Pencil Electrolysis

Enrichment Activity

Run electricity through mineral-enhanced water with a pH indicator to see dramatic color changes. Bubbles appear, too. Use a pH indicator chart, custom cards, and atomic tokens to interpret the color changes and correctly identify the bubbles at each pencil tip.

Question to investigate

The bubbles at both pencil tips look the same: Are they the same or different?

Chemistry concepts

- Water molecules are made of two hydrogen atoms and one oxygen atom—H_2O.
- A color-changing indicator can tell you whether a substance is an acid and or a base.
- Water or H_2O molecules can change to form the ions H_3O^+ (acid) and OH^- (base).
- Bubbles and color changes are signs that a chemical change may have occurred.
- *Electrolysis* is the process of using electricity to facilitate chemical reactions.

Activity logistics

- **Ages**: Due to the chemistry concepts and dexterity required, this activity is best suited for middle school students. However, with time and context, this activity can be successful with upper elementary students who are studying electricity, states of matter, and physical and chemical changes. It can also be successful with high school chemistry students as a quick introduction or reinforcement of concepts such as the autoionization of water, acids & bases, and chemical reactions.
- **Group Size**: Prepare one device and one set of cards for each group of 2-4 students. Find out how many students will be in attendance and their familiarity in working together.

Students unfamiliar with group-work will do better working alone or in pairs. If this is the case, prepare one device and one set of tokens for each student or pair of students you will meet.

- **Set-up**: Ask the teacher or adult leader to assist you in distributing materials. Typically, they have an established way to distribute materials, and clean up, efficiently that will preserve time for your activity.
- **Time**: This activity takes 30 minutes.

Prepare in advance

What you'll need

- 1 L water
- 1 cup (250 mL) Epsom salt
- 4 30-mL dropper bottles of universal indicator solution
- 4 sets of cards
  - Universal indicator pH color chart
  - Water molecule
  - Hydronium ion and Oxygen molecule
  - Hydroxide ion and Hydrogen molecule
- 4 plastic petri dishes
- 4 small plastic white plates to provide a white background for each petri dish and act as a spill tray
- 4 9-volt batteries
- 4 rubber bands
- 4 clear plastic cups
- 4 snap-in 9V battery connectors with alligator clip ends
- 8 pencils (#2 is preferred)
- 1 pencil sharpener
- 1 pair of pliers
- 1 pair of scissors
- 1 cup measure, 250 mL
- 1 permanent marker
- 1 bucket or waste container
- 100 paper towels

Notes about the materials

- The materials list provides enough supplies for up to 4 students working alone, 8 students working in pairs, or 16 students working in groups of four.
- If you plan present this activity with multiple groups, bring additional pencils and batteries. The pencil tips degrade in the reaction and batteries may become depleted.
- Use of a piece of heavy paper or tray will help define the workspace.
- This activity also works with a pH indicator made from red cabbage. In this case, the colors are blue (neutral), purple (acidic) and teal (alkaline).

Prepare the activity

Prepare the pencils

1. Use pliers to carefully pull the metal and eraser portion off 8 pencils.
2. Sharpen both ends of the pencils.

Copy and cut the cards

3. Make 4 copies of the sheet of cards. Each station requires its own Universal Indicator pH Color Chart.
4. Cut the cards along the lines to make 4 sets of 6 cards. If you plan to conduct this activity multiple times, you may choose to laminate the cards.

Make the solution

5. Use a permanent marker to label 4 clear plastic cups, *Epsom salt solution*.
6. Dissolve 1 cup of Epsom salt in 1 liter of water. Stir until dissolved.
7. Pour into a properly labeled bottle and seal tightly with cap.
8. Each group will use approximately 15 mL of Epsom salt solution.

Prepare on-site

Build the devices

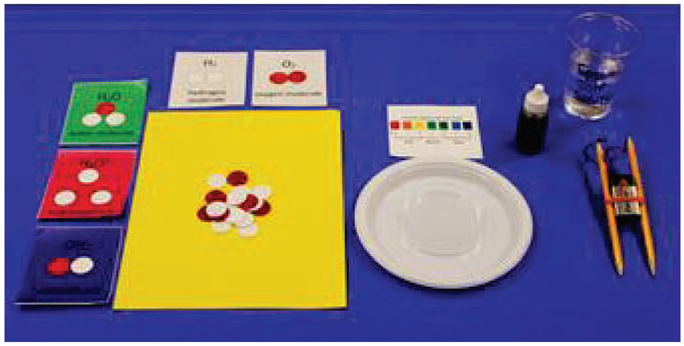
1. Snap a battery connector onto the terminals of each of 4 batteries.
2. Build each device by securing two pencils to a battery with a rubber band. Arrange the pencils around the battery, to look like the capital letter H.
3. Attach one alligator clip to one of the pencil tips above the battery. It is important to make good contact with the graphite (lead) in the pencil. Attach the other alligator clip to the tip of the other pencil.

Pour the solution

4. Half-fill each clear plastic cup with Epsom salt solution.

Group materials on your table

5. Each group will need 6 red and 12 white atomic tokens.
6. Have each group of students arrange their materials as shown.

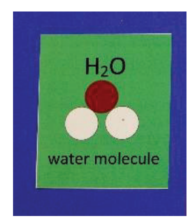


Facilitate the activity

Invite participation

1. **Introduce the activity by asking: Have you ever broken water? How did you do it?**
   If you drop a piece of ice on the floor, you might see it break into smaller pieces. If you put your hand under a faucet, you can break the flow of the water. In this activity, we are going use this device and electricity to break water molecules. [Vocabulary for teens] The process of using electricity to initiate a chemical reaction is called *electrolysis*.

2. **Tell students what water molecules are made of.**
   [*Show the green water molecule card as a guide.*] Scientists call water H_2O because this is the formula to make water. It takes two hydrogen (H) atoms [*Point to two white circles*] and one oxygen (O) atom [*Point to the red circle*] to make one water molecule. Have students use their atomic tokens to build 6 water molecules.



3. **Introduce the wired pencil-and-battery device.**
   [Optional: Nine to eleven year olds typically study electricity in science class. This may be a good connection to what they have recently learned.]
   Electricity is moving electrons. The electrons move from the battery [*Point to the + terminal*], through the wire, through the pencil, through the solution, to the other pencil tip, up through the pencil, through the wire, and back into the battery. This loop is called a **circuit**. Another chemistry tool that we are using is Epsom salt. Electricity needs help to move through water. The dissolved Epsom salt acts like an invisible bridge between the pencil tips so that electrons move and start a *chemical reaction.*

   [Optional: Eleven to thirteen year olds typically learn about the clues of chemical change, such as bubbling, color change, formation of a precipitate, and temperature change.] What signs should we look for to indicate that a chemical change is happening? *The clues of chemical change are bubbling, color change, formation of a precipitate, and temperature change.*

Support exploration

7. **Have children prepare their water**.
   [*Give the following instructions while children do what you say*]
   - Pour just enough Epsom salt solution to cover the bottom of the petri dish (approximately 15 mL).
   - Next, add about 30 drops of universal indicator to get a green color.

   Water molecules are too small to see, even with the most powerful microscope, so we are going to use this green *indicator* solution to let us know when the water molecules change.

8. **Use the device, observe changes, and then make a colorful design.**
   Hold your device in the green indicator solution like this. [*Model what children will do*] Do you notice any changes in the solution? *The solution surrounding one pencil tip becomes pink while the other becomes purple. There are also tiny bubbles at each pencil tip.* Once you notice the colors, move the pencil tips slowly through the water to create a design. Then take the device out of the solution and place it on the table.

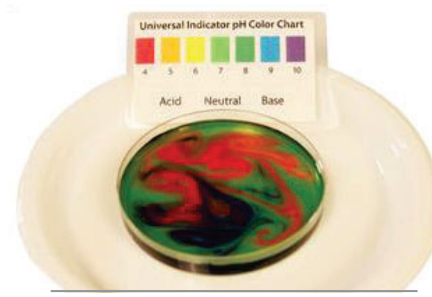


Photo Opportunity: Tell teens and adults that the color changes that are about to occur are dramatic. They may want to take a photo to remember this activity.

9. **Refer to the pH chart to interpret the color changes.**
   Can you find the colors you see in your dish in the pH chart? Water is neutral (green). The area near one pencil tip turned pink and the area near the other tip turned purple. What does pink mean? What does purple mean? *The pink means acid and the purple means base.*

Deepen understanding

10. **Use the cards and atomic tokens to find out what changes occurred in the pink and purple areas of the petri dish.**
    This chemical reaction uses electricity to change water (H_2O). These cards will give us clues about what is happening in each colored area.

    Pink (acid) card
    The pink card shows us what is happening in the pink are of your petri dish. As you started to see pink, the water molecules in that area were changing too. Using your atomic tokens, change your water molecules to make 4 H_30^+. [There will be two red atomic tokens remaining.] Look at the two gray cards. What can you make with your remaining tokens? *One molecule of oxygen.* Place the oxygen molecule card next to your pink card. Oxygen was in the tiny bubbles we saw at the pencil tip that changed the green indicator to pink.

    Green (neutral) card
    Make six water molecules again.

    Purple (base) card
    The purple card shows us what is happening in the purple area of your petri dish. What do you think the water molecules were doing as you started to see purple in your petri dish? Make 4 OH^-. [There will be two intact water molecules and four white atomic tokens remaining.] What can you make with your remaining tokens? *Two molecules of hydrogen.* Place the hydrogen molecule card near your purple card. Hydrogen was in the tiny bubbles we saw at the pencil tip in the purple area.

Support exploration

11. **Place the device in a green area of your petri dish and interpret the changes.**
    Look closely at the pencil tips.
    - Are the bubbles the same or different?
    - What are they made of?
    - Which pencil tip makes more bubbles than the other? Is this the same as what your atomic tokens show or is it different? *The pencil tip in the purple area makes more bubbles. We had two hydrogen molecules and only one oxygen molecule.*
    - The tiny bubbles you saw at the pencil tips contain either hydrogen or oxygen gas. If I wanted to collect the hydrogen to fuel a car or collect the oxygen for people to breathe, how would I know which bubbles to collect? *Bubbles in the pink area are oxygen gas. Bubbles in the purple area are hydrogen gas.*

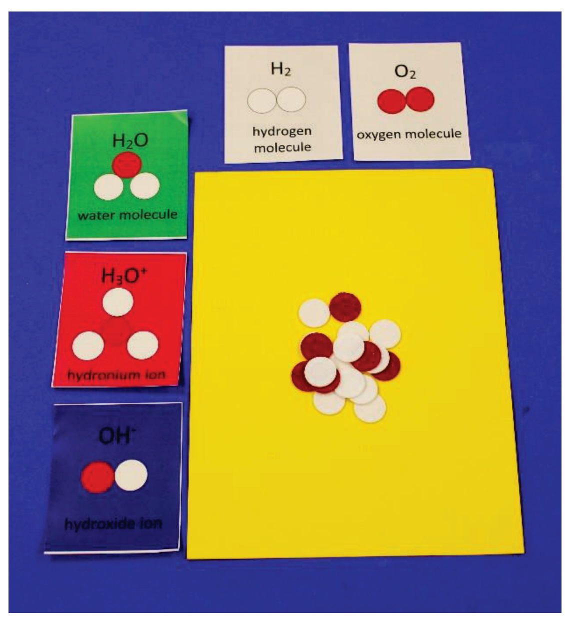
You used chemistry to figure out that even though the bubbles look the same, they are actually different!

[Optional: If you have time, and the students are interested, you may choose to encourage more exploration.] What might happen if you put the pencil tip that makes purple in a pink area? What might happen if you put the pencil tip that makes pink in a purple area? Try it and see.

Clean-up

Have each group clean up their own area

1. Circulate a waste container for students to empty the liquid from their petri dishes.
2. Distribute one or two paper towels per group and tell them to use it to dry the petri dish and plate.
3. Have students place their atomic tokens on the white plate.



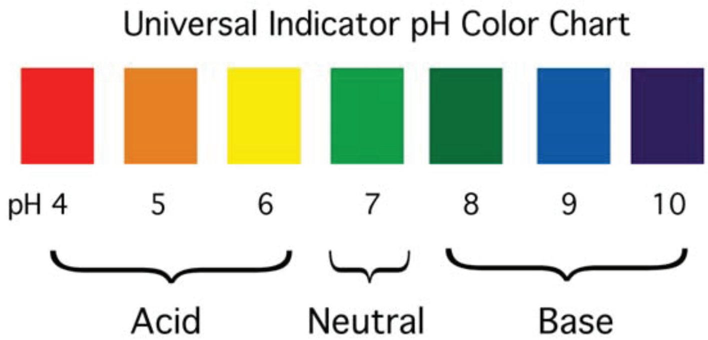
Select 5 student volunteers to gather items

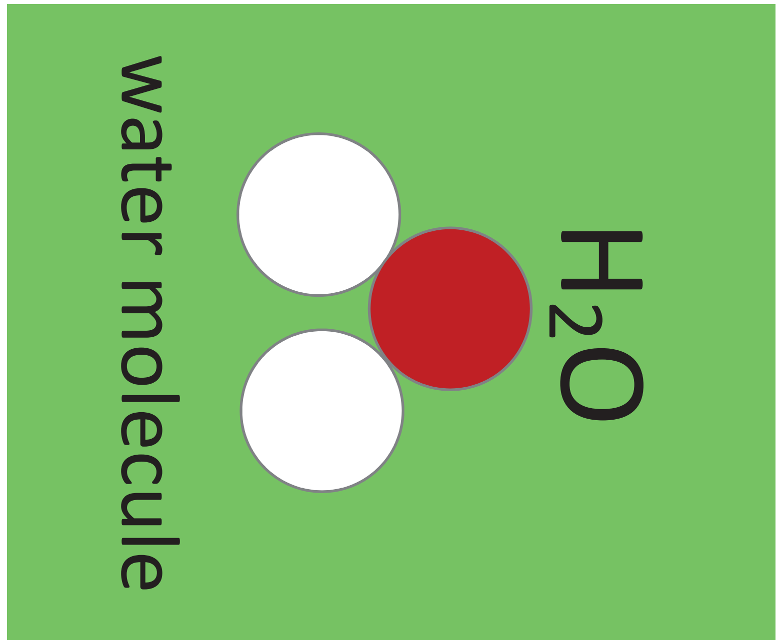
1. Provide a container or small zip-closing plastic bag to collect all of the red and white atomic tokens.
2. Collect the cards and heavy paper or trays.
3. Have another student collect the petri dishes and plates.

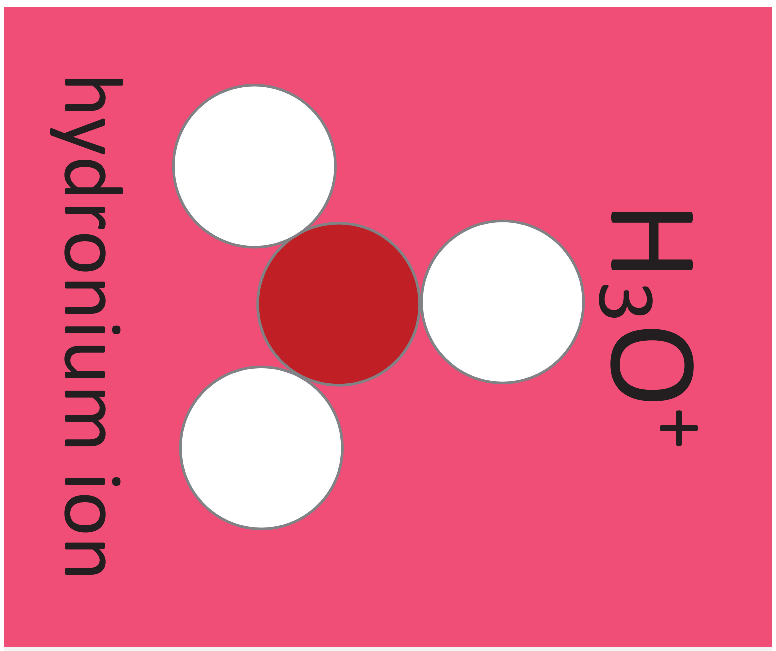
4. Have another student collect the capped bottles of universal indicator solution and cups of Epsom salt solution.
4. Assign a student to collect the pencil devices. You may choose whether students should keep these intact or disassemble them for you. Be sure to remove the battery terminal covers and clips before transporting the devices. Ensure that the batteries are arranged so that the terminals do not touch one another or any other conductive object when transported.

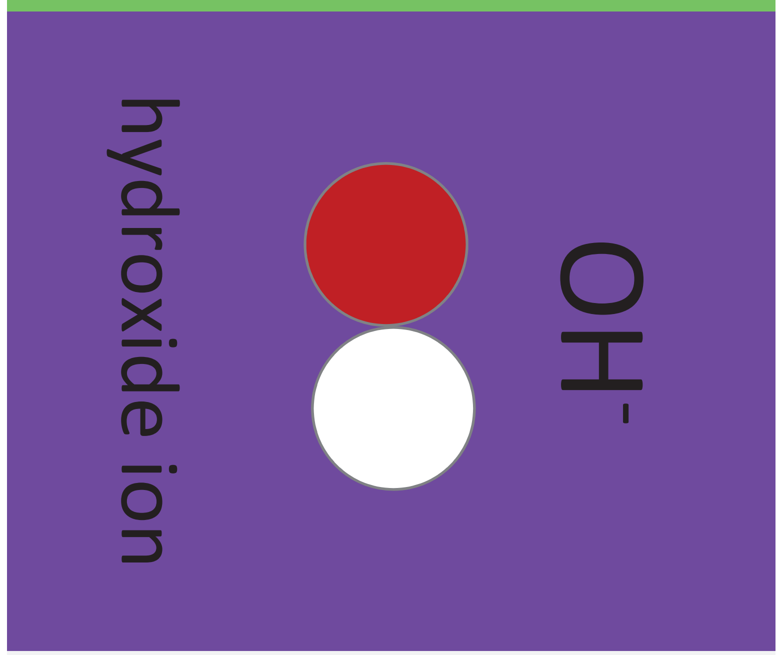
Proper disposal

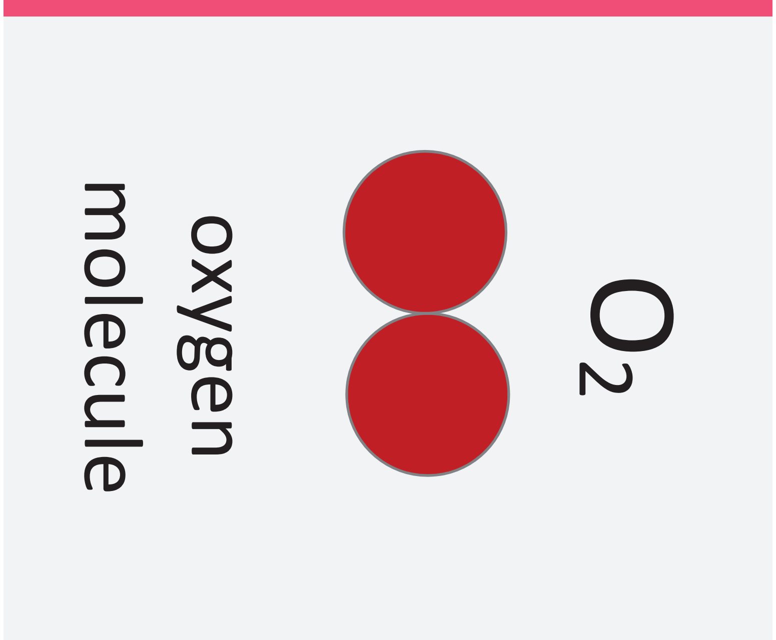
- If you are presenting this activity in a school or other facility without a lab, collect the waste liquid in your 1-liter container, secure the cap and take the liquid waste with you.
- The paper towels may be safely disposed of with the building's trash.
- The liquid waste will be acidic. Neutralize with baking soda before pouring down a sink. Follow with plenty of water.

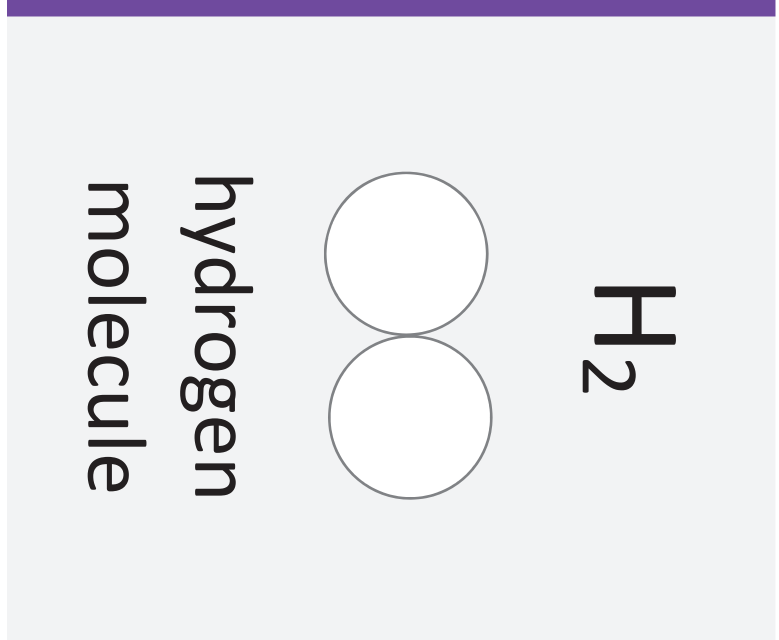

Universal Indicator pH Color Chart
pH 4
5
6
7
8
9
10
Acid
Neutral
Base


H2O
water molecule


H3O+
hydronium ion


OH-
hydroxide ion


O2
oxygen
molecule


H2
hydrogen
molecule