Fuel Cells – Futuristic Battery

Student Objectives
The student:
- will be able to explain the chemical reaction in the electrolysis procedure
- will be able to explain the chemical reaction occurring in the fuel cell
- will understand how conservation of energy relates to the electrolysis/fuel cell procedure
- will be able to explain the benefits and disadvantages of using fuel cells to generate electricity and power vehicles.

Key Words:
anode
cathode
catalyst
PEM
platinum

Time: 1 hour

Materials
- PEM reversible fuel cell with gas storage tanks (1 per group)
- photovoltaic panel, transformer or battery to match the fuel cell's input voltage and amperage (1 per group)
- wires with alligator clips (2 per group)
- small motor and propeller (1 per group)
- distilled water
- stopwatch (or watch with second hand)

Background

A fuel cell produces electricity. Similar to a battery, a fuel cell converts energy produced by a chemical reaction directly into usable electric power. But, unlike a battery, a fuel cell does not get 'used up'; it can generate electricity as long as it is supplied with hydrogen. Inside a fuel cell, hydrogen and oxygen combine to produce electricity and water. As a simple electrochemical device, a fuel cell does not actually 'burn' fuel, so it operates pollution-free. This also makes it quiet, dependable and fuel-efficient.

Inside most fuel cells, a selectively permeable membrane is sandwiched between two electrodes. Hydrogen gas feeds into the negative chamber (the anode), and oxygen enters the

other side in the positive chamber (the cathode). As the hydrogen atoms flow through the anode, a platinum-based catalyst separates the hydrogen protons from their electron. The charged protons are attracted to the oxygen on the other side and pass through the membrane. The electrons cannot pass through the membrane, and instead must get to the cathode via an electrical wire–creating electricity! When the electrons arrive at the cathode they recombine with the hydrogen protons and the oxygen atoms to make water. This process also generates some heat which can be used for other purposes.

An individual fuel cell produces low voltage DC electricity. To meet other power needs, fuel cells are put together in a 'stack', to create any voltage needed.

This experiment demonstrates the decomposition of water in a ratio of 2 volumes of hydrogen gas to 1 volume of oxygen.

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

In the fuel cell, the reverse of electrolysis takes place; the gases stored during electrolysis are reconverted into water.

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

This proves that this electrochemical reaction is reversible.

The first reaction (electrolysis) requires electrical energy, whereas the second reaction releases electrical energy. In any such energy cycle there will be losses. The conversion of one form of energy to another is never 100% efficient. The fuel cell, however, is about twice as efficient as the internal combustion engine.

Procedure

1. Divide the students into lab groups of 3 - 5 students per group.
2. Show the class the reverse PEM fuel cell.
3. Demonstrate how to fill the chambers for the electrolysis procedure
4. Demonstrate how to attach the fuel cell to the power source (photovoltaic panel, transformer or battery)
5. Pass out the equipment and have the students complete the experiment in their lab manuals.
   Note: If you have students who don't follow directions well, you may want to give them only one of the set of wires, check that they have it hooked up correctly, and then give them the other wire. The fuel cell can be damaged if the wires are crossed between the power source and the cell–positive must go to positive and negative to negative.
6. Assist students as necessary.
7. After the students finish the lab, show them the animation of a fuel cell (Internet Sites below).
8. Discuss the lab and fuel cell information. Questions you may wish to pose to your class:
   - Since we know that no energy transformation is 100% efficient, we know that the electricity produced by the fuel cell is less than the energy needed for the electrolysis procedure. We also know that energy cannot be created or destroyed, so what happens to the 'missing' energy? *(it turns into heat as a by-product of the reaction)*
   - How are fuel cells and batteries alike? *(batteries and fuel cells both produce*

electricity, they both have anodes and cathodes)

- How are fuel cells and batteries different? *(their chemicals are different, batteries run out and need recharged while fuel cells will continue as long as they have a supply of hydrogen)*
- How could we use fuel cells in the future?
- What are the advantages of using fuel cells to produce electricity? *(non-polluting, no moving parts, quiet)*
- What are the disadvantages of using fuel cells? *(no hydrogen infrastructure at the present time, cost)*

Key Words & Definitions

- **anode -** the negative terminal or chamber, as in a fuel cell
- **cathode** - the positive terminal or chamber, as in a fuel cell
- **catalyst** - a substance that modifies and increases the rate of a reaction without being consumed in the process
- **PEM** - Proton Exchange Membrane–refers to the most common type of fuel cell
- **platinum** - a heavy precious grayish white noncorroding malleable metallic element that fuses with difficulty and is used especially in chemical ware and apparatus, as a catalyst, and in dental and jewelry alloys

Related Research

1. Research NASA's use of fuel cells on the space shuttle and the space station.
2. Providing a reliable supply of hydrogen and an infrastructure for mobile uses such as cars, poses a host of transportation and storage problems. Have students pick a fuel cell application (a car, train, home, apartment complex or factory), and work up a plan to make this application a reality.
3. Have students create an advertising poster that promotes the use of fuel cells as an energy source.

Internet Sites

http://www.eere.energy.gov/hydrogenandfuelcells/fuelcells/basics.html
US Department of Energy, Energy Efficiency and Renewable Energy. Fuel Cell animation

http://www.eia.gov/kids/energy.cfm?page=hydrogen_home-basics
Department of Energy student hydrogen pages

Fuel Cells – Futuristic Battery

			.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	.11	.12
Grade 6														
Practice of Science	# 1	SC.6.N.1	**X**			**X**								
Grade 7														
Practice of Science	# 1	SC.7.N.1	**X**		**X**									
Energy Transfer & Transformations	# 11	SC.7.P.11		**X**										
Grade 8														
Practice of Science	# 1	SC.8.N.1	**X**											
Properties of Matter	# 8	SC.8.P.8					**X**			**X**				

Sixth Grade Benchmarks
Science–Big Idea 1: The Practice of Science

- SC.6.N.1.1 - Define a problem from the sixth grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.
- SC.6.N.1.4 - Discuss, compare, and negotiate methods used, results obtained, and explanations among groups of students conducting the same investigation.

Seventh Grade Benchmarks
Science–Big Idea 1: The Practice of Science

- SC.7.N.1.1 - Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.
- SC.7.N.1.3 - Distinguish between an experiment (which must involve the identification and control of variables) and other forms of scientific investigation and explain that not all scientific knowledge is derived from experimentation.

Science–Big Idea 11: Energy Transfer and Transformations

- SC.7.P.11.2 - Investigate and describe the transformation of energy from one form to another.

Eighth Grade Benchmarks

Science–Big Idea 1: The Practice of Science

- SC.8.N.1.1 - Define a problem from the eighth grade curriculum, using appropriate reference materials to support scientific understanding, plan and carry out scientific investigations of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.

Science–Big Idea 8: Properties of Matter

- SC.8.P.8.5 - Recognize that there are a finite number of elements and that their atoms combine in a multitude of ways to produce compounds that make up all of the living and nonliving things that we encounter.
- SC.8.P.8.8 - Identify basic examples of and compare and classify the properties of compounds, including acids, bases, and salts.

Science–Big Idea 9: Changes in Matter

- SC.8.P.9.2 - Differentiate between physical changes and chemical changes.

Fuel Cells – Futuristic Battery

1. Fill the water tanks of the fuel cell as directed. Attach the power source (PV cell, transformer or battery) to the fuel cell using wires with alligator clips.
   - Attach the red wire to the red terminal on the fuel cell and the positive post on the photovoltaic cell. Repeat with the black wire to the black terminal and the negative post on the PV cell.
   - If using a transformer, connect the red to red, and the black to black.
   - Remember, do not reverse the wires (polarity) as this will foul the fuel cell.

   Begin timing with a stopwatch as soon as you make the second connection. Record the level of gases at one minute intervals until both the hydrogen and oxygen tanks are completely full and the excess gas begins to bubble up. When the tanks are filled, record the time and disconnect the fuel cell from the PV cell (or transformer).

Time Interval	Hydrogen level	Oxygen level

3. What did you notice about the ratio of hydrogen and oxygen produced during the electrolysis procedure?

4. Why did the electrolysis procedure produce this ratio of hydrogen to oxygen?

5. Attach the fuel cell to a motor and propeller. (This time it doesn't matter which wire goes to which terminal on the motor–reversing the wires will only reverse the spin of the

motor.) Begin timing with a stopwatch as soon as you make the second connection, and record the level of gases at one minute intervals. When the motor stops or the hydrogen tank is almost empty (only one bubble of hydrogen left), remove the wires and record the time.

Time Interval	Hydrogen level	Oxygen level

6. What did you notice about the ratio of hydrogen and oxygen consumed by the fuel cell to produce electricity?

7. Why did the fuel cell consume this ratio of hydrogen to oxygen?

8. Write a balanced equation for the electrolysis procedure.

9. Write a balanced equation for the chemical reaction occurring in the fuel cell.

10. Compare and contrast the electrolysis procedure and the fuel cell procedure.

11. In the electrolyser, electrical energy is converted into chemical energy. The energy is stored as hydrogen gas. In the fuel cell, chemical energy is converted into electrical energy. For a given volume of hydrogen produced and used, will the fuel cell generate as much electrical energy as was needed to produce the hydrogen in the electrolyser? If not, why not?