Investigation 3:
Simple Electrolysis

Matter is made up of small particles that scientists call **atoms**. Atoms are often combined to form **molecules**. **Ionic compounds**, like sodium chloride, are composed of particles that form when atoms loose or gain electrons. An **element** is a substance consisting of atoms of one type.

Oxygen is an element and each molecule of oxygen is made up of two oxygen atoms joined chemically. In scientific shorthand oxygen is O and a molecule of oxygen is written as O_2.

In the same way, hydrogen is another element and each molecule of hydrogen is made up of two atoms of hydrogen joined chemically. A molecule of hydrogen is written as H_2.

A compound is described by its **formula**. For example, table salt is made up of one atom of the element sodium chemically joined with one atom of the element chlorine. This ionic compound is called sodium chloride. The shorthand for sodium is Na and the shorthand for chlorine is Cl. Therefore the formula for sodium chloride is written NaCl. Water is a compound containing two atoms of the element hydrogen and one atom of the element oxygen. The formula for water is H_2O.

Often, applying energy to a molecule can break it apart. The energy needed is usually heat, light, or electricity. The pulling apart is a type of change, called a chemical **reaction**. As the molecule breaks apart, its atoms may re-join to form different substances.

Later, these new substances might be used to make other compounds, or even make the original molecule again, and may give back some of the energy that was used in breaking apart the original molecule.

In this investigation we are going to look at the process of breaking up a compound. We will investigate what will happen if we let electricity flow through water.

Can you guess what might happen if we add enough energy to water to break it into its two elements, and then later let the elements re-join?

This kind of thinking about the background of an investigation can often help you with your observations and allow you to understand what you are seeing.

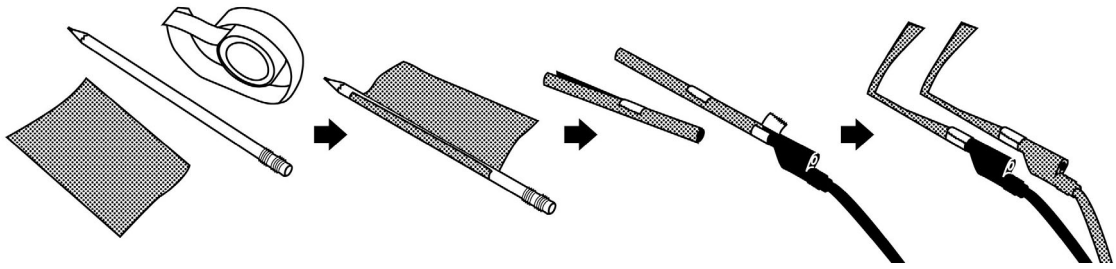
What evidence do we have that water can be taken apart using electricity?

You will need:

- goggles or eye protection
- solar panel from the *Fuel Cell Model Car Kit*
- two patch cords
- two 10cm x 5cm pieces of aluminum foil
- clear 200ml plastic cup or 250ml beaker
- 150 ml distilled water
- 15ml table salt
- 75 watt PAR30 incandescent lamp, or bright sunlight, or equivalent light source.
- utility tape to fasten aluminum foil
- magnifying glass (optional)

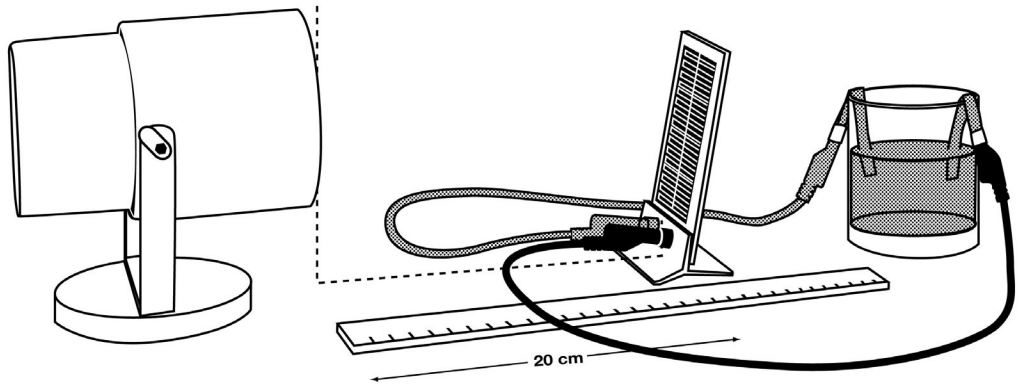
Procedure

1. Put on your goggles. Remember that they will only protect you if you wear them properly.
2. Roll a piece of aluminum foil around a pencil. Use a small piece of tape to hold the foil in a cylinder and slide it off the pencil. Place one end of the cylinder over the metal tip of a patch cord, squeeze the foil and wrap that end tightly with tape so it is secure. Flatten the other end of the foil cylinder, forming an **electrode**. Repeat this step with another piece of foil and the other patch cord.



3. Pour 150ml of distilled water into a small beaker or clear plastic cup.
4. Bend the aluminum electrodes and hang them on the edge of the beaker or plastic cup with the electrodes immersed in the water. The metal ends of the patch cords should not touch the water directly.
5. Place the solar panel directly facing the light source, but not closer than 20cm. Turn on the light, but do not connect the patch cords yet.
6. What do you think is going to happen when you connect the patch cords to the solar panel and why? Make an entry on your lab sheet before you continue.

7. Connect the patch cords to the solar panel - red to red and black to black. The connectors on the solar cell are colored in the usual way: red is positive, black is negative.



8. Observe what is happening under the water on the surface of each electrode

9. Lift the electrodes out of the water and set them aside. Add 15ml (1 tablespoon) of ordinary table salt to the water and stir until the salt is completely dissolved.
10. Replace the electrodes in the water, now a **salt solution**.
11. Observe what is happening under the salt solution on the surface of each electrode. You may wish to use a magnifying glass.

12. After recording your observations remove the electrodes from the salt solution and pull them off the patch cords. Dispose of the aluminum foil responsibly. Empty the salt-water solution and wash the cup or beaker so it is ready for use again. Disconnect the patch cords and return all equipment as directed by your teacher.
13. Take off your goggles and return them carefully.

Questions

1. What is the reason for ensuring the solar panel is perpendicular to the light source and no closer than 20 cm?

2. Why is salt added to the water and how does it change what happens when the electrodes are under the water and connected to the solar panel?

3. During electrolysis, the electrode attached to the black patch cord is called the CATHODE. Is the cathode positive or negative with respect to the other electrode?

4. During electrolysis, the electrode attached to the red patch cord is called the ANODE. Is the anode positive or negative with respect to the other electrode?

5. When the patch cords were connected to the solar panel what did you notice happening at the cathode when you observed carefully?

6. Was the same thing happening at the anode? What do you think is the reason for any differences in your observations?

7. What is the answer to the question at the start of the investigation: *What evidence do we have that water can be taken apart using electricity?*

8. Looking at the scientific formula for water, H_2O, what do you think happened in this investigation? How can you be sure?

9. What questions do you now have about this process?

10. What is the scientific name for this process?

Teaching supplement for Investigation 3: *Simple Electrolysis*

The major goal of this investigation is to allow the students to begin to ask questions surrounding energy and water. It is not a quantitative investigation that needs to be fully articulated into formulae and reactions as this will be developed in the next two investigations.

The learning objectives may be written:

- Students will set up apparatus according to instructions and will observe, make notes and answer questions after observing the electrolysis of water.
- Students will observe that when electrical energy is supplied to a dilute solution of water and salt, gases are produced at each electrode.
- Students will use the terms anode and cathode correctly to identify the positive and negative electrodes.
- Students will demonstrate correct safety procedures for this investigation.

Teacher Notes

In general, the term *anode* refers to the electrode where the oxidation reaction takes place; that is, a reaction where there is a loss of electrons. Similarly, *cathode* refers to the electrode where the reduction reaction takes place; that is, a reaction where there is a gain of electrons. In this investigation, the electrode attached to the positive (red) side of the solar panel releases oxygen, and is the *anode*. The other electrode, attached to the negative (black) side of the solar panel releases smaller hydrogen bubbles and is the *cathode*.

If you don't have beakers and are using plastic cups, try to use plastic cups wide at the base as they are more stable. They may be sold as *highball* glasses.

A dissecting microscope will make it easier to see the difference between anode and cathode bubbles at the electrodes. Putting the electrolyte and electrodes in a shallow dish such as a Petri dish allows observation with the microscope. With care, you can even place a shallow dish of electrolyte on the glass of an overhead projector.

If a very strong salt solution is used, the electrolysis will produce chlorine and oxygen. Telltale signs of this happening would be gases produced in equal amounts and a greenish hue to the gas produced at the cathode. However, at the salt concentration suggested in this procedure—15ml salt to 150 ml water—chlorine will not be produced.

Answers to the student questions

1. *What is the reason for ensuring the solar panel is perpendicular to the light source and no closer than 20 cm?*

   The solar panel is placed perpendicular to the light so the greatest amount of energy can be had from the light source. The light source must be at least 20cm away from the solar panel to avoid overheating.

2. *Why is salt added to the water and how does it change what happens when the electrodes are under the water and connected to the solar panel?*

   Salt is added to the water to allow electricity to flow through it. When it is added the electricity begins to flow and bubbles begin to appear on the surface of the tinfoil electrodes.

3. *During electrolysis, the electrode attached to the black patch cord is called the CATHODE. Is the cathode positive or negative with respect to the other electrode?*

The cathode is more negative than the other electrode.

4. *During electrolysis, the electrode attached to the red patch cord is called the ANODE. Is the anode positive or negative with respect to the other electrode?*

The anode is more positive than the other electrode.

5. *When the patch cords were connected to the solar panel what did you notice happening at the cathode when you observed carefully?*

When I connected the patch cords to the solar panel I noticed that the cathode was giving off lots of very small bubbles.

6. *Was the same thing happening at the anode? What do you think is the reason for any differences in your observations?*

When I looked at the anode after connecting the patch cords to the solar panel I noticed that larger bubbles were forming on it but they didn't come to the surface as often. I think that there were different gases being produced at each electrode.

7. *What is the answer to the question at the start of the investigation:* What evidence do we have that water can be taken apart using electricity?

We have seen that when electricity flows through water, different gases are produced at the two points where the current enters the water. Probably these gases are the elements that water is composed of.

8. *Looking at the scientific formula for water, H_2O, what do you think happened in this investigation? How can you be sure?*

Water is made up of two elements, hydrogen and oxygen. Both are gases and when water is taken apart by electricity the gases bubble up from the electrodes and escape into the air. I think we could collect the gases and test them to be sure of what they are.

9. *What questions do you now have about this process?*

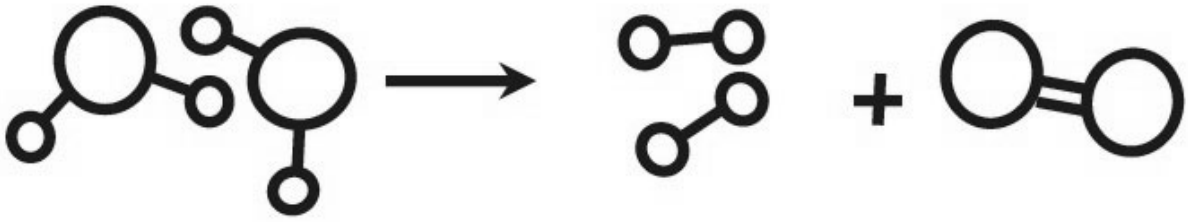
Accept any questions the students suggest. The students may want to know what would happen if we used stronger light or more solar panels or added something else to the water such as sugar or more salt in the water or whatever they suggest. Some may notice that the gases seem to be coming off in a different manner with more rapid bubbling, smaller bubbles, and such.

The process here is to encourage questions beyond the immediate experience so as to allow the natural curiosity of the student to suggest further investigation that may be part of these experiences or extras that may add greatly to the unit. It may be helpful to ask questions during the investigation that would promote such questions.

10. *What is the scientific name for this process?*

The scientific name for taking water apart by using electricity is electrolysis.

The Latin suffix -lysis means to dissolve or take apart thus electrolysis is the taking apart of something by using a flow of electrons.



$$2\,H_2O \longrightarrow 2H_2 + O_2$$

Water molecules — Hydrogen molecules — Oxygen molecule