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

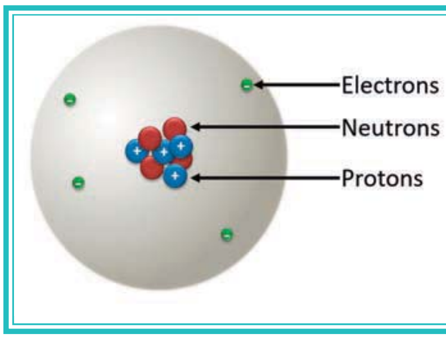
Pennies today are made of 97.5% zinc and coated with copper (2.5%). The zinc filling makes the pennies cheaper to produce and lighter, but the copper coating was added to preserve the appearance.

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

For younger students, emphasize the following concepts:

- Mixtures (air)
- Chemical reactions
- Physical and chemical properties

DIVING DEEPER

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.