

Activity 4, “Modeling the Fuel Cell Reaction”
from the SEPUP *HyTEC* Module

For use only by teachers who attended the Hydrogen and Fuel Cell sessions presented by Barbara Nagle at NSTA on March 20 and 21, 2009.

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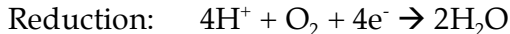
Phone (510) 642-8718 Fax (510) 642-3131 <http://www.sepuplhs.org/>

Activity 4 Modeling the Fuel Cell Reaction

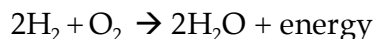
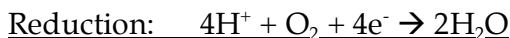
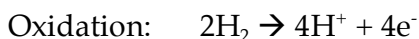
One kind of fuel cell is called a *Proton Exchange Membrane* (PEM) Fuel Cell. This type of fuel cell is already in use in buses, cars, and power generators, and may be widely used in the future. Like a battery, a fuel cell converts chemical energy into electricity. Unlike a battery, a hydrogen fuel cell continues to provide electricity as long as it is supplied with hydrogen and oxygen.

The chemistry of fuel cells has been understood since the 1830s. Like batteries, fuel cells create electricity through chemical reactions that involve the transfer of electrons. Chemists call these reactions **oxidation-reduction**, or **redox**, reactions. Redox reactions can be split into two parts, the oxidation half and the reduction half. Half-reactions that release electrons are called **oxidation reactions**; half-reactions that accept electrons are called **reduction reactions**.

Inside a PEM hydrogen fuel cell, electric current is generated using the two chemical half-reactions shown below.



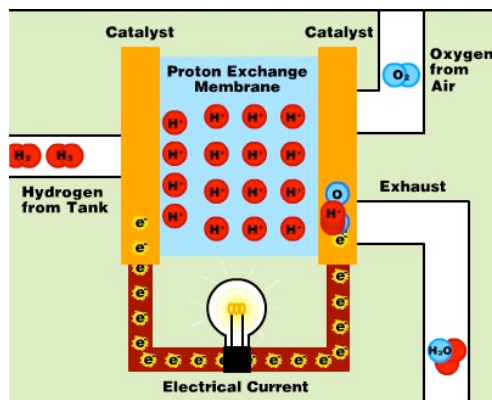
These equations can be added to obtain the complete equation. But first the oxidation reaction must be multiplied by two, so that the number of electrons in the reactants balances with the number of electrons in the products.



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Inside the fuel cell are two electrodes. Each electrode has a platinum catalyst that speeds up the redox reaction.

The electrode where oxidation occurs is called the anode. At the **anode**, hydrogen is oxidized and electrons are delivered to an external electrical circuit. In the previous activity, this circuit provided the power that let the electric motor turn the propeller. The electrons travel through this external circuit to the **cathode**. Reduction occurs at the cathode, where oxygen is reduced and the reactants combine to form water.



A *proton exchange membrane* separates the two electrodes. This membrane lets protons diffuse through, but blocks electrons, forcing the electrons to flow through an external circuit and generate current. At the cathode, these protons join in the reduction reaction to form water.

Since we can't see the electric current or the chemical reactions inside a fuel cell, using models and computer simulations can help us understand what is happening.

Challenge

How do the redox reactions in a fuel cell generate electricity?

Materials

For each team of two students

- 1 modeling set
- 1 fuel cell diagram
- 1 computer with modeling simulation

Procedure

Part A: Computer Simulation of a Fuel Cell

1. The simulation of a fuel cell is available on the SEPUP HyTEC website: http://www.sepuplhs.org/hytec/fuel_cells.html. Open the simulation on your computer screen and view the entire process. After clicking on "See Catalyst" and "See Exhaust Closeup," click "Reset" and discuss the following with your partner or group.

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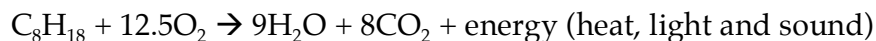
- a. Identify the anode and the cathode.
 - b. Describe what happens to the hydrogen and oxygen.
 - c. Explain how water gets generated at the exhaust port.
2. Click on "See Hydrogen Closeup." Write the half reaction for what happens at the anode. Then write one or more sentences explaining what is happening.
3. Click on "See Oxygen Closeup." Write the half reaction for what happens at the cathode. Then, explain what is happening in your own words.
4. Click on "See Exchange Membrane." Explain what would happen if the membrane were altered in a way that allowed electrons to pass through (in addition to protons).
5. Click on "See Electricity."
- a. What keeps electrons flowing through the circuit?
 - b. What could cause the electric light to go off?
6. Click on "See Exhaust Closeup." Why are fuel cells potentially better for the environment than internal combustion engines?

Part B: Modeling the fuel cell reaction

1. Working with a partner, use the appropriate pieces of the modeling set to build two hydrogen gas (H₂) molecules and one oxygen gas (O₂) molecule. In your notebook, draw each molecule.
2. Examine your models. Describe how the bonds in your O₂ and H₂ molecules are represented.
3. Place the two H₂ molecules on the anode side of the fuel cell diagram and the O₂ molecule on the cathode side.
4. Model the break up of H₂ at the anode. Move the broken pieces along the appropriate paths on the fuel cell diagram. Electrons should go through the circuit with the light bulb. The protons pass through the membrane.
5. Model the creation of water at the cathode. In your notebook, draw one of the two water molecules that are created.
6. Using the shapes of the molecular models and the picture of the fuel cell as a guide, create a storyboard of at least four frames depicting the chemical reactions that happen inside a fuel cell to create electricity. Be sure to label all parts as needed.

Analysis

1. Note that oxygen for fuel cell vehicles is obtained from the surrounding air. Why do you think that is?
2. Gasoline internal combustion engines release chemical energy through the combustion reaction shown below. Octane (C₈H₁₈) is a major constituent in gasoline.



- a. What are the main similarities between the H₂ fuel cell reaction and this internal combustion engine reaction?
- b. What are the main differences between the H₂ fuel cell reaction and this internal combustion engine reaction?