

## Preparation of a Fuel Cell

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### Purpose:

The object of this module is to construct and operate a simple hydrogen fuel cell, which converts chemical energy into electricity.

### Learning Objectives:

- Through an understanding of oxidation and electricity, students will be able to interpret the mechanisms of a fuel cell.

### Introduction:

Fuel cells are devices that convert a fuel and an oxidant directly into electricity. In this manner, they are similar to batteries. However, unlike batteries, fuel cells consume a reactant and will continue to produce electricity as long as this reactant is replenished when necessary. Batteries, on the other hand, store electrical energy chemically in a closed system.

Many combinations of fuel and oxidant are possible. A hydrogen cell, which will be created in this lab, uses hydrogen as a fuel and oxygen as an oxidant. In this fuel cell the hydrogen is electrochemically oxidized by the oxygen to produce electrons. These electrons are then forced to travel through a circuit by an electrolyte, or a polymer-electrolyte membrane (PEM). When this PEM is soaked with water it conducts protons, generated by oxidation of hydrogen, to the cathode where they combine with oxygen to form water.

### Materials:

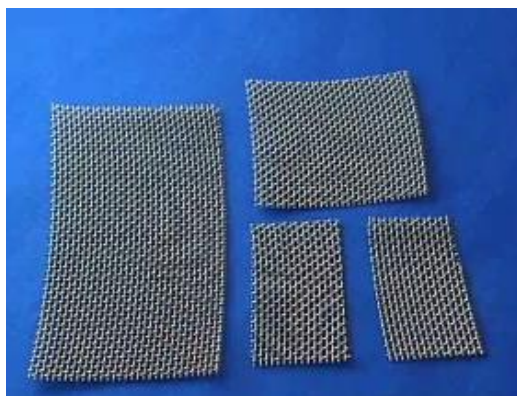
- Nichrome wire mesh
- Pencil (new, unsharpened – wood rather than mechanical)
- Cutter for Plastic, Sheet & Other Material  
Lexan, # PC-41
- Wood file
- Battery Clip, Molded, 6 inch Leads  
Mouser Electronics, #123-7016, \$0.83 ea.
- Battery, 1.5V
- 3 Kobiconn Test Clips, 10PC 5 Color Set  
Mouser Electronics, #13AC012
- Milliammeter
- Chloroplatinic acid  
Fisher, P154
- 250-mL beaker
- Distilled water
- Stir rod

- (2) 10cc Syringes  
Plastipak & LuerLok, #5604
- Petri dish
- Hot plate
- Tweezers
- Nafion membrane  
Aldrich, # 292567
- Scissors
- Ruler
- High Strength 5 Minute Epoxy  
Devcon, #S-205/20545
- Wooden stick
- Bunsen burner
- Ring stand
- Clamp
- Test tube holder
- Distilled water bottle
- Multimeter
- Sodium borohydride  
Aldrich Chemical Company, Inc.
- 250mL beaker
- Hydrogen lecture bottle
- Helium lecture bottle

## Procedure:

### Electrolysis Set-up:

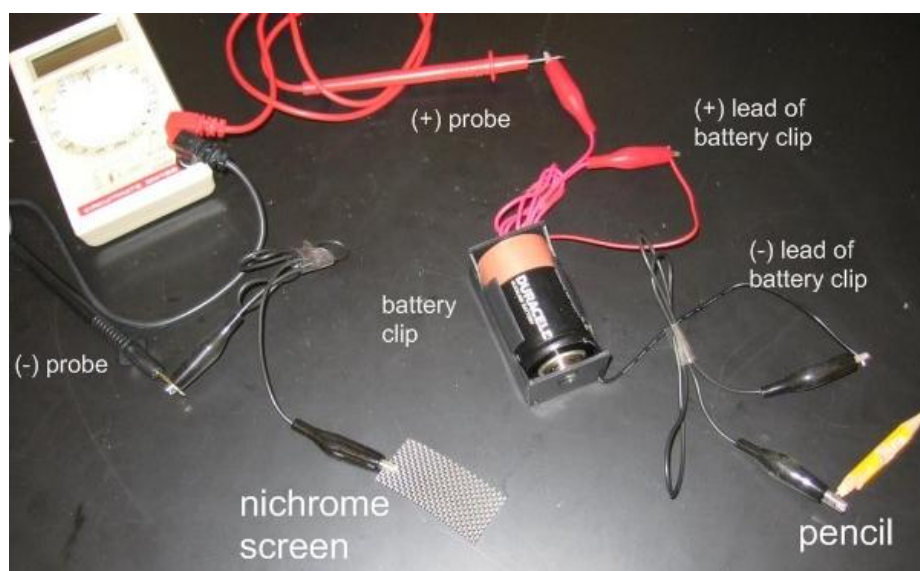
- 1) Obtain a nichrome screen and a pencil.
- 2) Cut (2) 1" x 2" pieces of nichrome screen.



- 3) Using a file remove some wood from the pencil to expose enough graphite, such that an alligator clip can be connected.



- 4) Obtain a battery clip, a 1.5V battery, and 3 alligator clips, and a milliammeter.
- 5) Snap the battery into the battery clip.
- 6) Connect one alligator clip to the negative probe of the ammeter. Connect the other end of this clip to the nichrome screen.
- 7) Connect another alligator clip to the positive probe of the ammeter. Connect the other end of this clip to the positive wire of the battery clip.
- 8) Now, take another alligator clip and attach it to the negative wire of the battery clip. Connect the other end of this clip to the exposed graphite of the pencil.



**Preparation of Chloroplatinic Acid:**

- 1) Calculate the amount of chloroplatinic acid (MM = 517.89g/mol) needed for 100mL of ~7mM solution.
- 2) Using the above calculation weigh out the necessary amount of chloroplatinic acid and place it in a 250mL beaker.

**Note: Wear gloves and goggles when handling this chemical.**

- 3) Add 100mL of water to the same beaker and stir the solution until everything is dissolved.

**Electrolysis:**

- 1) Place both the pencil and the nichrome screen into the same beaker with the chloroplatinic acid solution. Record the measured current of the system.

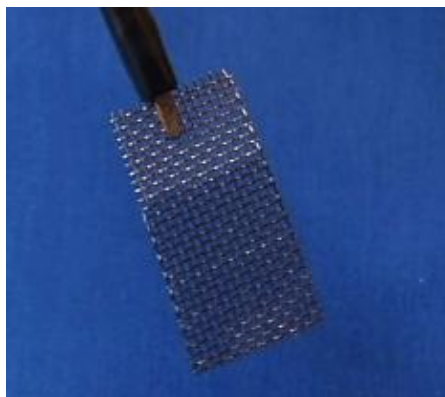


Measured current: \_\_\_\_\_

- 2) Platinum will begin to deposit on the nichrome screen. Deposit platinum for about 15-30 minutes.

Note: Based on a measured current of 0.2 – 1.0 milliamps. If the observed current is not within this range then try cleaning the exposed graphite of the pencil.

Note: The platinum coated portion of the nichrome screen should appear darker due to the roughness in the platinum deposit.



**Building the Fuel Cell:**

Tip: Begin running the second round of electrolysis as soon as the first is complete and carry-out steps 1-6 with the first syringe and nichrome screen.

- 1) While electrolysis is running obtain a syringe and remove and discard the plunger portion.



- 2) Once the electrolysis is complete, remove the nichrome screen and place it directly in a Petri dish.

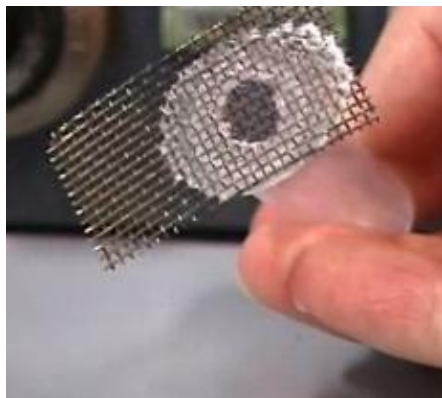
- 3) Place the Petri dish on a hot plate on high.



- 4) Press the open end of the syringe barrels flat against the platinum-coated portion of the nichrome screen.
- 5) Continue to apply even pressure to the barrel until the opening begins to melt to the nichrome.



- 6) Once the barrel is stuck to the nichrome lift the screen from the Petri dish with tweezers and quickly move it to the benchtop and apply pressure to the syringe barrel to form a smooth flat surface before the plastic re-solidifies.



- 7) Bend the uncoated portion of the nichrome screen away from the opening of the barrel.
- 8) Repeat steps electrolysis using a new nichrome screen. The same chloroplatinic acid solution can be reused. Use this page to repeat steps 1-7.
- 9) Obtain a sheet of Nafion membrane and cut out a 1" x 1" square.



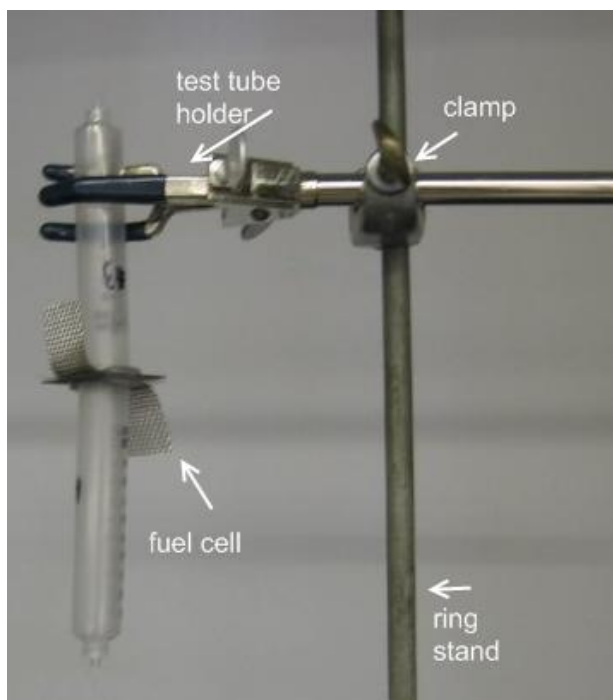
- 10) Prepare a 5 – minute epoxy in a weigh boat in the fume hood.
- 11) Using a wooden stick spread the epoxy around the opening of each tube.
- 12) Glue the square of Nafion membrane between the two openings by pressing the membrane against the nichrome covered opening of one barrel and pressing the other against it.



- 13) Using a Bunsen burner heat the end of a pair of tweezers. Use the heated tweezers to melt a small hole near the tip end of one of the syringes.

**Testing the Fuel Cell:**

- 1) Obtain a ring stand, a clamp, and a test tube holder. Clamp the test tube holder onto the ring stand and place the fuel cell in the test tube holder with upper compartment being the end with the melted hole.



- 2) Using a distilled water bottle add water to the upper compartment to check for leaks. Drain the compartment before proceeding.
- 3) Obtain a multimeter and attach the two alligator clips to the two bent portions of the nichrome screen.
- 4) Calculate the amount of sodium borohydride (MM = 37.83 g/mol) needed for 100mL of ~1.0M solution.
- 5) Using the above calculation weigh out the necessary amount of sodium borohydride and place it in a 250mL beaker.
- 6) Add 100mL of water to the same beaker and stir the solution until everything is dissolved.

- 7) Using a pipette add the solution of sodium borohydride to the upper compartment as a hydrogen source and measure the voltage produced by the fuel cell.

Measured voltage: \_\_\_\_\_

- 8) Next obtain lecture bottles of hydrogen and helium gas. Drain the compartments of liquid, rinse both sides of the Nafion membrane with distilled water, and drain again. Leave the membrane wet.

- 9) Flush the lower compartment with hydrogen gas and measure the voltage produced by the fuel cell.

Measured voltage: \_\_\_\_\_

- 10) Alternately flush the lower compartment with hydrogen and helium gas.

What happens?

**Discussion Questions:**

- 1) Draw a circuit diagram of the electrolysis set-up described in Steps 1-9.

- 2) Explain the purpose of the Nafion membrane in the fuel cell.



**References:**

- Fishbane, P. M., S. G. Gasiorowicz, & S. T. Thorton (2005). *Physics for scientists and engineers with modern physics*. Upper Saddle River, New Jersey: Pearson Education Inc.
- Kreuer, K.D. (2001). On the development of proton conducting polymer membranes for hydrogen and methanol fuel cells. *Journal of Membrane Science*, 185, Retrieved May 28, 2008, from [http://www.sciencedirect.com/science?\\_ob=ArticleURL&\\_udi=B6TGK-42Y7FHV-3&\\_user=615966&\\_rdoc=1&\\_fmt=&\\_orig=search&\\_sort=d&view=c&\\_acct=C00032238&\\_version=1&\\_urlVersion=0&\\_userid=615966&md5=8da5c571354f4f1d839426e1a213e3e0](http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TGK-42Y7FHV-3&_user=615966&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C00032238&_version=1&_urlVersion=0&_userid=615966&md5=8da5c571354f4f1d839426e1a213e3e0)
- Lisensky, G. (2005, November 28). Preparation of a fuel cell. *Interdisciplinary Education Group*, Retrieved June 4, 2008, from <http://www.mrsec.wisc.edu/Edetc/nanolab/fuelcell/text.html>

**Teacher Key:****Notes:**

- In Step 1 of Preparation of Chloroplatinic Acid, approximately 0.36 grams of chloroplatinic acid are needed.

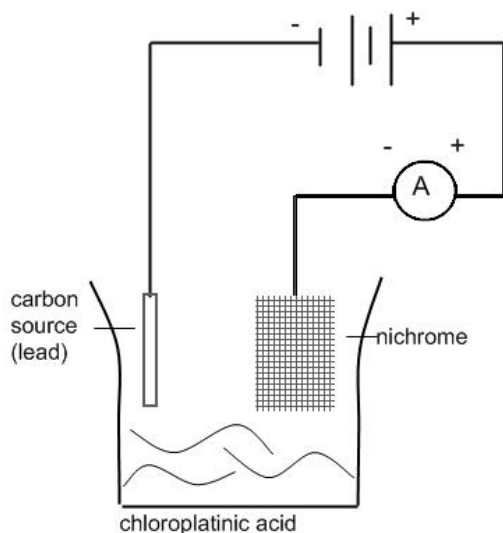
$$(517.89\text{g/mol}) \cdot (0.007\text{mol/L}) \cdot (0.100\text{L}) = 0.36\text{g}$$

- In Step 4 of Testing the Fuel Cell, approximately 3.78 grams of sodium borohydride are needed.

$$(37.83\text{g/mol}) \cdot (1\text{mol/L}) \cdot (0.100\text{L}) = 3.78\text{g}$$

**Discussion Questions:**

1)



- 2) In this fuel cell the Nafion membrane serves as the electrolyte, or the polymer-electrolyte membrane (PEM). When this PEM is soaked with water it conducts protons generated by oxidation of hydrogen to the cathode where they combine with oxygen to form water.
- 3) Yes, a great deal more voltage is produced by the hydrogen gas in comparison to the sodium borohydride. This is due to the fact that the sodium borohydride is a

liquid, while the hydrogen itself is a gas. Therefore, the hydrogen can move more easily through the membrane and into the circuit. To compensate for this one would need to increase the molarity or concentration of the sodium borohydride solution.

- 4) When introduced into the system the hydrogen gas acts as a fuel for the cell resulting in electricity. The helium on the other hand does not provide a source of hydrogen and therefore cannot act as a fuel and results in no voltage being produced by the cell.
- 5) Keeping the membrane wet ensures that the protons can travel through it, thereby maintaining efficiency of the fuel cell.

### **Class Discussion:**

- 6) The current theory is that the membrane is composed of rigid backbone structure with hair-like “defects” along the chain. It is believed that that hydrophobic perfluorinated backbone structures cluster together to form long rigid cylinders about 2.5 nanometers in diameter with the hydrophilic sulfonic acid structure groups acting as “hairs” to the inside of the water-filled tubes. When these sulfonic acid structures are hydrated, protonic charge carriers form and proton conductance occurs. The hydrophobic backbone provides the polymer with the morphological stability and prevents the polymer from dissolving in water.

These cylinders may not align perfectly, but they do connect to create water channels passing through the membrane material, which can be 10’s of microns thick. It’s this structure of relatively wide diameter channels, densely packed and running mostly parallel through the material that helps explain how protons can so easily diffuse through the membrane.

**Suggestions for lab placement:**

It could be used in the General Chemistry lab because it deals with two basic concepts: electrolysis and the process of oxidation.

**Supplies List (For 10 Students):**

- 3 4"x4" Nichrome wire mesh sheets
- 10 Pencils (new, unsharpened – wood rather than mechanical)
- Cutters for Plastic, Sheet & Other Material  
Lexan, # PC-41
- Wood files
- 10 Battery Clips, Molded, 6 inch Leads  
Mouser Electronics, #123-7016, \$0.83 ea.
- 10 Batteries, 1.5V
- 30 Kobiconn Test Clips, 10PC 5 Color Set  
Mouser Electronics, #13AC012
- 10 Milliammeters
- Chloroplatinic acid  
Fisher, P154
- 250-mL beakers
- Distilled water
- Stir rods
- 20 10cc Syringes  
Plastipak & LuerLok, #5604
- 5 Petri dishes (1 top or bottom per student)
- Hot plates
- Tweezers
- 1 sheet of Nafion membrane  
Aldrich, # 292567
- Scissors
- Rulers
- High Strength 5 Minute Epoxy  
Devcon, #S-205/20545
- Wooden sticks
- Bunsen burners
- 10 Ring stands
- 10 Clamps
- 10 Test tube holders
- Distilled water bottles
- 10 Multimeters
- Sodium borohydride

Aldrich Chemical Company, Inc.

- 250mL beaker
- Hydrogen lecture bottle
- Helium lecture bottle