SCIENTIFIC AMERICAN FRONTIERS

TEACHING GUIDE

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Future Car

Activity 2: Grades 9-12

Hydrogen Fuel

Today, we depend mostly on gasoline as a fuel for automobiles. In the future, however, our reliance may shift to a more common fuel substance, hydrogen. As a clean burning fuel, hydrogen may be used in new types of internal combustion engines. Of even greater promise is the use of hydrogen in fuel cells. Fuel cells harness chemical reactions to produce electric current. Without the wasteful generation of heat and unwanted pollutants, fuel cell technology may soon be powering generations of electric cars.

This activity page will offer:

- An introduction to the use of hydrogen as an automobile power source
- A hands-on activity in generating hydrogen
- An opportunity to bleach food coloring

Getting Hydrogen

Whether it is to be used as a clean-burning fuel or as a reactant in fuel cells, sources of hydrogen must be identified. The good news is that hydrogen is all around, especially in water. Every molecule of water contains two atoms of hydrogen. Freed from the water molecule, hydrogen atoms can combine together to form hydrogen gas. In this activity, you'll generate hydrogen gas by splitting water in a process called electrolysis.

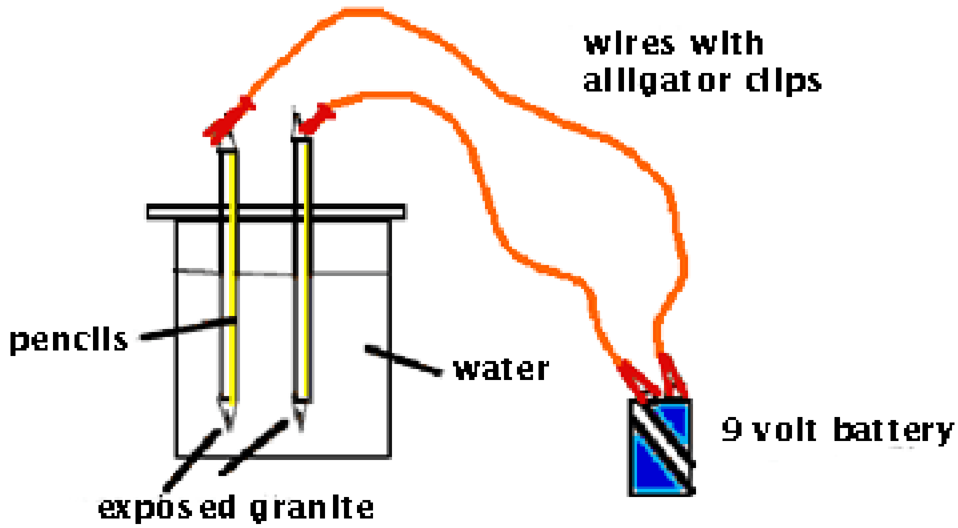
Materials

- Connecting wires with alligator clips at both ends
- 400-mL beaker (or large jar)
- Scrap cardboard
- Two #2 graphite pencils (With graphite exposed at both ends)*
- Tape
- One 9-volt battery
- Salt
- Wax paper
- Food coloring

- Small beaker
- Fumehood (steps 7-10)

  CAUTION: If students extend the activity to include steps 7-10, remind them of the dangers of inhaling chlorine gas. These steps should only be performed in a fumehood.

  *Teacher note: Prior to the activity, obtain a set of #2 pencils with eraser ends that have been removed. Use a pencil sharpener to expose graphite at both ends of the pencil. Then, dull the pencil points prior to distributing them to students.



Procedure
Basic Prototype

1. Work in teams of two. Cut out a section of cardboard that is larger than the mouth of the 400-mL beaker.
2. Carefully insert two prepared pencils into side-by-side slots punched into the cardboard. Make sure the holes are small enough to hold the pencils tightly in place.
3. Fill the beaker halfway with tap water.
4. Position the cardboard on top of the beaker. Adjust the heights of the pencils so that the exposed graphite is near the bottom of the beaker.
5. Use connecting wires to attach the top of each pencil to one of the 9-volt terminals.
6. Over time, you'll observe gas bubbles collecting on both of the exposed graphite shafts of the immersed pencils.
7. Fill a small beaker halfway with water and add about 1/2 teaspoon of table salt.
8. Add a drop of blue food coloring and mix up the solution.
9. Use a dropper to transfer about one mL to this dyed saline solution to the surface of a sheet of wax paper. Place this sheet of paper in a fumehood.
10. Within the fumehood, position the exposed pencil tips so they extend

into the liquid. Wait a few moments and you will observe both the appearance of bubbles and a change in the dye's intensity. This change in color is caused by the bleaching effect of generated chlorine.

CAUTION: Do not inhale the generated gas. Chlorine is an irritant.

Questions

1. Consider the polarity of the ions released when the water decomposed. Which gas collected at the cathode? Why?
2. Why were there more hydrogen bubbles than oxygen bubbles?
3. Where did the chlorine gas generated in step 10 come from?

Predicton

In addition to generating free chlorine gas, how might adding a "pinch" of salt affect the decomposition of water?

Redox Model

Consider the process by which water is decomposed into hydrogen and oxygen gas. Then, compare and contrast it with the fuel cell process in which these same gases are combined to produce water. Using toothpicks and gumdrops, construct a representation of this reversible reaction.

Hindenberg

People often connect hydrogen gas with the Hindenburg disaster. The Hindenburg was a German airship that was filled with hydrogen gas. It exploded at its mooring post in Lake Hurst, New Jersey on May 6, 1937. See a Quicktime video and learn more about this disaster at *http://www.vidicom-tv.com/tohiburg.htm*.

Getting the Lead Out

Although the inner part of a pencil is commonly called "lead," it's not. It's a carbon compound called graphite. Graphite is a soft carbon material that easily breaks apart in molecular sheets. Use Internet and print resources to find out why a pencil's graphite is mistaken for lead. You can learn more about the history of pencils and their components at the URL: *http://www.museums.org.za/sang/exhib/tri_arch/pencil.htm*

Web Connection

How Fuel Cells Work
http://auto.howstuffworks.com/fuel-cell.htm
A great and easy-to-follow introduction to the science of fuel cells.

Electrolysis of Water and Fuel Cell Operation

http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/electrol.html
The chemistry and thermodynamics of electrolysis of water and fuel cell process.

Hydrogen, Fuel Cells & Infrastructure Technologies Program

http://www.eere.energy.gov/hydrogenandfuelcells/
Department of Energy site that includes information about hydrogen and fuel cells.

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Questions

1. Consider the polarity of the ions released when the water decomposed. Which gas collected at the cathode? Why?
   (Oxygen. Oxygen ions are positive and the cathode is negative. Opposites attract.)
2. Why were there more hydrogen bubbles than oxygen bubbles? **(Water contains twice as many hydrogen atoms as oxygen atoms.)**
3. Where did the chlorine gas generated in step 10 come from?
   (Ions of chlorine that had formed when table salt (NaCl) was dissolved in water.)

Predicton

In addition to generating free chlorine gas, how might adding a "pinch" of salt affect the decomposition of water?

(The salt would make the water more conductive and therefore increase the rate of electrolysis.)