SOLAR ENERGY FOR THE CLASSROOM

Provided by Pierce Cedar Creek Institute
www.cedarcreekinstitute.org

Activity Overview
Grade Level: 6-8

General Description
Students complete a short reading on hydrogen as an energy carrier, and use solar electric panels to produce hydrogen and oxygen gases from the electrolysis of water.

Learning Outcome
After producing hydrogen and oxygen gases through hydrolysis, students realize that hydrogen can act as an energy carrier and therefore has many properties that are useful to humankind.

Science Content Standards
Content Area: Constructing New Scientific Knowledge (C) I.1.1
Standard: All students will generate scientific questions about the world based on observation.

Content Area: Constructing New Scientific Knowledge (C) I.1.2
Standard: All students will design and conduct scientific investigations.

Content Area: Reflecting on Scientific Knowledge (R) II.1.4
Standard: All students will describe the advantages and risks of new technologies.

Content Area: Reflecting on Scientific Knowledge (R) II.1.5
Standard: All students will develop an awareness of and sensitivity to the natural world.

Content Area: Ecosystems (LEC) III.5.6
Standard: All students will describe ways in which humans alter the environment.

Hydrolysis: Storing Solar Energy in Water

Background

The most common method of storing solar electricity is to use it to charge batteries. Solar electricity can also be used to split water molecules into hydrogen and oxygen, a process that allows the sun's energy to be stored as hydrogen for later use. The ability to isolate hydrogen gas is one of the basic principles behind the hydrogen fuel cell that is currently being developed as an alternative to the combustion of fossil fuels for powering automobiles. The energy produced in hydrogen fuel cells comes from the bonding of hydrogen with oxygen, a reaction in which energy is released and water is formed.

Materials

- Solar panel
- 500 ml (1 pint) plastic container (per student work group)
- Two small plastic bottles or test tubes (per student work group)
- Two 30 cm (12") lengths of bare wire (per student work group)
- Pencil (per student work group)
- Two alligator clamps (per student work group)
- Water
- Washing soda
- Matches
- Copies of student reading assignment: Hydrogen: An Energy Carrier (provided in curriculum)
- Safety goggles

Science Content Standards

Content Area: Matter and Energy (PME) IV.1.5
Standard: All students will construct simple circuits and explain how they work in terms of the flow of current.

Content Area: Matter and Energy (PME) IV.1.6
Standard: All students will investigate electrical devices and explain how they work using instructions and appropriate safety precautions.

Content Area: Changes in Matter (PCM) IV.2.4
Standard: All students will describe common energy transformations in every day situations.

Content Area: Waves and Vibrations (PWV) IV.4.4
Standard: All students will describe ways in which light interacts with matter.

Content Area: Geosphere (EG) V.1.5
Standard: All students will explain how technology changes the surface of the earth.

Methods

*Note: The solar panel must produce at least 3 volts for this to work!

1. Tightly coil 20 cm (8") of each piece of wire by wrapping it around a pencil.
2. Fill the container with warm water and dissolve 30 grams (1 ounce) of washing soda in the water (the soda speeds up the reaction).
3. Place the small bottles in the container and let them fill with water. While they are under water, insert the coiled ends of the wires into them.
4. Carefully move the bottles so that they are upside down under water.
5. Connect the remaining ends of the wires to the solar panel using the alligator clamps.
6. Set the panel in full sunlight. Observe as bubbles appear in the bottles. Since hydrogen has one extra electron, it will collect at the positive wire. Oxygen lacks the extra electron, so it will collect at the negative wire.
7. In as little as 10 minutes, the bottle connected to the positive pole of the panel will be filled with hydrogen gas. To demonstrate that it is hydrogen, have students work in pairs to "flame it off."
8. One student carefully covers the open end of the bottle (or test tube) with a finger or hand and lifts it from the water. It is important to keep the bottle upside down; hydrogen is lighter than air and will remain in the bottle in this position.
9. The second students lights the match and holds it above the bottle of hydrogen.
10. The first student then turns the bottle upright so that its opening is directly under the lighted match. The hydrogen gas will flow upward and a small pop will be heard as it burns. This characteristic pop is an indication that the gas collected in the bottle was indeed hydrogen (Hydrogen is the only explosive gas that could be produced).

Discussion/Assessment

- Once students have completed the reading (*Hydrogen: An Energy Carrier)*, discuss as a class what they have learned about hydrogen.
- Go over with students the overall and simplified chemical equations for the electrolysis of water (See *Background Information for Teachers).*
- As a follow-up, encourage interested students to investigate current research in fuel cell technology and its present and potential applications in daily life.
- Have students draw a diagram and provide written explanations of the energy conversions carried out in this investigation.

Radiant energy → solar cell → electrical energy → water → chemical energy

Through the photovoltaic effect, the energy of solar radiation is converted into electrical energy. Through electrolysis, electrical energy is converted into chemical energy stored in hydrogen gas.

Source: This activity was adapted from a number of activities found on the World Wide Web:

- *Electrolysis of Water at the Siraze Chemistry Club website: www.chemistry.lmt.md*
- *Electrolysis of Water* at the Resources for Chemistry Teachers and Students website: http://129.93.84.115/#NSF.
- *Solar-Powered Electrolysis of Water and the Hydrogen Economy* at the School Power…Naturally website: www.SchoolPowerNaturally.org

BACKGROUND INFORMATION FOR TEACHERS

Hydrogen: The U.S. government lists hydrogen as an alternative fuel for transportation even though very little hydrogen gas (H_2) exists naturally on Earth. Hydrogen (H), however, is the most abundant *element* in the universe. It is

- a major component of biomass, making up about 14% by weight of such carbon-based organic materials;
- one of two primary components of water (H_2O); and
- the 10th most abundant element in Earth's crust, where it is mainly present in water (H_2O), but also is present in such hydrocarbons as coal, petroleum, and natural gas.

For information on the abundance of hydrogen, see John Emsley, *Nature's Building Blocks*, Oxford University Press. 2001.

Electrolysis: Electrolysis is a process by which a chemical reaction is carried out by means of the passage of an electric current. For the electrolysis of water, water is oxidized at the anode (positive) and reduced at the cathode (negative).

In the electrolysis of water, the reaction at the cathode is:

$4H_2O + 4e- \rightarrow 2H_2 + 4OH^-$

The reaction at the anode is:

$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

The net reaction is:

$6H_2O \rightarrow 4OH^- + 4H^+ + 2H_2 + O_2$

The simplified balanced chemical reaction is:

$2\ H_2O \rightarrow 2\ H_2 + O_2$

This last equation reveals why the rate of hydrogen gas production is twice that of oxygen during the electrolysis of water. Be aware that both hydrogen and oxygen gases are heavier than air. This becomes important when students cover the test tubes to prevent gas from escaping. The tube should be held upright rather than up-side-down.

Given the contents of the water molecule, the only possible explosive gas that can form is hydrogen.

Production of Hydrogen: The United States produces approximately three billion cubic feet of hydrogen gas annually. The most common source for hydrogen production is natural gas. Natural gas is heated in the presence of steam to around 1,000^oC ($CH_4 + H_2O \rightarrow 3\ H_2 + CO$). In a second reaction using steam, the carbon monoxide and water are converted into carbon dioxide and hydrogen, ($H_2O + CO \rightarrow CO_2 + H_2$).

Passing steam over red-hot coals produces a mixture of equal parts hydrogen and carbon monoxide. This mixture is known as synthesis gas, a useful fuel that can be converted into methanol. Ethanol reacts with water in the presence of a rhodium catalyst, producing hydrogen and some heat. The electrolysis of water is not yet an economical process, although it has been suggested as a feasible way to store the energy from excess electricity derived from nuclear power plants or hydroelectric dams. Hydrogen also can be obtained from some kinds of bacteria and algae—the ones that give off hydrogen as they ferment the sugar glucose producing acetic acid.

Using Solar Energy to Produce Hydrogen: When steam is "superheated" to about 1,400°C, the water molecule literally begins to break apart into hydrogen and oxygen. This can be accomplished by mirrors focusing sunlight on a single location wherein steam is present. This method currently is considered impractical because of the amounts of energy needed to initiate the process and the expense of producing special containers that can withstand such high temperatures.

When water is heated to 300°C–1,000°C in the presence of powdered iron oxide, the iron rusts, tying up the oxygen and leaving behind hydrogen gas. This process also can be brought about by the focusing of sunlight by mirrors. The focused light reaches a location containing water and, in this case, powdered iron oxide. This method is considered practical because the production temperature for it is relatively low.

Electrolysis of water can be accomplished by passing DC current from a solar electric panel through an alkaline solution. Although this is not yet an economical process, improvements achieved include such methods as

- the electrolysis of steam inside porous electrodes of zirconium oxide
- the use of fuel cells for achieving electrolysis

The latter method is a newly rediscovered technology having potential efficiencies of 80%–90% and corrosive alkaline solutions are not necessary for this process to occur.

For additional information on producing hydrogen from solar energy sources, refer to Francisco Fantes, *Solar Hydrogen Energy: Mining the Oceans for the Holy Grail*, Winter 2003 issue of Harvard Science Review, *Climate and the Environment*, Vol. 16, No. 1. September 2002–January 2003. http:/hcs.harvard.edu/~hsr/winter2003.html

REFERENCES FOR BACKGROUND INFORMATION

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STUDENT READING ASSIGNMENT

Hydrogen: An Energy Carrier

The U.S. government lists hydrogen as an alternative fuel for transportation even though very little hydrogen gas (H_2) exists naturally on Earth. Hydrogen (H), however, is the most abundant *element* in the universe. It is

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- one of two primary components of water (H_2O); and
- the 10th most abundant element in Earth's crust, where it is mainly present in water (H_2O), but also is present in such hydrocarbons as coal, petroleum, and natural gas.

Energy is required to isolate hydrogen, in the form of hydrogen gas (H_2), from the elements present on Earth that combine chemically with H. Once separated, hydrogen gas has the potential to release energy in a controlled and useful manner. Because of this, it is said that hydrogen acts as an energy carrier; much of the energy used to produce hydrogen gas can later be extracted in a separate location for a useful purpose.

Many scientists/technologists believe hydrogen gas is likely to be the clean fuel of the future. When burned, it produces only heat and water resulting in almost no pollution. When fed into a fuel cell along with oxygen, the fuel cell produces electricity, water, and heat—no dangerous emissions. The U.S. space program has made use of this technology for decades to supply both electric power for spaceships and drinking water for crews.

Hydrogen gas and the useful energy it contains, when used as an energy source, are potentially

- storable
- transportable
- pollution-free
- useful in transportation systems, homes, and industry.

Also, hydrogen gas can be produced from a wide selection of abundant resources including biomass, water, and hydrocarbons. Yet, scientific and technological advances in storage, transportation, and fuel cell technologies will be needed before hydrogen gas can be economically used on a widespread basis.

How environmentally friendly hydrogen power ultimately will be is heavily dependent on where the hydrogen gas is obtained and what energy source is used to obtain it. For example, when hydrogen is obtained from a fossil fuel, a powerful greenhouse gas (carbon dioxide) is released. On the other hand, when hydrogen is obtained from water, it is the gas oxygen that is released

When fossil fuels are used as an energy source to isolate hydrogen gas, the process produces the same harmful emissions that we are familiar with today. The amount of emission, however, may be reduced if the production, transportation, and use of hydrogen gas turns out to be more efficient than the production, transportation, and use of a petroleum product such as gasoline or heating oil. Alternatively, when a renewable energy source such as solar electric, hydro, or wind power is used to isolate hydrogen gas, there are almost no emissions, although there are other environmental impacts that certainly should be considered.