Grades K-5

Pencil Electrolysis

Introduction:

The process by which we separate the elements hydrogen and oxygen from water is called **electrolysis.** The word "lysis" means to dissolve or break apart, so the word "electrolysis" literally means to break something apart (in this case water) using electricity. It is difficult to break up water into it's elements lots of energy is needed to do that. Through a chemical means though, we can separate the compound of water into the elements that combine to make it. Electrolysis is very easy - all you have to do is arrange for electricity to pass through some water between to electrodes placed in the water. It's as simple as that!

CAUTION! HEALTH & SAFETY: The reaction neutralizes the solution, which can be disposed of by pouring it down the drain.

Materials:

- A battery or solar panel with a voltage greater than 1.5 volts - 9 volt batteries work well.
- Two pieces of electrical wire about a foot long. It's convenient, but not necessary, if the wires have alligator clips at each end.
- Two number 2 pencils
- tap water
- small piece of cardboard
- electrical or masking tape.
- 1 teaspoon Epsom Salt
- Petri dish
- A glass
- 1 tablespoon red cabbage juice

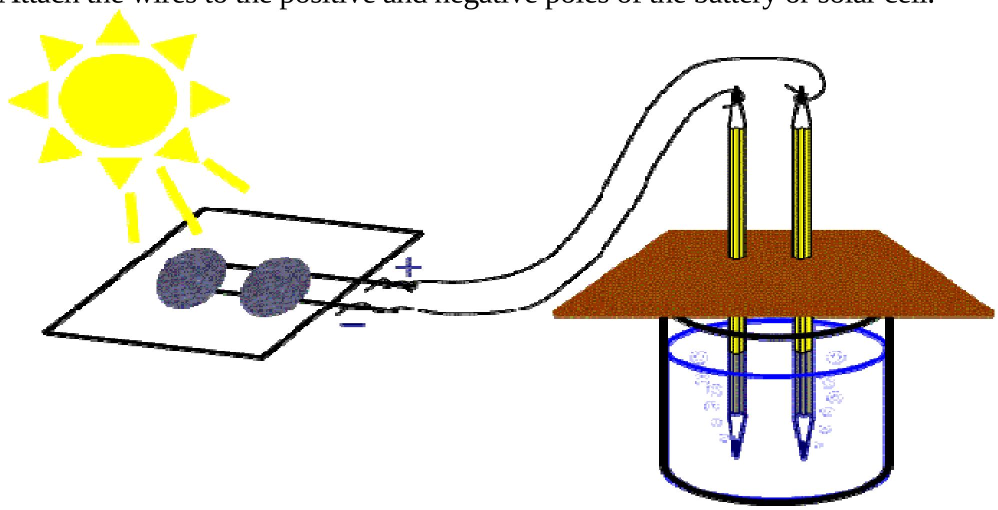
Procedure:

1. Remove the erasers and their metal sleeves from both pencils, and sharpen *both* ends of both pencils.
2. Fill the glass with warm water and add 1 teaspoon of Epsom salt and 1 tablespoon of red cabbage juice.
3. Stir the mixture thoroughly.
4. Pour some of the water mixture into the petri dish until it is ¾ of the way full.
5. Attach wires to the electrodes on the solar cell or battery, and the other ends to the tips of the pencils, as shown in the diagram below. It is important to make good contact with the graphite (lead) in the pencils. Secure the wires with tape.
6. Punch small holes in the cardboard, and push the pencils through the holes, as shown in the diagram below.

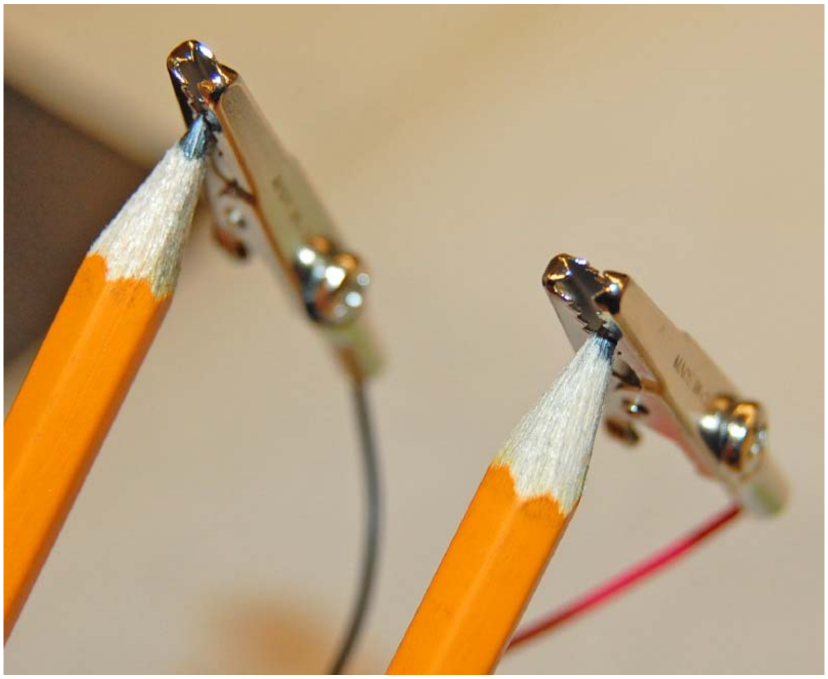
7. Place the exposed tips of the pencils in the water, such that the tips are fully submerged but are not touching the bottom, and adjust the cardboard to hold the pencils.
8. Wait for a minute or so: Small bubbles should soon form on the tips of the pencils. Hydrogen bubbles will form on one tip (associated with the negative battery terminal - the cathode) and oxygen from the other.

Diagrams

Attach the wires to the positive and negative poles of the battery or solar cell.



Make good contact with the graphite in the pencils.



Where’s the chemistry?

The chemical equation for electrolysis is:

$$\textbf{energy (electricity)} + 2\,H_2O \rightarrow O_2 + 2\,H_2\,.$$

At the cathode (the negative electrode), there is a negative charge created by the battery. This means that there is an electrical pressure to push electrons into the water at this end. At the anode (the positive electrode), there is a positive charge, so that electrode would like to absorb electrons. But the water isn't a very good conductor. Instead, in order for there to be a flow of charge all the way around the circuit, water molecules near the cathode are split up into a positively charged hydrogen ion, which is symbolized as H^+ in the diagram above (this is just the hydrogen atom without its electron, i.e. the nucleus of the hydrogen atom, which is just a single proton), and a negatively charged "hydroxide" ion, symbolized OH^-:

$$H_2O \rightarrow H^+ + OH^-\,.$$

You might have expected that H_2O would break up into an H and an OH (the same atoms but with neutral charges) instead, but this doesn't happen because the oxygen atom more strongly attracts the electron from the H - it *steals* it (we say the oxygen atom is more "electronegative" than hydrogen). This theft allows the resulting hydroxide ion to have a completely filled outer shell, making it more stable.

But the H^+, which is just a naked proton, is now free to pick up an electron (symbolized e^-) from the cathode, which is trying hard to donate electrons, and become a regular, neutral hydrogen atom:

$$H^+ + e^- \rightarrow H$$

This hydrogen atom meets another hydrogen atom and forms a hydrogen gas molecule:

$$H + H \rightarrow H_2,$$

and this molecule bubbles to the surface, and eureka! We have hydrogen gas!

Meanwhile, the positive anode has caused the negatively charged hydroxide ion (OH^-) to travel across the container to the anode. When it gets to the anode, the anode removes the extra electron that the hydroxide stole from the hydrogen atom earlier, and the hydroxide ion then recombines with three other hydroxide molecules to form 1 molecule of oxygen and 2 molecules of water:

$$4\,OH^- \rightarrow O_2 + 2\,H_2O + 4e^-$$

The oxygen molecule is very stable, and bubbles to the surface.

In this way, a closed circuit is created, involving negatively charged particles - electrons in the wire, hydroxide ions in the water. The energy delivered by the battery is stored by the production of hydrogen.

Enrichment Ideas

Is Hydrogen Dangerous?

Some people are worried that hydrogen might be too dangerous. It is true that hydrogen is a very explosive fuel, but so is natural gas and gasoline. For example, movies commonly depict automobiles burning up after crashing, and explosions involving natural gas are reported in the press from time to time. Two famous disasters involving hydrogen are the explosion of a zeppelin (an airship) called the Hindenburg (in 1937), and the explosion of the Space Shuttle Challenger (in 1986). You may want to study these disasters as a class project. The Hindenburg explosion, although often cited as an example of the danger of hydrogen, is thought by many to have been caused by flammable paint that caught fire from an electrical spark, and so might have caught fire even if the zeppelin had been filled with helium (an inert, nonflammable gas). Moreover, most of the people that died may have done so from coming into contact with burning diesel fuel (which powered the Hindenburg's airplane-type prop-engines) or from jumping of the Zeppelin before it landed.

Obstacles to a hydrogen-economy

There are two obstacles to a hydrogen-economy.

- **It takes a lot of volume (or energy) to store hydrogen** - usually five times or so the volume, at reasonable pressures, needed to store an equivalent amount of energy with gasoline. One company that has made headway on solving this problem, however, is Dynetek (www.dyneteck.com).
- **There is no hydrogen infrastructure:** Making the transition to a hydrogen economy might mean having to scrap the fossil fuel infrastructure that we have already developed. One company that has made progress on refueling equipment is Stuart Energy (www.stuartenergy.com).

Both of these problems might be surmounted by using **synthetic fuels**. For example, it is possible, using a catalyst, to combine water, carbon dioxide (extracted from the air), and renewable electricity to make fuels such as methanol, a carbon-based fuel. When this fuel is burned, water and carbon dioxide are produced. But because the carbon dioxide used initially to make the fuel was extracted from the air, the cycle is closed with respect to both water and carbon dioxide, and so won't contribute excess carbon dioxide to the atmosphere. Fuel cells can already use such fuels (either by extracting the hydrogen from the fuel prior to the fuel cell, or even directly in certain types of fuel cells).