LESSON 17: Color Clouds

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

DESCRIPTION

Demonstrate the relationship between temperature and the process of diffusion by placing drops of food coloring in water with different temperatures.

OBJECTIVE

This lesson demonstrates the relationship between temperature and the rate of diffusion. Students place drops of food coloring in hot and cold water to observe the effect of temperature on the rate of diffusion. This lesson can be extended to address other ways to affect the rate of diffusion.

CONTENT TOPICS

Scientific inquiry; measurement (temperature); states of matter; properties of matter; energy; diffusion

MATERIALS

- ❑ Clear plastic cups
- ❑ Hot and cold water
- ❑ Red food coloring
- ❑ Blue food coloring
- ❑ Stopwatch (optional)

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 222 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
- 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 cups. **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. Liquids and gases are considered fluids. A **fluid** is any substance made up of particles that flow or move freely. A fluid easily changes shape when a force is applied.

For example, if you push on a balloon filled with gas, you can easily change its shape. Likewise, if you push on a balloon filled with water, you can change the water balloon's shape as well.

Diffusion is the movement of fluid particles from an area of high concentration to an area of low concentration. Different factors can impact the rate at which the particles diffuse, such as temperature. **Temperature** is a measure of the average kinetic energy (energy of motion) of particles in a substance. It is a measure of how fast the particles are moving around. The temperature of a substance is measured using a thermometer.

Energy is defined as the capacity to do work or produce heat. Energy can take many different forms, including

light, sound, electricity, chemical bonds, mechanical motion, and thermal energy. **Thermal energy** is the total energy of particles in a substance.

The transfer of thermal energy from an object at a higher temperature to an object at a lower temperature is known as **heat**. Thus, temperature, thermal energy, and heat are related, but they are not the same thing.

When temperature increases, the kinetic energy of the particles has increased. The increased motion of the particles causes them to diffuse faster. Therefore, at higher temperatures, the rate at which fluid particles will diffuse is faster than at lower temperatures. In the experiment, the food coloring will diffuse faster in the hot water than in the cold water.

FORMULAS & EQUATIONS

Food coloring is a type of food additive that makes the food a certain color (or makes the color more vibrant). People have been adding color to food for thousands of years to enhance the appeal of the food, either by making it look more familiar or vibrant in color or simply for decoration. Food colorings were initially developed using spices, crushed seeds, or even crushed insects. However, more recently, chemists have developed synthetic food colorings to create even brighter colors and colors that are hard to find in nature. Different colors and food-coloring products contain a variety of chemical compounds, so there is not one exact formula.

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

The chemical formula for pure water is $\mathbf{H_2O}$.

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 diffusion can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on temperature and energy can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶Drops of food coloring placed in hot water will diffuse faster than drops of food coloring placed in cold water because of the faster motion of particles in the fluid.

Fun Fact

Without diffusion, it would be almost impossible to smell anything.

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DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the experiment as described on page 222, but spend more time on states of matter. Have students identify the different states of matter for materials used in the experiment. What are the cups? Solids! What about the food coloring and water? Liquids! In addition, show pictures of different things or point out things in the classroom and have the students identify the states of matter.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Demonstrate the relationship between temperature and the process of diffusion by placing drops of food coloring in water with different temperatures.

OBJECTIVE

This lesson demonstrates the relationship between temperature and the rate of diffusion and addresses other factors that impact diffusion. Students place drops of food coloring in hot and cold water to observe the different rates of diffusion.

OBSERVATION & RESEARCH

Matter exists primarily as a solid, liquid, or gas on the earth. Liquids and gases are considered fluids. A fluid is any substance made up of particles that flow or move freely. A fluid easily changes shape when a force is applied. For example, if you push on a balloon filled with gas, you can easily change its shape. Likewise, if you push on a balloon filled with water, you can change the water balloon's shape as well.

Diffusion is the movement of fluid particles from an area of high concentration to an area of low concentration. Different factors can impact the rate at which the particles diffuse, such as temperature, distance, and the concentration gradient.

Concentration gradient refers to the difference between the concentration of the two fluids. If the concentration gradient is zero, diffusion will not occur. If there is a large difference between the concentration of one fluid and the concentration of the other, then the particles will diffuse faster. In the experiment, the dye particles in the food coloring are very concentrated. When placed in the water, they will diffuse through the water where there are no dye particles.

Likewise, the distance the particles travel affects the rate of diffusion. Over short distances, such as through a small cup of water, fluid particles will diffuse faster than in a large pool of water.

In addition, temperature is a measure of the average kinetic energy (energy of motion) of particles in a substance. It is a measure of how fast the particles are moving around. The temperature of a substance is measured using a thermometer. Energy is defined as the capacity to do work or produce heat. Energy can take many different forms, including light, sound, electricity, chemical bonds, mechanical motion, and thermal energy.

Thermal energy is the total energy of particles in a substance. The transfer of thermal energy from an object at a higher temperature to an object at a lower temperature is known as heat. Thus, temperature, thermal energy, and heat are related, but they are not the same thing.

When temperature increases, the kinetic energy of the particles has increased. The increased motion of the particles causes them to diffuse faster. Therefore, at higher temperatures, the rate at which fluid particles will diffuse is faster than at lower temperatures. In the experiment, the food coloring will diffuse faster in the hot water than in the cold water.

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 diffusion can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry.*
- Additional information on temperature and energy can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

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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 the temperature of the water changes, do the results change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Fill one cup ¾ full with hot tap water.
2. Fill another cup ¾ full with cold tap water.
3. Then, at the same time, put two drops of red and two drops of blue food coloring gently into the water in each cup. You will need two people to make sure the drops go into each cup at the same time.
4. Observe what happens in each cup over the next 5–10 minutes. Diffusion is complete when the solutions are uniformly purple.

If a heating device is not readily available in the classroom, heat the water prior to class, and store it in a hot beveragve thermos to keep it as warm as possible.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. For example, what states of matter are used in the lesson? In which cup does the food coloring diffuse the fastest? You can use the chart provided in the activity sheet (or similar charts of your own) for students to record their observations.

NOTES

LESSON 17: Color Clouds

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.
- Compare and contrast solids, liquids, and gases and give examples of each.
- Define and give examples of fluids.
- Explain the process of diffusion.
- Define and differentiate between temperature, thermal energy, and heat.
- Understand the effect of temperature on the rate of diffusion.
- Explain other factors that influence the rate of diffusion (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.

- Before the experiment, ask your students if they can define diffusion. Explain the process and then ask if they can give examples of diffusion (perfume, cooking, chlorine added to a pool, etc.).
- Use a stopwatch to record the rate of diffusion. The time should be started when the second drops of food coloring touch the water. The time should be recorded for each cup once the water is uniformly purple.

REAL-WORLD APPLICATIONS

- Osmosis is a special example of diffusion. **Osmosis** is the diffusion of water across a semi-permeable membrane (a membrane that allows some ions or molecules to pass through but not others). Cell membranes allow water to pass in and out, but prevent the passage of certain unwanted solutes.
- The odor of cooking food diffuses through the air in the kitchen, allowing us to smell the food as it cooks. If the kitchen is open to other rooms, people are likely to soon smell the food in other rooms as the odor continues to diffuse through the air. You'll be able to smell the food better in the kitchen and nearby rooms because it has to travel less distance and is more concentrated.

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 17 ACTIVITY SHEET: Color Clouds

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)
Solid		
Liquid		
Gas		
Fluid		
Diffusion		
Temperature		
Energy		
Thermal energy		
Heat		

LESSON 17 ACTIVITY SHEET: Color Clouds

4. Consider how temperature might affect the rate of diffusion of food coloring in water and why.

▶**Write your hypothesis.** _____

_____

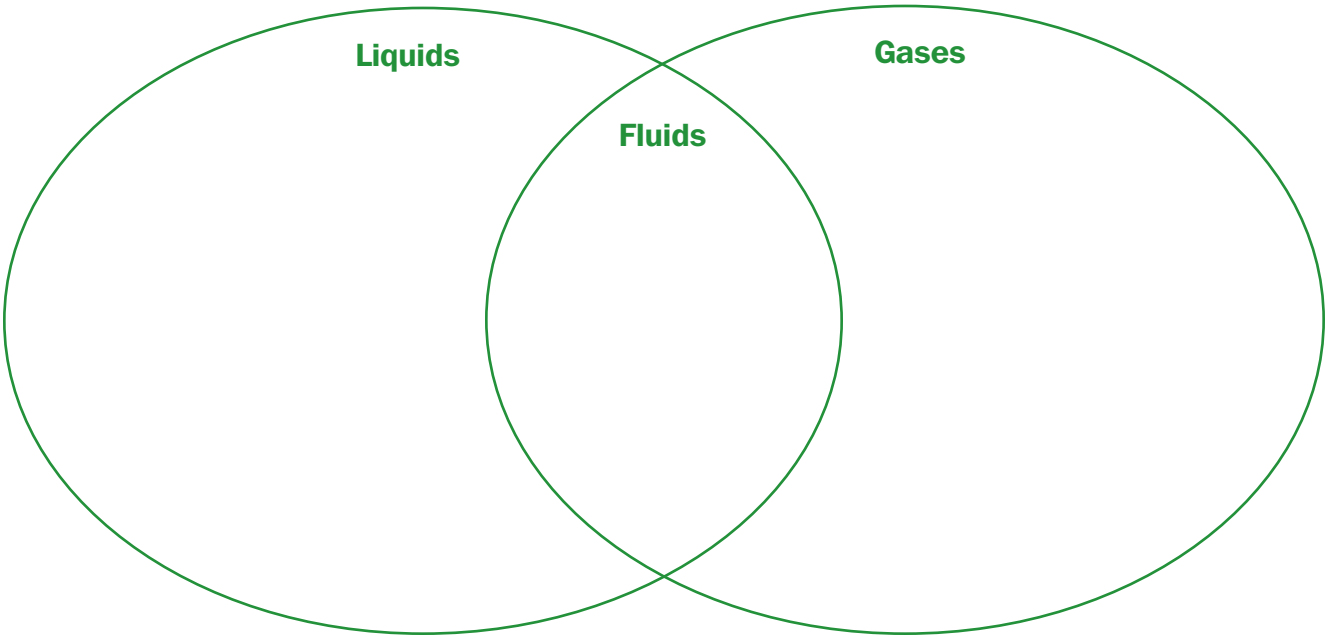
_____

PERFORM YOUR EXPERIMENT

1. Fill one cup ¾ full with hot tap water.
2. Fill another cup ¾ full with cold tap water.
3. Then, work with a partner to add food coloring to the cups. Put two drops of red and two drops of blue coloring into one cup. Your partner will do the same in the other cup. Make sure you and your partner add the drops at the same time.
4. Watch what happens in each cup over the next 5–10 minutes.

ANALYZE & CONCLUDE

1. In the Venn diagram below, compare and contrast the properties of liquids, gases, and fluids.



LESSON 17 ACTIVITY SHEET: Color Clouds

2. What happens when you add food coloring to the cup of hot water? _____

_____

_____

3. What happens when you add food coloring to the cup of cold water? _____

_____

_____

4. In which cup does the food coloring diffuse (spread out) faster? Why? _____

_____

_____

5. Circle the correct response: In general, the rate of diffusion ***increases / decreases*** as temperature increases.

6. List other examples of diffusion. _____

_____

_____

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

_____

_____

LESSON 17 ACTIVITY SHEET: Color Clouds

EXPAND YOUR KNOWLEDGE—ADVANCED

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

Term	Definition	Example (write or add image)
Concentration gradient		

2. Circle the correct response: Liquids and ***solids / gases*** can undergo diffusion.

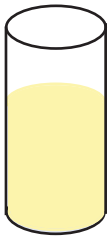
3. What other ways could you increase the rate of diffusion? _____

_____

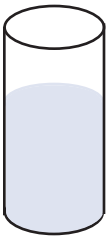
_____

4. Solution A is added to the glass of water shown below. Solution A will diffuse in the water. Using colored pencils, crayons, or markers, show what the combined solution will look like once diffusion is complete.

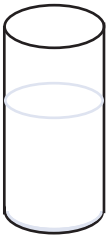
Solution A



Water



Combined Solution



LESSON 17 ACTIVITY SHEET: Color Clouds

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

OBSERVE & RESEARCH

1. Write down the materials you see. Plastic cups, hot and cold water, blue and red food coloring …

2. How might these materials be used? Plastic cups may be used to hold a substance. Water may be used to drink, bathe, or clean. Food coloring may be used to dye a substance. The food coloring may be added to water at different temperatures to observe the effects of temperature on diffusion.

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 that has 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, filling the bottom first.	
Gas	A state of matter that has no definite volume or shape; a gas will take the shape of the container that holds it, filling the entire container.	
Fluid	Any substance made up of particles that flow or move freely, such as a liquid or gas.	
Diffusion	The movement of particles from an area of high concentration to an area of low concentration.	
Temperature	A measure of the average kinetic energy of particles in a substance, generally identified by sensations of hot and cold.	
Energy	The ability to do work or produce heat.	
Thermal energy	The total energy of particles in a substance.	
Heat	The flow or transfer of thermal energy from one substance to another because of differences in temperature.	

LESSON 17 ACTIVITY SHEET: Color Clouds

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

4. Consider how temperature might affect the rate of diffusion of food coloring in water and why.

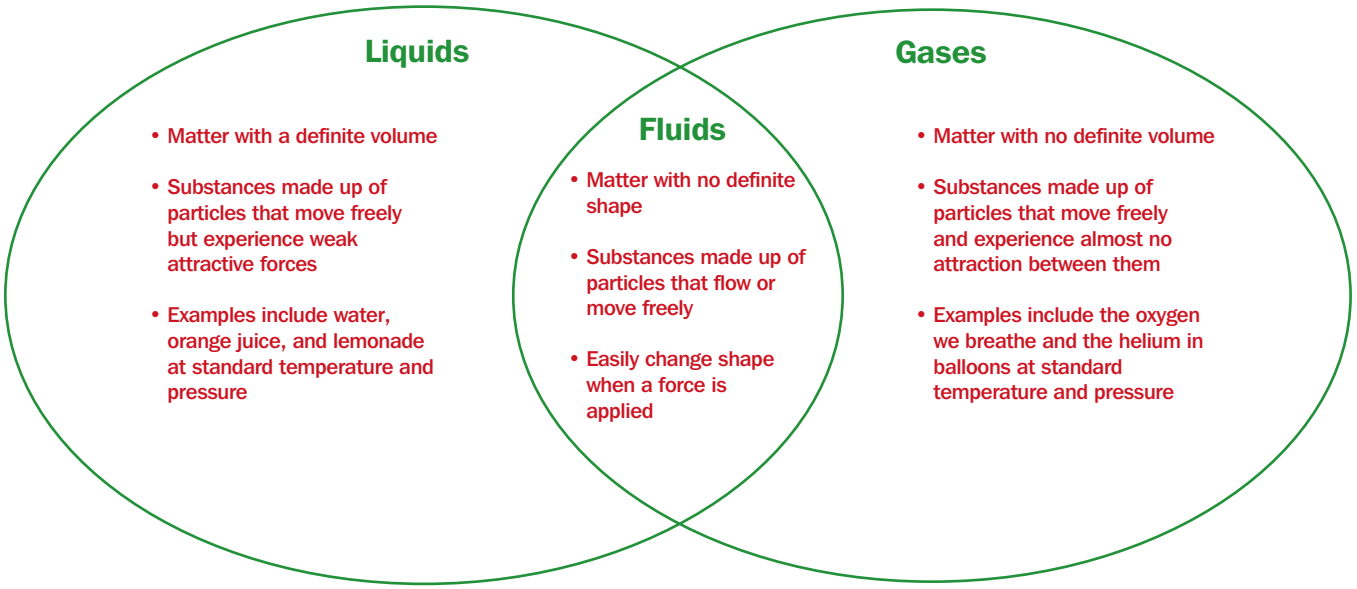
▶**Write your hypothesis.** Drops of food coloring placed in hot water will diffuse faster than drops of food coloring placed in cold water because the particles move faster at higher temperatures.

PERFORM YOUR EXPERIMENT

1. Fill one cup ¾ full with hot tap water.
2. Fill another cup ¾ full with cold tap water.
3. Then, work with a partner to add food coloring to the cups. Put two drops of red and two drops of blue coloring into one cup. Your partner will do the same in the other cup. Make sure you and your partner add the drops at the same time.
4. Watch what happens in each cup over the next 5–10 minutes.

ANALYZE & CONCLUDE

1. In the Venn diagram below, compare and contrast the properties of liquids, gases, and fluids.



LESSON 17 ACTIVITY SHEET: Color Clouds

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

2. What happens when you add food coloring to the cup of hot water? In hot water, the food coloring diffuses (spreads out) through the water quickly.

3. What happens when you add food coloring to the cup of cold water? In cold water, the food coloring diffuses (spreads out) through the water slowly.

4. In which cup does the food coloring diffuse (spread out) faster? Why? The hot water causes the food coloring to diffuse faster. At higher temperatures, particles move faster. This faster movement allows diffusion to occur more quickly.

5. Circle the correct response: In general, the rate of diffusion (*increases*) / *decreases* as temperature increases.

6. List other examples of diffusion. Other examples of diffusion include smells from cooking or perfume and smoke filling the air.

7. 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 …

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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 term. Then, provide an example of it by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Concentration gradient	The difference between the concentration of two fluids.	

2. Circle the correct response: Liquids and ***solids*** / ***gases*** can undergo diffusion.

3. What other ways could you increase the rate of diffusion? You can increase the rate of diffusion by increasing the temperature of the solution, stirring or shaking the solution, or increasing the concentration gradient.

4. Solution A is added to the container of water shown below. Solution A will diffuse in the water. Using colored pencils, crayons, or markers, show what the combined solution will look like once diffusion is complete.