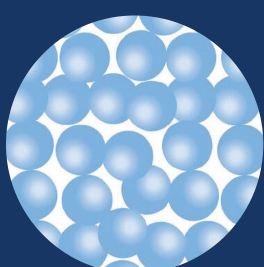
Notes

Fun Fact #2

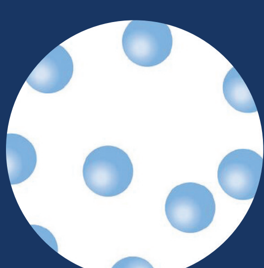
The density of ice is 0.92 g/mL which is less than that of water, 1.00 g/mL. This is why ice cubes float in glass of water. Most solids are denser than their liquid form, but water's unique molecular structure causes particles to be more spaced apart as a solid, and closer together as a liquid:



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

SICK SCIENCE EXPERIMENTS, SUMMER SCIENCE

KID-FRIENDLY PATRIOTIC LAYERED DENSITY DRINKS FOR 4TH OF JULY

By Blog Editor Susan Wells

From STEVE Spangler Science

As you know, all of us at The Spangler Labs enjoy a good liquid density column. Our 9-Layer Density Tower is shared across the internet. It is one of our most popular Pinterest experiment pins. We are always looking for new combinations of liquids to stack (we have a lot of free time).

One popular density column found around the internet is a summer drink recipe perfect for the 4th of July. We are going to focus on kid-friendly recipes.

This red, white and blue drink recipe uses a little science to delicately stack different drinks on top of each other. Your guests will think it's magic, you will know it's really science at work.

The different colored drinks are stacked by sugar density. The heaviest, or most sugary drink goes on the bottom, followed by the next sugary and ending with the least sugary. When choosing red, white and blue drinks, look at the sugar content per serving. Many bottles use an 8-ounce serving, while others use a 12-ounce serving. The bigger the difference between sugar contents, the better. A drink with 18 grams of sugar stacked on a drink with 21 grams may mix more than 18 grams of sugar on top of 40 grams of sugar. There are a lot of calorie or sugar-free drinks available. These are best for the top liquid.

Types of Drinks Used and Sugar Content

- Berry Blue Propel Zero – 0g
- Black Raspberry Red Glaceau Fruit Water Sparkling zero calorie – 0g
- Cool Blue Gatorade – 21g per 12oz serving
- Fruit Punch Gatorade – 21g per 12oz serving
- Pina Colada SoBe – 25g per 8oz serving
- Berry Lemonade Blue Jones Soda – 41g per 12oz serving
- Fruit Punch Welch's Chillers – 30g per 8oz serving
- Squirt Soda – 38g per 12oz serving

Most Sugar

Some Sugar

No Sugar

Step by Step for Stacking

1. Refrigerate the drinks before starting so the ice doesn't melt as you pour.
2. Fill glass with ice to the top.
3. Pour the heaviest or highest sugar content drink first.
4. Slowly and carefully pour the next highest sugar content drink. Pour or drizzle it into the ice or along the side of the glass to reduce splashing and mixing.
5. Pour the lightest or lowest sugar content drink on top.
6. Enjoy!

Learning Opportunities

Take your kids with you to the grocery store and compare sugar contents in different drinks. Ask a few questions while you are there.

- Why are the 0 grams of sugar drinks also calorie free?
- How many sugar packets equal the grams of sugar in each drink?
- Why are drinks with 0 grams of sugar still sweet?
- Why does the sugar content give the drinks different densities?
- Are drinks with 0 grams of sugar healthier or better for you?