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:

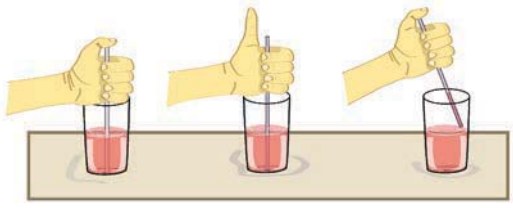
Prepare five salt solutions as described below, choosing an option on the basis of the group size and whether students will perform this activity individually or in teams. If preparing the solutions in large pitchers, fill the clear cups from the pitchers to a depth of at least 5 cm.

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.

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**.

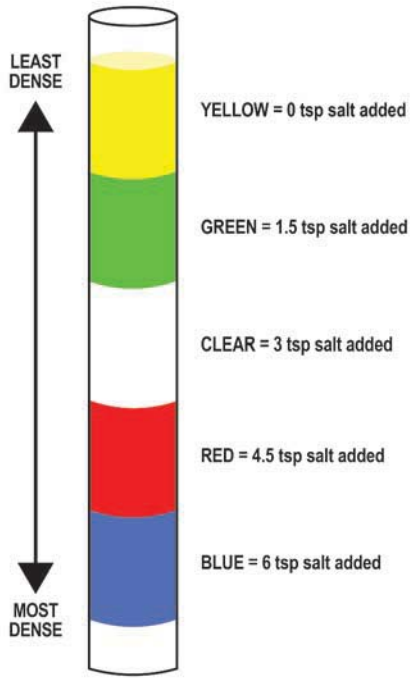
The density of water is 1 g/mL. As we add salt to a sample of water, the mass increases. The mass in the cup is now the mass of the water plus the mass of the salt. It may look like the salt disappears, but it is dissolved in the water, creating a saltwater solution.

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?

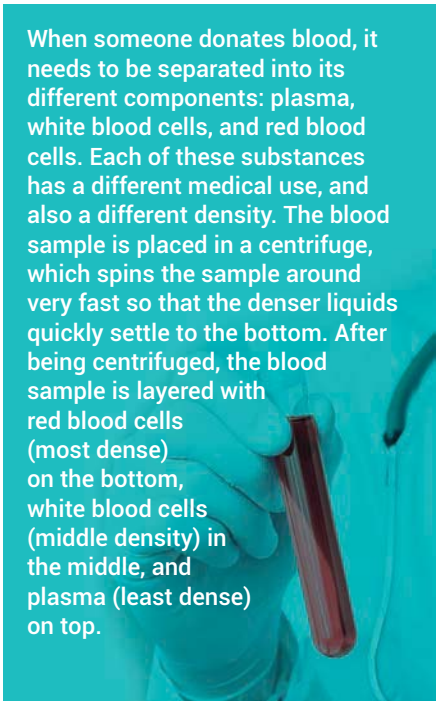
CHEMISTRY IN ACTION

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.