

# Helios, Taking Power From The Sun

## Electrolysis Of Water

*Lesson 1 of 3*

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**Grade Level:** 9-12

**Subject:** Chemistry

**Prep Time:** > 30 minutes

**Activity Duration:** 50-minute period

**Materials Category:** Special Requirements

National Education Standards				
<u>Science</u>	<u>Mathematics</u>	<u>Technology</u>		<u>Geography</u>
		<u>ISTE</u>	<u>ITEA</u>	
3c, 3f				

### Objective:

Students will use a 9-volt battery for the electrolysis of water. Students will examine the relationship between electron flow and chemical reactions.

### Materials:

(per group of 4)

- 9-volt commercial battery
- Two copper conducting wires
- Coffee filter
- Two 500mL (or larger) beakers
- Solution 1
- Solution 2
- Grease pencil

### Solution 1

(per group)

Add 40 mL of sodium chloride and a few drops of phenolphthalein to 500 mL of water. Add a few drops of vinegar. The vinegar is used to keep the solution slightly acidic. It will also prevent the red color from appearing prematurely because the solution is too basic.

If the solution is red, add vinegar drop by drop to the well-stirred solution until the red color just disappears.

### **Solution 2**

(per group)

Mix 500 mL of water and 40 mL of sodium chloride.

### **Related Links:**

[\*What are fuel cells?\*](#)

### **Supporting NASAexplores Article(s):**

Helios, Taking Power From The Sun

[http://www.nasaexplores.com/show2\\_article.php?id=01-009](http://www.nasaexplores.com/show2_article.php?id=01-009)

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## **Helios, Taking Power From The Sun**

### **Electrolysis Of Water**

*Teacher Sheets*

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### **Objective**

Students will use a 9-volt battery for the electrolysis of water. Students will examine the relationship between electron flow and chemical reactions.

## **Background Information**

The student background is very detailed. This section should be discussed prior to the lab.

## **Pre-lesson Instructions**

- Read the NASAexplores article, "Helios, Taking Power From The Sun."
- Review the basic concepts of redox reactions and how batteries work.
- This activity can also be used as a demonstration. Allow students to read the background information and after the demonstration answer the questions.
- Before doing this activity with students, the teacher must complete Part A and Part B several times without students participating in order to properly understand the procedure and to ensure safety.
- Stress safety. Remind students to wear safety glasses at all times.

## **Materials**

### **Solution 1**

(per group)

Add 40 mL of sodium chloride and a few drops of phenolphthalein to 500 mL of water. Add a few drops of vinegar. The vinegar is used to keep the solution slightly acidic. It will also prevent the red color from appearing prematurely because the solution is too basic.

If the solution is red, add vinegar drop by drop to the well-stirred solution until the red color just disappears.

### **Solution 2**

(per group)

Mix 500 mL of water and 40 mL of sodium chloride.

## Activity

- The red color will first appear at the cathode wire (solution 1) and will gain in intensity as the electrolysis proceeds. Later, solution 1 can be shaken to distribute color in the entire solution. The red color indicates the formation of hydroxide ions (basic). The intensity of the red color can be adjusted by adding more or less phenolphthalein.
- The sodium chloride acts as an electrolyte.
- At the cathode, reduction of water produces  $H_2$  bubbles and sodium hydroxide, (accounting for the red color).
- At the anode, oxidation of chloride produces  $O_2$  gas and  $Cl_2$ , which will tint the water green after a period of time.
- Two moles of hydrogen gas are produced at the cathode for each mole of oxygen gas produced at the anode.
- In Part B, sodium hypochlorite ( $NaOCl$ ) is produced by the reaction between the sodium hydroxide and chlorine because the cathode and anode are not separated.
- These reactions are used in industry to make hydrogen spacecraft fuel, the sodium hydroxide in Drano, sodium hypochlorite in bleach, and chlorine in water disinfectant.

## Extensions

Practice writing half-reactions.

Have students write a paper on changes in fuel sources and consumption in industry. Students may also research a comparison between countries and their fuel consumption.

## Helios, Taking Power From The Sun

### Electrolysis Of Water

*Student Sheet*

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#### Pre-lesson Questions

1. Who developed the first battery?
2. Define cathode, anode, salt-bridge, oxidation, reduction, and electrolyte.

#### Materials

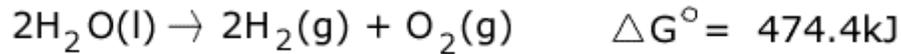
(per group of 4):

- 9-volt commercial battery
- Two copper conducting wires
- Coffee filter
- Two 500mL (or larger) beakers
- Solution 1
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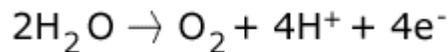
#### Background Information

Hydrogen is the most abundant element in the universe, constituting about 93% of all atoms. Hydrogen-powered fuel cells hold enormous promise as a power source for the future. Hydrogen has often been called the perfect fuel. Its major reserve on Earth (water) is inexhaustible. Hydrogen can be obtained from water by the process of electrolysis, which is the splitting of water molecules using electricity.

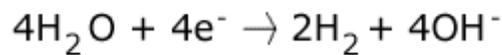
Electrolysis is the process in which electrical energy is used to cause a nonspontaneous chemical reaction to occur. Water in a beaker under atmospheric conditions (1 atm. and 25° C) will not spontaneously decompose to form hydrogen and oxygen gas due to a large standard free-energy value.



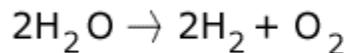
The addition of a small amount of salt is required for the formation of hydrogen and oxygen bubbles. Pure water contains too few ions for an effective current to form. The decomposition of water is a redox reaction. The oxidation reaction occurs at one electrode, and the reduction reaction at the other electrode. Water is oxidized at the anode. The reaction is...



Water is reduced at the cathode. The reaction is...



H<sub>2</sub> is produced at the cathode. In the decomposition reaction, the volume of H<sub>2</sub> produced is twice the volume of O<sub>2</sub>.



An electrolysis propulsion system consumes electrical energy to decompose water into hydrogen and oxygen. These gases are stored in separate tanks and used when needed in gaseous bipropellant thrusters for spacecraft propulsion. The propellant and combustion products are clean and nontoxic. As a result, costs associated with testing, handling, and launching would be greatly reduced, making electrolysis a cost-effective alternative. For deep space missions, water is also significantly easier to contain offering stability over a relatively wide temperature range.

Long flight times require a very lightweight energy storage system. Using a device called an electrolyzer, this system stores excess electrical energy generated by the solar cells to disassociate water molecules. Oxygen and hydrogen gases are accumulated in separate tanks. At night, when the solar cells stop producing electricity, the process is reversed. The oxygen and hydrogen gases are fed into a device called a fuel cell, which produces water and electricity. The electricity is used to power the Helios Prototype until the next morning when the cycle starts all over again.

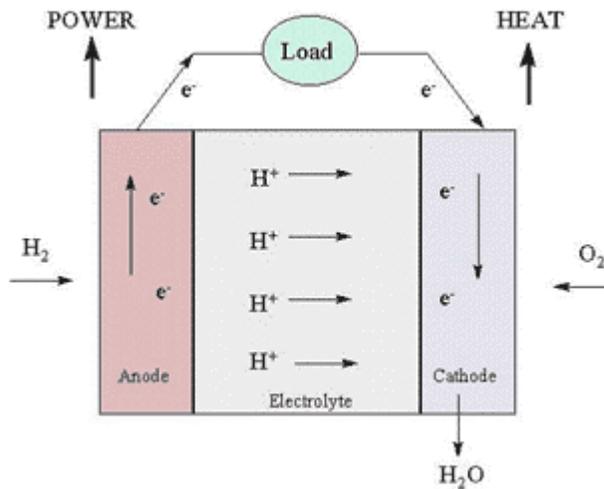
If this concept is proven, flights that last for several months are just around the corner. This aircraft will be able to do work more efficiently and at lower costs than our current space-based satellites. They could also monitor weather, track hurricanes, and provide coverage of disaster sites such as fires, mudslides, flooding and

earthquakes in order to more precise direct emergency resources.

In principle, a fuel cell operates like a battery. Unlike a battery, a fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied.

A fuel cell consists of two electrodes sandwiched around an electrolyte. Oxygen passes over one electrode and hydrogen over the other, generating electricity, water, and heat.

Hydrogen fuel is fed into the "anode" of the fuel cell. Oxygen (or air) enters the fuel cell through the cathode. Encouraged by a catalyst, the hydrogen atom splits into a proton and an electron, which take different paths to the cathode. The proton passes through the electrolyte. The electrons create a separate current that can be utilized before they return to the cathode to be reunited with the hydrogen and oxygen in a molecule of water.



## Lab Activity Part A

1. Label the beakers, solution 1 and solution 2.
2. Pour approximately 400 mL of solution 1 into the beaker labeled "beaker solution 1." Do the same for solution 2 into the second beaker.
3. Insert one wire into one beaker and another wire into the second beaker.
4. Connect the wire in solution 1 to the negative battery end.
5. Connect the wire in solution 2 to the positive battery end.
6. Fold the coffee filter paper and immerse the end in the two beakers. This will form a bridge between the two solutions.
7. After the filter was become wet from both solutions, record observations.

## Part B

1. Use two alligator clips to hold folded aluminum foil on opposite ends of an empty 500mL beaker (near the edge of the beaker).  
**DO NOT LET THE METAL PIECES TOUCH!**
2. Using copper wire, connect one the metal pieces to the negative end of a 9-volt battery.
3. Using another copper wire, connect the remaining metal piece to the positive end of the battery.
4. Gradually (**SLOWLY**) fill the beaker  $\frac{3}{4}$  with water.
5. Record observations.
6. Sprinkle salt into the water.
7. Record observations.

## Conclusion

Write a two-paragraph summary of this activity.

## Questions

1. Is solution 1 at the cathode or anode? Explain the reasoning behind your answer.
2. What difference would it make if the water used was tap water or deionized?
3. What is the significance of the coffee filter in Part A?
4. Why was salt added in Part B?
5. What is being produced at the cathode? At the anode?
6. How many moles of hydrogen gas is produced in comparison to oxygen gas?
7. Write the half reactions for electrolysis of water.
8. How could NASA and other aviation industries use electrolysis?
9. What are the advantages of using a fuel cell rather than a battery?
10. Molten aluminum chloride can be electrolyzed to produce metallic aluminum and chlorine gas.
  - a. Write the balanced half reactions.
  - b. Write the overall equation for the electrolysis.
  - c. What mass of aluminum metal can be produced if electrolysis is carried out for 24 hours at a current of 15 amperes?  
(1 ampere = 1 coulomb/second)