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:
electrolysis
fuel cell
membrane

Time: 1 hour

Materials
- PEM reversible fuel cell with gas storage tanks
- photovoltaic panel or transformer, .5 amps or less
- wires with alligator clips (2)
- small motor and propeller
- 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. Tell the students that they will be assisting in an experiment using a fuel cell to find out how a reversible fuel cell can break water molecules apart into hydrogen and oxygen and then recombine them to make usable electricity.
2. Show the class the reverse PEM fuel cell. Point out the tanks that the gases will collect in, and the membrane between them that will be used to help make electricity when the gasses come back together to form water again.
3. Fill the chambers for the electrolysis procedure:
   - Flip the fuel cell over so the bottom caps are up.
   - Remove the caps.
   - Fill one chamber completely with distilled water. (Remember, only distilled water is used, any other kind of water or any other liquid will ruin the membrane in the cell.) Make sure you fill the chamber until some water runs down the center tube.
   - Push the cap on from the center–this pushes out as much ambient air as possible.
   - Return the fuel cell to the upright position.
   - Repeat with the second chamber.
4. Give the students all a chance to look at the fuel cell with the water but no gas in the chambers.
5. Select one student to be the timer (with the stopwatch), one student to be the recorder (to write the information on the board), one student to read the hydrogen levels and one to read the oxygen levels. Make sure the students understand their jobs–at one minute intervals the timer will call out the time (1 minute, 2 minutes, etc), the hydrogen and oxygen readers will call out their gas levels (0 ml, 2 ml, etc), and the recorder will write them on the board in the appropriate space. See example below:

Time Interval	Hydrogen level	Oxygen level

6. Attach the fuel cell to the photovoltaic panel (or transformer):
   - 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.
   - Be sure to not reverse the wires (polarity) as this will foul the fuel cell.
7. The timer begins timing as soon as you make the second connection. At one minute intervals the hydrogen and oxygen levels are recorded. When the hydrogen tank is filled completely with gas and begins to bubble on the surface, discontinue the electrolysis procedure.
8. When this section of the experiment is completed, ask the students what they noticed about the volume (amount) of hydrogen and oxygen gases *(there is twice as much hydrogen as oxygen)*.
9. Ask the students why they think the electrolysis procedure produced this ratio of hydrogen to oxygen. If they need a hint, write H_2O in big letters on the board.
10. Assign another team (timer, recorder, and two level readers) for the fuel cell part of the experiment), and create a second chart on the board
11. 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 the 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.
12. When this section of the experiment is completed, ask the students what they noticed about the volume (amount) of hydrogen and oxygen gases that were used in the fuel cell *(there is twice as much hydrogen as oxygen used by the fuel cell)*.
13. Ask the students why they think the fuel cell used twice as much hydrogen as oxygen.
14. Tell the students that the fuel cell makes electricity when the hydrogen recombines with the oxygen (remind them of the motor and propeller spinning).
15. Show the students the Nova fuel cell show (if available) or a fuel cell animation (one is listed in the Internet Site section below)

16. After showing the fuel cell animation lead a discussion on fuel cells. Questions you may wish to pose to your class:
    - How are fuel cells and batteries alike? *(batteries and fuel cells both produce electricity)*
    - 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? *(Allow students to use their imagination, but encourage them to think of current uses of electricity as well as transportation uses)*
    - What are the advantages of using fuel cells to produce electricity? *(non-polluting, no moving parts, quiet)*

Further Research

1. Research NASA's use of fuel cells on the space shuttle and the space station.
2. Have students create drawings of a future hydrogen car or hydrogen powered house.
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

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			.1	.2	.3	.4	.5	.6
Nature of Matter	**Standard 1**	**SC.A.1.2-**	**X**				**X**	
	Standard 2	**SC.A.2.2-**	**X**					
Energy	**Standard 1**	**SC.B.1.2-**	**X**	**X**		**X**		
	Standard 2	**SC.B.2.2-**			**X**			
Nature of Science	**Standard 1**	**SC.H.1.2-**		**X**				
	Standard 2	**SC.H.2.2-**						
	Standard 3	**SC.H.3.2-**	**X**	**X**				

Benchmark SC.A.1.2.1 - The student determines that the properties of materials can be compared and measured.
Grade Level Expectations
The student:
Third
- determines the physical properties of matter using metric measurements that incorporate tools such as rulers, thermometers, balances

Fourth
- uses a variety of measurements to compare and contrast the physical properties of matter

Fifth
- uses metric tools to determine the density and volume of materials.

Benchmark SC.A.1.2.5 - The student knows that materials made by chemically combining two or more substances may have properties that differ from the original materials.
Grade Level Expectations
The student:
Fifth
- knows that materials made by chemically combining two or more substances have properties that differ from the original materials
- knows the difference between physical and chemical changes.

Benchmark SC.A.2.2.1 - The student knows that materials may be made of parts too small to be seen without magnification.
Grade Level Expectations

The student:
Fifth
- knows that materials may be made of parts too small to be seen without magnification.

Benchmark SC.B.1.2.1 - The student knows how to trace the flow of energy in a system.
Grade Level Expectations
The student:
Fourth
- knows how to trace the flow of energy in a system

Fifth
- knows how to trace the flow of energy in a system.

Benchmark SC.B.1.2.2 - The student recognizes various forms of energy.
Grade Level Expectations
The student:
Third
- knows different forms of energy

Fourth
- knows that there are a variety of sources for electricity

Fifth
- knows that energy can be described as stored energy or energy of motion.

Benchmark SC.B.1.2.4 - The student knows the many ways in which energy can be transformed from one type to another.
Grade Level Expectations
The student:
Fourth
- knows ways that energy can be transformed

Benchmark SC.B.2.2.3 - The student knows that the limited supply of usable energy sources places great significance on the development of renewable energy sources.
Grade Level Expectations
The student:
Third
- knows that alternate energy sources are being explored using natural and mechanical processes

Fifth
- knows that the limited supply of usable energy sources places great significance on the development of renewable energy sources.

Benchmark SC.H.1.2.2 - The student knows that a successful method to explore the natural world is to observe and record, and then analyze and communicate the results.
Grade Level Expectations
The student:
Third

- uses various kinds of instruments to collect and analyze information

Fourth

- uses metric tools to measure, record, and interpret data

Benchmark SC.H.3.2.1 - The student understands that people, alone or in groups, invent new tools to solve problems and do work that affects aspects of life outside of science.

Grade Level Expectations

The student:

Fourth

- knows that technologies often have costs, as well as benefits, and can have an enormous effect on people and other living things

Fifth

- knows areas in which technology has improved human lives
- knows that new inventions often lead to other new inventions and ways of doing things.

Benchmark SC.H.3.2.2 - The student knows that data are collected and interpreted in order to explain an event or concept.

Grade Level Expectations

The student:

Third

- understands that scientific information can be presented in several ways

Fourth

- constructs and analyzes graphs, tables, maps, and charts to organize, examine, and evaluate information.

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electrolysis - chemical change, especially decomposition, produced in an electrolyte by an electric current. For example, in electrolysis an electric charge breaks water into hydrogen gas and oxygen gas

fuel cell - an electrochemical cell in which the energy of a reaction between a fuel, such as hydrogen, and an oxidant, such as oxygen, is converted directly and continuously into electrical energy

membrane - A thin sheet of natural or synthetic material that is permeable to substances in solution