Energy Conservation and Transformation

Next Generation Science Standards

NGSS Science and Engineering Practices:

- ☑ Asking questions and defining problems
- ☐ Developing and using models
- ☑ Planning and carrying out investigations
- ☑ Analyzing and interpreting data
- ☐ Using mathematics and computational thinking
- ☑ Constructing explanations and designing solutions
- ☐ Engaging in argument from evidence
- ☑ Obtaining, evaluating, and communicating information

NGSS Cross-cutting Concepts:

- ☐ Patterns
- ☐ Cause and effect
- ☐ Scale, proportion, and quantity
- ☐ Systems and system models
- ☑ Energy and matter
- ☐ Structure and function
- ☑ Stability and change

NGSS Disciplinary Core Ideas:

- ☑ PS1.B: Chemical Reactions

Initial Prep Time

Approx. 10 min. per apparatus

Lesson Time

1 – 2 class periods, depending on experiments completed

Assembly Requirements

- Scissors
- Small Philips screwdriver

Materials (for each lab group):

- Horizon Renewable Energy Science Kit
- Distilled water
- AA batteries
- Stopwatch
- Horizon Renewable Energy Monitor or multimeter (optional)

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Lab Setup

- We recommend completing step 1 in Experiment 2 and steps 1 and 2 in Experiment 3 in the Assembly Guide for each electrolyzer so your students do not have to assemble the fan, cut tubing, or fill the electrolyzer initially.
- For this activity, your students will not need the solar panel or wind turbine parts of the lab kit.
- Please note that the PEM fuel cell's membrane should be kept from drying out. It's best to seal it in a plastic bag between uses. Before students use the cell, be sure it's filled with water and that the two small pieces of tubing are attached.
- Some of the parts of the car are quite small (such as tube caps) and can be lost easily. Setting up resource areas on lab tables with labeled containers for each group's pieces can prevent loss of these small parts and help keep the parts of each group's kit separate.
- If you don't have access to a multimeter or Horizon Renewable Energy Monitor, omit the Measurements section of this activity.

Safety

- Battery packs can short out and heat up if the red and black contacts touch each other while the unit is in the on position. Be sure to keep them off when not in use.
- Using regular tap water instead of distilled water will severely shorten the lifespan of the fuel cells. Distilled water can be found at most pharmacies or drug stores.
- Running electric current through dry fuel cells or attaching the battery packs backwards can destroy the fuel cells. Be sure to always connect red to red and black to black.
- Beware of water spills, and don't be surprised if someone tries to start a syringe water fight.

Notes on the Renewable Energy Science Kit:

- Direct sunlight, or a strong electric light, is necessary for operation. Overcast and indirect sunlight may not provide sufficient energy. Be sure any artificial light source is close to the solar panel.
- Be sure to line up the gaps on the inner cylinders of the H2 and O2 tanks so that bubbles can escape.
- You may need to inject more water into the O2 side of the cell if the electrolysis reaction is being sluggish. Wait 3 minutes and then try again.

Common Problems

- The motor's fan sometimes needs a little push to get started.
- If there's hydrogen left but the motor doesn't run, you may have to purge the fuel cell. Unplug the black plug and then quickly replace it to purge impure gases.
- If the water level doesn't change after purging the cells, make sure the gaps on the base of the inner cylinders are open so that water can fill them.

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Goals

- Understand how chemical reactions work
- Perform a reversible reaction
- Make calculations based on data

Background

Chemical reactions are the processes that create every compound in the universe. When two or more atoms form a bond, or break bonds and form new ones, a chemical reaction takes place that totally changes the characteristics of the materials involved.

Some chemical reactions are ones where simple substances are combined to make new, more complex compounds (synthesis) or where complex molecules are broken down into simpler molecules (decomposition). Water, one of the most common substances on Earth, is easily synthesized from hydrogen and oxygen, and also can be easily decomposed back into hydrogen and oxygen.

We can write out these reactions using chemical symbols like this:

$$2\ H_2 + O_2 \rightarrow 2\ H_2O$$
$$2\ H_2O \rightarrow 2\ H_2 + O_2$$

A hydrogen fuel cell can accomplish both of these reactions by using electricity. Running an electric current through the fuel cell when it's filled with water causes the water to split into hydrogen and oxygen. If the fuel cell is attached to a motor while oxygen and hydrogen are present, it will combine them into water and produce an electric current that powers the motor. To learn more about how a hydrogen fuel cell works, click here.

To find out more about how these chemical reactions work, we'll use the hydrogen fuel cell to power a small car, first by producing hydrogen and oxygen gas, then using those gases to generate electricity.

Procedure

1. Once the fuel cell starts producing hydrogen and oxygen gas from water, we will need to trap the gases to be able to use them for the reverse reaction. How can the gases be trapped using the materials provided?
2. The Oxygen side of the fuel cell needs to be filled with water. Observing the hydrogen fuel cell, why do you think only one side needs to be filled with water? Do you think it matters if the water is injected into the top or bottom outlet?
3. How can we tell how much gas has been generated from our reaction?
4. Does it matter how the battery pack is attached to the fuel cell? Why or why not?
5. If you're ready to capture the gases produced by the fuel cell, attach the battery pack. Observe what happens and record your observations below.

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Observations

Experimentation

1. You've produced hydrogen and oxygen from water. Now, connect the fuel cell to the motor. What happens?

Students should notice the fan begins to turn and can make note of any particular aspect of the fan's performance: sound of the motor, how long it runs, etc.

2. Generate more hydrogen and oxygen using the fuel cell, as before. Can you tell how much hydrogen you've generated? What is the volume of hydrogen produced?

Students should use the mL markings on the cylinders to answer. Responses will vary, but should not exceed 10mL.

3. What is produced faster: hydrogen or oxygen? Why do you think this is?

Hydrogen is produced faster (more accurately, a larger volume of hydrogen is produced) due to the ratio of hydrogen to oxygen in water.

4. How would you make more gas with this reaction? Devise an experiment that you could run to increase the amount of hydrogen and oxygen you produce. Describe your experiment below.

Gas could be stored in larger tanks, the current could run for a longer time, multiple fuel cells could be used, and more may be acceptable answers.

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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. Measure the current in Amps and the voltage in Volts while generating hydrogen and oxygen. Record your answers below:

(Answers will vary, but check that they are within reason, i.e. not 100V or >1A.)

Current: _____________ A

Voltage: ___________ V

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

Resistance: ____________ Ω

3. Measure the current in Amps and the voltage in Volts while combining the hydrogen and oxygen to produce water. Record your answers below:

Current: _____________ A

Voltage: ___________ V

4. Does it take more energy to split the hydrogen and oxygen or combine them? Explain your reasoning.

Measurements of current and voltage should both be higher when splitting the water than when recombining it. This would imply that more energy is required to split it than to recombine it.

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Analysis

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

Claim should reference the reaction of electrolysis and/or synthesis of water.
Example: "There is energy stored in the bonds of a water molecule."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "The energy to break water molecules into hydrogen and oxygen was higher than the energy to synthesize water."

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

Reasoning can draw from Background section and/or other materials used in class.
Example: "The Law of Conservation of Energy says that the extra energy must be stored somewhere since it can't be destroyed."

4. Use your observations to design an experiment you could run to increase the amount of electricity generated by the fuel cell. Describe your experiment below.

Change pressure/temperature of the water/gases, construct fuel cell with different materials, change the shape of the anode/cathode, and more are all ideas that could be tested. Students should identify control and experimental setups, and define the variable to be tested.

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Conclusions

1. How would you describe what happened during the decomposition and synthesis reactions you just observed in terms of the energy involved?

Energy is required to break the bonds that holds a water molecule together, so the electric energy from the battery can be used to split the water molecule. The chemical reaction of combining hydrogen and oxygen converts stored chemical energy back into electric energy.

2. Did all of the energy in the hydrogen transform into electrical energy? If not, where else did it go?

Heat from reaction, energy of new chemical bond, molecule vibrations, and others may be acceptable answers.

3. What kinds of measurements could you make to confirm that energy was conserved during these reactions?

Measuring small changes in temperature, measuring the forces applied to the car by the motor, measuring the electric current in the motor and battery, and more may be acceptable answers.