Lab: Electrolysis of Water

FOR THE TEACHER

Summary
In this lab, students will perform the electrolysis of water using a battery, test tubes, thumbtacks, and a plastic cup.

Grade Level
High school

AP Chemistry Curriculum Framework
- **Big Idea 3:** Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.
  - 3.12 The student can make qualitative or quantitative predictions about galvanic or electrolytic reactions based on half-cell reactions and potentials and/or Faraday's laws.
- **Big Idea 5:** The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.
  - 5.15 The student is able to explain how the application of external energy sources or the coupling of favorable with unfavorable reactions can be used to cause processes that are not thermodynamically favorable to become favorable.

Objectives
By the end of this lab, students will
- Understand how electrolysis chemically separates water into hydrogen and oxygen gas.

Chemistry Topics
This lab supports students' understanding of
- Electrolysis
- Electrochemistry

Time
**Teacher Preparation:** 15 minutes
**Lesson:** 45 minutes

Materials
- 9-V battery
- 2 metal-only thumbtacks
- Condiment cup
- 2 test tubes
- Baking soda solution
- Phenolphthalein

Safety
- Safety goggles should always be worn when working in a lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.
Teacher Notes

- The baking soda solution doesn’t need to be prepared to any specific concentration. A small amount of baking soda is needed to allow for the flow of electricity through water, if distilled water is being used. If using tap water, there may be enough minerals in your water to omit baking soda. This could be another extension for this experiment.

FOR THE STUDENT

Lesson

Electrolysis of Water

Background

Electrolysis is the process of breaking molecules into smaller components by using an electric current. Electrolysis requires an electrolyte solution, so the electrolyte is in the form of ions. Anions are drawn through the solution to the anode, the positive electrode. The anode is where oxidation takes place. Oxidation involves the loss of electrons. Contact with the anode tends to strip off electrons. At the same time, cations move through the solution to the cathode, the negative electrode. The cathode is where reduction takes place. Reduction involves the gain of electrons. Contact with the cathode tends to gain electrons. The process of electrolysis results in new substances.

Electrolysis is used in industry in many ways. By passing an electrical current through a solution that contains dissolved ions, the ions can participate in chemical reactions. Depending on the ions, the voltage, and other factors, this can lead to the formation of new compounds. In electrolysis, electrical energy is used to cause a nonspontaneous chemical reaction. Electrolysis is often used to obtain elements that are too chemically reactive to be found free in nature. Electrolysis is used to separate metals like aluminum, silver, or gold from a compound dissolved in solution. If one of the electrodes is a metal, it will become covered or plated with any metal in the solution. This is how objects are electroplated.

Water is a simple chemical made from two gases: hydrogen and oxygen. Every molecule of water has two atoms of hydrogen for every atom of oxygen. If an electrical current is passed between electrodes through water, water is split into its two parts in two reactions: 4 H₂O + 4 e⁻ → 2 H₂ + 4 OH⁻ and 2 H₂O → O₂ + 4 H⁺ + 4 e⁻

Water has solvent properties because it is polar. Water molecules have charged ends (+ and -). These charged ends interact with charges on other polar substances to dissolve them. The presence of ions in solution is what allows water to conduct electricity. Pure water is, in fact, not a conductor. Water can be made conductive by using an electrolyte that does not react under the conditions of the experiment.

Purpose

To use electrolysis to separate water into hydrogen and oxygen gas.

Materials

9-V battery
2 metal-only thumbtacks
Condiment cup
2 test tubes
Baking soda solution
Phenolphthalein
Procedure

1. Label the negative terminal of the battery.
2. Mark two spots on the inside bottom of the condiment cup the same distance apart as the two terminals of the 9-V battery.
3. Push one tack through one mark so its head is on the outside of the cup, pin poking inside.
4. Before pushing in the second tack, be sure the two tacks will not touch.
5. Fill the plastic condiment cup halfway with baking soda solution.
6. Fill the test tubes completely full with baking soda solution.
7. One person should hold the cup, and two other people cap the filled tubes with a thumb and then invert the tubes over the pins of the thumbtacks. There should be no air in the test tubes, they should be completely full of solution.
8. Add 2–3 drops of phenolphthalein indicator to the baking soda solution in the cup.
9. Without allowing the test tubes to tilt at all, place the cup over the battery so the terminals touch the tacks. Your apparatus should now look like the diagram. You may want to practice getting the test tubes, thumb tacks, and battery aligned without baking soda solution first.
10. Observe each test tube, especially the volume of solution. Record your observations.
11. When one test tube is mostly empty of solution, get your teacher’s attention.
12. Your teacher will light a wood splint. When splint is lit, remove test tube from negative terminal and cap with thumb.
13. Point the opening of the test tube away from people and place splint into the tube. Record your observations.

If time permits
Extension A: Repeat steps 12 and 13 to test the gas from the positive terminal but use a glowing, NOT burning, splint.
Extension B: Repeat the collection of the gases. When one test tube is half filled, turn the battery, switching the terminals. Collect as much of the mixture of gases as time will permit. Test the mixtures with a burning splint.

Analysis

1. On the diagram, label the anode and cathode. In each tube, label the gas formed, the half reaction that occurs, and whether the half reaction is oxidation or reduction.
2. Explain why pure water does not conduct electricity and will not undergo electrolysis.
3. Explain why water with baking soda conducts electricity and undergoes electrolysis.
4. What was the purpose of adding phenolphthalein indicator to the solution?
5. How can you tell which test tube is collecting hydrogen gas and which one is collecting oxygen gas before you test them?
6. Which gas is attracted to the positive electrode and which gas to the negative?
7. Can you explain why each of these gasses prefers a certain electrode?
8. Write a balanced chemical equation for the decomposition of water.
9. Is this reaction endothermic or exothermic?
10. Write a balanced chemical equation for the synthesis of water.
11. Is this an endothermic or exothermic reaction?