Electrolysis and Hydrogen Fuel Cells

National Energy Foundation

Objective:

Students will be able to explain how hydrogen can be extracted from water and design and conduct an experiment demonstrating how water can be broken down into hydrogen and oxygen.

Materials and Curriculum Correlations ▼

Introduction

Hydrogen can be obtained by electrolysis of water. Electrolysis is the process by which water is separated into its two components: hydrogen and oxygen. In a fuel cell, hydrogen gas combines with oxygen from the air and produces electricity for the motor and its emissions are heat and water.

Electrolysis takes place in a unit called an electrolyzer. There are different types of electrolyzers all needing an energy source to work. Renewable energy sources or nuclear energy are good carbon-free sources.

Water used for electroylsis is used with electrolyzers like sodium, potassium hydroxide or solid plastics and ceramics, all of which increase the water's ability to conduct electricity. When electricity is applied, bubbles of oxygen gas (O_2) form at the anode and bubbles of hydrogen gas (H_2) form at the cathode. The bubbles are easily seen. Twice as much hydrogen gas is produced as oxygen gas.

Once the power source is taken off the electrodes, some gas bubbles remain on the electrodes. Due to these gas bubbles, a voltage difference will be seen when measured.

Procedure

1. Distribute copies of the student sheet.
2. Assist students as needed during the experiment.
3. Ask the groups to develop testable questions based on an observation they found particularly interesting. Some possible experimental questions:
   a. What gases are being made? (The students should find they are making oxygen and hydrogen. They also could smell for chlorine, although at the recommended concentrations of chlorine should not evolve.)
   b. What gas is at each electrode? (One method to test the gases is to collect each gas in a separate test tube. Because hydrogen is lighter than air, the test tube should be held upside down when testing with a flaming wood splint. Oxygen is about the same density as air, so the test tube should be held up and tested with a glowing splint.)
   c. What happens if more/less electrolyte (baking soda) is added?
   d. Why is there a voltage difference after the power is turned off?
4. Ask the groups to design a procedure, using whatever materials they need, that will provide an answer to their experimental question. Allow the groups to discuss their procedure then ask them to record their procedures.

5. Have the groups conduct their investigations. Where appropriate, provide additional equipment. Bring the groups back together after their investigations are completed to present their individual experimental question, procedure, designs and results. Identify new questions that emerged to investigate.
6. Clean up the materials from the reaction investigations.
7. Lead a discussion on what the students observed and the significance of their observations.

   Points to cover may include the following:

   - Electrolysis produced a chemical change.
   - Energy and mass are conserved in this system.
   - Some energy is lost to heat.
   - The process can be reversed using a fuel cell, hydrogen and oxygen combined to make electricity and water.
   - Hydrogen is used as a combustible fuel on spacecraft, such as the space shuttle, and can also be used to make electricity with a fuel cell.
   - Hydrogen is an alternative, renewable resource and is nonpolluting when used as an energy source.

Answers to Questions on "Electrolysis"

1. Bubbles are formed. Also may mention the break down of aluminum foil.
2. Bubbles are formed (twice as many as at the cathode). Also may mention the breakdown of aluminum foil.
3. Electrical energy is transformed into chemical energy.
4. No energy transformation is 100 percent efficient, heat is a by-product.
5. The amount of bubbles would double.
6. Answers may vary, but voltages start at a level close to the voltage of the power supply and fall steadily.
7. Answers will vary.

Problems

1. The reactant is water, a clear colorless liquid. The products are hydrogen and oxygen, clear colorless gases.
2. $2H_2O \Rightarrow 2H_2 + O_2$
3. Water decomposes into hydrogen and oxygen when electrical energy is added.
4. Aluminum breaks down during the reaction, platinum would not.

To Know and Do More

1. How does varying the concentration of the baking soda (the electrolyte) in the water affect the number of bubbles produced by the electric current?
2. How does varying the amount of electricity in the hydrolysis circuit affect the amount of gas being produced?
3. How could you capture and measure the amount of gas produced?
4. Where is hydrogen currently being used in your state or province? How much is used per year? Where is it produced?
5. Are there any hydrogen fueling stations in your area for hydrogen fuel cell cars? Where is the nearest one to your location? Visit the U.S. Department of Energy's Alternative Fuels Data Center at *afdc.energy.gov* to research hydrogen fueling locations.
6. How does the research and production of hydrogen in your state help the economy? The environment?
7. What is a hydrogen fuel cell? How does it work?

Materials Needed:

- Photovoltaic cell (3 Volt minimum) or 9 Volt battery
- Sodium bicarbonate (baking soda)
- Beaker, large, about 17 ounces
- Stirring rod or spoon
- Digital multimeter, with ranges of 0 - 2 DCV and 0 - 20 DC
- Student sheet
- 2 pieces of aluminum foil about 2.5 inches x 4 inches
- 2 wires with alligator clips on both ends
- Water
- Graduated cylinder
- 2 test tubes

Curriculum Correlations

K-ETS1 - 1
1-ETS1 - 1
2-ETS1 - 1
3-ETS1 - 1
3-ETS1 - 2
3-ETS1 - 3
4-PS3 - 2
4-PS3 - 4
4-ESS3 - 1
4-ESS3 - 2
4-ETS1 - 1
4-ETS1 - 2
4-ETS1 - 3
5-PS1 - 1
5-PS1 - 2
5-PS1 - 3
5-PS1 - 4
5-ESS3 - 1
5-ETS1 - 1
5-ETS1 - 2
MS-PS1 - 2
MS-PS1 - 4
MS-PS1 - 6
MS-PS3 - 3
MS-ESS3 - 3
MS-ETS1 - 1
MS-ETS1 - 2
MS-ETS1 - 3
MS-ETS1 - 4
HS-PS1 - 2
HS-PS1 - 3
HS-PS1 - 4
HS-PS1.A
HS-PS1.C
HS-PS2 - 6
HS-PS3 - 1
HS-PS3 - 3
HS-ESS3 - 4
HS-ETS1 - 1
HS-ETS1 - 2
HS-ETS1 - 3
HS-ETS1 - 4

▶ Student Sheet

Electrolysis

National Energy Foundation

Electrolysis is a technique used by scientists to separate a compound or molecule into its component parts. By adding electricity to a liquid and providing a path for the different particles to follow, a liquid, such as water, can be separated into hydrogen and oxygen.

Materials

- Photovoltaic cell (3 Volt minimum) or 9 Volt battery
- 2 pieces of aluminum foil 2.5 inches x 4 inches
- Sodium bicarbonate or baking soda
- 2 wires with alligator clips on both ends
- Beaker or cup, approximately 17 ounces
- Water
- Stirring rod or spoon
- Graduated cylinder
- Digital multimeter, with ranges of 0-2 DCV and 0-20 DCV
- 2 test tubes
- Safety goggles

Procedure

1. Set up your electrolysis apparatus.
    - Accordion-fold each piece of aluminum foil the long way so that you have two pieces approximately one-half inch x 2.5 inches. These are going to be your electrodes.
    - Press each electrode flat.
    - Bend the top one-half inch of each electrode over to act as a hanger. They will be hung on the inside of your beaker or cup.
    - Clip one wire lead to the hanger of one electrode. Repeat with the other lead on the other electrode.
    - Fill a beaker with 9 ounces of water and add 1 teaspoon sodium bicarbonate or baking soda and stir until dissolved.
    - Hang the electrodes on the inside of the beaker so that they hang down into the water. They should hang a couple inches apart; do not let them touch during the experiment.

    Add more water, if necessary.
2. Using your multimeter, test for voltage across the electrodes and record the beginning voltage below.
    Voltage across the electrodes before connecting to a power supply: _____.
3. Hook your electrolysis apparatus to the power supply.
    - Clip the other end of each wire lead to a photovoltaic panel or a battery. Remember, red is positive and black is negative. Make a note which electrode is attached to the positive end (the cathode) and which is attached to the negative (the anode).
    - If using photovoltaics, take your electrolysis device outside into the sun.

Questions

1. What did you see happening at the cathode?

2. What did you see happening at the anode?

3. Because energy cannot be created or destroyed, what happened to the electrical energy?

4. If you left this apparatus working long enough, it would heat up the water. Why?

5. If you doubled the amount of electricity flowing through the water, what would you expect to happen?

6. After some bubbles have formed, the power source should be disconnected. Test for voltage while the power source is attached and after the power source is disconnected. Fill in the table below.

Elapsed Time	**Voltage**
Voltage across electrodes before connecting the power supply	
Voltage immediately after disconnecting power supply	
10 seconds	
20 seconds	
30 seconds	
40 seconds	
50 seconds	
60 seconds	

Independent Group Investigation

Record your group's questions and observations below.

1. Problem and hypothesis

2. Procedure

3. Materials

4. Collect the materials necessary and conduct your experiment. Record your observations below.

5. Did your results support your hypothesis? Explain why or why not.

6. What further questions emerged during this experiment?

Cleanup and Disposal

Follow your teacher's instructions regarding cleanup of your station and disposal of any chemicals.

Problems

1. Name and describe the reactant and products in the electrolysis experiment.

2. Write a balanced equation for the reaction that took place.

3. Why does this reaction happen?

4. Fuel cells use platinum for the electrodes. We used aluminum in this lab. Why don't fuel cells use aluminum?