LESSON 12: Density Totem

ESTIMATED TIME **Setup:** 5 minutes | **Procedure:** 10–15 minutes

• DESCRIPTION

Create layers of oil, corn syrup, and water to explore density and mixtures.

• OBJECTIVE

This lesson introduces the concept of density by combining oil, corn syrup, and water in a container. Students pour corn syrup, then water, and finally oil into a container and observe as the liquids form three separate layers. The lesson can be extended to introduce solutions and solubility.

• CONTENT TOPICS

Scientific inquiry; measurement; properties of matter (density); mixtures (solutions)

To reduce waste, you can do the experiment, or part of it, as a demonstration.

• MATERIALS

- ❑ Clean 16-oz clear plastic or glass jars with lids or clean clear plastic bottles with lids
- ❑ Clear plastic cups
- ❑ Blue and red food coloring
- ❑ Spoons for mixing
- ❑ Vegetable oil
- ❑ Light corn syrup
- ❑ Water
- ❑ Measuring cup

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 391–393 for more detailed information about safety in the classroom.

Jump ahead to page 156 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter

OBSERVATION & RESEARCH

BACKGROUND

Mass and volume are common units of measure. Mass is a measure of the amount of matter in a substance. It's the amount of "stuff" in a substance. Volume is the amount of space an object occupies. Mass and volume can be used to determine another useful physical property—density.

Density is an important concept in chemistry that is defined as the mass of an object per unit volume. Density is a physical property of matter that describes how closely packed together the atoms or molecules of a substance are. The formula used to calculate density is **d = m/v**, where d is the density, m is the mass of the object, and v is the volume of the object. Scientists use density in different ways. They use it to identify unknown substances and to separate different liquids.

The approximate density of pure water is 1.0 gram per milliliter (g/mL). This means that one milliliter of water will have a mass of one gram and, therefore, weigh one gram on the earth. In general, a substance that is less dense than water will rest on top of the water, and a substance that is denser than water will sink.

Among the liquids used in this experiment, corn syrup is the densest substance, followed by water, and then oil.

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When these substances are gently added together in a container, they will form layers based on their density. Therefore, the syrup will rest on the bottom, water will be suspended in the middle, and the oil will rest on top.

FORMULAS & EQUATIONS

Density is the mass of an object per unit of volume. The density of an object can be calculated using the following equation:

d = m/v

Density is measured in grams per milliliters or grams per cubic centimeters. One cubic centimeter (cm^3 or cc) is equal to one milliliter (mL).

Tap water is a mixture of pure water, minerals, and other substances.

The chemical formula for pure water is **H_2O**.

Triglycerides are the main component of vegetable oil. A triglyceride is a chemical compound formed from one molecule of glycerol and three fatty acids. Triglycerides have lower densities than water. When solid, they are called "fats" or "butters"; when liquid, they are called "oils." Vegetable oils have a density of approximately 0.9 g/mL.

Corn syrup is a sweet syrup produced by milling corn into cornstarch and then putting the cornstarch through the process of acid hydrolysis. The density of corn syrup is approximately 1.4 g/mL. Corn syrup is almost entirely made of dextrose, a sugar. Dextrose is also known as glucose.

High-fructose corn syrup (HFCS) is different from regular corn syrup. HFCS, an ingredient in many snacks and soft drinks, is a combination of glucose and fructose, generally with about 55% fructose.

The chemical formula for dextrose (glucose) is **$C_6H_{12}O_6$**.

The chemical formula for fructose is **$C_6H_{12}O_6$**.

Dextrose (glucose) and fructose are structural isomers, which means that their chemical formula is the same, but their atoms are arranged in a completely different order.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mass, volume, and density can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶Corn syrup, vegetable oil, and water have different densities and will form layers with the least dense liquid resting on the top and the densest liquid on the bottom.

Fun Fact

Bone density is a medical term that describes the amount of mineral content in a certain volume of bone. It is measured using a special X-ray and used to diagnose the bone disease osteoporosis.

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DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Conduct the experiment as described on page 156, but spend more time on measurement. Have students take different measurements of the liquids if you have the necessary equipment. For example, measure the mass of a $^1/_3$ measuring cup on a balance. Then, add the liquid to the measuring cup, and measure the mass again. Have the students subtract the mass of the measuring cup from the mass of the cup with the liquid inside to figure out the mass of the liquid. Then have students calculate the density of the liquid using the density formula. Inform students that $^1/_3$ cup is equal to approximately 78 mL.

If you don't have the necessary equipment, discuss how they could find the mass and volume of the substances, and then use some examples to practice calculating density.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Add oil, corn syrup, and water to a container to form three separate layers as a result of density differences.

OBJECTIVE

This lesson introduces the concepts of density and solubility by combining oil, corn syrup, and water in a container. Students pour corn syrup, then water, and finally oil into a container and observe as the liquids form three separate layers.

OBSERVATION & RESEARCH

Mixtures are all around us, and many can be found in our kitchens! A **mixture** is made of two or more substances that are combined physically. When you combine peanut butter and jelly on bread, you create a mixture. A solution is a specific type of mixture. A **solution** is a uniform mixture in which one or more substances (solutes) are dissolved in another substance (solvent). Dissolving sugar in water creates a solution. The solute is sugar, and the solvent is water.

In addition, **solubility** is a physical property that describes the ability of a chemical substance (the solute), to dissolve in a solvent to create a uniform solution. A substance that dissolves in another substance is **soluble**. For example, sugar and salt are soluble in water. If a substance does not dissolve, it is **insoluble**. For instance, butter is insoluble in water. A **miscible** liquid is a liquid that will mix in all proportions to become a uniform solution. On the other hand, oil and water are **immiscible**; they will not mix.

Density is an important concept in chemistry that is defined as the mass of an object per unit volume. Density is a physical property of matter that describes how closely packed together the atoms or molecules of a substance are. The formula used to calculate density is **d = m/v**, where d is the density, m is the mass of the object, and v is the volume of the object. Scientists use density in different ways. They use it to identify unknown substances and to separate different liquids.

If a solution with a lower density is added to a solution with a greater density, the less dense solution will rest on top of the denser solution. On the contrary, if a solution with a greater density is added to a solution with a lower density, the higher density solution will naturally fall to the bottom. However, if the two solutions are soluble or miscible, as the denser solution moves through the less dense solution, they will mix.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mixtures and solutions can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on density can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on solubility can be found in the Chemicals by Volume—Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.

LESSON 12: Density Totem

DIFFERENTIATION IN THE CLASSROOM

Among the liquids used in this experiment, corn syrup is the densest substance, followed by water, and then oil. When these substances are gently added together in a container, they will form layers based on their density. Therefore, the syrup will rest on the bottom, water will be suspended in the middle, and the oil will rest on top.

Oil and water are immiscible, so they will not mix. On the other hand, corn syrup, which is essentially sugar, is soluble in water. When the water is carefully added to the denser corn syrup, they do not mix right away because of their different densities. However, if you put the lid tightly on your density totem and shake it, all three substances will mix together. If you then let the container sit for a few minutes, the oil will separate out and rise back to the top, but the corn syrup and water will be permanently mixed together. Shaking the density totem causes the corn syrup to dissolve in the water.

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If other substances of different densities are added, will the results change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Add $^1/_3$ cup of water to two clear plastic cups. Add two drops of blue food coloring to each cup of water and stir.
2. Carefully add $^1/_3$ cup of corn syrup to the first cup of water. Then, add $^1/_3$ cup of vegetable oil to the second cup of water.
3. Make a prediction: What do you think will happen if you combine corn syrup and vegetable oil?
4. Test your prediction by putting $^1/_3$ cup of oil in the third plastic cup. Next, in a measuring cup, add two drops of red food coloring to $^1/_3$ cup of corn syrup, and add this mixture to the oil in the plastic cup.
5. Carefully dispose of the liquids in your three plastic cups. (Do not pour the oil down the drain. Collect the oil and allow it to solidify—freeze it to speed up the process. Then, put it in the trash.) Wash the cups and dry them.
6. Next, pour $^1/_3$ cup of oil into one of the clean plastic cups, $^1/_3$ cup of water into the second plastic cup, and $^1/_3$ cup of corn syrup into the third plastic cup.
7. Add two drops of blue food coloring to the cup of water, and add two drops of red food coloring to the cup of corn syrup. Stir both cups.
8. Pour the liquid that you think will remain on the bottom into one of the clear glass jars. Carefully add the next liquid that should rest on the bottom liquid. Don't stir! Finally, pour in the liquid that you think will rest on top of the other two liquids.

If using the higher level differentiation material:

1. Repeat steps 6–8 to make a second density totem using the other jar.
2. Put the lids tightly on both jars and shake up the contents of one of the jars. Compare the two jars.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. For example, which substance was the densest? Which substance was the least dense? You can use the table provided in the activity sheet (or a similar one of your own) for students to record their data.

LESSON 12: Density Totem

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Describe and identify different types of measurements, such as mass and volume.
- Calculate the density of a solution if given mass and volume.
- Understand density and why liquids of different densities can be layered.
- Compare and contrast mixtures and solutions (see ***Differentiation in the Classroom***).
- Define and identify solutions, solutes, and solvents (see ***Differentiation in the Classroom***).
- Explain solubility and identify soluble and insoluble substances (see ***Differentiation in the Classroom***).
- Give example of miscible and immiscible substances (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternate methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples or have a discussion to generate other ideas as a class.

- Try out other liquid combinations, such as oil and vinegar or water and vinegar. The oil will rest on top of the vinegar because vinegar has a density of almost 1 g/mL. Therefore, the density of water and vinegar are about the same.

K-4 See **Lesson 23: Buoyant Butter** for another introductory lesson on density.

5-8 See **Lesson 19: Liquid Rainbow** for a more complex lesson on density.

REAL-WORLD APPLICATIONS

- Some people make their own oil and vinegar salad dressing—a vinaigrette. Oil and vinegar are insoluble, so they will not naturally mix together. When the liquids are added together, the oil will rest on top of the vinegar because the oil is less dense. However, continuously shaking the bottle of dressing will cause the liquids to mix temporarily, creating a special type of mixture known as an emulsion.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 12 ACTIVITY SHEET: Density Totem

OBSERVE & RESEARCH

1. Write down the materials you see. _____

_____

_____

2. How might these materials be used? _____

_____

_____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mass		
Volume		
Density		

4. Consider what will happen when corn syrup, vegetable oil, and water are added together in a jar and why.

▶**Write your hypothesis.** _____

_____

_____

LESSON 12 ACTIVITY SHEET: Density Totem

PERFORM YOUR EXPERIMENT

1. Add 1/3 cup of water each to two clear plastic cups. Add two drops of blue food coloring to each cup of water and stir.
2. Carefully add 1/3 cup of corn syrup to the first cup of water. Then, add 1/3 cup of vegetable oil to the second cup of water.
3. Make a prediction: What do you think will happen if you combine corn syrup and vegetable oil?
4. Test your prediction. Put 1/3 cup of oil in the third plastic cup. Next, in a measuring cup, add two drops of red food coloring to 1/3 cup of corn syrup. Then, add this mixture to the oil in the plastic cup.
5. Carefully dispose of the liquids in your three plastic cups. (Do not pour the oil down the drain. Collect the oil and allow it to solidify—freeze it to speed up the process. Then, put it in the trash.) Wash the cups and dry them.
6. Next, pour 1/3 cup of oil into one of the clean plastic cups. Pour 1/3 cup of water into the second plastic cup. Pour 1/3 cup of corn syrup into the third plastic cup.
7. Add two drops of blue food coloring to the cup of water. Add two drops of red food coloring to the cup of corn syrup. Stir each solution.
8. Pour the liquid that you think will remain on the bottom into one of the clear glass jars. Carefully add the next liquid that should rest on top of the bottom liquid. Don't stir! Finally, pour in the liquid that you think will rest on top of the other two liquids.

ANALYZE & CONCLUDE

1. Record your observations in the table below.

	Cup 1: Water and Corn Syrup	Cup 2: Water and Vegetable Oil	Cup 3: Corn Syrup and Vegetable Oil	Jar: Water, Corn Syrup, and Vegetable Oil
Record the order of the substances in the cup/jar.	**Top:** **Bottom:**	**Top:** **Bottom:**	**Top:** **Bottom:**	**Top:** **Middle:** **Bottom:**
Which of the substances is the densest?				

LESSON 12 ACTIVITY SHEET: Density Totem

2. What happens when you add corn syrup to the first cup of water? _____

_____

_____

3. What happens when you add vegetable oil to the second cup of water? _____

_____

_____

4. Predict what will happen when corn syrup and vegetable oil are added together in a plastic cup? Explain.

_____

_____

_____

5. Was your prediction correct? What happens when you add corn syrup to the cup of vegetable oil? _____

_____

_____

6. Which substance is the least dense? _____

7. Which substance is the densest? _____

8. Is your hypothesis valid? Why or why not? If not, what would be your next steps? _____

_____

_____

LESSON 12 ACTIVITY SHEET: Density Totem

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture		
Solution		
Soluble		
Insoluble		
Miscible		
Immiscible		

2. What happens to the three liquids when you shake the jar? Why? _____

_____

_____

3. What does the formation of a purple layer tell you about the liquids? _____

_____

_____

LESSON 12 ACTIVITY SHEET: Density Totem

ANSWER KEY *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you see. Glass jars, plastic cups, food coloring, spoons, vegetable oil, light corn syrup, water, measuring cup …

2. How might these materials be used? Glass jars and plastic cups may be used to hold a substance. Food coloring may be used to dye a substance. Spoons may be used to eat a food or stir a substance. Vegetable oil, light corn syrup, and water may be used in cooking. These materials may be combined to compare the properties of the oil, corn syrup, and water.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mass	A measure of the amount of matter in a substance.	
Volume	A physical property that measures the amount of space a substance occupies.	
Density	A physical property of matter that describes how closely packed together the atoms of an element or the molecules of a compound are; the amount of matter per unit of volume (d = m/v).	

4. Consider what will happen when corn syrup, vegetable oil, and water are added together in a jar and why.

▶ **Write your hypothesis.** Corn syrup, vegetable oil, and water have different densities and will form layers, with the least dense liquid resting on the top and the densest liquid on the bottom.

LESSON 12 ACTIVITY SHEET: Density Totem

ANSWER KEY *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Add 1/3 cup of water each to two clear plastic cups. Add two drops of blue food coloring to each cup of water and stir.
2. Carefully add 1/3 cup of corn syrup to the first cup of water. Then, add 1/3 cup of vegetable oil to the second cup of water.
3. Make a prediction: What do you think will happen if you combine corn syrup and vegetable oil?
4. Test your prediction. Put 1/3 cup of oil in the third plastic cup. Next, in a measuring cup, add two drops of red food coloring to 1/3 cup of corn syrup. Then, add this mixture to the oil in the plastic cup.
5. Carefully dispose of the liquids in your three plastic cups. (Do not pour the oil down the drain. Collect the oil and allow it to solidify—freeze it to speed up the process. Then, put it in the trash.) Wash the cups and dry them.
6. Next, pour 1/3 cup of oil into one of the clean plastic cups. Pour 1/3 cup of water into the second plastic cup. Pour 1/3 cup of corn syrup into the third plastic cup.
7. Add two drops of blue food coloring to the cup of water. Add two drops of red food coloring to the cup of corn syrup. Stir each solution.
8. Pour the liquid that you think will remain on the bottom into one of the clear glass jars. Carefully add the next liquid that should rest on top of the bottom liquid. Don't stir! Finally, pour in the liquid that you think will rest on top of the other two liquids.

ANALYZE & CONCLUDE

1. Record your observations in the table below.

	Cup 1: Water and Corn Syrup	Cup 2: Water and Vegetable Oil	Cup 3: Corn Syrup and Vegetable Oil	Jar: Water, Corn Syrup, and Vegetable Oil
Record the order of the substances in the cup/jar.	**Top:** Water **Bottom:** Corn syrup	**Top:** Vegetable oil **Bottom:** Water	**Top:** Vegetable oil **Bottom:** Corn syrup	**Top:** Vegetable oil **Middle:** Water **Bottom:** Corn syrup
Which of the substances is the densest?	Corn syrup	Water	Corn syrup	Corn syrup

LESSON 12 ACTIVITY SHEET: Density Totem

ANSWER KEY *Below are suggested answers. Other answers may also be acceptable.*

2. What happens when you add corn syrup to the first cup of water? When you add corn syrup to water, the corn syrup falls to the bottom of the cup.

3. What happens when you add vegetable oil to the second cup of water? When you add vegetable oil to water, the vegetable oil rests on the top of the water.

4. Predict what will happen when corn syrup and vegetable oil are added together in a plastic cup? Explain.

Answers will vary.

5. Was your prediction correct? What happens when you add corn syrup to the cup of vegetable oil? Answers to predictions will vary. When you add corn syrup to the vegetable oil, the corn syrup falls to the bottom of the cup and does not mix with the vegetable oil.

6. Which substance is the least dense? Vegetable oil is the least dense.

7. Which substance is the densest? Corn syrup is the densest.

8. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 12 ACTIVITY SHEET: Density Totem

ANSWER KEY *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture	A physical combination of two or more substances that can be physically separated.	
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Soluble	The ability of a substance to dissolve in another substance.	
Insoluble	The inability of a substance to be dissolved into another substance.	
Miscible	The ability to mix evenly; the ability to mix in all proportions to form a homogeneous solution.	
Immiscible	The inability to mix evenly; the inability of two or more substances to form a homogeneous mixture when combined.	

2. What happens to the three liquids when you shake the jar? Why? All three liquids will mix when the jar is shaken, but the vegetable oil will separate from the other solutions when the jar is set back down. However, the water and the corn syrup will remain mixed because the corn syrup is soluble in water.

3. What does the formation of a purple layer tell you about the liquids? The formation of a purple layer tells us that the water, dyed blue, and the corn syrup, dyed red, mix because the corn syrup is soluble in water. Shaking the jar causes these substances to mix.