LESSON 32: T-Shirt Tie-Dye

ESTIMATED TIME **Setup:** 5 minutes | **Procedure:** 15–20 minutes

- **DESCRIPTION**
  Use colored permanent markers to create fun, tie-dye designs on T-shirts.

- **OBJECTIVE**
  This lesson demonstrates solubility and absorption through the process of tie-dyeing. Students use colored permanent markers and alcohol to create colorful designs on T-shirts. The lesson can be extended to explore polarity and diffusion.

- **CONTENT TOPICS**
  Scientific inquiry; mixtures (solutions); separation processes (absorption, chromatography)

- **MATERIALS**
  - ❑ White T-shirt
  - ❑ Permanent colored markers
  - ❑ Isopropyl rubbing alcohol (70%)
  - ❑ Cups and/or jars (at least a three-inch diameter)
  - ❑ Eye dropper or pipette
  - ❑ Rubber bands

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 398 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

Tie-dyeing has been around for decades and is a fun, colorful way to decorate plain T-shirts. Tie-dye is a form of art and expression, but it also involves a lot of chemistry. Dye is a natural or synthetic substance used to apply color to or stain other materials, such as fabrics and fibers. Permanent markers contain dyes that will be absorbed by fabrics, such as T-shirts. **Absorption** is a process by which matter takes in another substance. The absorbed substance is spread throughout the absorbing matter, such as when a kitchen sponge soaks up water.

Like most other things around us, dyes are mixtures. A **mixture** is made of two or more substances that are combined physically. A **solution** is a homogeneous mixture in which one or more substances (the solutes) are dissolved into another substance (the solvent). Solutions are made up of elements or compounds mixed together at the molecular level. For example, salt may be dissolved in water to form a saltwater solution. The salt is the solute, and the water is the solvent.

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, salt is soluble in water. If a substance does not dissolve, it is **insoluble**. For instance, butter is insoluble in water.

LESSON 32: T-Shirt Tie-Dye

Many markers are soluble in water, so they are called washable markers. If you tried to tie-dye a T-shirt with washable markers, the colorful design would be washed away if the shirt was put in the washing machine. Therefore, permanent markers are used in this experiment. The dye in permanent markers is insoluble in water. The colors can't be easily washed away. However, the dye in permanent markers is soluble in rubbing alcohol.

In the experiment, the dye in permanent markers will be absorbed by the T-shirt, but the colors will only spread so far through the material. When rubbing alcohol is added to the dye, the dye dissolves. The T-shirt will absorb the alcohol, which can travel farther through the shirt. Therefore, the dye that is dissolved in the alcohol can travel farther through the shirt, spreading the ink. When the alcohol dries, the dye remains as part of the T-shirt. The T-shirt can then be washed because the dye will not dissolve in 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 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 the properties of solutions can be found in the Chemicals by Volume—Solutions section in CEF's *Passport to Science Exploration: Chemistry Connections*.
- Additional information on absorption can be found in the Laboratory Separations section in CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

FORMULAS & EQUATIONS

Markers are made up of dyes. Dye is a natural or synthetic substance used to apply color or to stain other materials, such as fabrics and fibers. Dyes are often mixtures of different colored particles. Although our eyes may only "see" one color, each of the separate colors keep their color properties within the mixture. Therefore, different colors can be separated out of some dyes. There is not one exact formula because different colors and types of markers contain a variety of different chemical compounds.

The substance used to dissolve the dye is isopropyl alcohol.

The chemical formula for isopropyl alcohol (isopropanol) is $\mathbf{C_3H_8O}$ or $\mathbf{(CH_3)_2CHOH}$.

At a normal room temperature, it is a clear, flammable liquid. Isopropyl alcohol is commonly called rubbing alcohol.

HYPOTHESIS

▶Drawing designs on a T-shirt using permanent colored markers and then adding rubbing alcohol will dissolve the dye and allow the colors to spread through the fibers of the T-shirt.

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the experiment as described on page 398, but spend more time on solutions and solubility. Mix salt in a cup of water to help the students visualize what a solution is and understand the parts of the solution. Then discuss other substances that are solutions, like lemonade and apple juice (flavoring and water or apples and water).

Then, add oil or a little butter to a cup of water. Try to mix the substance, so the students can observe what is happening. Then discuss solubility.

LESSON 32: T-Shirt Tie-Dye

DIFFERENTIATION IN THE CLASSROOM

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Use colored permanent markers to create fun, tie-dye designs on T-shirts.

OBJECTIVE

This lesson demonstrates various properties of liquids, specifically solutions. Students use colored permanent markers and alcohol to create colorful designs on T-shirts and explore solubility, polarity, diffusion, and chromatography.

OBSERVATION & RESEARCH

Tie-dyeing has been around for decades and is a fun, colorful way to decorate plain T-shirts. Permanent markers contain dyes that are absorbed by fabrics, such as T-shirts. Dyes are solutions. A **solution** is a homogeneous mixture in which one or more substances (the solutes) are dissolved into another substance (the solvent).

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**. If a substance does not dissolve, it is **insoluble**. Many markers are soluble in water, so they are called washable markers. However, the dye in permanent markers is insoluble in water. The colors can't be easily washed away. However, the dye is soluble in rubbing alcohol.

Solubility is also related to polarity. **Polar substances** are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side. Generally, polar solutes will only dissolve in polar solvents. Polar substances include acetic acid, salt, and sugar. **Nonpolar substances** are made up of particles that have an even distribution of electrons. The charges on the particles are neutralized. Nonpolar solutes generally only dissolve in nonpolar solvents. Nonpolar substances include oil and benzene. Isopropyl (rubbing) alcohol has both polar and nonpolar components, so it can dissolve both polar and nonpolar substances.

In the experiment, the dye in permanent markers will be absorbed by the T-shirt, but the colors will only spread so far through the material. When the rubbing alcohol is added to the dye, the dye dissolves. The T-shirt will absorb the alcohol, which can travel farther through the shirt because of diffusion and the process of chromatography. **Diffusion** is the movement of particles from an area of high concentration to an area of low concentration. Therefore, the alcohol spreads from an area of high concentration to an area of low concentration, spreading the ink.

Likewise, **chromatography** is a group of separation processes used to separate and analyze complex mixtures based on differences in their structure or composition. During chromatography, a mixture is moved over a stationary material, called the **stationary phase**. The mixture that flows over the material is called the **mobile phase**. The different parts that make up the mobile phase flow through the stationary phase at different rates. As a result, the components separate, generally leaving behind distinct bands of the different components.

In this experiment, as the dye and alcohol solution move through the T-shirt, the different color components of some of the colored markers may move through the paper at different rates. As a result, some colors may separate, leaving behind different bands of colors. When the alcohol dries, the dye remains as part of the T-shirt. The T-shirt can then be washed because the dye will not dissolve in 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.

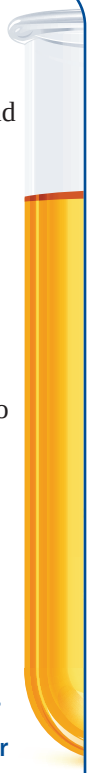
- Additional information on mixtures and solutions can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry.*
- Additional information on solutions, solubility, and polar substances can be found in the Chemicals by Volume—Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.
- Additional information on chromatography can be found in the Laboratory Separations section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

LESSON 32: T-Shirt Tie-Dye

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 you change the type of liquid [solvent], does the dye behave differently?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE



1. Position one layer of the T-shirt over the mouth of the cup. Stretch the fabric over the opening and hold it in place with a rubber band.
2. Use the permanent colored markers to add small dots, lines, or designs to the part of the T-shirt that is stretched over the cup.
3. Use a dropper to place 5–10 drops of alcohol on the designs. Wait a few minutes for the alcohol to soak the colors.
4. Repeat steps 1–3 several times on different areas of the T-shirt.

Make sure the proper safety procedures are followed to protect students from the dyes and alcohol. Students should protect their clothing with a lab apron or lab coat, and wash their hands immediately after conducting the experiment.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What happens when the dye is initially added to the T-shirt? What happens when you add the alcohol? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

NOTES

LESSON 32: T-Shirt Tie-Dye

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 the process of absorption and how it relates to tie-dyeing.
- Define and provide examples of different types of mixtures.
- Define and identify solutions and the parts of a solution.
- Define soluble and insoluble substances and give examples.
- Differentiate between polar and nonpolar substances (see ***Differentiation in the Classroom***).
- Explain the processes of diffusion and chromatography (see ***Differentiation in the Classroom***).

Fun Fact

Shibori is a Japanese term for several methods of dyeing cloth. It includes a form of tie-dying that is used to create intricate designs on kimonos (traditional Japanese garments).

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.

- Have the students bring in plain white T-shirts and create their own designs so they can take their shirts home. You can ask the students to closely examine their T-shirts after the experiment and look for color separations to explore chromatography.
- If you do not wish to do a T-shirt tie-dye experiment, you can simply use a paper towel to achieve the same results and teach the same lesson. Simply lay the paper towel on a surface that will not be ruined by the ink and make a design. Then, add the alcohol and observe. Likewise, smaller pieces of cloth can be used to create bandanas or wrist bands.

REAL-WORLD APPLICATIONS

- The leaves of most plants are green because they contain chlorophyll, and chlorophyll is green. However, not all leaves are the same shade of green. Leaves contain several different kinds of chlorophyll and some other pigments. The process of chromatography is used to separate the different pigments in plants and determine which pigments it contains.

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 32 ACTIVITY SHEET: T-Shirt Tie-Dye

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)
Absorption		
Mixture		
Solution		
Solute		
Solvent		

4. Consider what will happen if you apply colored marker ink and rubbing alcohol to a white T-shirt and why.

▶**Write your hypothesis.** _____

_____

_____

LESSON 32 ACTIVITY SHEET: T-Shirt Tie-Dye

PERFORM YOUR EXPERIMENT

1. Position one layer of the T-shirt over the mouth of the cup. Stretch the fabric over the opening and hold it in place with a rubber band.
2. Use permanent colored markers to add small dots, lines, or designs to the part of the T-shirt stretched over the cup.
3. Use a dropper to place 5–10 drops of alcohol on the dots, lines, or designs.
4. Wait a few minutes for the alcohol to soak the colors and observe.
5. Repeat steps 1–4 several times on different areas of the T-shirt.

ANALYZE & CONCLUDE

1. What happens when you press the markers to the T-shirt? _____

_____

_____

2. What happens to the ink designs when you add drops of alcohol? _____

_____

_____

3. Do you think you will get a similar result if you place water on the ink designs? Why or why not? _____

_____

_____

4. Why do you use permanent colored markers instead of washable markers? _____

_____

_____

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

_____

_____

LESSON 32 ACTIVITY SHEET: T-Shirt Tie-Dye

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)
Polar substance		
Nonpolar substance		
Diffusion		
Chromatography		
Stationary phase		
Mobile phase		

2. Do any of the color spots have different colored edges? Is so, what colors? Why do you think this happened?

_____

_____

_____

3. Why do some of the colors separate into different colors? What is this separation process called? _____

_____

_____

LESSON 32 ACTIVITY SHEET: T-Shirt Tie-Dye

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

OBSERVE & RESEARCH

1. Write down the materials you observe. A white T-shirt, permanent colored markers, rubbing alcohol, cups, eye droppers, rubber bands, vinegar …

2. Predict how these materials may be used. A white T-shirt may be worn. Permanent colored markers may be used to draw or write. Rubbing alcohol may be used as a disinfectant. Cups may be used to hold a substance. These materials may be used to tie-dye T-shirts and demonstrate absorption and solubility.

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)
Absorption	A process by which matter soaks up or takes in another substance.	
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).	
Solute	A substance that is dissolved in a solution	
Solvent	A substance capable of dissolving another substance	

4. Consider what will happen if you apply colored marker ink and rubbing alcohol to a white T-shirt and why.

▶ **Write your hypothesis.** Adding rubbing alcohol to permanent marker designs on a T-shirt will dissolve the dye and allow the colors to spread through the fibers in the T-shirt.

LESSON 32 ACTIVITY SHEET: T-Shirt Tie-Dye

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

PERFORM YOUR EXPERIMENT

1. Position one layer of the T-shirt over the mouth of the cup. Stretch the fabric over the opening and hold it in place with a rubber band.
2. Use permanent colored markers to add small dots, lines, or designs to the part of the T-shirt stretched over the cup.
3. Use a dropper to place 5–10 drops of alcohol on the dots, lines, or designs.
4. Wait a few minutes for the alcohol to soak the colors and observe.
5. Repeat steps 1–4 several times on different areas of the T-shirt.

ANALYZE & CONCLUDE

1. What happens when you press the markers to the T-shirt? The colored markers stain the T-shirt, and you can make designs from the dye.

2. What happens to the ink designs when you add drops of alcohol? When you add drops of alcohol, the dye from the markers spreads farther through the fabric.

3. Do you think you will get a similar result if you place water on the ink designs? Why or why not? If you place only water on the designs, it will not have the same effect because the dye is not soluble in water. Therefore, only the water would spread through the T-shirt.

4. Why do you use permanent colored markers instead of washable markers? Washable markers are soluble in water. The dye would wash away in water. The dye in permanent markers is insoluble in water and can't be easily washed away.

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 32 ACTIVITY SHEET: T-Shirt Tie-Dye

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)
Polar substance	A substance made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.	
Nonpolar substance	A substance made up of particles that have an even distribution of electrons; the charges on these particles are neutralized.	
Diffusion	The movement of particles from an area of high concentration to an area of low concentration.	
Chromatography	A group of separation processes used to separate and analyze complex mixtures based on differences in their structure or composition.	
Stationary phase	A stationary material over which a mixture flows during a chromatography separation process.	
Mobile phase	The mixture that flows over the stationary material in a chromatography separation process.	

2. Do any of the color spots have different colored edges? If so, what colors? Why do you think this happened?

Yes, colors like green and purple have different colored edges because the rubbing alcohol will separate the dye into its constituent colors. Green may be split into yellow and blue. Purple may be split into blue and red.

3. Why do some of the colors separate into different colors? What is this separation process called? The different color components of some of the colored markers may move through the fabric at different rates. As a result, the colors separate, leaving behind different colors. This separation process is called chromatography.