Build a Fuel Cell

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Date Created: 2008
Subject: Chemistry
Level: High School
Standards: *New York State-Physical Setting/Chemistry* *(www.emsc.nysed.gov)*
Standard 1- Analysis, Inquiry and Design
Standard 4 - The Physical Setting
Standard 6 - Interconnectedness: Common Themes
Standard 7- Interdisciplinary Problem Solving
Schedule: One Hour

Objectives:

Connect to and build upon students' knowledge of oxidation-reduction reactions in order to introduce the chemistry involved in fuel cell technology.

Students will:

- Build a Hoffman Apparatus that demonstrates electrolysis of water.
- Convert their Hoffman apparatus into a fuel cell
- Explain the oxidation-reduction reaction taking place in the Hoffman Apparatus.
- Explain the relationship between a Hoffman Apparatus and a fuel cell
- Observe and record signs of a chemical reaction.
- Measure and record voltage produced by their fuel cell.

Vocabulary:

Electrolysis
electrocatalyst
electromotive
force
kinetics
electrolyte

Materials:

For Each Student:
1 pair safety Goggles
Activity Sheets
1 volt meter
2 alligator clip connection wires
1 straight pin
1 piece of parafilm

For Each Pair:
3-4 plastic pipettes
.5 yd of copper wire
1 Petri dish
30 ml saturated Na_2SO_4 solution (pre-mixed with bromothymol blue)
3-4 graphite golf pencils
1 Battery (6V or 9V)

For the Teacher:
Fuel Cell demo kit

Safety:

Safety goggles should be worn at all times during the "explore" portion of this activity.

Science Content for the Teacher:

Summary

The fuel cell effect will be demonstrated in this activity. While not an exact demonstration of the type of fuel cell used in hydrogen cars (among other technologies), the underlying principles of fuel cells are exhibited here; plus, how this apparatus compares to a real working fuel cell can be readily discussed.

The demonstration involves a simple Hoffmann apparatus for the electrolysis of water. Using two graphite electrodes, and separate compartments for the evolution of hydrogen and oxygen, small volumes of both gases are readily collected when a battery powers the cell. Removing the battery, and replacing it with a volt meter, students are able to measure a significant potential difference from the fuel cell effect of the recombination reaction of hydrogen and oxygen (combustion).

Fuel Cell Effect

The fuel cell effect is simply the ability to measure an electromotive force across two electrodes when coupled (via electrolyte) half-reactions occurring there combine to yield a spontaneous net reaction ($\Delta G<0$). Although similar to a galvanic cell, in a fuel cell the chemical reactions occur at the electrodes, but do not consume or build up the electrodes. In the typical galvanic cell, zinc is dissolved and copper is plated. In a fuel cell, the electrodes are electrocatalysts which provide a surface for the fuel to be oxidized (anode) and the oxidant to be reduced (cathode). Fuel cells today are primarily built on combustion reactions of different fuels, e.g. hydrogen, methanol, formic acid. However, other, non-combustion reactions, can also be used to build a fuel cell.

The theoretical potential difference of the fuel cell depends on the reaction (ΔE of oxidant – fuel). The electrocatalyst surfaces on which the reaction occurs will strongly affect the measured voltage. Likewise, since the kinetics of the reactions are strongly affected by the electrocatalysts, the current that can be drawn from the fuel cell depends highly on the electrocatalysts employed. This is the primary difference between the demonstration fuel cell and an actual, commercial fuel cell.

Demo Fuel Cell and Commercial Fuel Cell

In this demonstration fuel cell, graphite electrodes are used at the anode and cathode. While the recombination of hydrogen and oxygen does occur at graphite electrodes connected via the electrolyte, these reactions are not favored on graphite. Therefore, the voltage measured is less than expected, and nearly no useful current can be drawn from the fuel cell. In practical fuel cells, electrodes are based on electrocatalysts of platinum (or alloys of Pt). Although extremely expensive, Pt enables very high voltages (especially for H2) plus usable currents. High currents are especially captured due to ultra-high surface area electrodes made possible by using nanoparticle platinum metal in the electrode.

Preparation:

- Make 300ml of a saturated Na_2SO_4 solution.
- Add about 1mL of bromothymol blue.
- Adjust the pH using $NaHCO_3$ (baking soda) so that the bromothymol blue indicator turns green.

Classroom Procedure:

Engage (Time: 15 mins.)

When students enter the room, have the fuel cell demonstration kit running.

(This kit uses a solar cell to provide the electricity necessary to electrolyze water, then uses a fuel cell to create a charge strong enough to run a small electric fan.)

Using a "K,W,L"* chart, ask student to tell what they already know about fuel cells and what they already know about what is going on in the kit you have. Then, ask student to list some things they would like to know about fuel cells and any theories they have about how the demonstration kit works.

*Note: This activity assumes that students have some prior knowledge of oxidation-reduction reactions. Therefore, they should have some idea, or at least an educated theory about what is going on in the demonstration kit.

Explore (Time: 30 mins.)

- Tell students that in order to better understand fuel cells and the demo at the front of the room, they will be building their own version in pairs. If they did not already point this out during the engage discussion, make sure students know there are two stages in, or parts to the demonstration kit, and that they should recognize some of what is going on from prior work with oxidation-reduction reactions. Students will begin by building the part that, on the demonstration kit, uses a solar panel. In their version they will use a battery as an energy source.

- Pass out Activity Sheet 1: Build A Hoffman Apparatus. This sheet includes building instructions and space for students to record observations as they go.

- Pass out Activity Sheet 2: Convert Your Hoffman Apparatus into a Fuel Cell. This sheet also includes building instructions and space for observations and data collection.

Explain (Time: 15 mins.)

Complete the “K, W, L”* chart by recording what students have learned about fuel cells from the activity.

Discussion Questions:

- How does the fuel cell demo kit work?
- What is the relationship between a Hoffman Apparatus and a fuel cell?
- What are the strengths and weaknesses of the fuel cell in this activity?
- How are students’ fuel cells similar and/or different from fuel cells being used in commercial applications?
- What are the strengths and weaknesses (advantages and disadvantages) of fuel cells being used in commercial applications today?

** A KWL chart is a comprehension strategy used to activate background knowledge prior to an activity. The teacher divides a piece of chart paper into three columns. The first column, 'K', is for what the students already know about the topic. This step is to be completed before the activity. The next column, 'W', is for students to list what they want to learn about the topic during the activity. This step is also to be completed before the reading. The third column, 'L', is for what the students learned from the activity. This step, of course, is done after finishing theactivity.*

Assessment:

The following rubric can be used to assess students during each part of the activity. The term "expectations" here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

1= exceeds expectations
2= meets expectations consistently
3= meets expectations occasionally
4= not meeting expectations

	Engage	Explore	Explain
1	Shows leadership in the discussion and offers creative ideas reflecting a good understanding of chemistry.	Completes work accurately while providing an explanation for what is observed. Works very well with partner(s).	Provides an in-depth explanation of findings, making good use of vocabulary terms. Fills out worksheet clearly.
2	Participates in the brainstorm and shows an understanding of the chemistry involved.	Completes work accurately and works cooperatively with partner(s).	Provides clear explanation of findings. Fills out worksheet clearly.
3	Contributes to the brainstorm, but shows little understanding of chemistry.	Works cooperatively with partner(s), but makes some careless mistakes with the procedure.	Provides a limited explanation of findings. Fills out some of the worksheet.
4	Does not participate in brainstorm. Shows no understanding of chemistry.	Has trouble working with partner(s). Does little to complete the procedure.	Is not clear in explanation of findings. Does not fill out worksheet.

Safety:

Safety goggles should be worn at all times during the "explore" portion of this activity.

Acknowledgments:

Per-Odd Eggen and Lise Kvittingen, Department of Chemistry, Norwegian University of Science and Technology, Norway, and Truls Grønneberg, Department of Chemistry, University of Oslo, Norway.