Electrolysis

Overview: This lab is a lot of fun, because we're breaking apart molecules and setting them on fire. Pay close attention to how to do this one safely so your eyebrows stay attached.

What to Learn: A water molecule is two hydrogen atoms and one oxygen atom. You're going to use electricity to split apart the water molecule into smaller pieces: hydrogen ions (positively charged hydrogen) and oxygen ions (negatively charged oxygen). The positive hydrogen ions zip over to the negative terminal and form tiny bubbles right on the wire. Same thing happens on the positive battery wire. After a bit of time, the ions form a larger gas bubble.

Materials

- 2 test tubes, glass or plastic
- 2 alligator clip leads
- 1 disposable cup
- Distilled water
- One 9 volt battery with battery clip
- Salt or sodium sulfate

Lab Time: Have fun and please follow the directions carefully. This could be dangerous if you're not careful.

1. Have fun and please follow the directions carefully. This could be dangerous if you're not careful.
2. Fill the cup two-thirds with water.
3. Fill your test tubes with water. Place your thumb over the end, and invert and insert into the water cup. You want an entire test tube filled with water. Do this for both test tubes. A few bubbles are okay.
4. Connect your battery to two alligator clip leads, one lead for each terminal.
5. Insert one alligator clip into each test tube.
6. You should now have two inverted test tubes filled with water, each with their own alligator clip wire.
7. Put a tablespoon or so of salt into the water and stir it up. The salt allows the electricity to flow better through the water. If you have access to sodium sulfate, use it, as the reaction will progress faster.
8. You should see bubbles rising into the test tube. If you don't see bubbles, check the wires and battery connection.
9. When the test tube is mostly full of gas, ask an adult to test for flammability. Before they do, which tube do you think is filled with oxygen and which is hydrogen? Write down your guess here:

    a. Positive wire:_____

    b. Negative wire:_____
10. What did you *really f*ind?

    a. Positive wire:_____

    b. Negative wire:_____

11. Cleanup: Clean everything thoroughly after you are finished with the lab. After cleaning with soap and water, rinse thoroughly. Chemists use the rule of "three" in cleaning glassware and tools. After washing, chemists rinse out all visible soap and then rinse three times more.
12. Storage: Place all chemicals, cleaned tools, and glassware in their respective storage places.
13. Disposal: Dispose of all solid waste in the garbage. Liquids can be washed down the drain with running water. Let the water run awhile to ensure that they have been diluted and sent downstream.

Reading

If you guessed that this has to do with electricity and chemistry, you're right! But you might wonder how they work together. Back in 1800, William Nicholson and Johann Ritter were the first ones to split water into hydrogen and oxygen using electrolysis. (Soon afterward, Ritter went on to figure out electroplating.) They added energy in the form of an electric current into a cup of water and captured the bubbles forming into two separate cups, one for hydrogen and the other for oxygen.

It takes energy to split a water molecule. (On the flip side, when you combine oxygen and hydrogen together, it makes water and a puff of energy. That's what a fuel cell does.) Back to splitting the water molecule – as the electricity zips through your wires, the water molecule breaks apart into smaller pieces: hydrogen ions (positively charged hydrogen) and oxygen ions (negatively charged oxygen). Remember that a battery has a plus and a minus charge to it, and that positive and negative attract each other.

So, the positive hydrogen ions zip over to the negative terminal and form tiny bubbles right on the wire. Same thing happens on the positive battery wire. After a bit of time, the ions form a larger gas bubble. If you stick a test tube over each wire, you can capture the bubbles and when you're ready, ignite each to verify which is which.

If the match burns brighter, the gas is oxygen. If you hear a *POP!,* the gas is hydrogen. Oxygen itself is not flammable, so you need a fuel in addition to the oxygen for a flame. In one case, the fuel is hydrogen, and hence you hear a pop as it ignites. In the other case, the fuel is the match itself, and the flame glows brighter with the addition of more oxygen.

When you put the match to it, the energy of the heat causes the hydrogen to react with the oxygen in the air and *"POP*," hydrogen and oxygen combine to form what? That's right, more water. You have destroyed and created water! (It's a very small amount of water, so you probably won't see much change in the test tube.)

The chemical equations going on during this electrolysis process look like this:

A reduction reaction is happening at the negatively charged cathode. Electrons from the cathode are sticking to the hydrogen cations to form hydrogen gas:

$2\ H^+_{(aq)} + 2e^- \rightarrow H_{2(g)}$

$2\ H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2\ OH^-_{(aq)}$

The oxidation reaction is occurring at the positively charged anode as oxygen is being generated:

$2\ H_2O_{(l)} \rightarrow O_{2(g)} + 4\ H^+_{(aq)} + 4e^-$

$4\ OH^-_{(aq)} \rightarrow O_{2(g)} + 2\ H_2O_{(l)} + 4\ e^-$

Overall reaction:

$2\ H_2O_{(l)} \rightarrow 2\ H_{2(g)} + O_{2(g)}$

Note that this reaction creates twice the amount of hydrogen as oxygen molecules. If the temperature and pressure for both are the same, you can expect to get twice the volume of hydrogen to oxygen gas. (This relationship between pressure, temperature, and volume is the Ideal Gas Law principle.)

This is the idea behind vehicles that run on sunlight and water. They use a solar panel (instead of a 9V battery) to break apart the hydrogen and oxygen and store them in separate tanks, then run them both back together through a fuel cell, which captures the energy (released when the hydrogen and oxygen recombine into water) and turns the car's motor. Cool, isn't it?

Exercises

1. Why are bubbles forming?
2. Did bubbles form at both wires, or only one? What kind of bubbles are they?
3. What would happen if you did this experiment with plain water? Would it work? Why or why not?
4. Which terminal (positive or negative) produced the hydrogen gas?
5. Did the reaction create more hydrogen or more oxygen?

Answers to Exercises: Electrolysis

1. Why are bubbles forming? (Bubbles form as the gases are produced. As the water molecule breaks apart into smaller pieces: hydrogen ions [positively charged hydrogen] and oxygen ions [negatively charged oxygen], they bubble up into the test tube.)
2. Did bubbles form at both wires or only one? What kind of bubbles are they? (Hydrogen bubbles formed at one of the wires and oxygen formed at the other.)
3. What would happen if you did this experiment with plain water? Would it work? Why or why not? (You need the electrolytes to carry the current through the water and separate the water molecule into its ions. Without it, the water acts like a weak insulator and no bubbles will form.)
4. Which terminal (positive or negative) produced the hydrogen gas? (The positive hydrogen ions zip over to the negative terminal and form tiny bubbles right on the wire.)
5. Did the reaction create more hydrogen or more oxygen? (Since water is two hydrogen atoms and one oxygen atom, this experiment generates twice as much hydrogen as oxygen.)