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.

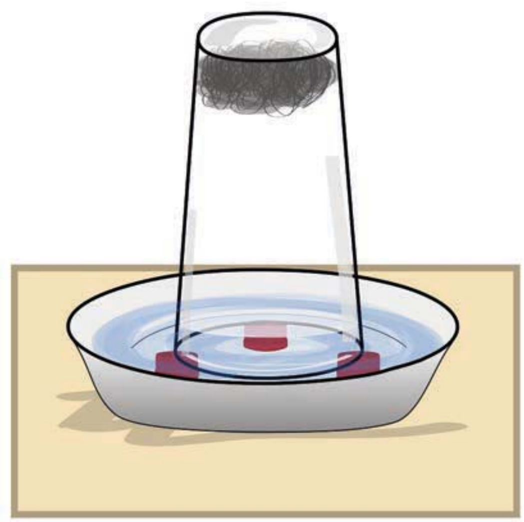
Fun Fact #1

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.

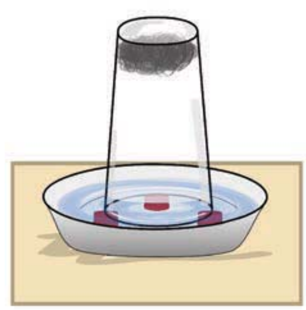
The iron in the steel wool and the oxygen gas in the air react to form rust, or iron oxide. **Rust** is a dull brown substance that is formed when iron reacts with moist air. During this reaction, the iron is **oxidized**. Something is oxidized when it loses electrons. In this case, iron loses electrons 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
Reactants are higher in energy
Releases energy, feels warm to the touch
Reactants → Products + *energy*
Burning, rusting

Endothermic reaction
Products are higher in energy
Absorbs energy, feels cold to the touch
Reactants + *energy* → Products
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

For younger students, emphasize the following concepts:

- Physical and chemical properties of mixtures
- Chemical reactions

DIVING DEEPER

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

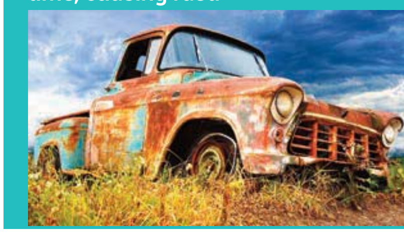
- Ask students to write a paragraph or create a time lapse video explaining how the reaction works over time. They can add new vocabulary words and chemical equations to their explanation.
- Students should find something in their home, school, or community that has undergone an oxidation reaction (an 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!