Fifth Edition

YOU BE THE CHEMIST™

ACTIVITY GUIDES

Hands-on Science for Grade K-8 Students

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Chemical Reactions: Acids & Bases

Background Activity Guides:

RUBBER EGGS | **EGG DYE SOLUTIONS** | **EXPLODING BAGS**

Chemical Reactions: Acids & Bases

All matter in the universe is made up of atoms. There are 118 different types of atoms called **elements**, which are shown on the periodic table. These 118 different types of atoms can be combined in millions of different ways to form unique substances.

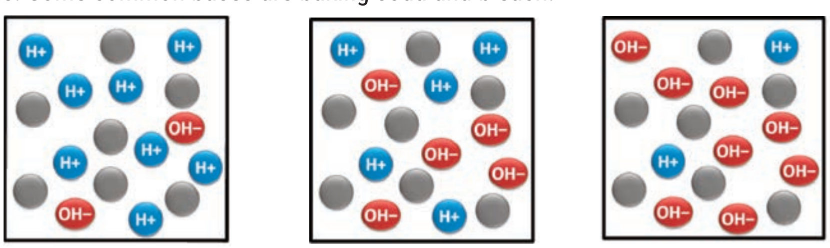
Table sugar is made of a molecule called sucrose. Sucrose is composed of 12 carbon atoms, 22 hydrogen atoms, and 11 oxygen atoms bonded together in a specific way. Smartphone screens respond to your finger because of a layer of indium tin oxide, which conducts electricity and is transparent. Some smartphones have more than 60 different elements in them!

Sucrose, the molecule in table sugar, contains carbon, hydrogen, and oxygen: *$C_{12}H_{22}O_{11}$*

Indium tin oxide, used in smartphone screens, is made up of indium, tin, and oxygen *ITO*

There are many different ways to classify and describe chemical compounds. For example, many compounds can be categorized as either acids or bases based on their characteristics and properties. Whether something is acidic or basic depends on its molecular composition and its concentration of hydrogen ions, H^+, and hydroxide ions, OH^-. An **ion** is a charged particle that is formed when an atom gains or loses electrons. A **hydrogen ion**, H^+, is formed when a hydrogen atom loses one electron, giving it a charge of 1+. A **hydroxide ion**, OH^-, contains an oxygen atom that has gained one electron, and has a charge of 1−.

In pure water, the concentration of hydrogen ions is exactly equal to the concentration of hydroxide ions. Water is **neutral**, as is any other solution with equal concentrations of H^+ and OH^-. **Acids** are solutions with a higher concentration of hydrogen ions, H^+. When an acidic substance is dissolved in water, it releases hydrogen ions. Some common acids are vinegar, orange juice, and coffee. **Bases** are solutions with a high concentration of hydroxide ions, OH^-, and a low concentration of hydrogen ions. They are the opposite of acids. Some common bases are baking soda and bleach.

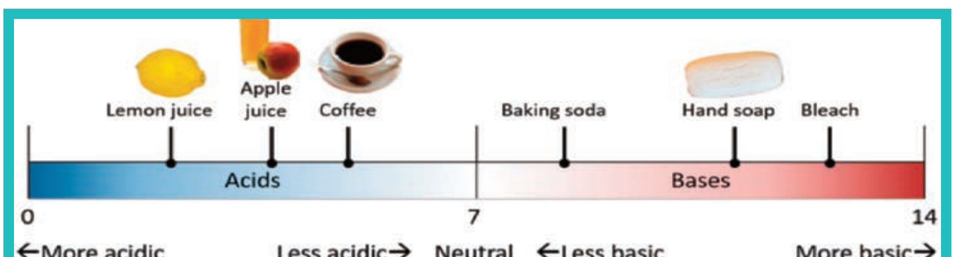


Acid
High concentration of H^+
Low concentration of OH^-

Neutral
Equal concentrations of H^+ and OH^-

Base
High concentration of OH^-
Low concentration of H^+

The **pH scale** measures how acidic or basic a solution is. The pH of a solution can be between 0 and 14 and is based on the concentration of hydrogen ions. The higher the concentration of hydrogen ions, the lower the pH. Pure water is neutral and has a pH of 7. Substances with a pH less than 7 are acids, and substances with a pH greater than 7 are bases.



Lemon juice is more acidic, or is a "stronger acid," than either apple juice or coffee. Similarly, bleach is a stronger base then either hand soap or baking soda.

Acids and bases react with each other. This reaction is called **neutralization**, because the pH of the product is closer to neutral that that of either of the reactants. An acid can neutralize a base, and a base can neutralize an acid.

Neutralization is just one of many types of chemical reactions. A **chemical reaction** is a change that takes place when the atoms of a substance are rearranged. During a reaction the bonds between atoms are broken or formed. All the substances that are present at the beginning of a reaction are the **reactants**. All the new substances that are produced during the reaction are the **products**. The products are different from the reactants, and have different physical and chemical properties that those of the reactants.

Chemical reaction
Reactants → Products

Let's explore some of the ways that we use acids and bases in chemical reactions!

Notes

ENGAGE YOUR STUDENTS

Before beginning any of these activities, use the following ideas to engage your students in learning about chemical reactions:

- Start with an overview of physical versus chemical changes, including their definitions and how we distinguish them. Show students are variety of pictures, video clips, or demos and ask them whether a physical or chemical change has occurred, and the evidence they have for their answer. Some examples of physical changes could be melting an ice cube, mixing sand and salt, shredding paper, crushing a can, or chopping wood. Examples of chemical changes could be roasting a marshmallow, baking a cake, cooking an egg, food rotting, iron rusting, a match burning, or digesting food.
- Chemical reactions are all around us! Encourage students to discuss and come up with examples of chemical reactions, where the substances that you start with undergo an irreversible change.

Rubber Eggs

Section **CHEMICAL REACTIONS** *Topic* **ACIDS & BASES**

Estimated Time Setup: 5-10 minutes; Procedure: 3-5 days

OVERVIEW

Students soak an egg in vinegar and within a few days the shell seems to disappear!

In this activity, students place a raw or hardboiled egg in a cup of vinegar. The basic calcium carbonate in the egg shell reacts with the acidic acetic acid in vinegar, and the shell dissolves into carbon dioxide, water, and calcium acetate. After a few days, the shell-less egg is all that is left, and students can easily see inside the egg and experiment further!

MATERIALS

For one setup:

- 1 hardboiled egg
- 1 cup of vinegar
- Clear cup
- 1 cup measurer

INQUIRY QUESTIONS

Getting Started:

- Are the changes in this activity due to a chemical or physical change?

Learning More:

- What changes occur when an egg is left in vinegar?

Diving Deeper:

- What type of chemical reaction occurs between an egg shell and vinegar?

CONTENT TOPICS

This activity covers the following content topics: acids and bases, chemical reactions, chemical changes, physical changes

This activity can be extended to discuss the following: human anatomy, nutrition, indicators, pH, animal life cycle and development

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:

- **2-PS1-1:** Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.
- **5-PS1-4:** Conduct an investigation to determine whether the mixing of two or more substances results in new substances.
- **MS-PS1-2:** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

ACTIVITY NOTES

This activity is good for:

- Individuals
- Pairs
- Small groups
- Demonstrations

Safety Tips & Reminders:

- The activity can be performed with a raw egg, but be sure that an adult handles it or closely supervises young students since they will have to handle it gently.
- Be sure to wash eggs with warm, soapy water before using.
- There is no eating or drinking in the lab, even when we are working with normally edible materials.
- The vinegar and egg may have a strong odor. We recommend conducting this experiment in a well-ventilated area.
- Review the Safety First section in the Resource Guide for additional information.

ENGAGE

Use the following ideas to engage your students in learning about chemical reactions and acids and bases:

- Start with the final product: show some eggs with the shells removed. Ask students to brainstorm how you might have removed the shell. This is more entertaining with raw eggs, but could be much messier!
- For more of a life sciences focus, start with the anatomy of an egg. Students can dissect, label, and learn about each part and its function in development or protection. Use this activity as a way to examine the membrane and intact insides of the egg more closely.

See more ideas for engagement in the Acids & Bases Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

Fun Fact #1

The membrane of an egg is actually made of two separate layers: the internal and the external shell membranes. The egg shell is also filled with pores, allowing gases to move between the environment and the growing chick in the egg.

EXPLORE

Procedure:

1. Add one cup of vinegar and add it to the clear cup.
2. Place the egg in the vinegar, ensuring it is completely submerged (add more vinegar if it is not!).
3. Let the set up sit in a well-ventilated area (i.e. near a window) for 3-5 days. Record your observations daily.
4. After 3-5 days, carefully remove the egg from the vinegar and rinse. Observe and record your observations.

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- What are the physical properties of the egg at the start?
- Observe the setup at the start of the experiment and every day. What do you notice?
- Why do you see bubbles? Where might they be coming from? What gas is in the bubbles?
- Draw a picture of the egg each day and note and changes.
- What are the physical properties of the egg at the end of the experiment?
- What is the chemical formula for vinegar? What chemical makes up an egg shell? Look these chemicals up online or in a textbook. What can you find about their properties?
- Is what you saw in this reaction a chemical or physical change? What is your evidence?

Notes

EXPLAIN

What's happening in this Activity?

First review the Acids & Bases Background section to gain a deeper understanding of the scientific principles behind this activity.

During a **chemical reaction** the **reactants** change into completely new substances known as the **products**, and bonds between atoms are broken or formed. Chemical reactions occur all around us. Each substance reacts in a unique way, depending on what atoms it contains and how they are bonded to each other.

Many substances can be categorized as either acids or bases, each of which reacts in a distinctive way. A substance that gives up hydrogen ions, H^+, is an **acid**. A substance that accepts hydrogen ions is a **base**. An **ion** is a charged particle formed when an atom gains or loses an electron. Ions can be either positive or negative. For example, H^+ is positive and OH^- is negative. Positive ions and negative ions are attracted to each other and form bonds—in other words, opposites attract!

Acids and bases often react with each other in **neutralization reactions**. When an egg is placed in vinegar, there is an acid-base reaction between the vinegar and the eggshell. Vinegar is a solution of acetic acid, CH_3COOH, in water. Most of the eggshell—around 95%—is calcium carbonate, $CaCO_3$. The rest of the eggshell is made of proteins.

Notice that the acetic acid is part of a mixture in vinegar, and the calcium carbonate is part of a mixture in the eggshell. Even though both reactants are part of a mixture, the reaction still takes place. This is because when multiple substances are physically mixed, each substance still retains its own chemical properties. Acetic acid in vinegar reacts the same way that pure acetic acid would react.

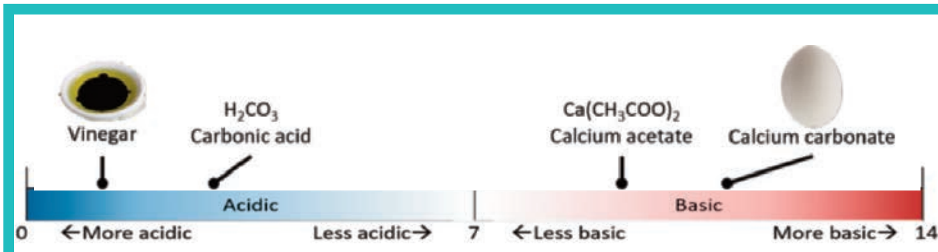
Acetic acid and calcium carbonate react to produce a new acid, called carbonic acid, and calcium acetate.

Acetic acid from vinegar	+	Calcium carbonate from the eggshell	⟶	Carbonic acid	+	Calcium acetate
$2CH_3COOH(l)$	+	$CaCO_3(s)$	⟶	$H_2CO_3(aq)$	+	$Ca(CH_3COO)_2(aq)$

During this step, the acetic acid dissolves the eggshell. It changes the solid calcium carbonate into dissolved carbonic acid and calcium acetate. Once vinegar has dissolved the shell, it leaves behind the soft inside of the egg. Without its shell, the egg is only covered by a thin membrane.

In the equation, the letters to the right of each compound indicate its state of matter. (l) is liquid, (s) is solid, and (g) is gas. Something that is (aq), which stands for **aqueous**, is dissolved in water. We start with solid eggshell and liquid acetic acid, and the products are both aqueous.

The products are all closer to neutral than the reactants. Acetic acid is a stronger acid than carbonic acid, and calcium carbonate is a stronger base than calcium acetate.



Notes

EXPLAIN continued

In addition to being a weaker acid than acetic acid, carbonic acid is unstable. As soon as it is formed, the carbonic acid decomposes. During a **decomposition reaction**, a larger molecule breaks down into two or more smaller molecules. There is only one reactant, and bonds in the reactant are broken to form two or more products.

When carbonic acid decomposes, it produces carbon dioxide gas and water. This is why you might see tiny bubbles on the surface of the egg during this process. The gas bubbles that form on the egg are one way we can tell that a chemical reaction is taking place.

Step 1: Vinegar (acetic acid) reacts with the eggshell (calcium carbonate) to produce carbonic acid
$CH_3COOH + CaCO_3 \rightarrow H_2CO_3 + Ca(CH_3COO)_2$

Step 2: Carbonic acid decomposes into carbon dioxide gas and water
$H_2CO_3 \rightarrow H2O + CO_2$

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED	DIVING DEEPER
For younger students, emphasize the following concepts: • Different types of chemical reactions • New substances formed in chemical reactions • Properties and characteristics of acids and bases • Opposite charges attract	**For more advanced students, emphasize the following concepts:** • Neutralization reactions • Ions – cations and anions • Aqueous solutions • Decomposition reactions

Notes

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Conduct this experiment with a control: have a second egg in water for the duration of the experiment and compare the two at the end.
- Want to see how the experiment progresses each day? Set up the experiment with a few eggs and start them all at the same time. Each day, remove one egg, wash and dry it, set it aside and label with the day it was removed. At the end of the experiment line the eggs up in order to see the progression of how the shell was removed day by day.
- Try other acids, like soda, juices, or different concentrations of acids. Which worked the best? What differences do students see?
- At the end of the experiment, leave the egg sitting out for another day. Do you notice any changes the next day? The egg might feel harder again as it absorbs carbon from carbon dioxide in the air.
- How does the concentration of the acid affect the results? Try making several samples of vinegar and water with various concentrations (i.e. ½ water and ½ vinegar, ¾ water and ¼ vinegar, etc.). Students can plot the pH (test with litmus paper or look up an estimate) versus the amount of time taken for the egg shell to fully dissolve.
- If you used a hardboiled egg, try bouncing it at the end of the experiment! Or, if you used a raw egg, try bouncing it in a sink. How high can it go?
- If you used a raw egg, now that the shell is removed you can use this opportunity to examine the inside of an egg! Turn the lights down and hold the egg in front of a flashlight. What can students see?
- Teach about osmosis and how membranes are permeable in this easy extension. If you used a raw egg for the first part of the experiment, after the shell is removed place the egg in a glass and cover with corn syrup. Let it sit for around three days, and you will notice the egg shrink! The egg membrane lets certain particles – like water – pass in and out. In this case, water leaves the egg and moves into the solution because of osmosis: the movement of water from a less concentrated solution into a more concentrated one to equalize the concentrations on both sides of the membrane. There is more water in the egg than in the corn syrup, so it moves through the membrane, out of the egg, and into the syrup. Place the shrunken egg into a glass of water next and let it sit for a few days. See if the reverse process happens now! (If you want to prove to students that the water is moving in and out, try using food dye to color the water first! You can also weigh the egg before and after each step.) Test out different liquids to see which ones make the egg grow, and which ones make the egg shrink.
- Add in some physics: do the experiment with a dozen raw eggs, then test how strong the membrane is by dropping them from various heights or placing different weights on them. (Warning: this will be messy, so ensure you do this outside or with plenty of space and table coverings inside!)
- Write a secret message or design with a white way crayon on the eggs before putting it in the vinegar. The wax covers and protects the egg shell and does not react with vinegar. At the end of the experiment the shell will be gone everywhere except where you drew with the crayon!

EVALUATE

- Ask students to draw a diagram of the experiment and label each chemical present (both reactants and products) along with a short explanation of what is happening in the experiment.
- Provide groups of students with mystery liquids, which could be acids, bases, or neutral. Students can explore the properties of the liquids and test the pH with an indicator (like litmus paper) or look it up online to check the pH once they know what it is. Have them make a guess: will this react with the calcium carbonate and dissolve the shell? Why or why not? Test it out and see if the predictions were correct!
- Make this a research project! We know that calcium carbonate has many different functions and uses in our world and in our bodies. Have your students do some research and learn more about this compound and what they find most interesting about its functions.

Fun Fact #2

Calcium carbonate is found in our bones, teeth, and in minerals around the world.

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

The chemical in the egg shell – calcium carbonate – is the same thing that makes up our bones. You can try this experiment with chicken bones, and even tie them into knots at the end!

Too much acidity can wear away at tooth enamel. The acids in soda pops, fruit juices, and other types of highly acidic foods and beverages can corrode the calcium in your teeth, leading to sensitivity, cavities, or other health problems.

Calcium in the eggshell supports the structure of the shell. People also need calcium. Calcium helps to support bone and tooth structure, which is why we say that calcium keeps bones and teeth strong! Milk and other dairy products are primary sources of calcium in human diets, as are dark-green, leafy vegetables. Many foods have been fortified with added calcium. By eating a wide variety of foods with calcium, you can help ensure that you get the calcium you need each day to stay strong and healthy.

Careers in Chemistry

- Farmers need to ensure that the eggs their hens produce have strong shells that won't break in transit. The strength of the shell (or the amount of calcium carbonate) is related to a variety of factors, such as diet, age, the environment, and more.
- Calcium carbonate is common in pharmaceutical medicine. Tablets of calcium carbonate are used as an antacid, and calcium supplements are used to prevent osteoporosis.
- Many living things in the ocean, such as oysters and clams, have shells made of calcium carbonate. Because of increasing carbon dioxide in the atmosphere from human emissions, the ocean is becoming more acidic. Oceanographers, marine biologists, chemists, and other types of scientists are studying the risk that this poses for calcium carbonate shells that dissolve in strong acids.

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Notes

Egg Dye Solutions

Section **CHEMICAL REACTIONS** *Topic* **ACIDS & BASES**

Estimated Time Setup: 5 minutes; Procedure: 10-15 minutes

OVERVIEW

Students discover how acids and bases can impact the amount of dye an egg shell can absorb through a chemical reaction.

In this activity, students dye three eggs: one in an acid, one in a base, and one in neutral water. Though the dyeing solutions are the same colors at the start, the egg in the acidic solution will be dyed much darker than the other two samples. The acid reacts chemically with the calcium carbonate and protein egg shell, thereby allowing the dye to better bind to the shell.

INQUIRY QUESTIONS

Getting Started:

- Is dyeing an egg a physical or chemical change, or both? How can we create a dye that will color an egg best?

Learning More:

- What chemicals are in the shell of an egg, and how might they react to an acidic or basic solution?

Diving Deeper:

- What chemical reactions take place when an egg is placed in an acidic, basic, or neutral solution, and how do these impact the dyeing process?

CONTENT TOPICS

This activity covers the following content topics: acids and bases, chemical reactions, chemical change

This activity can be extended to discuss the following: nutrition, pH scale, indicators

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:

- **2-PS1-1:** Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.
- **5-PS1-4:** Conduct an investigation to determine whether the mixing of two or more substances results in new substances.
- **MS-PS1-2:** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MATERIALS

For one setup:

- 3 hardboiled eggs
- 3 cups
- 3 plastic spoons
- 1 cup of a household acid (i.e. vinegar, lemon juice, orange juice)
- 1 cup of a household base (i.e. borax, milk of magnesia, ammonia)
    - Note: If your sample is a solid, like borax, first add to one cup of water until no more solid can dissolve. Use this liquid solution for the experiment.
- 1 cup water
- Food coloring
- Masking tape and marker

Optional materials:

- Red and blue litmus paper

ACTIVITY NOTES

This activity is good for:

- Individuals
- Pairs
- Small groups
- Large group
- Demonstration

Safety Tips & Reminders:

- This activity can be a bit messy, so we recommend covering your work surface with newspaper or a plastic tablecloth, and that students wear gloves.
- Be sure to wash eggs with warm, soapy water before using.
- There is no eating or drinking in the laboratory—even when we are working with normally edible materials.
- Review the Safety First section in the Resource Guide for additional information.

ENGAGE

Use the following ideas to engage your students in learning about chemical reactions and acids and bases:

- Ask your students if they have ever dyed eggs. If so, how do they do it? What do they think is the best way to get brightly-colored eggs?
- Challenge students to think of the best way to dye an egg. How much time would they leave it in? How much food coloring would they add? What liquid solution do they use? What other factors might make a difference?

See more ideas for engagement in the Acids & Bases Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

Notes

EXPLORE

Procedure:

1. Test each acid or base sample with litmus paper to determine whether it is an acid or a base. If you do not have litmus paper, ask students to make a guess or look up the values online.
2. Fill one cup with water.
3. Fill each other cup with either an acid or base sample.
4. Label each cup with the name of the acid or base sample used.
5. Add 3-5 drops of the same food coloring to each cup and mix with the spoon. If the samples are not the same color, add more food coloring until they are (i.e. milk of magnesia is white, so more food coloring will have to be added for it to appear the same color as the other samples).
6. Place each egg in its corresponding cup, ensuring that the egg is completely covered by the liquid (add more if it is not!).
7. Let eggs soak for 10 minutes.
8. After 10 minutes, remove each egg and gently rinse under water.
9. Observe and record the appearance of each egg.

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Make a prediction at the start: is each liquid an acid, base, or neutral? Why do you think this? Confirm your prediction with pH paper or by looking up the pH of your sample online or in a textbook.
- Do you think each egg will be the same color at the end of the experiment? Why or why not?
- Look closely at the eggs as they are submerged. Do you notice anything? Do the three eggs look like they are responding the same way in the liquids?
- After the eggs have been removed and rinsed, take note of the appearance of each egg. Are they similar or different?
- Examine each egg closely or using a hand lens. What do can you notice up close?
- Which dye solution worked the best? Which worked the worst?
- Are acids, bases, or neutral solutions best for dyeing eggs bright colors? Why might this be the case?

EXPLAIN

What's happening in this Activity?

First review the Acids & Bases Background section to gain a deeper understanding of the scientific principles behind this activity.

During a **chemical reaction** the **reactants** change into completely new substances known as the **products**, and bonds between atoms are broken or formed. Chemical reactions occur all around us—for example, when we dye eggs different colors! Each of these reactions is affected by the conditions around it, like temperature and concentration. Changing the conditions could make a reaction happen faster or slower or could make a reaction not happen at all.

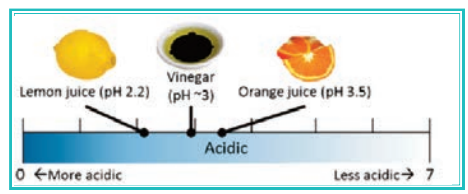
Fun Fact #1

Did you know: hens with white ear lobes typically produce white eggs, and hens with colored ear lobes usually produce brown eggs – though there is no nutritional difference between white or brown-shelled eggs.

Another factor that can affect reactions is pH. The **pH scale** measures how acidic or basic something is. pH can range from 0 to 14. **Acids** are substances with a pH less than 7. **Bases** are substances with a pH greater than 7. Whether something is acidic, basic, or neutral depends on the concentration of hydrogen ions, H^+. In a strong acid, there is a high concentration of H^+ ions floating around. All of these H^+ ions can make other compounds act differently.

An **ion** is a charged particle formed when an atom gains or loses and electron. Ions can be either positive or negative. For example, H^+ is positive and OH^- is negative. Positive ions and negative ions are attracted to each other and form bonds—in other words, opposites attract!

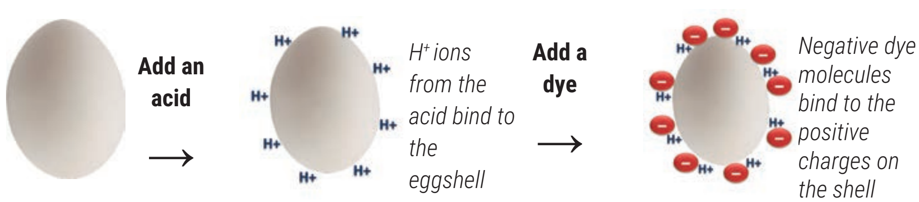
Vinegar is a solution of acetic acid, CH_3COOH, in water. When acetic acid is in water, it breaks down to release H^+ ions. When something breaks down into positive and negative ions, like acetic acid does in water, it is called **dissociation**. This dissociation is why vinegar is acidic.



Lemon juice and orange juice also contain acids that dissociate to release H^+. Lemon juice contains citric acid, and orange juice contains multiple kinds of acids. The pH of the acid solution in this experiment depends on which acid you use, and on how much you dilute it with water.

When an egg is placed in an acidic solution, where there are lots of loose hydrogen ions floating around, the hydrogen ions bind to proteins in the egg's shell. All of these H^+ ions crowding around the eggshell give it a positive charge.

The dye that we use to color eggs also dissociates in water. Dye molecules have a positive part and negative part. The negative part is what gives the dye its color. In water, the positive and negative parts break apart from each other. Since opposites attract, the negative dye molecules floating around bind to the positive charges on the eggshell.



Without the acid present, the dye molecules don't chemically bind to the eggshell. We can see this by comparing how well each of dye solutions colored the egg. In neutral and basic solutions, some dye molecules may get stuck in the pores of shell and color it slightly, but there are no extra H^+ ions to help bind the dye to the shell. More dye molecules will be attached to the shell in the acidic solution, giving it a more intense color.

EXPLAIN continued

The dye molecules binding isn't the only thing that happens when the egg is placed in acid. The proteins that bind to H^+ are only a small part of the eggshell. Most of the shell—around 95%! —is calcium carbonate, $CaCO_3$. Acid reacts with calcium carbonate and makes it dissolve, producing bubbles of carbon dioxide gas. This is why small bubbles form on the egg's surface in acid solution. If the solution is too acidic, the shell will dissolve.

So how can we tell whether the solution is not acidic enough, too acidic, or just right? An **indicator** is a substance that changes color at different levels of acidity. **Litmus paper** is commonly used as an indicator. Some litmus paper turns a different color for each number on the pH scale. Other litmus paper just indicates acid or base. For example, blue litmus paper turns red when it is in an acidic solution. Red litmus paper turns blue in a basic solution.

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED

For younger students, emphasize the following concepts:

- Different types of chemical reactions
- Properties and characteristics of acids and bases
- Reactions are affected by conditions like temperature and pH
- Opposite charges attract

DIVING DEEPER

For more advanced students, emphasize the following concepts:

- Neutralization reactions
- Ions – cations and anions
- Aqueous solutions
- Substances can dissociate in solutions

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Want to check out another fun experiment with eggs and vinegar? Go to the Rubber Eggs Activity Guide!
- Does temperature matter? Try the experiment again using three samples: hot water, half hot water and half room temperature vinegar, and half room temperature water with half room temperature vinegar. Do the results differ?
- Use a wax crayon to write or draw on the eggs at the start of the experiment. The dye will not adhere to the wax-covered parts of the egg. Why do students think this might be?
- Want more vibrant colors? Soak the eggs for an hour or two to see more drastic results.
- How does the concentration of the acid change the results? Try the experiment again but with solutions of varying concentration: 1 cup water, 1 cup water plus 1 tsp. vinegar, 1 cup water plus 2 tsp. vinegar, etc. Check the pH and see how well each works!
- There are an endless number of acid-base reactions in the natural world around us, and even in our own bodies. Task students with looking up some examples online and presenting them to their peers. Or, can they make a list of acids and bases in their environment? If they are unsure, provide pH paper and ask them to test at least 3 substances and report back to the class.

Notes

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

Egg-dyeing kits that can be bought at the store also recommend adding vinegar to water to get the most colorful eggs!

Too much acidity can wear away at tooth enamel. The acids in soda pops, fruit juices, and other types of highly acidic foods and beverages can corrode the calcium in your teeth, leading to sensitivity, cavities, or other health problems.

Careers in Chemistry

- Developing dyes is a serious science, and one that has been around for centuries. Chemists and artists often work together to develop the perfect colors for various industries and uses.
- Color scientists in the food industry are tasked with producing dyes that are edible, taste good (or have no taste!), easy to manufacture, are specific colors, and approved by the Food and Drug Administration.

Notes

EVALUATE

- Provide groups of students with various household acids, or vinegar diluted to different concentrations. Ask them to test the pH or look it up if they know the name of the sample. Based on the original experiment, students should make a prediction as to how well the food coloring will be absorbed into the egg shell. What evidence do they have? They can test it out and see how close their predictions were.
- Have individual students draw a diagram of what is happening at the molecular level in this acid-base reaction. Can they make a single or multi-panel cartoon or image that visually represents what is happening? Or can they create an advertisement for an egg dye company with recommendations on best practices for dyeing eggs?
- At the end of class, have each student fill an exit ticket about the experiment. It could ask them to explain which substance – the acid, base, or neutral liquid – worked best for dyeing eggs bright colors and why. Or provide them with mystery substances with known pH measurements and ask them to write or draw and label what they think will happen if those samples are used to dye a series of eggs.

Fun Fact #2

Depending on the breed of chicken, hens might lay their own 'dyed' eggs that are white, pink, brown, blue, green, speckled, striped, and more! The color of the egg is based on the genetics of the hen, and chickens can be bred to produce chicks that lay eggs of specific colors.

Exploding Bags

Section **CHEMICAL REACTIONS** *Topic* **ACIDS & BASES**

Estimated Time Setup: 5 minutes; Procedure: 5 minutes

OVERVIEW

Students will mix two substances to observe how an 'explosive' new substance is formed through a chemical reaction.

In this activity, students mix baking soda, warm water, and vinegar in a plastic bag and watch as reactants suddenly turn into products: a liquid and a gas. As the reaction proceeds and produces more gas, the plastic bag will inflate and then 'explode' open. Students can explore how matter changes form in chemical reactions, an acid-base reaction, that gases take up space, and that chemical reactions often coincide with thermal energy changes.

INQUIRY QUESTIONS

Getting Started:

- How do we know a chemical reaction has taken place?

Learning More:

- What physical, chemical, and thermal changes happen in this reaction?

Diving Deeper:

- Why do vinegar and baking soda react with one another, and what products do they form?

CONTENT TOPICS

This activity covers the following content topics: chemical reactions, acids and bases, energy, chemical changes, properties of matter, endothermic reactions, chemical formulas

This activity can be extended to discuss: balancing equations

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:

- **5-PS1-4:** Conduct an investigation to determine whether the mixing of two or more substances results in new substances.
- **MS-PS1-2:** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MATERIALS

For one setup:

- Vinegar
- Baking soda
- Warm water
- Sandwich or quart-size sealable plastic bag
- 2 squares of Charmin® toilet paper
- ¼ cup liquid measurer
- Spoon

ACTIVITY NOTES

This activity is good for:

- Pairs
- Small groups

Safety Tips & Reminders:

- We recommend doing this activity over a sink, pan, bin, or outside since the contents in the bag may spill.
- While the 'explosion' is more of a 'pop' and is contained in the bag, safety goggles are recommended.
- The water should be warm, not hot! If it is too hot it could melt the plastic bag.
- Review the Safety First section in the Resource Guide for additional information

ENGAGE

Use the following ideas to engage your students in learning about density:

- For 'explosive' experiments like this, sometimes the best engagement is the demo itself! Try it as described in the procedure or use a volcano to make it more fun.
- There are great videos of similar reactions, but on a much larger scale! Find videos of 'explosive' reactions that others have tried but may be too big to do in the classroom.

See more ideas for engagement in the Acids & Bases Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

EXPLORE

Procedure:

1. Scoop two large spoonfuls of baking soda to the center of a square of Charmin® toilet paper.
2. Wrap the toilet paper around the baking soda.
3. Wrap a second square of Charmin® toilet paper around the first so the baking soda is held in the paper.
4. Have one student hold the plastic bag open, and another student add ¼ cup vinegar and ¼ cup warm water to the bag.
5. Seal the bag almost entirely closed and hold the wrapped baking soda over a small opening in the corner.
6. Have one student drop the baking soda into the bag and another student quickly seal the bag.
7. Gently swirl the contents of the bag so the toilet paper soaks up the liquid, then place the bag on the table. Watch as the bag inflates and pops!

Notes

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Take notes on the content of the bag prior to and after adding the baking soda. Are they the same or different? What are the physical properties?
- What are the reactants in this experiment? Can you write their chemical formulas?
- Make a prediction about the temperature of the product: will they feel warm or cold? After a few minutes, feel the bottom of the bag with your hands. Was your prediction correct? Why does this happen? What does it mean?
- Draw and label diagrams showing each stage of the reaction. Why did the bag 'explode'?
- What are the products in this reaction? Can you write their chemical formulas? What are the physical properties of the products?

Fun Fact #1

In July of 2017, the Oregon Museum of Science and Industry made a 34-foot, super-sized volcano! They filled it with 66 gallons of vinegar, 50 gallons of baking soda, water, and red food dye for effect. You might see it in the Guinness Book of World Records soon, and find the video online!

EXPLAIN

What's happening in this Activity?

First review the Acids & Bases Background section to gain a deeper understanding of the scientific principles behind this activity.

During a **chemical reaction** the **reactants** change into completely new substances known as the **products**, and bonds between atoms are broken or formed. Chemical reactions occur all around us. Each substance reacts in a unique way, depending on what atoms it contains and how they are bonded to each other.

Many substances can be categorized as either acids or bases, each of which reacts in a distinctive way. A substance that gives up hydrogen ions, H^+, is an **acid**. A substance that accepts hydrogen ions is a **base**. An **ion** is a charged particle formed when an atom gains or loses an electron. Ions can be either positive or negative. For example, H^+ is positive and OH^- is negative. Positive ions and negative ions are attracted to each other and form bonds—in other words, opposites attract!

Acids and bases often react with each other in **neutralization reactions**. When vinegar and baking soda are mixed, the two react because vinegar is acidic and baking soda is basic. Vinegar is a solution of acetic acid, CH_3COOH, in water. When acetic acid is in water, it breaks down to release H^+ ions. When something breaks down into positive and negative ions it is called **dissociation**.

Baking soda is made of the compound sodium bicarbonate, $NaHCO_3$. It breaks down in water into Na^+ and HCO_3^-. Since HCO_3^- is negative, it is attracted to the oppositely charged H^+ ions from vinegar.

One of the products is a new acid, carbonic acid. Carbonic acid, H_2CO_3, is unstable and so a second reaction takes place right away. The carbonic acid breaks down into carbon dioxide and water in a **decomposition reaction**. During a decomposition reaction, a larger molecule breaks down into two or more smaller molecules. There is only one reactant, and bonds in the reactant are broken to form two or more products.

Step 1: Vinegar (acetic acid) reacts with baking soda (sodium bicarbonate) to produce carbonic acid
$CH_3COOH + NaHCO_3 \rightarrow H_2CO_3 + CH_3COONa$

Step 2: Carbonic acid decomposes into carbon dioxide gas and water
$H_2CO_3\ (aq) \rightarrow H_2O\ (l) + CO_2\ (g)$
The (aq) means carbonic acid is dissolved in water. (l) means liquid, and (g) means gas.

All the gas that this decomposition reaction produces makes the bag inflate. Even though we can't see it, the extra gas particles flying around take up more space in the bag than the liquid and solid reactants did. If the reaction produces enough gas, the bag will explode!

Baking is soda is used in cooking things like bread, muffins, and cake. When bread rises in the oven, it is because the baking soda is reacting to produce carbon dioxide gas.

During this experiment, the bag feels cold to the touch. This is because the reaction is **endothermic**, meaning that it takes in or absorbs energy from its surroundings. Other reactions release energy and feel warm to the touch. These are **exothermic reactions**.

Notes

EXPLAIN continued

Any feeling of "hot" or "cold" is because of the transfer of energy. The type of energy related to temperature is called **thermal energy**. When you touch something and it feels hot, thermal energy is flowing from the object to your hand. When something feels cold, thermal energy is being transferred from you to the object. If you hold the bag during this experiment, it feels cold because you lose some thermal energy to the reaction mixture.

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED

For younger students, emphasize the following concepts:

- During a chemical reaction new substances with different properties are formed
- Many substances can be characterized as acids or bases based on how they behave
- Opposite charges are attracted to one another
- Acids and bases react with one another

DIVING DEEPER

For more advanced students, emphasize the following concepts:

- The pH scale is used to measure how acidic or basic a substance is
- Acids donate H^+ ions and bases can accept H^+ ions
- Ions have a charge, which can be either positive or negative
- Many things dissociate, or break down into ions, in water
- Some chemical reactions absorb energy and others release energy

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- You might have seen this reaction before at a local science fair as an exploding volcano! Help students make this into a more explosive and creative project by building a volcano, adding food coloring and liquid dish soap, and researching how real volcanos work in nature.
- Another modification for a more explosive reaction is to do the experiment in a bottle with Dawn® Ultra dishwashing liquid soap. What might the purpose of the dish soap be? (Hint: what is captured in the soapy bubbles? How does this make the reaction more visible compared to the original Exploding Bags procedure?)
- If a student's bag did not 'explode,' ask them to brainstorm the reasons why. What can they do to ensure the bag will 'explode?' Help them write out the potential variables they could adjust and test a variety of solutions to see what works best.
- Does the size of the bag matter? Try the experiment again with a snack, sandwich, quart, and gallon bag using the same amount of reactants and see what happens.
- What is the purpose of the toilet paper? Try the reaction again with dropping the baking soda directly into the bag. Do you have enough time to seal the bag and experience the full reaction?
- Ask students whether the amount of each reactant matters in this experiment. Try the experiment a few more times, each time changing the amount of each reactant. Do they see a pattern? Which reactant limits the amount of product that can be made?
- See what difference the temperature of the water makes. Ask students to make a prediction, then try the experiment again with cold, room temperature, and warm water. Are there any differences? What might be the purpose of the warm water? What if you do the experiment without water?
- Explore whether this is a physical or chemical reaction. What defines each type of reaction? What are some examples? What is the evidence that shows what type of reaction this is? Hint: write or draw the reactants and products. Are they the same or different?
- For more advanced students: write out the chemical formulas for the reactants and products. Ask students to balance the equation.
- Ask students to draw a diagram showing the movement of energy in the system. Where does the energy (heat) go in the reaction? Can they add this to their chemical equation? (Hint: if the products felt cold, energy is flowing into the reaction and it is endothermic, so heat is one of the inputs.)
- Doing this activity in the fall? Try it out in a jack-o-lantern! Place a small cup in the pumpkin and add in your liquids. You can be generous: ½ cup warm water, ½ cup vinegar, big squirt of Dawn® Ultra dishwashing liquid soap, a couple drops of food coloring (optional). Drop a heaping spoonful of baking soda into the cup, stir, and watch it foam out of the jack-o-lantern!

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

You have already experienced this reaction dozens of times, especially if you are a baker or eat baked goods! Baking soda is a common ingredient in baked goods because when it reacts with acidic ingredients like vinegar, yogurt, buttermilk, or cream of tartar it produces carbon dioxide bubbles and makes dough rise!

Both vinegar and baking soda are common cleaning, deodorizing, and disinfecting products. Baking soda is commonly added to toothpaste, all-purpose cleaners, and various soaps and shampoos. It also absorbs odors, which is why people sometimes put open boxes of baking soda in their refrigerators and why it is added to kitty litter. Vinegar is often added to liquid cleaning or disinfecting products. There are lots of recipes for make-your-own cleaners using baking soda, vinegar, or both since they are such inexpensive, effective products!

Careers in Chemistry

- Developing, testing, manufacturing, and selling cleaning products is a big industry! Chemists work hard to create products that work best on specific surfaces, for certain types of stains or impurities, that are safe to use in the home, and good for the environment. Inexpensive and accessible products like baking soda and vinegar are common components in these products.
- How do you make the chewiest cookie? The fluffiest? One that doesn't spread out too much in the oven? Food scientists test dozens of different recipe tweaks to make sure baked goods you buy in the grocery store or make in your home are the best they can be.

EVALUATE

- Can students prove whether a chemical reaction took place? Provide vocabulary words learned throughout this unit and ask students to write what they observed and whether a chemical or physical change took place using new vocabulary and evidence from their experiences. They can present their writing to a peer to review and provide feedback or share their thoughts orally with the class.
- The reaction in this experiment is an acid-base reaction. Design a research project for students to explore other acid-base reactions in the world around them. What are some common acids and bases? What types of acid-base reactions happen in your body? In nature? In the school? What are the products of these reactions? Have each student or student pair/group share their findings with the class and see what commonalities or differences they note between their discoveries.