Fifth Edition

YOU BE THE CHEMIST™

ACTIVITY GUIDES

Hands-on Science for Grade K-8 Students

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Basics of Chemical Reactions

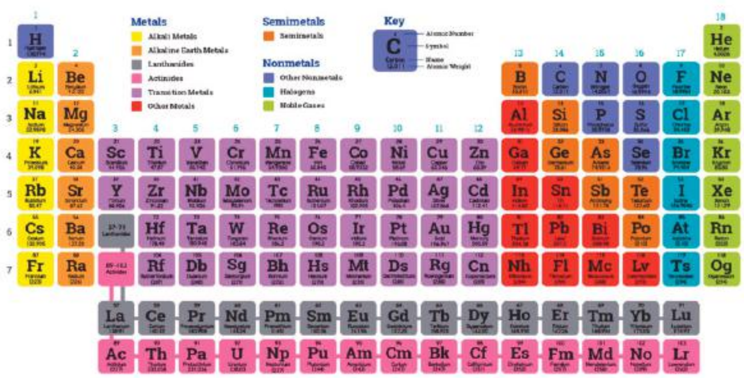
Background

Activity Guides:

BROWN BANANAS | LUMPY LIQUIDS | RUSTING WOOL | CLEANING PENNIES

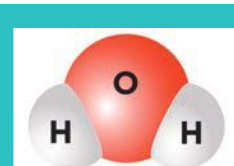
The Basics of Chemical Reactions

All matter is made up an array of 118 building blocks called **elements**, each of which is unique. Think of the 26 letters in the English alphabet. This paragraph is made of various combinations of those 26 letters, just as is any book, magazine, text message, or street sign. Similarly, all the matter in the universe is made of some combination of the 118 different elements on the periodic table. The smallest unit of an element, and the one we use to describe matter, is an **atom**.



Chemical composition means the types of atoms in a substance and how those atoms are arranged. For example, pure water has two types of atoms in it: hydrogen and oxygen. Every oxygen atom is bonded to two hydrogen atoms. Every substance is defined by its chemical composition. All the properties of water—how it looks, feels, and behaves—are because of the way its atoms are bonded together.

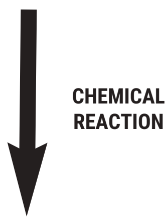
One water molecule: one oxygen atom (O) bonded to two hydrogen atoms (H).



Looking at chemical composition helps us understand the different properties of matter and the ways matter can change. **Physical properties** are properties of matter that can be observed without changing a substance's chemical composition. Some examples are color, mass, density, boiling point, odor, and hardness. Similarly, a **physical change** is any change in a substance's form that does not change its chemical composition. A sample of water can be tested for any physical property, or undergo any physical change, and it will still be made of oxygen atoms that are each bonded to two hydrogen atoms.

Chemical properties describe how something reacts with other substances and changes its chemical composition. Some examples are reactivity, toxicity, and flammability. A chemical property of the compound butane, the fuel used in lighters, is that it burns easily. Whenever a lighter produces a flame, it is actually butane atoms reacting with oxygen in the air. As they burn, the butane and oxygen change and become carbon dioxide and water vapor. Chemical properties can be observed when a chemical reaction takes place.

Physical Property	Chemical Property
Can be observed without changing chemical composition	Observed when a chemical reaction takes place
Color, mass, density, boiling point, odor, hardness	Reactivity, toxicity, flammability



A **chemical change** or **chemical reaction** is a change that takes place when the atoms of a substance are rearranged, and the bonds between atoms are broken or formed. During a chemical reaction, the chemical composition of a substance changes. The substances that are present at the end of a chemical reaction are different from what was there before the reaction. All substances at the beginning of a reaction are called the **reactants**. All new substances produced during the reaction are called the **products**. The products have different physical and chemical properties than the reactants.

Chemical equations are written as shown below. All the reactants are listed to the left of the arrow, and all the products are listed to the right of the arrow.

$$\text{Reactants} \xrightarrow{\text{Chemical reaction}} \text{Products}$$

Chemical reactions occur around us all the time. An example is baking cupcakes. You start with mixing many different ingredients to form the batter. Mixing these ingredients leads to physical changes. However, heating them causes a chemical change. When the batter is heated (baked) in the oven, a new substance— a cupcake! —is formed. This change is irreversible. Even when the cupcakes cool down to room temperature, the original ingredients do not appear again.

Not every chemical reaction occurs in the same way, and there are many different types of chemical reactions.

Let's try some activities so you can experience the basics of chemical reactions in action!

ENGAGE YOUR STUDENTS

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

- Start with an overview of physical versus chemical changes, including their definitions and how we distinguish them. Show students a 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.

- There are some beautiful examples of precipitation reactions! Check out this one with lead iodide in slow motion or this from the series Beautiful Chemistry.

Brown Bananas

Section **CHEMICAL REACTIONS** *Topic* **BASICS OF CHEMICAL REACTIONS**

Estimated Time Setup: 10 minutes; Procedure: 4-5 days

OVERVIEW

Students will observe how fruit ripens, and how this process can be affected by a variety of packaging.

In this activity, students place bananas in three different packaging materials: a paper bag, plastic bag, and plastic wrap. Control bananas receive no packaging. Over the course of a week, students observe how the ripening process is affected by the fruits' surroundings. Students learn that ripening is a chemical process that requires oxygen flow to produce ethylene – a plant hormone that causes the fruit to change color and grow softer and sweeter.

MATERIALS

For one setup:

- 4 green, unripe bananas
- Brown paper bag
- Sealable gallon plastic bag
- Plastic wrap

INQUIRY QUESTIONS

Getting Started:

- What physical changes can we observe with our senses as fruit ripens?

Learning More:

- What chemical changes occur when fruit ripens?

Diving Deeper:

- What is the chemistry of ripening and how do environmental factors affect these processes?

CONTENT TOPICS

This activity covers the following content topics: physical changes, chemical changes and reactions, diffusion, chemistry of fruit ripening, enzymes, catalysts

This activity can be extended to discuss: agricultural processes, food production and storage, glucose production, diabetes, hormones, environmental science

NGSS CONNECTIONS

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

- 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:

- Pairs
- Small groups
- Large groups
- Project or take-home assignment

Safety Tips and Reminders:

- There is no eating or drinking in the laboratory—even when we are working with normally edible materials.
- Ensure that this experiment is set up in a place where it will not attract unwanted animal visitors!
- Review the Safety First section in the Resource Guide for additional information

Fun Fact **#1**

The average American eats 27 pounds of bananas each year!

ENGAGE

Use the following ideas to engage your students in learning about the basics of chemical reactions:

- Start with a discussion about how food is harvested, packaged, and transported to grocery stores, and then to students and their families. How long do students think this process takes? Why is fruit still fresh when it arrives in their local grocery stores, and how can they keep fruit fresh longer once they get home?
- Start with a dilemma: you want to make banana bread and need ripe bananas, but these are still green! Is there a good way to speed up the ripening of a banana if you don't have time to wait?
- Do some group brainstorming: what do students think happens when fruit ripens? What changes do they notice? What chemical changes might be happening? If needed, prompt them to think about changing appearances and smells. What do they think causes this?
- If possible, go to a few local grocery stores and take photos of how the bananas are packaged. Some might be left out, others might be wrapped up or in some sort of packaging. Show the photos to the students and ask why they think they are packaged or displayed in these ways. How might this affect the rate at which it ripens?
- Do a blind taste test! (Even though eating is not usually allowed in the laboratory, you can make exceptions as needed.) Provide unlabeled samples of ripe and unripe fruit. Do students see, feel, or taste any difference? Ask them to describe each sample. Can they tell which sample was ripe and which was unripe? How? What changes occur during ripening?

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

EXPLORE

Procedure:

1. Place one banana in a paper bag and fold the top down several times so it is closed.
2. Place a second banana in a plastic bag and seal, leaving some air in the bag.
3. Wrap a third banana tightly in a few layers of plastic wrap, ensuring the ends are sealed.
4. Leave the fourth banana out in the open as a control.
5. Wait 4-5 days without tampering with the wrappings, then open to observe the results.




Notes

EXPLAIN

What's happening in this Activity?

First review the Basics of Chemical Reactions Background section to gain a deeper understanding of the scientific principles behind this activity.

When a fruit ripens, it changes in a variety of ways. The fruit generally becomes sweeter, it softens, and its color changes—often it becomes less green. This is all because of chemical reactions happening in the fruit. The tissue of the fruit softens because of molecules that break down the walls of cells in the fruit. The color changes because a compound called chlorophyll, which is responsible for the green color of plants, is being degraded. The taste becomes sweeter because sharp-tasting acids are broken down, and starches are converted into sugars like glucose. These are all chemical changes. Bananas are usually picked before they are ripe, so they can be transported long distances without being damaged.

In this activity, there are three liquid samples: water, light corn syrup, and vegetable oil. When they are put together they make distinct layers based on differences in density. The density of each substance differs because each has a different chemical makeup—each is made up of different molecules with varying sizes, atomic weights, and molecular arrangements. If you calculate or research the density of each liquid sample, you will find that the light corn syrup has the greatest density, followed by water, then vegetable oil. This aligns with what you saw: the light corn syrup forms the bottom layer, with water in the middle, and vegetable oil on top.

Unripe Bananas

Ripe Bananas

One of the things that triggers the ripening process is a plant hormone called ethylene. Hormones are substances produced by living things, like plants and animals, that regulate the biological processes we rely on to survive. Ethylene is an odorless gas with the formula C_2H_4: each molecule contains two carbon atoms and four hydrogen atoms.

Fruits ripen when exposed to ethylene, and also produce ethylene themselves as they ripen. Plants also produce ethylene when heated or bruised. To produce ethylene, plants need oxygen from the air around them.

When more ethylene is present, the chemical reactions associated with ripening occur faster. Ethylene helps the starch in the fruit breaks down more quickly into sugars like glucose. The cell walls are broken down more quickly, and the green compound chlorophyll degrades faster. Because of its effects on the ripening process, ethylene is said to be a **catalyst**. A **catalyst** is a substance that changes the rate of a reaction but is not used up by the reaction.

When a fruit produces ethylene gas, that gas travels through the air because of a process called diffusion. **Diffusion** is the movement of fluid (liquid or gas) particles from an area of high concentration to an area of low concentration. This means that the ethylene gas emitted by a plant spreads out after being released. If there are other fruits nearby, they are affected by that additional ethylene in the air.

DATA COLLECTION & ANALYSIS

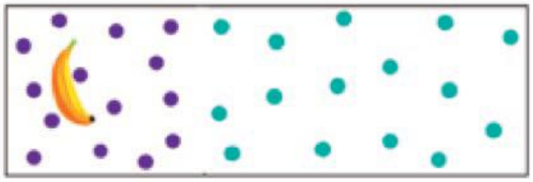
Analyze and discuss the results of this activity using the following questions:

- Describe the physical properties of the unripe bananas. What do they look, feel, or smell like?
- Draw and label your experimental setup on the first day.
- Write observations each day for the bananas you can see.
- On the last day draw and label your results. Describe any changes to each banana and differences between the bananas. Why do you think they ripened at different rates?
- Describe the physical properties of the ripe bananas. What do they look, feel, or smell like? Do you think ripening is a physical or chemical change? Provide evidence for your answer.

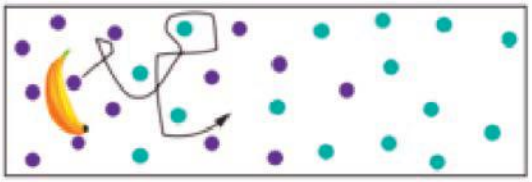
Fun Fact #2

Humans also have catalysts called enzymes in our bodies to help reactions like digestion occur. Without an enzyme catalyst, the slowest known biological reaction would like 1 trillion years. With an enzyme catalyst, this reaction, which is essential to creating our DNA, happens in just 10 milliseconds.

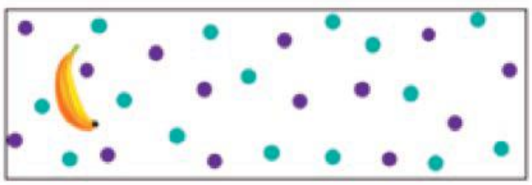
EXPLAIN continued



When the banana produces ethylene, there is a high concentration of ethylene (represented by the purple dots) right around the banana, and none in the surrounding air (blue).



The ethylene particles spread out away from the banana, from the area with a high ethylene concentration to an area with a low ethylene concentration.



The ethylene spreads out until it reaches equilibrium. *Equilibrium* is when all the gases are spread evenly throughout the area. Because the banana keeps producing ethylene, in real life the ethylene gas may never fully reach equilibrium.

The conditions also must be right for the reactions behind ripening to occur. Environmental conditions, like temperature and pressure, affect whether or not a reaction occurs and how fast it proceeds. The enzymes in plants do not function if the environment is too cold. Therefore, storing fruits in cold places can stop them from ripening and make them ripen slower.

In this experiment, the banana sealed tightly in plastic wrap should ripen the slowest, if at all. Because it is wrapped tightly, it is not exposed to any oxygen in the air and cannot produce any ethylene. The banana wrapped in a plastic bag with air inside will ripen faster because it has access to oxygen. The ethylene produced by that banana is contained, and the high concentration of ethylene in the bag makes the banana ripen quickly as well. The banana in the paper bag should ripen fastest. Like the plastic bag, the paper bag keeps the ethylene produced by the banana contained. But the paper bag also allows additional oxygen to pass through because it is **porous** (has very small holes). The banana in the paper bag is kept in close contact with its own ethylene, and also has an unlimited supply of oxygen.

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: • Basics of chemical reactions • Basics of diffusion	**For more advanced students, emphasize the following concepts:** • Catalysts and their effect on the rate of reactions • Factors that affect chemical reactions

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.

- Fruits produce more ethylene in response to bruising. Try the experiment again, but this time use bruised bananas. Use bananas from the same bunch, and bruise some while leaving others as they are. Do the bruised bananas ripen faster or slower than the unbruised bananas?
- More fruit, more ethylene! Do the results change if there are more bananas in each setup (i.e. a bag with 2-3 bananas instead of one)? Test it out!
- Many people put fruits and vegetables in the refrigerator. Is this an effective way to slow ripening and keep fruit fresh? Try placing bananas in a variety of temperatures. How does this affect ripening? Does light exposure have any effect?
- Other fruits produce ethylene gas while ripening, too. Try placing bananas alongside different fruits (i.e. apple, pear, lemon) in clear plastic bags so you can observe the ripening process. Which fruit exhibits the fastest ripening?
- Take time lapse photos of your experiment. Photograph each banana each day to create a slideshow to better visualize how the ripening happened. You can even extend the experiment to one or two weeks to see the full progression.
- Integrate conservation of matter into this activity. Have students record the mass of each banana at the start of the experiment. Do they think the mass will stay the same or change by the end of the experiment? Why? Measure the mass at the end of the experiment. What did they find?
- Which fruits ripen by producing ethylene gas? Do some research, then try the experiment again, but use a different fruit in each bag along with a control outside of the bag.

CHEMISTRY IN ACTION

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

Real-World Applications

Results from experiments like these are used every day as people store their produce. Want to make guacamole but only have unripe avocados? Put a bunch of them together in a bag with an ethylene-producing fruit, like an apple or banana, and they will ripen in a snap!

Ethylene absorbing pads, beads, or bags can often be found in fruit packaging. These products quickly absorb ethylene while fruit is stored so it doesn't overripen in transit.

Careers in Chemistry

- There are many people and scientists involved in fruit production and distribution processes, including those who grow, harvest, transport, store, advertise, check for quality, and more. You can find videos online to learn how bananas are harvested, packaged, and distributed, and learn fascinating facts about the science of how quality is measured and the ways in which produce is stored to ensure you get the freshest product!
- The US Department of Agriculture provides guidance for food production, storage, nutrition and more. The scientists and policy makers work to ensure Americans are eating food that is good for them and that we are educated about where our food comes from and its nutritional benefits. They even have a YouTube channel where you can check out some produce storage hacks!

EVALUATE

- Present students with a new experimental setup with slightly different packaging for each banana. Examples could be a shoebox, mesh bag, paper towel, or plastic container. What do they predict will happen and why? What evidence do they have from the first experiment to back up their ideas?
- Provide a variety of scenarios for students to solve based on their results from this experiment. For example, if you want to quickly ripen a bunch of bananas, what setup would you try? If you want to keep them unripe as long as possible, what would you do? Thinking beyond the constraints of the experimental setup: can they design a more effective mechanism or packaging to control the ripening of a banana?
- Add a research component to this experiment: ask students to investigate how bananas are harvested, packaged, and transported to local grocery stores. How might these processes help bananas stay fresh and not ripen too quickly? Students can collect data from labels to see where bananas they eat are coming from in the world and plot out the travel route and the steps taken before the bananas arrive at their home.
- Ask students to write a proposal to a local grocery store recommending a better way to store their produce. Students should draw diagrams of their proposal and include the associated costs. Their proposal should indicate the problem they are aiming to solve, their solution, the science behind the effects it would have, and the benefits for the store and its customers.

Lumpy Liquids

Section **CHEMICAL REACTIONS** *Topic* **BASICS OF CHEMICAL REACTIONS**

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

OVERVIEW

Students experience a fascinating chemical reaction: precipitation of a solid out of a mixture of solutions!

In this activity, student create two solutions: one with Epsom salt, and the other with powdered laundry detergent. As they slowly add one solution into the other, they will see a solid form. The chemical reaction of two liquid solutions forms a solid right before their eyes.

INQUIRY QUESTIONS

Getting Started:
- How do we know if a chemical or physical reaction has taken place?

Learning More:
- What changes do we observe in a precipitation reaction?

Diving Deeper:
- What is the chemical process by which a precipitate is formed?

CONTENT TOPICS

This activity covers the following content topics: mixtures, solutions, separation techniques, chemical reactions, chemical separations, precipitation, solubility, measurement techniques

This activity can be extended to discuss the following: filtration, physical separations, hard vs. soft water, balancing equations, chemical formulas, aqueous solutions, conservation of mass, double replacement reactions

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:
- Epsom salt
- 1 tsp. powdered laundry detergent containing sodium carbonate (Tide® or Gain® Powdered Laundry Detergent)
- Water (1/2 cup room temperature and 2 tbsp. warm)
- 2 clear plastic cups
- 3 drops food coloring
- Eye dropper
- Teaspoon and tablespoon measurers

ACTIVITY NOTES

This activity is good for:
- Individuals
- Pairs
- Small groups

Safety Tips & Reminders:
- Beware that this activity requires powdered laundry detergent that contains sodium carbonate, which is used as a water softener. Not every brand will have sodium carbonate added, so double check this before purchasing, otherwise the experiment will not work.
- 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:

- Challenge students to think of how a solid can be made from mixing two liquids. Have they ever experienced this? How might this be possible?
- Demonstrate this experiment but without using any food coloring. As students watch the solid precipitate form, ask them to brainstorm what could be in each solution and how this is possible.
- There are some beautiful examples of precipitation reactions! Check out this one with lead iodide in slow motion or this from the series Beautiful Chemistry.

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

Fun Fact #1

Epsom salt is hydrated magnesium sulfate, and the name originates from the town of Epsom in England, where water contains high concentrations of this substance.

EXPLORE

Procedure:

1. Add 1/2 cup water and 1 tsp. of Tide® or Gain® powdered laundry detergent to a plastic cup and stir to dissolve.
2. In a second cup, add 2 tbsp. warm water and 1 tbsp. Epsom salt, and stir to dissolve.
3. Add 3 drops of food coloring to the cup containing the Epsom salts.
4. Using the eye dropper, take up some of the colored Epsom salt solution. Submerge the tip of the full eye dropper in the detergent solution.
5. While observing from the side, slowly squeeze the colored Epsom salt solution out of the eye dropper and into the detergent solution. Record your observations.

DATA COLLECTION & ANALYSIS

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

- Draw a picture and describe both the Epsom salt and laundry powder solutions.
- Make a prediction: what will happen when you add one solution to the other?
- As you complete step 5, record your observations. What do you see? Why might this be happening?
- Do you think there was a chemical change, physical change, or both in this activity? How do you know? Provide evidence for your answer.

Notes

EXPLAIN continued

What's happening in this Activity?

First review the Basics of Chemical Reactions Background section to gain a deeper understanding of the scientific principles behind this activity.

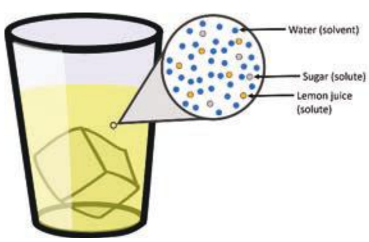
Most of the things around us are mixtures. **Mixtures** are two or more substances that are combined physically. The different substances that are combined to create the mixture are the **components**. Since the parts of the mixture only are combined physically, the chemical compositions of the different parts don't change. For example, in any mixture that contains water, the water will still be composed of oxygen atoms each bonded to two hydrogen atoms.

Since the chemical compositions of the mixture's components remain unchanged, each component in the mixture still has the same physical and chemical properties as it does when it is by itself. Water in a mixture has the same boiling point, density, and reactivity as pure water. A **separation process** divides a mixture of substances into two or more distinct parts based on the different properties of the substances in the mixture.

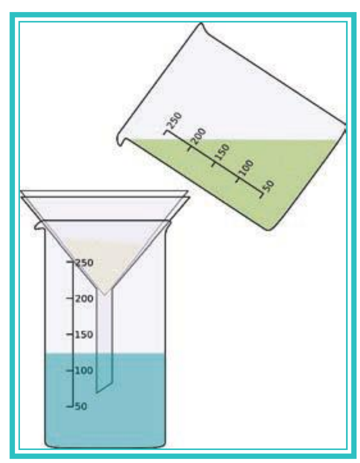
Think of a bowl of trail mix. Each of these parts still has its own unique properties, so we can separate the mixture into the different parts. One physical property that is different is color. Because the parts of the mixture look different, it is easy to pick out the chocolate pieces or the peanuts. This is a physical separation because it uses differences in a **physical property** (color).

Chemical separations use chemical properties to separate a mixture. The components of the mixture react differently because of their unique properties, so a chemical reaction can be used to separate parts of the mixture. Chemical separations are useful for substances that are mixed on a molecular level.

A **solution** is a type of mixture in which one or more substances (called the **solutes**) are dissolved in another substance (called the **solvent**). The different parts of a solution are mixed evenly throughout, so every part of the solution has the same appearance and composition. Lemonade is a solution of lemon juice and sugar (the solutes) in water (the solvent).



One way to separate the parts of a solution by chemical separation is a **precipitation reaction.** During a precipitation reaction, parts of a liquid solution react to form a solid. The solid that forms is called a **precipitate**. Precipitation is useful because it is then easy to separate this solid from the rest of the solution, usually by some physical means.



The precipitate is usually isolated by **filtration**, which is a physical separation process that separates components based on particle size. The mixture is passed through filter paper, which has very small pores (or holes). Filtration is often used to separate solids and liquids. The liquid parts of the mixture can pass through the holes in the filter, but the solid parts cannot. The liquid that flows through the filter paper, which does not contain any solid particles, is called the **filtrate**.

We use filtration after we cook pasta in water. Once the pasta is done, it is poured through a strainer with holes that allow water – but not the cooked pasta – to pass through. We also use filtration to make tea and coffee, but with a filter (the tea bag or paper coffee filter) with much smaller holes so that the tea leaves and coffee grounds cannot pass through.

EXPLAIN continued

In this experiment, Epsom salt (the solute) is mixed with water (the solvent) to create an Epsom salt solution. A second solution of powdered laundry detergent dissolved in water is also created. In this solution, laundry detergent is the solute and water is the solvent.

Epsom salt is made of a compound called magnesium sulfate, which has the formula $MgSO_4$. The powdered laundry detergent contains a compound called sodium carbonate, which has the formula Na_2CO_3. Sodium carbonate, commonly known as soda ash, is used as a water softener to prevent clothing from being harmed while it is in the wash. Most water has many minerals dissolved in it, and is known as "hard water." Water softeners remove the dissolved minerals from hard water through precipitation.

When the Epsom salt solution and laundry detergent solutions are mixed, the magnesium sulfate in Epsom salt and the sodium carbonate in laundry detergent react to form a precipitate. Magnesium carbonate, a new solid with the formula $MgCO_3$, is formed. Sodium sulfate, Na_2SO_4, is also formed, but it stays dissolved in the water. In the chemical equation below, (aq) means that a compound is "aqueous," or dissolved in water. A compound with (s) next to it is a solid.

Dissolved magnesium sulfate	+	Dissolved sodium carbonate	→	Solid magnesium carbonate	+	Dissolved sodium sulfate
$MgSO_4(aq)$	+	$Na_2CO_3(aq)$	→	$MgCO_3(aq)$	+	$Na_2SO_4(aq)$

The precipitate, solid magnesium carbonate, could be easily separated using filtration. If the mixture was poured through filter paper, the water and all the dissolved compounds would pass through the paper, but the precipitate (magnesium carbonate) would be unable to pass.

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: • Physical and chemical properties of mixtures • Separating components of mixtures	**For more advanced students, emphasize the following concepts:** • Chemical equations and reactions • Precipitation reactions • Filtration

Fun Fact #2

Epsom salt is often used as a plant fertilizer because the sulfur it contains aids plants' production of vitamins, amino acids, and enzymes.

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.

- Take the experiment one step further: filter out the precipitate. Place filter paper (or a paper towel or coffee filter) over a third cup and pour the solution with the precipitate over it. The filter paper will retain the precipitate since the particles are too big to pass through the pores in the paper. Students can then examine the precipitate more closely.
- Make connections to more separation techniques (see the Separation Techniques activities!). Students can try the processes of filtration, decanting, and centrifugation. Which is most effective? Which is most efficient?
- Make a more colorful experiment by having samples of the Epsom salt solution dyed different colors. Use a separate eye dropper in each dyed solution. Students can then form different colored precipitates within their laundry detergent solution.
- Extend this into a study on conservation of mass. Students can record the mass of the solutions in step 3, and then the mass again in step 5. Are they the same or different? Students can remove the precipitate and measure that separately as well!
- Prior to the experiment, ask students to brainstorm what changes indicate that a chemical reaction has occurred. After completing their experiment, ask them to refer to their brainstorming again: did a chemical reaction take place? What evidence do they have?
- For more advanced students: ask them to research the reactants and write the chemical formulas for them. Can they determine the chemical formulas for the products? Is this equation balanced? Which is the insoluble precipitate?

CHEMISTRY IN ACTION

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

Real-World Applications

Precipitation reactions are one of the many techniques used to clean water so it is safe for human consumption.

Precipitation reactions happen all around us! Have you ever noticed deposits in kettles, pots or pans, or even in the bathtub or sink? Those might in part be due to minerals that precipitated out of your water and were left behind as solids in your home!.

The process of precipitation is used to separate silver from natural spring water. In the water, the silver is dissolved. It can be removed by adding potassium chloride (KCl). The reaction between the silver and the potassium chloride creates a solid silver compound that can then be processed further to remove pure silver.

Careers in Chemistry

- Performing a precipitation reaction is one of the ways to get the purest product in a separation. Chemists use this technique to ensure they get the best separation possible during a chemical reaction.
- Solid Solution Strengthening is a technique that uses precipitation to make metals stronger by adding other chemicals to them. For example, steel is made from iron that is strengthened with things like carbon, nickel, copper, and more.

Notes

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EVALUATE

- Ask students if they can write a description of what happened in the reaction along with evidence for why a chemical change took place.
- Ask students to research other precipitation reactions online. Instruct them to share what they learn about the reactants and products, including the precipitate, with a peer. Request that they use a visual aide.
- For advanced students: ask them to draw out the steps of the reaction, along with the chemical formulas, to show how the substances move and recombine.

Rusting Wool

Section **CHEMICAL REACTIONS** *Topic* **BASICS OF CHEMICAL REACTIONS**

Estimated Time Setup: 5-10 minutes; Procedure: 2-3 days

OVERVIEW

Students observe steel wool as it undergoes an oxidation reaction over the course of a few days, forming rust.

In this experiment, students create a simple setup that allows them to observe steel wool undergo a chemical change. As the days pass, the iron in the steel wool reacts with the oxygen in the moist air, causing the steel wool to rust and the water level to rise in the cup as oxygen is used in the reaction.

INQUIRY QUESTIONS

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

Learning More:
- Why does the water level rise in the cup over time?

Diving Deeper:
- What is the chemical reaction that causes the wool to rust, and can this reaction explain why the water level rose in the cup?

CONTENT TOPICS

This activity covers the following content topics: chemical reactions, oxidation, metals, properties of matter, alloys, physical changes, chemical changes, displacement

This activity can be extended to discuss: respiration, photosynthesis, balancing chemical 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:
- Shallow bowl
- Steel wool (super fine grade size 0000, soap free)
- Wax crayon, dry erase marker, or tape
- 3 equal-sized bottle caps
- Tall glass cup or graduated cylinder
- Bendable straw
- Water

ACTIVITY NOTES

This activity is good for:
- Project or take-home assignment
- Demonstration
- Pairs
- Small groups
- Large groups

Safety Tips and Reminders:
- The steel wool used in this experiment should not contain any soap or cleaner products. It should be labeled as "super fine grade 0000 steel wool," which can be found in hardware stores.
- This experiment takes two to three days to see results, so be sure to budget time to check in on this experiment later!
- 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:

- Show the students examples of steel wool from the package, and steel wool that has been used for a long time and is rusted. Pass around either the two examples or two pictures. Ask students to examine them and write their observations. What are the physical properties of each? Have students examine each under a hand lens. Do they think a physical or chemical change occurred? What evidence do they have?

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

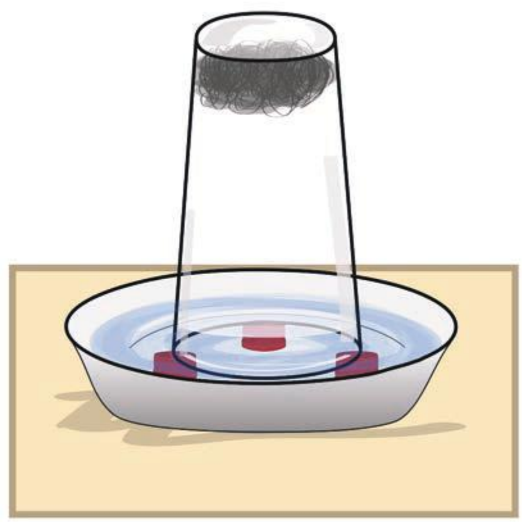
Fun Fact #1

Steel wool was invented in 1917 by Edwin Cox, who was a door-to-door cookware salesman. He developed steel wool as a cleaning tool and free gift to anyone who invited him in their home to demonstrate his cookware products. It took only a few months for his invention to take off, and he quit his job to sell steel wool full time! His wife named the product "S.O.S" for "Save Our Saucepans," which is still the name of a major steel wood manufacturer today!

EXPLORE

Procedure:

1. Take the steel wool pad and spread apart the fibers.
2. Moisten the steel wool with water and shake off any excess.
3. Gently push the steel wool pad to the bottom of the cup or graduated cylinder (without squeezing the fibers back together too much). You can tape it to the cup to stay in place if needed.
4. Fill the bowl with water and place the 3 bottle caps near the center of the bowl.
5. Take the cup with the steel wool, turn it upside down, and rest the overturned cup on the bottle caps so its mouth is submerged in the water but is raised off the bottom of the bowl.
6. Ensure the water level in the bowl is the same as the water level in the cup. If it is not, use the straw to add more air into the cup until the water levels are equal.
7. Mark the starting water level on the cup with a crayon, marker, or tape.
8. Leave the setup for 2-3 days, observing it periodically and recording any changes that have taken place.



DATA COLLECTION & ANALYSIS

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

- Draw the original setup.
- Make a prediction: what do you think will happen over the next few days?
- Record your observations of the water level at different time intervals. (Measure the height of the mark on the glass in centimeters using a ruler or using the markings on the graduated cylinder.) After 2-3 days, has the water level changed? If so, how? Why might this have happened?

Time	Water level (cm)

- Graph the data on graph paper. Do you notice a relationship?
- Is the water level inside the glass rising or falling?
- What is causing the water level to change inside the glass?
- Write down any other changes you noticed inside the glass. What do you think caused the change?
- What substance forms when iron and oxygen interact in moist air? (What is its chemical name? What is its common name?)

EXPLAIN

What's happening in this Activity?

First review the Basics of Chemical Reactions Background section to gain a deeper understanding of the scientific principles behind this activity.

Steel wool is a material made of very thin and flexible strands of steel. Steel is a uniform mixture of different types of metals, or an **alloy**. Steel wool is predominantly an alloy of two metal elements: iron and carbon. Iron on its own is a very soft metal but mixing carbon into iron makes it harder and more durable. The mixture of carbon and iron has properties in-between those of carbon and those of iron. Steel wool is good for polishing wood and metal, and cleaning cooking equipment, because the combination of metals gives it just the right balance between flexibility and hardness.

In the same way that steel wool is a mixture, the air around us is a mixture of gases. Air is made up of 78% nitrogen and 21% oxygen. The remaining 1% is a mixture of many gases, including argon, carbon dioxide, and water vapor. When wet steel wool is exposed to air, it reacts with air to form rust. Water is necessary to help facilitate this reaction; dry steel wool doesn't rust on its own. Since there is water vapor (small water droplets) in the air, iron will rust over time when exposed to the air.

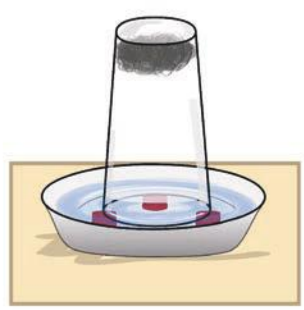
The iron in the steel wool and the oxygen gas in the air react to form rust, or iron oxide. **Rust** is a dull brown substance that is formed when iron reacts with moist air. During this reaction, the iron is **oxidized**. Something is oxidized when it loses electrons. In this case, iron loses electrons to oxygen, and oxygen gains electrons. You've probably seen rust around you in many places—on old bicycles, nails, or other metal objects.

The basic formula for rust is Fe_2O_3—"Fe" represents iron, and "O" represents oxygen. These one- or two-letter abbreviations for each element are called chemical symbols.

Iron from the steel wool	+	Oxygen gas from the air	→	Iron oxide (known as rust)
$4Fe(s)$	+	$3O_2(g)$	→	$2Fe_2O_3(s)$

Even though the oxygen gas is mixed with other gases in the air—nitrogen, argon, and more—it still reacts with iron. And even though the iron is mixed with carbon in steel wool, it still reacts with oxygen. This is because when different substances are mixed physically, they each still retain their own unique physical and chemical properties.

In this experiment, oxygen in the cup reacts with the steel wool. This removes the oxygen from the air mixture, because the oxygen becomes part of the iron oxide compound. The missing oxygen creates a vacuum—the air can no longer fill the space inside of the cup. As oxygen is consumed, the water level rises in the jar to fill the void. Since about 20% of air is oxygen, the volume of gas in the jar should decrease by about 20%.



EXPLAIN continued

Almost all chemical reactions come with a change in energy too. Every chemical compound has a certain amount of energy stored in its chemical bonds. Since the reactants and products are different substances, they have different amounts of energy.

If the reactants have more energy than the products, a reaction releases energy to its surroundings. **Exothermic reactions** are all chemical reactions that release energy, often in the form of heat, light, or sound. If the products have more energy than the reactants, a reaction absorbs energy from its surroundings. **Endothermic reactions** are chemical reactions that absorb energy, and that can't occur without the input of energy. Endothermic reactions feel cold to the touch, because they take away energy from their surroundings.

Exothermic reaction	**Endothermic reaction**
Reactants are higher in energy	Products are higher in energy
Releases energy, feels warm to the touch	Absorbs energy, feels cold to the touch
Reactants → Products + *energy*	Reactants + *energy* → Products
Burning, rusting	Photosynthesis

The reaction that forms rust is an exothermic reaction, meaning that it releases energy. While the reaction is occurring, the top of the cup should feel slightly warm to the touch. That feeling of heat is energy being transferred from the reaction mixture to the surroundings—in this case, your hand.

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: • Physical and chemical properties of mixtures • Chemical reactions	**For more advanced students, emphasize the following concepts:** • Energy and chemical reactions • Exothermic and endothermic reactions • Pressure

Fun Fact #2

Steel wool comes in a number of "grades" that explain the coarseness and therefore how it should be used. As an example, super-fine grade steel wool, number 0000, like the one used in this activity, is for stain removal. Coarse grade steel wool, number 3, is used for removing paint from floors.

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.

- There are tons of cool experiments that can be done with steel wool – some of which are fun to watch but too dangerous to do in the classroom. Find some examples online and discuss them as a class!

- If the experiment is left for a longer period of time, will it continue to progress (i.e. will the wool keep rusting and the water level keep rising)? Why or why not? Try leaving the experiment off to the side of the classroom and checking every week. Are there any changes? (Hint: What might be a limiting factor? If all the oxygen in the cup gets used up, will the reaction continue?)
- After the experiment is complete, you can leave the steel wool out beside the window sill for the next few months. Have students check on it every week and keep a log of their observations. Does the reaction keep going? Is it happening faster or slower than before? Why?
- Why is wet steel wool used instead of dry steel wool? Try the experiment again, but this time do not wet the wool. Better yet, set up two side-by-side experiments: one where the wool is wet and one where it is dry. What differences can be seen as the reaction progresses?

EVALUATE

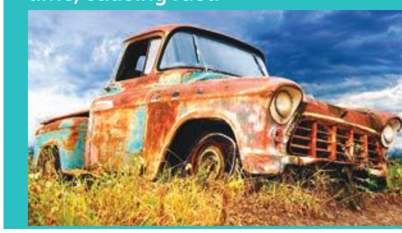
- Ask students to write a paragraph or create a time lapse video explaining how the reaction works over time. They can add new vocabulary words and chemical equations to their explanation.
- Students should find something in their home, school, or community that has undergone an oxidation reaction (an easy one is to find something that has rusted!). Have students take a photo or draw what they found and explain or draw how the rusted look came to be and why. What is the chemistry behind what they found? Ask them to create an explanation that could be understood by a younger student or sibling.
- Now that students know how the reaction work, can they design something that will prevent rust? Group students into teams to create a product (or sketch the design if they cannot create it) for a specific industry that might have this need. They can present their proposals to other teams or to the class, and include the problem scenario, how it happens, their proposed solution, costs, and benefits. Students can grade one another using a peer assessment rubric.

CHEMISTRY IN ACTION

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

Real-World Applications

The oxidation reaction seen here also happens all around us, as many of our appliances, machines, tools, and structures have iron in them and are exposed to moisture and oxygen over time, causing rust.



Careers in Chemistry

- Iron is found in metal alloys that make up a lot of things in the world around us, so how do we prevent them from rusting and weakening over time? Entire industries have sprung up to solve this problem in various ways. One way is with rust-resistant alloys, which have a layer of chromium(III) oxide over them that slows down rusting. Another method is with galvanization, which is when the object is covered in a layer of metallic zinc or cadmium that provides protection for many decades. Various coatings and paintings are applied to structures like cars to prevent rusting – which is why you often see rusting on a car if there has been paint damage. There are many more techniques!
- Since the early 1800's, scientists have been working to develop steel alloys that do not rust and crumble over time. The first patent for stainless steel was in the US in 1919. Stainless steel is a steel alloy that has come to prominence because, unlike steel with iron in it, this steel does not rust – hence the name 'stainless.' This steel is used in cookware, cutlery, major appliances, surgical tools, and in food processing machinery. Today, there are dozens of different types of steel used for different purposes, and more are still being developed!

Cleaning Pennies

Section **CHEMICAL REACTIONS** *Topic* **BASICS OF CHEMICAL REACTIONS**

Estimated Time Setup: 5-10 minutes; Procedure: 10-20 minutes

OVERVIEW

Students will use lemon juice to transform an old, dull penny into a shiny, new-looking one!

In this activity, students explore a chemical reaction with lemon juice and old pennies that have been affected by oxidation and are dark in color. Students watch as the coin's appearance changes before their eyes: the dull exterior of the penny is removed, and it becomes shiny-looking once more.

MATERIALS

For one setup:

- One dull, dark penny (best if minted between 1962 and 1982)
- Bounty® paper towels
- Lemon juice or lemon

INQUIRY QUESTIONS

Getting Started:

- Is cleaning a penny a physical or chemical change?

Learning More:

- What physical and chemical changes occur when lemon juice is added to a dull penny?

Diving Deeper:

- What chemical reaction is occurring when pennies grow dull over time? What chemical reaction happens when lemon juice is added?

CONTENT TOPICS

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

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

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.

ACTIVITY NOTES

This activity is good for:

- Individuals
- Pairs
- Small groups

Safety Tips & Reminders:

- Pennies minted between 1962 and 1982 will work best for this experiment because they have a very high copper content, but any penny should work!
- Do not use a coin that is valuable (i.e. from an old coin collection) since this experiment does remove some of the copper coating.
- Even when working with food products, there is no eating in the lab!
- If you are using the juice from a lemon, be sure to cut the lemon for the students and have the students wear protective eyewear when juicing.
- 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:

- Show students a variety of pennies of different colors: some shiny and some dull. Ask students why they are different colors. What could cause it and how might we reverse this effect?

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

Fun Fact #1

The US nickel is 75% copper; the dime, quarter, and half dollar are 91.7% copper; and the Susan B. Anthony dollar is 90% copper.

EXPLORE

Procedure:

1. Place a dull, dark penny on a Bounty® paper towel.
2. Place one drop of lemon juice in the middle of the penny and leave it for 10 minutes.
3. Using another paper towel, wipe the lemon juice off the penny. Record your observations.

DATA COLLECTION & ANALYSIS

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

- Draw the penny at the start of the experiment. What physical properties can be observed or measured?
- Make a prediction: what do you think will happen when you add lemon juice to the penny?
- What was left on the paper towel when you wiped the penny clean? What do you think it is?
- Draw the penny at the end of the experiment. What physical properties can be observed or measured?
- Did a chemical or physical change occur? What is your evidence?

Notes

EXPLAIN continued

What's happening in this Activity?

First review the Basics of Chemical Reactions Background section to gain a deeper understanding of the scientific principles behind this activity.

Originally, pennies (one-cent coins) were made of pure copper. In the 1970s, copper became more expensive, making the copper in a penny worth more than one cent. Now, pennies are made of zinc with a thin layer of copper on the outside. The copper coating is what gives pennies their shiny reddish-gold color. Overtime, however, pennies sometimes turn a dull, dark-brown color.

New Penny

Old Penny

Fun Fact #2

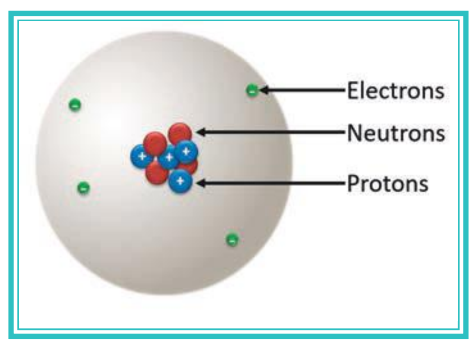
Pennies today are made of 97.5% zinc and coated with copper (2.5%). The zinc filling makes the pennies cheaper to produce and lighter, but the copper coating was added to preserve the appearance.

Copper and zinc are both metal elements from the periodic table. Copper is a **malleable** metal, meaning that it can be molded or reshaped easily. Copper was the first metal ever that people melted and formed into different shapes, all the way back in 5000 BC. Copper can also conduct electricity, so it is often used in wiring.

Pennies can change color because the copper is exposed to air. Air is mixture made up of 78% nitrogen and 21% oxygen. The remaining 1% is a mixture of many gases, including argon, carbon dioxide, and water vapor. The copper on the outside of the penny reacts with the oxygen gas molecules in the air. A new solid, copper oxide, is produced. The copper oxide is a darker color and leaves a dull coating on the penny.

Pure, solid copper from the penny	+	Oxygen gas from the air	$\longrightarrow$	Solid copper oxide forms on the penny
$2Cu(s)$	+	$O_2(g)$	$\longrightarrow$	$2CuO(s)$

Let's take a closer look at what's involved when atoms react. Every atom is made up of three different parts: **protons, neutrons**, and **electrons**. Protons have a charge of 1+, neutrons have no charge, and electrons have a charge of 1−. The protons and neutrons are found in a very tiny area in the center of the atom. The negatively-charged electrons zoom around the large outer region of the atom. An atom reacts by losing, gaining, or sharing electrons.



The reaction between copper and oxygen is an example of an **oxidation** reaction, which is any reaction where electrons are transferred from one atom to a different atom. At the beginning of the reaction, both the solid copper and the oxygen gas are **neutral**—the number of protons (1+ charge) exactly balances out the number of electrons (1− charge). During the reaction, each copper atom loses two electrons in order to form a bond with oxygen. Similarly, each oxygen atom gains two electrons to bond with copper. The penny changes color over time because of this oxidation reaction.

Not oxidized: coated in pure copper

Oxidized: coated in copper oxide

EXPLAIN continued

Oxidation is all around you in other ways too—and not all oxidation reactions involve the element oxygen. The formation of rust on iron metal is because of an oxidation reaction between iron and oxygen. When fruit is exposed to air for a long time, it turns brown because of a different oxidation reaction. Even the digestion of food in our bodies is an oxidation reaction!

In this experiment, we add lemon juice to the surface of a penny that has been oxidized. The lemon juice is a liquid, so it helps to loosen up the dirt on the penny. More importantly, the key component of lemon juice is citric acid, which has the formula C6H8O7. Citric acid reacts with the copper oxide on the outside of the penny and breaks it down.

Copper oxide on the oxidized penny	+	Citric acid from lemon juice	⟶	Copper Citrate	+	Water
$2CuO(s)$	+	$C_6H_8O_7(aq)$	⟶	$Cu_2C_6H_4O_7$ (aq)	+	$2H_2O(l)$

Lemon juice is only about 5% citric acid. The lemon juice is strong enough to dissolve copper oxide, but not strong enough to dissolve pure copper. Wiping off the penny clears away the products, copper citrate and water, revealing the penny's underlying shiny copper coating!

You might find that your penny doesn't look shiny and good as new. Copper oxide is just one of many compounds that can form on the outside of a penny overtime. Especially when a penny is exposed to moist air, other compounds including copper sulfides and copper carbonates can form. Whenever we touch a penny, the oil and dirt from our hands can also transfer to the penny's surface. These can prevent the lemon juice from fully cleaning the penny.

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: • Mixtures (air) • Chemical reactions • Physical and chemical properties	**For more advanced students, emphasize the following concepts:** • Atomic structure • Chemical reactions at molecular level • Oxidation reactions

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.

- Discover how the concentration of the lemon juice changes the effectiveness of the reaction. Try the experiment again but with lemon juice that has been diluted different amounts. Does it still work?
- Investigate how time affects the experiment. Students can put lemon juice in a series of plastic cups. They can gather enough pennies of the same color so one can go in each cup (or a few in one cup if it is wide enough). Students can drop all the pennies in at the same time and start a stopwatch. At different, timed intervals they can remove, rinse, and dry a penny then label it with the time it was left in the lemon juice. At the end of the experiment they can line the pennies up. What is the optimal amount of time needed to clean a penny? They can graph the time versus the color on a numbered scale (i.e. 1 = dark, 5 = light).
- Student can test the pH of the lemon juice (or other solutions used) experimentally with litmus paper. Do they see a pattern in the substances that clean the pennies well?
- Try "cleaning" a penny with a different household acid, like another fruit juice or vinegar. Students can research different acids that they can find at home or school and run a test to see which works best.
- Pennies become "dull" looking due to oxidation with the air. Can students find other examples of materials in their school, home, or community that have a chemical change when exposed to the air? Ask students to take photos, draw a picture, or make a list of what they find and share their examples with the class.
- Test this experiment on other dull coins, like quarters, nickels, or dimes. Do they see the same effects? Why or why not?

CHEMISTRY IN ACTION

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

Real-World Applications

Copper is often combined with other metals to create alloys. Examples of copper alloys include brass, an alloy of copper and zinc, and bronze, an alloy of copper and tin. These alloys are created to increase the hardness and strength of copper.

When a penny or other copper object is exposed to moist air for a long period of time, it will acquire a dull, green coating, commonly called a patina or verdigris. This coating is a mixture of copper compounds, including copper carbonate, which provides the green color. The coating serves as a protective layer that prevents the copper from further corrosion. This coating is what covers the Statue of Liberty, which is made of copper and was initially a shiny, reddish-brown color.

Careers in Chemistry

- The US Mint is a federal agency that regulates and produces coins. They even have a STEM initiative to recruit more employees with a science background for quality control, coin chemistry, cleaning solutions development, and more!
- There are tons of careers that revolve around working with copper, including as an architect, scientist, geologist, electrician, and many more! Because copper is so versatile and offers many unique properties, scientists continue to develop new applications and uses for this metal.

EVALUATE

- Challenge students to make their own cleaning solutions from household products. They can try things like soda, vinegar, baking soda solutions, salt water, ketchup, hot sauce, soap – anything they think might work! Each student can keep a lab journal of their procedure and create a poster to show their results. Students can compare and contrast to determine which cleaning product worked best.
- Based on what they learned in this activity, what is another cleaning item that could be used on copper products? What is the scientific reason why this might work well? Test it out and see!
- Task students with creating a step-by-step guide for how this experiment works, along with other questions or areas for further research they have. What are other areas where they can apply what they have learned?
- The composition of the penny has changed many times over the past 100 years. Have students research the composition of each penny they have and see if there are similarities or differences when the tests are run with pennies that are made of the same or different materials.