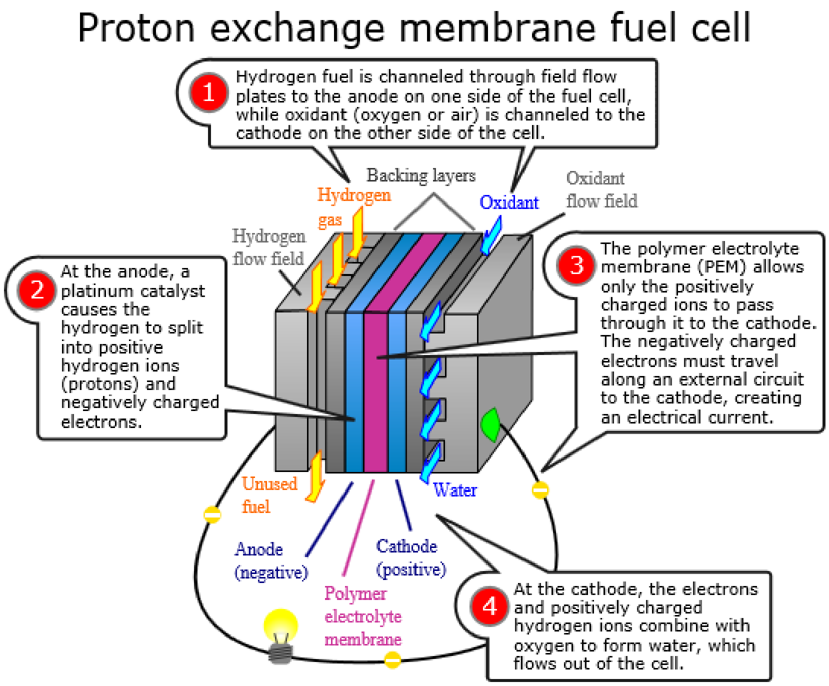
Fuel Cells & Redox Reactions

Subject Area(s) Chemistry

Associated Unit Hillsborough County School District Chemistry Unit 16: Redox



Proton Exchange Membrane Fuel Cell

ADA Description: Diagram of the components of a fuel cell with explanations of the hydrogen flow, the anode, the polymer electrolyte membrane, and the cathode.

Source/Rights: Copyright © http://www.newworldencyclopedia.org/entry/fuel_cell

Caption: Diagram of fuel cell components and their functions

Grade Level 10 (10-12)

Time Required **(3) 50 minute class periods**

Summary

Students will use the metal of their choice as the catalyst in a simple fuel cell to make connections between fuel cells and redox concepts. They will be required to develop analysis questions based on their results, write balanced equations (using the half reaction method), and identify the oxidized and reduced species involved in the production of electricity from a fuel cell.

Engineering Connection

Chemical engineers must understand basic interactions of matter to develop products and systems that provide functional solutions to everyday needs. Fuel cells are a promising source of power that will help diversify world energy costs. Like engineers, students must understand the chemical reactions behind a fuel cell so that they may investigate improvements to the current designs. The most common catalyst used in fuel cells are platinum group metals which are available in limited quantities and are costly compared to more commonly used metals. If alternatives can be developed, fuel cells costs could be lowered and therefore be more widely available for use.

Engineering Category =

2. Engineering analysis or partial design

Keywords

Fuel cell, oxidation, reduction, half reaction

Educational Standards

State STEM Standard

CPALMS, 2008, SC.912.P.8.8 Characterize types of chemical reactions, for example: redox, acid-base, synthesis, and single and double replacement reactions.

CPALMS, 2008, SC.912.P.8.10 Describe oxidation-reduction reactions in living and non-living systems.

ITEEA Standard

ITEEA, 2000, Standard 10, I (grades 9-12) Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace

Pre-Requisite Knowledge

Balancing equations, chemical reactions,

Learning Objectives

After this lesson, students should be able to:

- Students will gain a basic knowledge of fuel cell historical development and current usage as a foundation to their own investigations. (Day 1)
- Students will chose, develop, and test a metal catalyst of their choice and hypothesis as to its efficacy. (Day 2)
- Students will analyze the functions of a fuel cell and determine that power production is dependent upon oxidation and reduction reactions. (Day 3)

Introduction / Motivation (5E – Engage)

Is that really a light powered by lemons? Did you know that you can create a battery from pennies? How does that work? Electricity is a necessity of modern life and while we may know a few things about current and positive and negative wires, we generally don't understand the chemical nature of it.

It is possible you have heard of fuel cells. How are they related to electricity? How are they different from batteries? Do you really know how fuel cells work? When were fuel cells discovered? Are they used for anything right now? What is the future of fuel cells? In this lesson, you will develop an understanding of how fuel cells work so that you may modify a design and perhaps understand how the chemistry behind the functions of the fuel cell components is affected.

Lesson Background & Concepts for Teachers (5E – Explain)

1. **Before the lesson:**

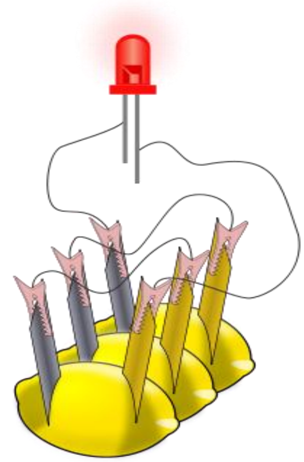
- Students will begin work on day 1 in groups of 4. On day 2, students will create their fuel cells in pairs. Finally, on day 3, the students will return to groups of 4 to complete their data analysis
- This lesson is designed to allow the student as much independent learning as possible. There are some guided elements in place to keep the students on track.
- There are excellent resources listed in the multimedia list for use in class and as a review for the teacher who is unfamiliar with fuel cells.
- If you are not already comfortable with hydrogen generation, make sure to practice it first. Especially if you haven't allowed your students to generate hydrogen themselves. There are a number of methods and you should choose one that you feel competent with.
- If computer resources are uncertain, printing out articles on fuel cells to use as a class set for day 1 research would work but be careful not to direct the students' exploration of fuel cells to narrowly.
- Some suggested components of their group posters: BRIEF history of fuel cells, basic design and components, common uses, chemical reactions involved

Figure 2

ADA Description: A series of 3 lemons connected to a small LED bulb as a battery. Each lemon has two electrodes (1 zinc on the left and 1 copper on the right) piercing the skin. Each electrode has an alligator clamp attached to it. Each alligator clamp is wired to an opposite electrode and then finally to the LED bulb.

Source/Rights: Copyright © Wikipedia

Caption: Figure 2: Lemon Battery



Vocabulary / Definitions

Word	Definition
PEM:	Acronym for polymer electrolyte membrane. A fuel cell that incorporates a solid polymer membrane used as its electrolyte.
anode:	The terminal on a device where current flows in from outside.
cathode:	The terminal on a device where current flows out.
membrane:	A pliable sheet-like structure acting as a boundary, lining or partition.

Safety:

- **Safety glasses are required for all (students, teachers, observers, etc) as well as chemical resistant gloves for all active participants.**
- **Hydrogen generation can be handled in a number of ways. Be sure to follow all safety precautions for your chosen method.**

Associated Activities (5E – Explore)

Day 1: Quick write: What is creating the energy to power the light? Can you write a rough equation? Research fuel cell, create poster, and present findings to class

Day 2: Modify an existing design for a fuel cell. Changeable variables include the type of metal, the thickness of the metal, and how many plates in the fuel cell. Students should be able to build, test, and collect their data today.

Day 3: Students will be grouped by the variable they chose to modify and will compare their results. After all groups have reported out to the class and discussion has ended, students should use the time remaining to begin their analysis questions.

Assessment (5E – Evaluate)

Pre-Lesson Assessment
Descriptive Title: Redox Day 3 Quiz (Day 1)

Post-Introduction Assessment
Descriptive Title: Fuel Cell Component Quiz (Day 2)

Lesson Summary Assessment
Descriptive Title: Fuel Cell Lab Report (Begun day 3)

Homework
Descriptive Title:

Day 1. Research metal properties, pick one be prepared to explain why you think it would be useful as a catalyst in a fuel cell.

Day 2: Write and balance the reactions involved in the fuel cell. Use the half-reaction method and identify the oxidized species, reduced species, the oxidation agent, and the reduction agent.

Day 3: Lab Report Analysis questions

Lesson Extension Activities (5E – Extension)

Is there a way to improve the fuel cell you've created? Submit a design and detail the improvements you've made. In particular, how do your design changes affect the chemistry of the fuel cell? (include with final lab report)

Additional Multimedia Support

See another fuel cell diagram at
http://www.blogcdn.com/www.bloggingstocks.com/media/2007/02/fuel-cell01.gif

An excellent explanation of fuel cells as well as a couple of hydrogen generation methods

http://www.teachengineering.org/view_activity.php?url=collection/wsu_/activities/wsu_oxygen_hydrogen_activity1/wsu_oxygen_hydrogen_activity1.xml

Video demonstrating building a simpler fuel cell.

https://www.youtube.com/watch?v=_avejV7J7Wk

References

Lemon Battery

http://en.wikipedia.org/wiki/Lemon_battery

Nafion fuel cell single layer procedure

http://education.mrsec.wisc.edu/290.htm

Attachments

Redox Day 3 Quiz

Fuel Cell Component Quiz

Lab procedure

Fuel Cell Lab Report Rubic

Contributors

Sandra Gebhard (Hillsborough County School District)

Supporting Program

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Attachments

Redox Day 3 Quiz

Define oxidation and reduction.

What is the oxidation number of an element?

What is the most common oxidation number for oxygen and hydrogen?

Fuel Cell Component Quiz

What are the 4 general components of a fuel cell?

Fuel Cell Lab Report Rubric

Summary of results with any equations

Analysis of results (include any graphs)

What was your original hypothesis and did the data support it?

Errors?

Next steps.

Lab Procedure:

Procedure

Part I: Plating the electrodes (may be done the day before)

Step 1. Cut nichrome screen into 1" x 2" pieces. 1 screen is needed for each electrode and for all additional neutral plates. You will need at least two but no more than 5.

Step 2. Connect the negative lead of a 1.5 V battery to the nichrome screen. Connect the positive lead to the exposed graphite in a pencil. If an ammeter is available, include it in the circuit.

Step 3. Place the two electrodes in a ~7 mM solution of the metal acid of your choice and begin the electrolysis. The current should be about 0.2-1.0 milliamps.

Step 4. Electrolysis of this solution will deposit the metal on the negative electrode. Deposit the metal for about 15-30 minutes. As the solution is electrolyzed, hydrogen may be evolved. Shake the electrode to remove hydrogen bubbles so that all the nichrome stays in contact with the electrolysis solution. The metal-coated portion of the nichrome will look clearly look different that the uncoated wire. In general, the metal plating will not be shiny. This is due to the roughness of the coating.

Part II: Assembling the fuel cell

Step 1. Obtain two plastic plates. These will serve as the outer covers of your fuel cell.

Step 2. Obtain as many (1" x 1") squares of Nafion membrane and rubber washers as are necessary to have one between each layer.

Step 3. Assemble the stack. It should be cover, washer, electrode, washer electrode, etc for all layers and then the top cover. Have instructor verify your setup before proceeding.

Step 4. Prepare 5-minute epoxy.

Step 5. Spread epoxy around each rubber gasket and carefully reassembly your stack. Apply pressure continually while you wait for the epoxy to harden.

Step 6. Add water and check for leaks.

Step 7. Connect the tube from the hydrogen generator to the anode. The oxygen will be supplied by the air.

Step8. Connect the wires to the spark and begin gathering data.

Step 9. Clean up as directed by teacher.

Materials

The membrane and electrodes were assembled several months prior to use. The device was activated by wetting the membrane with distilled water and supplying hydrogen gas to the lower compartment.

- Nichrome wire mesh
- Chloroplatinic acid (Fisher P154) and any other metal acids as desired.
- Nafion membrane (Aldrich 292567)
- 5-minute epoxy
- Hydrogen generator

Equipment

- AA Battery holders: Mouser (#534-139) http://www.mouser.com
- Wires with alligator clips: Mouser (#13AC012) http://www.mouser.com.
- Wooden pencil
- Multimeter, spark,
- Plastic squares
- Tweezers