LESSON 22: Mysterious Mixtures

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

DESCRIPTION

Use the process of chromatography to separate mixed dyes into the different colors that make up the dye.

OBJECTIVE

This lesson examines mixtures and demonstrates the separation process of chromatography. Students will use food coloring and filter paper to observe chromotagraphy in action. The lesson can be extended to discuss dyes and pigments.

CONTENT TOPICS

Scientific inquiry; measurement; properties of matter; mixtures (solutions); separation processes (chromatography)

MATERIALS

- ❑ 8-oz paper or plastic cups
- ❑ White coffee filters
- ❑ Metric ruler
- ❑ Scissors
- ❑ Food coloring (red, blue, yellow)
- ❑ Water
- ❑ Pencils
- ❑ Clear plastic tape
- ❑ Tablespoon

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 273 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

Most of the things around us are mixtures, like the air, the ocean, and food coloring! A **mixture** is made of two or more substances that are combined physically. A mixture can be classified as either homogeneous or heterogeneous.

A **homogeneous mixture** is a type of mixture that is considered to be the same throughout. Homogeneous mixtures are mixed evenly. Therefore, each part of the mixture seems to be the same. 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. On the other hand, a **heterogeneous mixture** is a type of mixture in which the makeup is not the same throughout. Heterogeneous mixtures are not mixed evenly, so they do not appear uniform.

In a mixture, the chemical structure of each part of the mixture remains the same. Therefore, scientists are able to separate mixtures into their original parts. Separating a mixture of substances into two or more distinct products is called a **separation process**. A separation process uses the different properties of a mixture’s parts to get them to separate. A mixture can be separated either through physical or chemical means.

A physical separation process uses physical properties to separate the parts of a mixture. This separation occurs without changing the chemical properties of the parts. Common physical separation processes include filtration and distillation. Another way chemists can separate parts of a mixture is through a process called chromatography. **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, different solutions are made by mixing water with different colors and amounts of food coloring. Next, a chromatography process is used to separate the different parts of the different solutions. When the end of the filter paper is placed in a solution, the paper will begin to absorb the liquid. As the solution moves up the paper, the different color components move through the paper at different rates. As a result, the colors separate, leaving bands of color along the paper based on how far that color component can travel through the paper. (The cup with red, yellow, and blue may only separate into two colors, red and green. In this case, the red separated out, but the yellow and blue stayed mixed and migrated up the paper at the same rate.)

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 appear more familiar, 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.

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 basic separation processes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on chromatography can be found in the Laboratory Separations section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

HYPOTHESIS

▶Different food colorings and water can be combined to create uniform solutions. When the edge of a strip of filter paper is placed in the solution, the different colors of the solution will flow through the paper at different rates and separate into different bands of color on the paper.

LESSON 22: Mysterious Mixtures

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

For younger students, this lesson can demonstrate that most things are made up of parts, and some parts we cannot see.

DESCRIPTION

Create colored solutions and then use a separation process to identify the different colored parts in each solution.

OBJECTIVE

This lesson introduces different types of mixtures and a separation process that can be used to identify the different parts of a mixture.

OBSERVATION & RESEARCH

Most of the things around us are mixtures, like the air, the ocean, and food coloring! A **mixture** is made of two or more substances that are combined physically. A mixture can be classified as either homogeneous or heterogeneous.

A **homogeneous mixture** is a type of mixture that is considered to be the same throughout. Homogeneous mixtures are mixed evenly. Therefore, each part of the mixture seems to be the same. Examples of homogeneous mixtures are apple juice and brass. In liquid form, homogeneous mixtures are generally called solutions. 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. Apple juice is a solution. The juice looks (and tastes) the same whether it is poured from the top, middle, or bottom of the bottle. Similarly, brass is a mixture of metals that looks the same throughout.

On the other hand, a **heterogeneous mixture** is a type of mixture in which the makeup is not the same throughout. Heterogeneous mixtures are not mixed evenly, so they do not appear uniform. Examples of heterogeneous mixtures include pizza and peanut butter and jelly sandwiches. The different parts of these mixtures can be clearly seen.

In this experiment, different solutions are made by mixing water with different colors and amounts of food coloring. Students should notice that once the water and colors are mixed together, the liquid looks the same throughout. It is a solution—a homogeneous mixture.

Next, a special **separation process** is used to separate the different parts of the different solutions. A separation process uses the different properties of a mixture's parts to get them to separate. In the experiment, when the end of the filter paper is placed in a solution, the paper will begin to absorb the liquid. As the solution moves up the paper, the different color components move through the paper at different rates. As a result, the colors separate, leaving bands of color along the paper based on how far that color component can travel through the paper. (The cup with red, yellow, and blue may only separate into two colors, red and green. In this case, the red separated out, but the yellow and blue stayed mixed and migrated up the paper at the same rate.)

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Perform the experiment as described on page 273, but explore different separation processes further. Discuss other separation processes and how they are used (distillation, precipitation, etc.).

Another option is to discuss dyes in more details. What are the differences between natural and synthetic dyes? What are the differences between food colorings and other dyes? Discuss regulations that help to ensure food colorings are safe to eat.

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 basic separation processes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 22: Mysterious Mixtures

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 colors in the solution change, do the colors on the paper change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Fill each cup with three tablespoons of water.

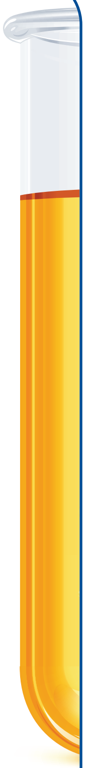
2. Put three drops of red and three drops of blue food coloring into one cup. Put three drops of red and three drops of yellow in a second cup, and put three drops of each color—red, blue, and yellow—in a third cup.

3. Write the color combinations in each cup on a piece of masking tape, and tape it to the bottom of the corresponding cup where students cannot see it.

4. Take an unused coffee filter, and cut three strips about 10 cm long and 2 cm wide. Wrap one end of a strip around a pencil, and lower the other end so that it goes about 1 cm into the water. Tape the filter paper to the pencil, and place the pencil on the rim of the cup.

5. Repeat step 4 for your two other cups.

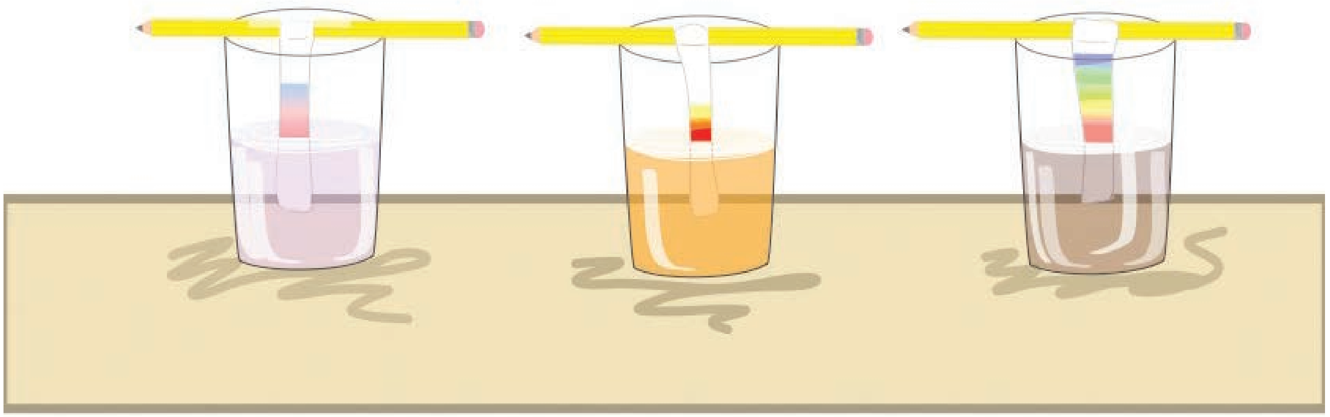
6. Have the students observe and then guess (if they don't already know) which cup contains which food coloring. If green appears on the filter strips, ask the students how this is possible.



DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What is a solution? What colors were separated from each solution? You can use the table in the activity sheet (or a similar one of your own) for students to record their data.

NOTES



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 hypothesis. 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.
- Define and provide examples of different types of mixtures.
- Compare and contrast homogeneous and heterogeneous mixtures.
- Define and identify a solution and the parts of a solution.
- Understand the process of chromatography and how it is used to separate mixtures.

Fun Fact

In the 16th century, Spanish explorers observed the Aztecs collecting tiny cochineal insects that fed on red cactus berries. These insects were crushed to produce a red pigment for coloring food.

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.

- Prepare the solutions before class. When the students arrive, tell them that the cups contain mixtures of different colors and that you need to figure out what colors are in the cups. Ask them if they know any methods you could use. Challenge them to predict what colors are in the solutions based on their physical observations. Introduce chromatography as a separation process, but do not tell them how it works to separate the colors. Then perform the experiment, and have students compare their predictions against the actual results.
- If green appears, ask students if they notice anything odd about their results. They may produce a number of answers, but eventually remind students that green is not a primary color. Green is a mixture of blue and yellow. Ask students to consider why those two colors did not separate.

REAL-WORLD APPLICATIONS

- The separation process of chromatography is used in conducting forensics for crime scene investigations, by pharmaceutical companies in analyzing the amounts of specific chemicals in their products, by hospitals in determining the alcohol in patients' blood, and by environmentalists studying the level of pollutants in our water supply.

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 22 ACTIVITY SHEET: Mysterious Mixtures

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)
Mixture		
Separation process		
Chromatography		
Stationary phase		
Mobile phase		

4. Consider how colors can be separated from a solution of food coloring and water using filter paper and why that process would work.

▶ **Write your hypothesis.** ______________________________

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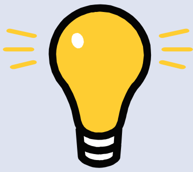

LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

PERFORM YOUR EXPERIMENT

1. Fill each cup with three tablespoons of water.
2. Put three drops of red and three drops of blue food coloring into one cup. Put three drops of red and three drops of yellow in a second cup. Put three drops of each color—red, blue, and yellow—in a third cup.
3. Write the color combinations in each cup on a piece of masking tape. Tape it to the bottom of the corresponding cup where you cannot see it.
4. Take an unused coffee filter, and cut three strips about 10 cm long and 2 cm wide. Wrap one end of a strip around a pencil, and lower the other end so that it goes about 1 cm into the water. Tape the filter paper to the pencil, and place the pencil on the rim of the cup.
5. Repeat step 4 for your two other cups. Observe.

Always be careful when using scissors and other sharp objects.

ANALYZE & CONCLUDE

1. In the table below, record your observations of the colors in each cup. Then make a prediction about which colors you think will appear on the paper. After completing the experiment, record the colors that did appear on the paper.

Cup Number	Color(s) in Cup	Color(s) on Paper: Predictions *(what you think will appear)*	Color(s) on Paper: Actual *(what actually appears)*
1			
2			
3			

LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

2. In what order do the colors appear on the different papers? In what order are the colors of the rainbow? Compare.

3. Does green appear on your filter paper? If so, why? What colors make green?

4. Why do the colors separate?

5. If you use black ink, what do you think will happen? Why?

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

LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

SHARE YOUR KNOWLEDGE

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)
Homogeneous mixture		
Solution		
Heterogeneous mixture		

2. List the colors of the rainbow. ____________________

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3. Which of those colors are made by mixing two other colors together? Explain. ____________________

____

____

4. List other substances that are mixtures. Explain why they are mixtures, and write what types they are.

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LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

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

OBSERVE & RESEARCH

1. Write down the materials you observe. Plastic cups, coffee filters, ruler, scissors, food coloring, water, pencils, tape, tablespoon ...

2. Predict how these materials may be used. Plastic cups may be used to hold a liquid. Coffee filters may be used to separate a solid from a liquid. A ruler may be used to measure. Food coloring may be used to dye a substance. Water may be used to drink, bathe, or clean. These materials may be combined to demonstrate a separation process.

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)
Mixture	A physical combination of two or more substances that can be physically separated.	
Separation process	A process that divides a mixture into two or more distinct substances.	
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.	

4. Consider how colors can be separated from a solution of food coloring and water using filter paper and why that process would work.

▶**Write your hypothesis.** Filter paper placed in a solution of mixed-color dyes will absorb the solution and separate the colors based on the rate at which the different components can move through the paper.

LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

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

PERFORM YOUR EXPERIMENT

1. Fill each cup with three tablespoons of water.
2. Put three drops of red and three drops of blue food coloring into one cup. Put three drops of red and three drops of yellow in a second cup. Put three drops of each color—red, blue, and yellow—in a third cup.
3. Write the color combinations in each cup on a piece of masking tape. Tape it to the bottom of the corresponding cup where you cannot see it.
4. Take an unused coffee filter, and cut three strips about 10 cm long and 2 cm wide. Wrap one end of a strip around a pencil, and lower the other end so that it goes about 1 cm into the water. Tape the filter paper to the pencil, and place the pencil on the rim of the cup.
5. Repeat step 4 for your two other cups. Observe.

Always be careful when using scissors and other sharp objects.

ANALYZE & CONCLUDE

1. In the table below, record your observations of the colors in each cup. Then make a prediction about which colors you think will appear on the paper. After completing the experiment, record the colors that did appear on the paper.

Cup Number	Color(s) in Cup	Color(s) on Paper: Predictions *(what you think will appear)*	Color(s) on Paper: Actual *(what actually appears)*
1	Red, blue	Answers will vary	Red, blue
2	Red, yellow	Answers will vary	Red, yellow
3	Red, blue, yellow	Answers will vary	Red, green or Red, yellow, green, blue

LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

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

2. In what order do the colors appear on the different papers? In what order are the colors of the rainbow? Compare.

In cup one, the colors that appeared were red and then blue. In cup two, the colors were red and then yellow. In cup three, the colors were red and then green. The colors of the rainbow are red, orange, yellow, green, blue, and violet. The order of the colors reflects the order of the colors in the rainbow.

3. Does green appear on your filter paper? If so, why? What colors make green? Yes, green appears on the filter paper from cup three. The red separated out, but the yellow and blue dyes mixed and migrated up the paper at the same rate. Blue and yellow make green.

4. Why do the colors separate? The colors separate because they have different molecular sizes and weights and move through the paper at different rates. The color particles will separate and form distinct bands of color according to their size.

5. If you use black ink, what do you think will happen? Why? Black ink is made of all colors. If you were to use black ink, the different colors that make up black will show up on the coffee filter paper. It should look like a rainbow.

6. 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 22 ACTIVITY SHEET: Mysterious Mixtures

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

SHARE YOUR KNOWLEDGE—BEGINNERS

Have students complete this section if you used the beginners' 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)
Homogeneous mixture	A type of mixture that is considered to be the same throughout; the substances are evenly mixed.	
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Heterogeneous mixture	A type of mixture in which the makeup is not the same throughout; the substances are not evenly mixed.	

2. List the colors of the rainbow. Red, orange, yellow, green, blue, violet.

3. Which of those colors are made by mixing two other colors together? Explain. Orange is made by mixing red and yellow. Green is made by mixing yellow and blue. Violet is made by mixing red and blue.

4. List other substances that are mixtures. Explain why they are mixtures, and write what types they are.

Other substances that are mixtures include apple juice and brass. They are mixtures because they are made up of two or more substances that are combined physically. Apple juice and brass are homogeneous mixtures. They appear the same throughout. Heterogeneous mixtures include pizza and chicken noodle soup. These mixtures are not the same throughout.