SCIENCE CAREER ADVENTURES

Fuel Cell Engineer: Fuel for Cars

NGSS Standard: MS-PS1-5

Adventure Description:

In this adventure, you will think like a fuel cell engineer to build a model of a hydrogen gas station to fuel school buses.

Activity

Teacher Note: Allow 10 minutes to prepare student materials for this activity as described in the Handout: Instructions for Teacher Prep. Allow an additional 10 minutes to build two of your own hydrogen gas stations. The gas stations can be set up using the student Handout: How to Build a Working Model that Creates Hydrogen Gas or by using the Video: Experiment Set Up. You can decide whether or not to share the video with your students as well. Set up one of your hydrogen gas stations to start collecting hydrogen before class begins. Use the other hydrogen gas station to demonstrate the building process for students.

Step 1: Background on Hydrogen Fuel (10 minutes)

- Show Video: Fuel for Cars.
- Show Handout: Making Hydrogen Gas. Explain that this handout shows how hydrogen gas can be made. Energy and liquid water molecules can be combined to create hydrogen and oxygen gas molecules.
- Ask students to count how many atoms start out as water and how many atoms end up as gas. Expect students to count 4 atoms of hydrogen and 2 atoms of oxygen starting out as water and 4 atoms of hydrogen and 2 atoms of oxygen ending up as gas. You end up with the exact same atoms that you started with. The idea that you have the same number of atoms before and after a reaction is called conservation of mass.
- Now, ask students to look at the number of molecules of the liquid water and the hydrogen and oxygen gas. The model shows that if you start with two molecules of water, you end up with three molecules of gas. Two of the molecules of gas are hydrogen and one molecule of gas is oxygen. The atoms have been rearranged to make a different number of molecules.

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- Tell students that they are going to build a working hydrogen gas station model to demonstrate to a school board how hydrogen gas can be created and stored to fuel school buses.

Step 2: Prepare to Build the Hydrogen Gas Station (10 minutes)

- Ask students what the purpose of a gas station is. Explain that gas stations provide a location for gas to be stored before it is put into cars. Explain to students that they will be creating their own gas station that will store hydrogen gas.
- Show students your gas station that you created ahead of time.
- Provide students with Handout: How to Build a Hydrogen Gas Station. As a class, read through the steps and explain to students that they will first complete Steps 1 and 2. Explain that students will watch you (the teacher) demonstrate a step. Then, they will complete the step themselves.
- Divide students into pairs. Provide each pair with the following: one clear cup of salt water filled close to the top, two large metal paper clips, a D cell battery, a small test tube, and masking tape.

Step 3: Building the Hydrogen Gas Station (10 minutes)

- Demonstrate how students should bend their paper clips as shown in the hand out.
- Now, have students bend their paper clips, as shown in the handout. Keep extra paperclips on hand in case any students break their paper clips.
- Demonstrate how students should attach paperclips to a battery.
- Now, have students attach the straight "top" of each paper clip to opposite sides of the battery, as shown in the handout.
- Assure students that the batteries are not very strong and will not give them a shock (this is because some students will think the batteries are going to shock them and some don't want to touch the paperclips to the batteries)
- Remind students not to let the paper clips touch each other. If the paper clips touch each other they will get hot and drain the battery.
- Students should secure the paper clips with tape, but they will also hold the paper clips tight to the battery when they start creating hydrogen with their model.

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Step 4: Creating Hydrogen Gas (5–10 minutes)

- Explain to students that they will now create hydrogen gas that will be stored in the gas station. They will complete Steps 4-6.
- Students will watch you (the teacher) demonstrate a step. Then, they will complete the step themselves.
- Demonstrate how students should hold the paperclips securely to opposite ends of the battery by placing your thumb over one paper clip at one end of the battery and your pointer finger over the other paper clip at the other end and squeezing firmly.
- Then slowly lower the hooks of your paper clips into your cup of water.
- Now, have students do the same thing, as shown on the handout. Remind students to:
  - Hold their paper clips securely to their battery
  - Make sure the tips of their hooks remain underwater
  - Not to let their paper clips touch each other in the water
  - Take turns holding the paperclips tightly to the battery to make sure they have a good connection
- Ask students if one hook is showing a change happening faster than the other hook. Discuss how the hook attached to the negative end of the battery is forming smaller bubbles but they are forming faster. Explain that these are hydrogen bubbles. Eventually, bubbles will also form on the positive end. These bubbles will be larger but less of them will form. Explain that these are oxygen bubbles.
- Demonstrate how students will submerge a test tube full of clean water into their cup of water as shown in the handout.
- Now, have students submerge their own test tube into the water.

Step 5: Gas Collection (5 – 10 minutes)

- Explain to students that you won't be demonstrating for this step. Instead, students will wait for 5-10 minutes while hydrogen gas is collected.

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- Options for while students wait:
    - Ask them why they think there were more but smaller hydrogen bubbles compared to oxygen bubbles.
    - Show Handout: Making Hydrogen Gas. Discuss how the equation shows that more (but smaller) hydrogen molecules being created compared to the oxygen molecules.

Step 6: Gas Extraction

- After 10 minutes, demonstrate how to carefully removing hooks from the water while leaving the inverted test tube in the water so that hydrogen does not escape.
- Have students carefully remove their hooks from the water but leave their test tubes in the water.
- Have students take the masking tape and paper clips off of the batteries and return these supplies to you.

Step 7: Discussing Hydrogen Gas Stations (10 minutes)

- Show students the model that you set up before class started is still collecting hydrogen gas.
- Discuss pros and cons for using hydrogen gas. For example, discuss how a "pro" is that hydrogen gas doesn't pollute the environment. However, a "con" is that it takes a long time and multiple steps to collect hydrogen gas.
- Discuss how the school district could create hydrogen gas that they need for the buses faster. Allow students to express and discuss different ideas. If students don't come up with them on their own suggest things such as: Using more powerful energy or electricity to split water into hydrogen and oxygen, finding ways to get the hydrogen out of other materials that have hydrogen in them, and finding ways to use renewable energy (like solar cells or wind turbines) to create the electricity used to split water or other materials.

Extra Time?

- If you have extra time, we suggest having a discussion on how they can test to see if the gas in the test tube is hydrogen. We know that hydrogen and oxygen react to produce water and energy. It is important that gas stations give people hydrogen gas that can be used to create energy.

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- Tell students that one way to show that the hydrogen gas that they have collected is a good fuel is to see if it explodes. Explain this can be done by holding a lighter to the hydrogen to see if it explodes in a gentle "poof".
- Wearing safety glasses, take turns testing each students hydrogen that they collected by doing the following:
    - Stand next to the students clear cup of water that is holding the inverted test tube.
    - Remove the test tube in one steady movement, straight up out of the water.
    - Turn the test tube on its side while at the same time lighting the lighter and placing it just inside the top of the test tube.
    - Wait for a gentle poof as the hydrogen combines with oxygen in the air to become water.
    - After you have tested all of the student's hydrogen, test the model that you set up ahead of time. Your supply should be large enough to give a satisfying "poof.
    - If you choose to have any students assist you, have them wear safety glasses as well

Materials List

Provided online:

- Video: Fuel for Cars
- Video: Experiment Set Up
- Handout: Instructions for Teacher Prep
- Handout: How to Build a Working Model that Creates Hydrogen Gas
- Handout: Making Hydrogen Gas

Not Provided online (each student or group needs):

Teacher:

- 2 clear cups of salt water filled close to the top
- 4 large metal paper clips
- 2 D cell batteries
- 2 small test tubes (or medicine cups)
- Masking tape
- Optional for "Extra Time" Activity: butane lighter and safety goggles.

Each Student Group:

- One clear cup of salt water filled close to the top
- Two large metal paper clips
- D cell battery
- Small test tubes (or medicine cups)
- Masking tape

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Instructions for Teacher Prep

Create models ahead of class:

- Use directions on student Handout: How to Build a Working Model that Creates Hydrogen Gas. You can also watch Video: Experiment Set Up
- Set up your own working model ahead of time. This way you will have collected quite a bit of hydrogen gas by the time students finish their models. You can use tape to hold your battery, paper clips and test tube in place.
- Set up the parts for a second model that you can use to demonstrate the steps as the students build their models.

Prepare materials for students:

- Prepare 1 cup of slightly salty water for each pair of students. Adding a little bit of salt to tap water will help the reaction happen more rapidly.
- Add about a teaspoon of salt to every gallon of water or just throw a pinch of salt into each cup.

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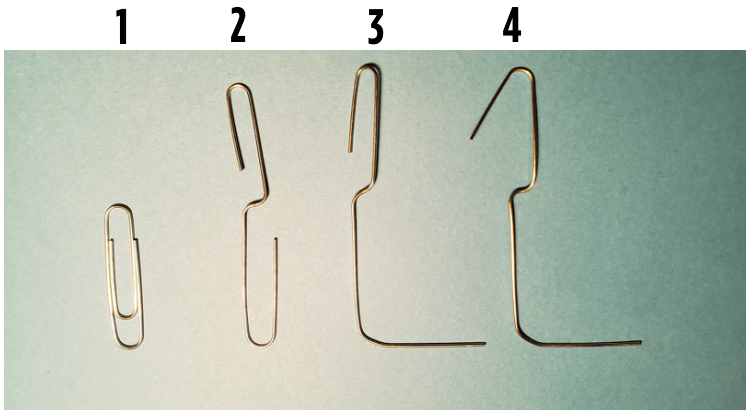
How to Build a Working Model that Creates Hydrogen Gas

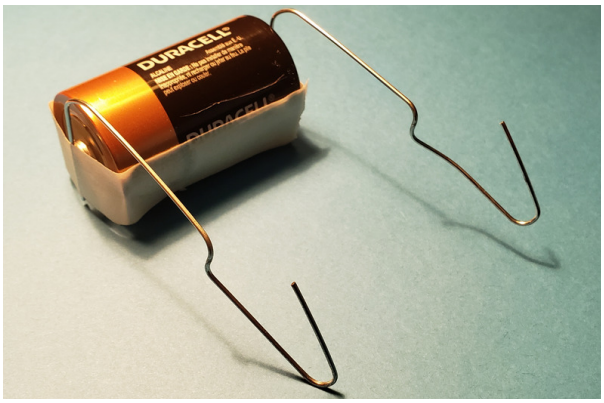
Step 1: Bend paper clips into hooks.

- Unfold paper clip using the steps in the picture below:



Step 2: Attach paper clips to battery using masking tape.

- Make sure that the paper clips do not touch each other.



Step 3: Hold the paperclips tightly to the battery as you lower the hooks into the cup of water.

- Make sure the hooks do not touch each other in the water.
- Try not to let the tips of the hooks come out of the water.
- Take turns holding the paperclips tightly to the battery to make sure you have a good connection.
- One hook should show a change happening faster than the other hook. Is that hook attached to the + or – end of the battery?

Step 4: Collecting the hydrogen gas.

- Now that your model is creating hydrogen, you need to capture the hydrogen.
    - Fill your test tube with clean water.
    - Put your thumb over the opening of the test tube.
    - Turn the test tube upside down (no water comes out because your thumb is there, right!?!)
    - Put your thumb and test tube under the top surface of the water.
    - Remove your thumb and the water should still stay in the test tube.
    - Guide the test tube over the hook that is creating hydrogen
    - You are now collecting hydrogen gas! (The oxygen is just bubbling out into the air.)

Step 5: Monitoring Gas Collection

- Collect as much hydrogen gas as you can. The longer you can leave your experiment running, the more gas you will collect!
- Be careful not to let the test tube come out of the water.

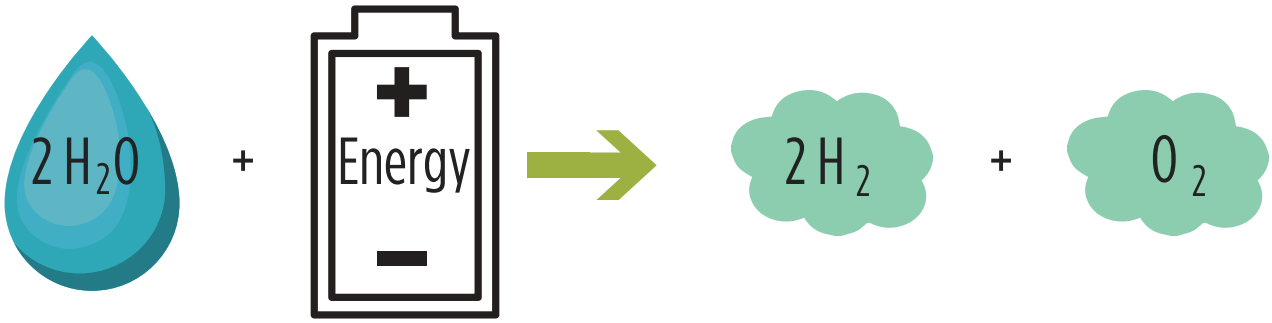
Step 6: Removing the Test Tube

- When you are done collecting hydrogen gas, carefully remove the hooks of the paper clips from the water without removing the test tube.
- The hydrogen gas will stay safely at the top of the test tube.

Making Hydrogen Gas

What is actually happening to produce hydrogen gas from water?

When two water molecules are given energy from the sun, or in this case, a battery, they react. The water molecules break apart and rejoin to form two molecules of hydrogen gas and one molecule of oxygen gas.



Or look at it this way: