Ethanol Combustion

Goals

- Use an ethanol fuel cell to produce an electric current
- Conduct experiments to study its performance
- Make calculations based on data

Background

Any organic molecule with an –OH group attached to a carbon atom is an alcohol. The common term "alcohol," as in the substance found in alcoholic beverages, refers to the alkane with the chemical name ethanol (CH_3CH_2OH).

Ethanol is a naturally-occurring product of fermentation reactions, one of the many ways in which microorganisms break down organic matter. Ancient humans harnessed this natural process and fermented many different types of grains and fruits to create the different alcoholic beverages we still have today.

Today, ethanol has uses beyond drinking: it is a source of fuel for heating homes and powering cars and trucks. Most gas stations today have up to 10% ethanol mixed in with the fossil fuels they distribute at the pump. This not only reduces the amount of oil needed to fuel conventional cars, but also decreases pollution since ethanol can be "recycled" by growing plants that pull carbon out of the atmosphere.

Ethanol fuel cells combust ethanol as well, but unlike in gasoline engines they do it without actually setting it on fire. When exposed to the catalyst inside the fuel cell, ethanol reacts in one of two ways. If the ethanol is completely combusted, the reaction is:

$$C_2H_5OH + 3O_2 \rightarrow 3H_2O + 2CO_2$$

But under certain conditions, the ethanol oxidizes to form acetic acid:

$$C_2H_5OH + O_2 \rightarrow CH_3OOH + H_2O$$

During this activity, we will use an ethanol fuel cell to generate an electric current and decompose ethanol using both of the above reactions. We will manipulate the conditions of the reaction to see if we can change the output.

Procedure

1. Your fuel cell is attached to a fuel tank, which will be moving the ethanol solution into the fuel cell when you remove the clamp on the tube. For now, leave it there and look at your fuel cell.
2. Where do you think you'd find the products of your chemical reaction exiting the fuel cell?
3. Attach the red and black wires to the fuel cell. Then attach the other ends of the wires to the fan. Why do you think we need two wires?

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4. Open the clamp on the fuel tank tube to let ethanol solution into the fuel cell.
5. Once liquid flows out of the unclamped tube, replace the clamp on the fuel tank tube. What happens to the fuel cell and fan? Record your observations below.
6. To clean out your fuel cell after use, fill the syringe with distilled water and disconnect the fuel tank tube from the fuel cell.
7. Attach the syringe to the fuel cell and push the distilled water into the fuel cell.
8. Disconnect the syringe and its tube from the fuel cell and fill the syringe with air.
9. Use the syringe to push air into the fuel cell. Your fuel cell is now ready to be used again.

Observations

Experimentation

1. How does the concentration of the ethanol solution affect the ethanol reaction? You'll test multiple concentrations. First, calculate how much ethanol and distilled water you'll need to prepare solutions of the following concentrations:

Concentration:	mL Ethanol:	mL H2O:	Solution Total mL:
5%	3	57	60mL
7%	4.2	55.8	60mL
10%	6	54	60mL
12%	7.2	52.8	60mL
15%	9	51	60mL

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2. Now follow the procedure described above with the different concentrations. Be sure to clean out your fuel cell and fuel tank between each trial. Record your observations below:

Concentration:	Time until fan starts (sec):	pH paper color when placed under exhaust tube:	Other observations:
5%			
7%			
10%			
12%			
15%			

3. How does the temperature of the solution affect the ethanol reaction? Using ethanol solutions of different temperatures, run your fuel cell as described in the procedure section. Be sure to clean out your fuel cell and fuel tank between each trial. Record your observations below:

Temperature:	Time until fan starts (sec):	pH paper color when placed under exhaust tube:	Other observations:

4. What happens if we change the temperature of the air around the fuel cell? Using a hair dryer or other heating device, run your fuel cell as described in the procedure section. IMPORTANT: Use the heating device on a low setting, as ethanol can be dangerous at temperatures above 60°C. Use your thermometer to make sure your heater isn't heating the air beyond that temperature before you begin. Record your observations below:

Trial	Time until fan starts (sec):	pH paper color when placed under exhaust tube:	Other observations:
Unheated air			
Heated air			

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Measurement

For this section, you will need a multimeter or the Horizon Renewable Energy Monitor. For an introduction to using a multimeter, click here.

1. Using the conditions that started the fan the fastest according to your experiments, record the current in Amps and highest voltage in Volts produced while the fuel cell is powering the fan motor. Record your answers below:

Time:	Current (A):	Voltage (V):
0 min		
2 min		
4 min		
6 min		
8 min		
10 min		

2. Voltage is equal to the current in amps multiplied by the resistance in ohms (V = IR), so according to your data what is the resistance of the motor in ohms?

Resistance: _____ Ω

3. Power is the current in amps multiplied by the voltage in volts (P = IV), so according to your data how much power in watts is your fuel cell producing?

Power: _____W

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Analysis

1. Make a scientific claim about what you observed while running your ethanol fuel cell.

2. What evidence do you have to back up your scientific claim?

3. What reasoning did you use to support your claim?

4. Design an experiment that would test what conditions allow the fuel cell to run for the longest period of time. Describe your experiment below:

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Conclusions

1. Based on your experiments, what conditions created the most efficient reactions of ethanol?

2. In the human body, ethanol is converted into acetic acid. Why do you think the human body doesn't convert it into carbon dioxide and water?

3. What do you think could be done to increase the rate of this reaction?