LESSON 9: Egg-Dye Solutions

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

• DESCRIPTION
Use food dye and a variety of acids and bases to determine which solution works best for dyeing eggs.

• OBJECTIVE
This lesson addresses the differences between acids and bases and how they interact with eggshells. Students place eggs into various acid and base solutions containing food dyes to determine which solution works best for dyeing the eggs. The lesson can be simplified to reinforce the concept of chemical reactions.

• CONTENT TOPICS
Scientific inquiry; mixtures (solutions); atomic structure; acids and bases; physical changes; chemical reactions

• MATERIALS
- Sample of household acids: vinegar, lemon juice, orange juice
- Sample of household bases: borax, milk of magnesia, ammonia
- Hard-boiled eggs (3–6 per group)
- Food coloring or dye
- Cups
- Plastic spoons (one per cup)
- Red and blue litmus paper (optional)
- Wax crayon (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 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 119 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.B: Chemical Reactions
- EST1.B: Influence of Engineering, Technology, and Science on Society and the Natural World

(see Analysis & Conclusion)

OBSERVATION & RESEARCH

BACKGROUND
To describe certain chemical compounds, chemists use the terms “acid” and “base.” You can determine whether a solution is an acid or a base by determining the concentration of hydrogen ions (H⁺). An ion is an atom or molecule that has lost or gained one of more of its outer electrons. Therefore, the total number of electrons is not equal to the total number of protons, so an ion will have either a negative or a positive electric charge.

In general, a solution that contains a concentration of hydrogen ions (H⁺) greater than the concentration in pure water is called an acid. Common household acids include lemon juice, vinegar, soda pop, and orange juice. Likewise, a solution containing an excess of hydroxide ions (OH⁻) or an H⁺ concentration less than that of pure water is called a base. Common household bases include ammonia, baking soda, milk of magnesia, borax, and bleach. Solutions containing an H⁺ concentration equal to that of pure water are neutral.
LESSON 9: Egg-Dye Solutions

The concentration of hydrogen ions in acids and bases are measured on the pH scale. The higher the concentration of H⁺, the lower the pH will be. A substance with a pH lower than 7 is considered to be acidic. The lower the concentration of H⁺, the higher the pH will be. A substance with a pH higher than 7 is considered to be basic. Most substances range from 0 to 14 on the pH scale, with 0 being the most acidic, 7 being neutral, and 14 being the most basic. Pure water is neutral with a pH of 7.

Scientists often need to know if a substance is an acid or a base. To do so, they use indicators—substances that change color at different levels of acidity. Litmus paper is often used as an indicator. Blue litmus paper turns red in the presence of an acid, and red litmus paper turns blue in the presence of a base.

An eggshell is mainly made of calcium carbonate with a protein coating. Neutral and basic solutions will not cause any change to the eggshell, except that some dye may get stuck in the pores of the shell giving it a slight color. On the other hand, the acetic acid in vinegar will react with the protein of the shell, allowing the dye to chemically bind to it. Likewise, acetic acid also reacts with calcium carbonate, causing the shell to dissolve. If you use too much vinegar or let an egg sit in the vinegar too long, the acid will eventually dissolve the eggshell completely.

FORMULAS & EQUATIONS
The acids used in this experiment range in pH from approximately 2.0 to 3.5.

Vinegar is very diluted acetic acid. Therefore, vinegar is a mixture of acetic acid and water, which generally has a pH ranging from 2.4 to 3.4.

The chemical formula for acetic acid is CH₃COOH.

Lemon juice contains citric acid and has a pH ranging from 2.0 to 3.0. Orange juice also contains citric acid and generally has a pH around 3.5.

The chemical formula for citric acid is C₆H₈O₇.

The bases used in this experiment range in pH from approximately 9.5 to 11.6. Thus they are considered to be moderately basic.

Borax has a pH of about 9.5 and the formula Na₂B₄O₇ • 10H₂O or Na₂[B₄O₅(OH)₄] • 8H₂O.

Milk of magnesia is another common household base and has a pH of approximately 10.5. Milk of magnesia is a mixture of magnesium hydroxide in water. It has a milky appearance which is the reason for its name.

The chemical formula for magnesium hydroxide is Mg(OH)₂.

Common household solutions of ammonia have a pH of about 11.5.

The chemical formula for ammonia is NH₃.

Eggshells contain the element calcium in the form of the compound calcium carbonate.

The formula for calcium carbonate is CaCO₃.

See Lesson 6: Rubber Eggs for information on the reaction between the acetic acid in vinegar and the calcium carbonate in eggshells.

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 ions can be found in the Atomic Structure section of CEF’s Passport to Science Exploration: The Core of Chemistry.

• Additional information on acids, bases, and indicators can be found in the Acids, Bases, and pH section of CEF’s Passport to Science Exploration: Chemistry Connections.

HYPOTHESIS
When placing eggs in different solutions containing food dye, the pH of the solution will create different reactions, resulting in varying levels of color absorption.
LESSON 9: Egg-Dye Solutions

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

DESCRIPTION
Use solutions with different levels of acidity to dye eggs and illustrate a chemical reaction.

OBJECTIVE
This lesson addresses the differences between acids and bases and how they interact with eggshells. Students place eggs into various solutions to observe physical and chemical changes.

OBSERVATION & RESEARCH
Matter can undergo a number of changes. A physical change is any change in a substance’s form that does not change its chemical makeup. The chemical formula of the substance stays the same before and after the change. Breaking an egg in half does not change the chemical makeup of the egg. Thus, breaking an egg is a physical change. Likewise, placing a whole, hard-boiled egg into a basic solution with dye may result in a minor color change if some of the dye particles become trapped in the pores of the eggshell. Yet again, the chemical makeup of the egg is still the same, in the same way that coloring on a piece of paper does not change the chemical makeup of the paper.

On the other hand, a chemical change or chemical reaction occurs when two or more substances interact, producing a change in the substances. As a result of a chemical reaction, new substances with new properties are formed. The starting material or materials for a chemical reaction are referred to as the reactants. The substance or substances produced from a chemical reaction are called products. Sometimes a secondary product, a byproduct, can also be created at the same time as the desired product(s).

An eggshell is mainly made of calcium carbonate with a protein coating. When you let an egg soak in vinegar, the acetic acid will react with the protein of the shell, allowing the dye to chemically bind to the shell. Likewise, acetic acid also reacts with calcium carbonate, causing the shell to dissolve. If you use too much vinegar or let an egg sit in the vinegar too long, the acid will eventually dissolve the eggshell completely. The bubbles that form on the egg are carbon dioxide and are a sign that a chemical reaction is taking place.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Use this lesson to explore acids and bases further, including their properties and the reactions in which they participate. For example, review acid-base reactions or acid-metal reactions. Look at different chemical equations to identify the reactants and products of these reactions.

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 physical and chemical changes can be found in the Classification of Matter section of CEF’s Passport to Science Exploration: The Core of Chemistry.
- Additional information on chemical reactions can be found in the Chemical Reactions section of CEF’s Passport to Science Exploration: Chemistry Connections.
- Additional information on food chemistry and health can be found in the Applications of Chemistry in Everyday Life section of CEF’s Passport to Science Exploration: Chemistry Concepts in Action.
LESSON 9: Egg-Dye Solutions

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 level of acidity changes, will the effect on the eggshell be the same?) Review the information in the Scientific Inquiry section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Test each of your solutions with litmus paper to determine if they are acids or bases. If you do not have litmus paper, have the students make predictions before you tell them which are acids and bases.

2. Fill one cup with water to serve as a control.

3. Pour a different acid or base into each remaining cup. Make sure you pour enough solution into the cup to submerge the egg. (For borax, which is a solid, create a borax solution by dissolving borax into warm water until no more borax can be added. Milk of magnesia can also be diluted in water.)

3. Add 3–5 drops of food coloring/dye to the water cup. Add the same color dye to the other cups, and try to make the colors in all cups the same shade.

Making the solutions the same shade may require different amounts of food coloring per solution. For example, since milk of magnesia is white, its solution will be softer in color and will require more drops of food coloring.

4. Place an egg in each cup, and let the eggs soak for 10 minutes.

5. After 10 minutes, remove each egg from its solution. The milk of magnesia egg should be very gently rinsed under water. Be sure not to mix up the eggs.

6. Observe each egg’s appearance.

NOTES

EXPERIMENTATION

This experiment can be messy, so you may want to protect the work surface with newspaper. Students should also wear gloves to protect their hands.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What are the properties of the substances used in the experiment? You can use the charts on the activity sheet (or similar charts of your own) for students to record their data.
LESSON 9: Egg-Dye Solutions

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.
- Define and understand the difference between acids and bases.
- Understand pH and identify the pH of different solutions.
- Define and identify the properties of acid-base indicators.
- Differentiate between physical and chemical changes (see Differentiation in the Classroom).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lessons 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, have the students predict whether each solution is an acid or a base. Then, use the litmus paper to determine the answer.
- Use a wax crayon to write or draw on a few eggs. In the best egg-dyeing solution (the vinegar solution), the dye will not adhere to the part of the eggshell with the wax. Discuss the properties of wax with your students.

REAL-WORLD APPLICATIONS

- Dyes have been used since ancient times to color various fabrics. Today, both natural and synthetic dyes are used to color fabrics, but not all dyes work on all fabrics. Certain types of dyes work well on polyester but do not work well on cotton and vice versa.

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.

Fun Fact

Bases can be used to neutralize acids and vice versa.

Fun Fact

Originally, dyes were made from vegetables, edible flowers, fruits, coffee, tea, plants, and minerals. For example, people used saffron to color cloth a vibrant yellow, and indigo plants produced a rich blue dye.
LESSON 9 ACTIVITY SHEET: Egg-Dye Solutions

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.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Example (write or add image)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base</td>
<td></td>
<td></td>
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<tr>
<td>Dye</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Consider how changing the level of acidity in a solution will affect the amount of dye absorbed by the eggshell and why.

▲ Write your hypothesis. 

____________________________________________________________________________________________________

____________________________________________________________________________________________________

____________________________________________________________________________________________________
PERFORM YOUR EXPERIMENT

1. Determine which solutions are acids and which are bases. Follow your teacher’s instructions.

2. Then, fill one cup with water and pour a different acid or base into each remaining cup. Make sure you pour enough into each cup to submerge the egg. (For borax, which is a solid, create a borax solution by dissolving borax into warm water until no more borax can be added. Milk of magnesia can also be diluted in water.)

3. Add 3–5 drops of food coloring to the water cup. Add the same color dye to the other cups, and try to make the color in all cups the same shade.

   Making the solutions the same shade may require different amounts of food coloring per solution. For example, since milk of magnesia is white, its solution will be softer in color and will require more drops of food coloring.

4. Place an egg in each cup, and let the eggs soak for 10 minutes.

5. After 10 minutes, remove each egg from its solution. (The milk of magnesia egg should be very gently rinsed under water. Be sure not to mix up the eggs.)

6. Observe each egg's appearance.

ANALYZE & CONCLUDE

1. Complete the chart below.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Prediction: Acid or Base?</th>
<th>Result: Acid or Base?</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>
LESSON 9 ACTIVITY SHEET: Egg-Dye Solutions

2. Describe any differences you see in each solution as the eggs soak. __________________________________________

____________________________________________________________________________________________________

____________________________________________________________________________________________________

3. Shade the ovals below to represent the resulting color of each egg (the amount of dye absorbed by each egg in the different solutions). Below each egg image, write in the solution that was used.

<table>
<thead>
<tr>
<th>Solution #1</th>
<th>Solution #2</th>
<th>Solution #3</th>
<th>Solution #4</th>
<th>Solution #5</th>
<th>Solution #6</th>
</tr>
</thead>
<tbody>
<tr>
<td>___________</td>
<td>___________</td>
<td>___________</td>
<td>___________</td>
<td>___________</td>
<td>___________</td>
</tr>
</tbody>
</table>

Vinegar

4. Are acids or bases better for dyeing eggs? Explain. ____________________________________________________

____________________________________________________________________________________________________

____________________________________________________________________________________________________

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

____________________________________________________________________________________________________

____________________________________________________________________________________________________
LESSON 9 ACTIVITY SHEET: Egg-Dye Solutions

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.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Example (write or add image)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical change</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical change</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reactant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Byproduct</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Why does vinegar work so well when dyeing eggs? ________________________________________________________
____________________________________________________________________________________________________
____________________________________________________________________________________________________

3. What is the composition of vinegar? __________________________________________________________________
____________________________________________________________________________________________________
____________________________________________________________________________________________________
LESSON 9 ACTIVITY SHEET: Egg-Dye Solutions

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

OBSERVE & RESEARCH

1. Write down the materials you observe. Household acids (vinegar, lemon juice, orange juice), household bases (borax, milk of magnesia, ammonia), hard-boiled eggs, food coloring ...

2. Predict how these materials may be used. The household acids and bases may be used in a variety of ways. Hard-boiled eggs may be eaten or used for decorating. The food coloring may be used to dye other substances. These materials may be combined to examine the differences between acids and bases and to observe chemical reactions.

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

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Example (write or add image)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).</td>
<td></td>
</tr>
<tr>
<td>Ion</td>
<td>An atom or group of atoms that has lost or gained one or more of its outer electrons; an ion will have either a positive or a negative charge.</td>
<td></td>
</tr>
<tr>
<td>Acid</td>
<td>A solution that contains an excess of hydrogen ions (H⁺); acids have a higher concentration of hydrogen ions than pure water.</td>
<td></td>
</tr>
<tr>
<td>Base</td>
<td>A solution that has an excess of hydroxide ions (OH⁻); bases have a lower concentration of hydrogen ions than pure water.</td>
<td></td>
</tr>
<tr>
<td>Dye</td>
<td>A soluble substance used to stain or color fabrics and fibers, such as paper, cotton, etc.</td>
<td></td>
</tr>
</tbody>
</table>

4. Consider how changing the level of acidity in a solution will affect the amount of dye absorbed by the eggshell and why.

▶ Write your hypothesis. When placing eggs in different solutions containing food coloring, acidic solutions will react with the eggshell and absorb more dye.
PERFORM YOUR EXPERIMENT

1. Determine which solutions are acids and which are bases. Follow your teacher’s instructions.

2. Then, fill one cup with water and pour a different acid or base into each remaining cup. Make sure you pour enough into each cup to submerge the egg. (For borax, which is a solid, create a borax solution by dissolving borax into warm water until no more borax can be added. Milk of magnesia can also be diluted in water.)

3. Add 3–5 drops of food coloring to the water cup. Add the same color dye to the other cups, and try to make the color in all cups the same shade.

   Making the solutions the same shade may require different amounts of food coloring per solution. For example, since milk of magnesia is white, its solution will be softer in color and will require more drops of food coloring.

4. Place an egg in each cup, and let the eggs soak for 10 minutes.

5. After 10 minutes, remove each egg from its solution. The milk of magnesia egg should be very gently rinsed under water. Be sure not to mix up the eggs.

6. Observe each egg’s appearance.

ANALYZE & CONCLUDE

1. Complete the table below. Answers will vary depending on the solutions used in the experiment. Sample answers are provided below.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Prediction: Acid or Base?</th>
<th>Result: Acid or Base?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinegar</td>
<td>Answers will vary</td>
<td>Acid</td>
</tr>
<tr>
<td>Lemon juice</td>
<td>Answers will vary</td>
<td>Acid</td>
</tr>
<tr>
<td>Ammonia</td>
<td>Answers will vary</td>
<td>Base</td>
</tr>
<tr>
<td>Borax</td>
<td>Answers will vary</td>
<td>Base</td>
</tr>
</tbody>
</table>
2. Describe any differences you see in each solution as the eggs soak. **Bubbles form on the eggshell soaking in the vinegar,** which shows that there is a chemical reaction occurring between the acid and the eggshell. In the ammonia solution, there is no noticeable change ...

3. Shade the ovals below to represent the resulting color of each egg (the amount of dye absorbed by each egg in the different solutions). Below each egg image, write in the solution that was used.

<table>
<thead>
<tr>
<th>Solution #1</th>
<th>Solution #2</th>
<th>Solution #3</th>
<th>Solution #4</th>
<th>Solution #5</th>
<th>Solution #6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinegar</td>
<td>Lemon Juice</td>
<td>Ammonia</td>
<td>Borax</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Are acids or bases better for dyeing eggs? Explain. **Acids work better than bases to dye eggs because acids react with the eggshell allowing the dye to be absorbed.**

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 9 ACTIVITY SHEET: Egg-Dye Solutions

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.

<table>
<thead>
<tr>
<th>Term</th>
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<th>Example (write or add image)</th>
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</thead>
<tbody>
<tr>
<td>Physical change</td>
<td>A change that alters the form or appearance of a substance but does not change its chemical makeup or create a new substance.</td>
<td></td>
</tr>
<tr>
<td>Chemical change</td>
<td>A change that takes place when atoms of one or more substances are rearranged, and the bonds between the atoms are broken or formed to produce new substances; also known as a chemical reaction.</td>
<td></td>
</tr>
<tr>
<td>Reactant</td>
<td>A starting material for a chemical reaction.</td>
<td></td>
</tr>
<tr>
<td>Product</td>
<td>A substance formed as a result of a chemical reaction.</td>
<td></td>
</tr>
<tr>
<td>Byproduct</td>
<td>A secondary product that is created from a chemical reaction at the same time as the primary, desired product(s).</td>
<td></td>
</tr>
</tbody>
</table>

2. Why does vinegar work so well when dyeing eggs? Vinegar works well when dyeing eggs because it is an acid. Acids work better than bases to dye eggs because acids react with the protein in and may even begin to dissolve the eggshell, which allows the dye to be absorbed.

3. What is the composition of vinegar? Vinegar is a mixture of acetic acid and water. The high acidity levels in vinegar come from the acetic acid.