LESSON 7: Milk Rainbow

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

DESCRIPTION

Create swirls of color in milk and explore a property of liquids known as surface tension.

OBJECTIVE

This lesson will demonstrate the property of surface tension and the effect that soap, a surfactant, has on the surface tension of milk. Students will apply soap to milk with food coloring on the surface to visualize the effect of soap on the surface tension of milk. The lesson can be extended to discuss a type of mixtures called emulsions.

CONTENT TOPICS

Scientific inquiry; states of matter; properties of matter; attractive forces (surface tension); mixtures

MATERIALS

- ❑ Whole milk
- ❑ Waterproof plate or shallow bowl
- ❑ Food coloring
- ❑ Liquid dish soap
- ❑ Cotton swabs

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 95 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
- PS1.B: Chemical Reactions
- PS2.A: Forces and Motion
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Matter exists primarily as a solid, liquid, or gas on the earth. Solids have a definite volume and a definite shape. Examples of solids are chairs, books, and trees. Liquids have a definite volume but no definite shape. Examples of liquids are water and orange juice. Gases have no definite shape and no definite volume. Examples of gases are the oxygen we breathe and the helium that fills balloons.

Along with differences in shape and volume, the different states of matter have other unique properties. For example, surface tension is a property of liquids that describes the attraction of liquid particles at the surface. The strong attraction of particles at the surface of the liquid creates a surface "film" that makes moving an object through the surface of a liquid more difficult than moving the object when it is completely submerged in the liquid. Surface tension is also the reason liquids tend to keep a low surface area. For example, water droplets will tend to form into a sphere rather than spreading out flat.

Milk is a white liquid produced by female mammals and is the primary source of nutrition for young mammals

LESSON 7: Milk Rainbow

until they can digest other foods. Humans, especially children, often consume the milk of other mammals as a part of their diet. In the United States, cow's milk is produced on an industrial scale and is the most commonly consumed form of milk. Milk is made mostly of water, but it also contains vitamins, minerals, fats, and proteins.

Water has a very high surface tension because of strong attractions between the water molecules (hydrogen bonding). Because milk is primarily water, it also has a high surface tension. In this experiment, the high surface tension of the milk supports the dye molecules on the surface and keeps the dye relatively centralized. (The tendency to keep a low surface area minimizes the distance that the dye will spread across the milk's surface.)

In contrast, soap is a surfactant. A **surfactant** (or surface active agent) is a substance that has the ability to reduce the surface tension of a liquid. Therefore, when a drop of liquid dish soap is added to milk, the surface tension of the milk is reduced. As this occurs, the fat (butterfat) and protein particles in the milk can move more freely and easily. In addition, the soap interacts with the fat and protein particles in the milk, causing the particles to move around. This action can be seen as the dye swirls through the milk.

FORMULAS & EQUATIONS

Milk is a liquid made mostly of water, but it also contains vitamins, minerals, fats, and proteins. Milk is a unique substance known as a colloid, so it does not have a specific chemical formula. A **colloid** is a mixture in which very small particles are spread evenly through another substance. In milk, the fat globules, proteins, vitamins, and minerals are spread throughout the water.

The molecules that make up soaps and detergents have two main parts (ends) that behave differently. One end of a soap molecule is attracted to water, while the other components are repelled by water but attracted to fats.

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 states of matter and properties of matter, including surface tension, can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶When drops of liquid dish soap are added to milk with drops of food coloring on the surface, the soap will reduce the surface tension of the milk and react with the fat. This interaction will cause the particles in the milk to move around and create swirls of color.

Fun Fact

The fat content of milk depends on the type of milk (skim, whole, etc.) and the type of cow. Holstein-Friesian cows tend to produce milk with a lower percentage of butterfat than Jersey cows.

LESSON 7: Milk Rainbow

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Use **Lesson 15: Floating Paper Clips** to introduce the concept of surface tension. Then, perform this experiment to add some color to the lesson and explore the concept further!

Pour small drops of water on a plate to illustrate surface tension. Students should notice that the water does not spread out completely. Instead, it will form droplets, and those droplets will attract other small droplets to form larger "puddles."

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Examine the composition of the milk and how soap interacts with the components of the milk.

OBJECTIVE

This lesson examines the properties and composition of milk and uses soap to illustrate the effects of surfactants on the properties and components of milk.

OBSERVATION & RESEARCH

Most of the things around us are mixtures, like the air we breathe and the orange juice we drink! A **mixture** is made of two or more substances that are combined physically. Mixtures are generally classified as homogeneous or heterogeneous. A **homogeneous mixture** is a type of mixture that is considered to be the same throughout. Solutions, like apple juice, are homogeneous mixtures. A **heterogeneous** mixture is a type of mixture in which the makeup is not the same throughout. They are not evenly mixed. For example, pepperoni pizza and chicken noodle soup are heterogeneous mixtures. Not all mixtures, however, are simply homogeneous or heterogeneous.

Milk is classified as a **colloid**. A colloid is a mixture in which very small particles are spread evenly through another substance. It is a type of mixture between homogeneous and heterogeneous. Specifically, milk is a type of colloid called an emulsion. **Emulsions** consist of liquids spread through other liquids. The liquids in an emulsion do not completely mix like the particles in a solution do. Instead the particles of one liquid are suspended in the other. Emulsions generally have a cloudy appearance and will often separate if not continuously mixed. Examples of emulsions include mayonnaise and oil and vinegar salad dressing.

Milk is a natural emulsion of fats (oils) and proteins spread throughout water. Raw milk will eventually separate, with the fat rising to the top. However, store-bought milk generally looks homogeneous. The reason is that most store-bought milk goes through a process called homogenization that breaks down the fat particles so the milk appears to have a uniform consistency.

Because milk is mainly made of water, it has properties similar to water, such as a high surface tension. **Surface tension** is a property of liquids that describes the attraction of liquid particles at the surface. The strong attraction of particles at the surface of the liquid creates a surface "film" that makes moving an object through the surface of a liquid more difficult than moving the object when it is completely submerged in the liquid.

Soap is a surfactant. A **surfactant** is a substance that has the ability to reduce the surface tension of a liquid. Therefore, when a drop of liquid dish soap is added to milk, the surface tension of the milk is reduced. As this occurs, the fat and protein particles in the milk can move more freely and easily. In addition, the molecules that make up soaps and detergents have two main parts (ends) that behave differently. The ends attracted to fat will move and clump together around the fat particles. As this movement occurs, the dye moves through the milk as well, creating colorful swirls in the milk.

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 properties of matter, mixtures, and colloids can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 7: Milk Rainbow

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 soap is not added to the milk, do the results change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Fill the plate with whole milk, and let the milk settle for a minute.
2. Add several drops of different food coloring close together, but separate, in the center of the plate of milk.
3. Dip a cotton swab in the liquid dish soap, and then touch the tip of the cotton swab to the milk's surface near the drops of food coloring. Observe the reaction.
4. Then, move the swab to different areas of the plate to initiate more reactions.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What happened when the dye was first added to the milk? What happened when the soap was added? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

NOTES

LESSON 7: Milk Rainbow

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.
- Differentiate between the different states of matter.
- Understand the property of surface tension.
- Describe the effect of soap, a surfactant, on surface tension.
- Describe the general composition of milk.
- Compare and contrast homogeneous and heterogeneous mixtures (see ***Differentiation in the Classroom***).
- Define and identify colloids (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative 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 the experiment using other types of milk, such as skim milk, and observe the results. You may also want to try other liquids, like water or oil. Are the results the same? Discuss why or why not?
- Set up the experiment as described in the lesson, but before adding the soap, try a different test first. Dip the cotton swab in water, and touch the cotton swab to the milk. Observe what happens. Likewise, if you put a water-soaked cotton swab in the middle of a dye droplet, what happens? Discuss these results with the class.

K-4 See **Lesson 26: Swimming Specs** for a simplified lesson on surface tension.

5-8 See **Lesson 15: Floating Paper Clips** for an introductory lesson on surface tension.

REAL-WORLD APPLICATIONS

- You may have seen commercials for liquid dish soaps that claim the soap has the ability to "cut the grease." Grease is mostly fat. While one part of the soap is attracted to water, other parts bind to the fat. Moving the soapy water around allows the soap to pull the grease away from the dishes or your hands, and be rinsed away by the water.
- Along with being homogenized, the milk found in most grocery stores has also been pasteurized. Pasteurization is a process of heating a food, usually a liquid, to a specific temperature and for a specific length of time to kill bacteria, molds, and yeast. This process was invented by French chemist and biologist Louis Pasteur in 1863 (see the ***Famous Chemist*** section in the ***Resource Guide***).

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 7 ACTIVITY SHEET: Milk Rainbow

OBSERVE & RESEARCH

1. Write down the materials you observe. _____

_____

_____

2. Predict how these materials may 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)
Solid		
Liquid		
Gas		
Surface tension		
Surfactant		

4. Consider how the addition of liquid dish soap will affect milk with food coloring on the surface and why.

▶**Write your hypothesis.** _____

_____

_____

LESSON 7 ACTIVITY SHEET: Milk Rainbow

PERFORM YOUR EXPERIMENT

1. Fill the plate with whole milk, and let the milk settle for a minute.
2. Add several drops of different food coloring close together, but separate, in the center of the plate of milk.
3. Dip a cotton swab in the liquid dish soap. Then, touch the tip of the cotton swab to the milk's surface near the drops of food coloring. Observe.
4. Try touching the cotton swab to different areas of the plate of milk to initiate more reactions.

ANALYZE & CONCLUDE

1. What happens when you first place the drops of food coloring on the milk's surface? _____

_____

_____

2. What happens to the food coloring when you touch the milk with the cotton swab soaked in soap? _____

_____

_____

3. What are the components of milk? (What makes up milk?) _____

_____

_____

4. What effect does the soap have on the surface tension of the milk? _____

_____

_____

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

_____

_____

LESSON 7 ACTIVITY SHEET: Milk Rainbow

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		
Homogeneous mixture		
Heterogeneous mixture		
Colloid		
Emulsion		

2. What other substances are considered surfactants? _____

_____

_____

3. Why do the components of grocery store milk not separate? _____

_____

_____

LESSON 7 ACTIVITY SHEET: Milk Rainbow

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

OBSERVE & RESEARCH

1. Write down the materials you observe. Milk, food coloring, liquid dish soap, cotton swabs ...

2. Predict how these materials may be used. Milk may be used for drinking. Food coloring may be used to make food products or other substances colorful. Liquid dish soap may be used to remove dirt and grease. Cotton swabs may be used as an applicator. These materials may be used together to explore physical properties.

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)
Solid	A state of matter characterized by a definite volume and a definite shape.	
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it.	
Gas	A state of matter that has no definite volume or shape.	
Surface tension	A property of liquids that describes the attraction of liquid particles at the surface; the strong attraction of particles at the surface of a liquid creates a surface "film."	
Surfactant	Any substance with the ability to reduce the surface tension of a liquid; also known as a surface active agent.	

4. Consider how the addition of liquid dish soap will affect milk with food coloring on the surface and why.

▶**Write your hypothesis.** When liquid dish soap is added to milk with drops of food coloring on the surface, the soap reduces the surface tension of the milk and reacts with the fat. This interaction causes the fat particles in the milk to move and create swirls of color.

LESSON 7 ACTIVITY SHEET: Milk Rainbow

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

PERFORM YOUR EXPERIMENT

1. Fill the plate with whole milk, and let the milk settle for a minute.
2. Add several drops of different food coloring close together, but separate, in the center of the plate of milk.
3. Dip a cotton swab in the liquid dish soap. Then, touch the tip of the cotton swab to the milk's surface near the drops of food coloring. Observe.
4. Try touching the cotton swab to different areas of the plate of milk to initiate more reactions.

ANALYZE & CONCLUDE

1. What happens when you first place the drops of food coloring on the milk's surface? When droplets of food coloring are placed onto the milk's surface, the food coloring stays suspended on the surface in a small area.

2. What happens to the food coloring when you touch the milk with the cotton swab soaked in soap? When you touch a cotton swab soaked in soap to the milk, the colors spread throughout the milk creating colorful swirls.

3. What are the components of milk? (What makes up milk?) Milk is made mostly of water, but it also contains vitamins, minerals, fats, and proteins.

4. What effect does the soap have on the surface tension of the milk? Soap is a surfactant, which reduces the surface tension of the milk and allows the food coloring to move around the milk.

5. 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 7 ACTIVITY SHEET: Milk Rainbow

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.	
Homogeneous mixture	A type of mixture that is considered to be the same throughout; the substances are evenly mixed.	
Heterogeneous mixture	A type of mixture in which the makeup is not the same throughout; the substances are not evenly mixed.	
Colloid	A mixture, between homogeneous and heterogeneous, in which very small particles are spread evenly throughout another substance.	
Emulsion	A colloid that consists of liquids spread throughout other liquids; the liquids in an emulsion do not completely mix and are often unstable.	

2. What other substances are considered surfactants? Other soaps and laundry detergents are examples of surfactants.

3. Why do the components of grocery store milk not separate? Raw milk will actually separate because it is an emulsion. However, most milk purchased at grocery stores goes through a process called homogenization. This process breaks down the fat in the milk so it has a more uniform consistency, which, in turn, keeps the components of milk from separating.