

Electrolysis

Student Objective

The student:

- will be able to explain how hydrogen can be extracted from water
- will be able to design and conduct an experiment demonstrating how water can be broken down into hydrogen and oxygen
- will develop a hypothesis and design an experiment to obtain data relative to the hypothesis
- will analyze results and develop a conclusion.

Key Words:

compound
electrolysis
electrolyte
element

Time:

(2) class periods

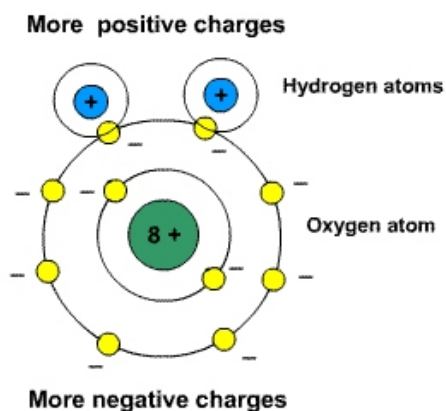
Materials:

- photovoltaic cell (3V min) or 9-volt battery (1 per group)
- piece of aluminum foil 6 cm x 10 cm (2 per group)
- sodium chloride
- wires with alligator clips on both ends (2 per group)
- beaker, larger than 250 ml (1 per group)
- water
- stirring rod or spoon
- graduated cylinder (several per class)
- digital multimeter, with ranges of 0-2 DCV and 0-20 DCV (1 per group)
- test tubes (2 per group)

Background Information

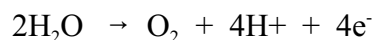
When you add sodium chloride (salt) to the water, the salt ions increase its conductivity, which helps to increase the reaction rate. Water is a polar molecule. (If students are not aware of what a polar molecule is then explain: The arrangement or geometry of the atoms is such that one end of the molecule has a positive electrical charge and the other side has a negative charge. Water is a polar molecule in that the way the atoms bind in the molecule are such that there are

excess electrons on the oxygen side and a lack or excess of positive charges on the hydrogen side of the molecule.) Knowing about polarity should help students understand why each gas moves to a particular electrode.

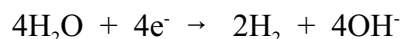


This solution forms an electrolyte, allowing current to flow when a voltage is applied. When electricity is applied, bubbles of oxygen gas (O_2) form at the anode, and bubbles of hydrogen gas (H_2) form at the cathode. The bubbles are easily seen. Twice as much hydrogen gas is produced as oxygen gas.

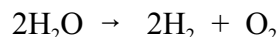
At the anode, water is oxidized:



At the cathode, water is reduced:



Note that there is a net balance of electrons in the water. 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. The net reaction:



The electricity can be supplied by a solar cell or a battery if sunshine is not available. 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.

Christian Freidrich Shoenbein carried out this same type of experiment and had his results published in 1839. Sir William Robert Grove discovered these gases could be recombined and form energy. He is known as the father of the fuel cell.

Procedure

1. Divide the students into lab groups of 3 - 4 students per group.
2. Inform the students that the directions for this lab are in their Laboratory Manual. They are to follow the directions, perform the lab, and complete the questions in their lab manuals.
3. Assist students as needed during the experiment.

4. 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 could also smell for chlorine, although at the recommended concentrations 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. Since 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 is added?
 - d. Why is there a voltage difference after the power is turned off?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:
 - electrolysis produced a chemical change
 - conservation of energy in this system
 - some energy is lost to heat
 - the process can be reversed using a fuel cell—hydrogen and oxygen are combined to make electricity and water
 - hydrogen is used as a combustible fuel on the Space Shuttle and can also be used to make electricity with a fuel cell
 - hydrogen is a renewable resource, and is non-polluting when used as an energy source

Further Research

1. How does varying the concentration of the salt 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 the state of Florida? How much is used per year? Where is it produced?
5. How does the research and production of hydrogen in the state help our economy? our environment?

6. What is a hydrogen fuel cell? How does it work?

Related Reading

- ***Energy Through Hydrogen–Research Notes*** by Averil Macdonald & Martyn Berry (Heliocentris, 2003), pages 22 - 25

Internet Sites

http://www.bellona.no/en/energy/hydrogen/report_6-2002/22871.html

Environmental Foundation Bellona's report on commercial water electrolysis methods

http://www.fsec.ucf.edu/hydrogen/research/solar_h2_production.htm

Florida Solar Energy Center's research on solar-hydrogen production

<http://www.fsec.ucf.edu/hydrogen/research/production.htm>

Florida Solar Energy Center. Current hydrogen production techniques including relative costs

<http://northland.cc.mn.us/biology/Biology111/animations/dissolve.html>

Northland College. Animation of how ionic compounds dissolve—in this case, salt in water.

Electrolysis

Laboratory Exercises

- 2 Answers may vary slightly, but should be close to zero.
- 4 Bubbles formed at the electrode. Answers may also mention the breakdown of the aluminum foil
- 5 Bubbles formed at the electrode in approximately double the amount as the cathode (positive). Answers may also mention the breakdown of the aluminum foil.
- 6 The electrical energy is transformed into chemical energy
- 7 No energy transformation is ever 100%, heat is a common by product.
- 8 The total amount of bubbles would double.
- 9 Answers may vary, but voltages start at a level close to the voltage of the power supply and fall steadily.
- 10-15. Each group's experiment hypothesis, materials, procedure, and conclusion will vary. Students should show coherent and complete thoughts and a knowledge of experimental design.

Problem Set

1. The reactant is water, a clear colorless liquid. The reactants are hydrogen and oxygen, both of which are clear colorless gasses.
2. $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$
3. A compound may be separated into its component elements when energy is added. In this case, as the electric energy passes through the water it separates the water molecules into hydrogen and oxygen molecules.
4. Answers may vary slightly, but students should mention the durability of the aluminum versus platinum. They should have noticed the deterioration of the aluminum during their experiments.

Electrolysis

			.1	.2	.3	.4	.5	.6	.7	.8
Nature of Matter	Standard 1	SC.A.1.4-				X	X			
	Standard 2	SC.A.2.4-		X						
Energy	Standard 1	SC.B.1.4-		X				X	X	
	Standard 2	SC.B.2.4-								

Benchmark SC.A.1.4.4 - The student experiments and determines that the rates of reaction among atoms and molecules depend on the concentration, pressure, and temperature of the reactants and the presence or absence of catalysts.

Benchmark SC.A.1.4.5 - The student knows that connections (bonds) form between substances when outer-shell electrons are either transferred or shared between their atoms, changing the properties of substances.

Benchmark SC.A.2.4.2 - The student knows the difference between an element, a molecule, and a compound.

Benchmark SC.B.1.4.2 - The student understands that there is conservation of mass and energy when matter is transformed.

Benchmark SC.B.1.4.6 - The student knows that the first law of thermodynamics relates the transfer of energy to the work done and heat transferred.

Benchmark SC.B.1.4.7 - The student knows that the total amount of usable energy always decreases, even though the total amount of energy is conserved in any transfer.

Electrolysis

compound - composed of two or more substances, ingredients, elements, or parts

electrolysis - chemical change, especially decomposition, produced in an electrolyte by an electric current

electrolyte - a compound decomposable, or subjected to decomposition, by an electric current

element - a substance composed of atoms having an identical number of protons in each nucleus; elements cannot be reduced to simpler substances by normal chemical means

Electrolysis

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.

Safety

- Safety goggles and apron must be worn throughout this activity.

Procedure

In this experiment you will be taking a sample of salt water and adding a flow of electricity to it (the electrolysis). You will see the hydrogen and oxygen bubbling up.

1. Set up your electrolysis apparatus
 - Accordion-fold each piece of aluminum foil down the long way so that you have two pieces approximately 1 cm x 6 cm. These are going to be your electrodes.
 - Press each electrode flat.
 - Bend the top 1 cm of each electrode over to act as a hanger. They will be hung on the inside of your bowl.
 - Attach one end of each wire to the hanger of your electrode.
 - Add sodium chloride to the water (one teaspoon per 50 mL), and stir until dissolved.
 - Hang the electrodes on the inside of the bowl 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 salt water if necessary.
2. Test for voltage 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
 - Attach the other end of each wire to your photovoltaic panel or a battery. Make a note which electrode is attached to the positive and which is attached to the negative.
 - If using photovoltaics, take your electrolysis device outside into the sun.

Answer the following questions

4. What did you see happening at the positive electrode?

5. What did you see happening at the negative electrode?
6. Since energy cannot be created or destroyed, what happened to the electrical energy?
7. If you left this apparatus working long enough, it would heat up the water. Why?
8. If you doubled the amount of electricity flowing through the water, what would you expect to happen?
9. 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 question and observations below.

10. Hypothesis:

11. Procedure

12. Materials

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

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

15. 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.
- Wash your hands thoroughly with soap and water after all your work is finished.

Electrolysis

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?