Electochemistry

Electrolysis of Water

OVERVIEW

During electrolysis, electrical energy is used to cause a nonspontaneous chemical reaction to occur. Electrolysis is often used to obtain elements that are too chemically reactive to be found free in nature.

In this experiment electrolysis will be used to separate water into hydrogen gas and oxygen gas. During this experiment you will perform certain tests for the products of each of the half-reactions involved in the process.

Reduction will occur at the cathode. At this electrode hydrogen gas and hydroxide ions are formed. The electrons required for this reduction will come from the power source.

$$4H_2O + 4\ e^- \rightarrow 2\ H_2 + 4\ OH^-$$

Oxidation will occur at the anode, producing oxygen gas and hydrogen ions. The electrons that are produced will return to the power source:

$$2H_2O \rightarrow O_2 + 4\ H^+ + 4\ e^-$$

Adding the two half-reactions together gives us a net reaction of:

$$6\ H_2O \rightarrow 2\ H_2 + O_2 + 4\ H^+ + 4\ OH^-$$

The H^+ and OH^- that are produced will combine to form 4 H_2O.

$$6\ H_2O \rightarrow 2\ H_2 + O_2 + 4\ H_2O$$

Finally we can simplify our overall equation to:

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

Two alternatives methods are given in this lab. One involves using a Brownlee electrolysis apparatus. If one is not available it is not difficult to assemble your own using common lab equipment. Using this method allows you to collect hydrogen and oxygen gases.

The second method using simpler materials, but does not provide a way to collect the two gases.

PURPOSE

- To use electrolysis to separate water into hydrogen and oxygen gas.

SAFETY

- Small amounts of explosive hydrogen gas will be generated. Safety goggles should be worn when testing for the presence of hydrogen gas.

EQUIPMENT AND MATERIALS

Option 1: Brownlee Electrolysis Apparatus

- Brownlee electrolysis apparatus
- D.C. power source or commercial battery (9V)
- phenolphthalein indicator
- vinegar
- test tube holder
- candle
- wood splint

Create your own Brownlee apparatus

- insulated copper wire with alligator clips on one end
- large glass jar
- 2 test tubes
- test tube clamps and ring stands to hold the inverted test tubes in place

Option 2

In this method, easily set up as a home experiment, hydrogen gas and oxygen gas will not be collected.

- two 250 mL beakers or glass jars
- coffee filter
- insulated copper wire (alligator clips optional)
- salt water solution (approximately 8 teaspoons of table salt, NaCl, in 500 mL of water)
- vinegar
- phenolphthalein

PROCEDURE

Option 1: Brownlee Electrolysis Apparatus

1. Fill the large beaker approximately three quarters full with water.

2. Fill both test tubes completely with water.

   You may find the next step easier if you cover the open ends of the test tube with a small piece of paper.

   Invert the test tubes, placing the open tops under water in the large jar. Both test tubes should be completely full of water with no bubbles. Allow the paper you used to cover the test tubes to drop off under water.

3. Clamp the inverted test tubes in place in the Brownlee apparatus. The electrodes will be inside the test tubes.

   If creating your own set up, place the free ends of the copper wire inside the test tubes, one wire for each tube. The alligator clips will be used to attach the wire to the power source.

4. Add a few mL of vinegar to the water, which will help conduct the electric current.

5. Connect the wires to the power source to begin the electrolysis.

6. Record your observations. Continue the electrolysis until several cm of gas have been allowed to collect in each of the two test tubes. Note the relative amount of gas that collect in each tube. Be sure to indicate which test tube is attached to which post of the power source or battery.

7. Add a few drops of indicator solution to the beaker. Watch for any colour changes that occur near the mouths or inside the two test tubes. Record any changes you observe, making note of which test tube produced the change.

8. You will test the gas collected in each of the test tubes, one at a time. When testing the gas inside a test tube, carefully remove the tubes from the water, keeping the test tubes inverted so the gas doesn't escape. Use a test tube holder or clamp to hold the test tubes while performing the tests.

   Place the candle on a glass square or other suitable support and light it.

   In the test tube that was attached to the **negative post** of the power source, test for the presence of hydrogen gas in the test tube:

   a. Remove the test tube from the water and keep it inverted. Allow the water to drain out.
   b. Holding the test tube with a test tube holder, bring the open end of the tube over the lit candle.
   c. A pale blue flame or a soft pop sound indicates hydrogen is present.

   Next use the clamp to hold the test tube that was attached to the **positive post** of the power source, and test for the presence of oxygen gas:

   a. With the test tube still inverted, bring its open end over the glowing (blown out) candle.
   b. If the candle again bursts into flame, the gas is oxygen.

   Alternate test for oxygen:

   a. Light a wood splint, then blow it out.
   b. Place the smoldering splint inside the test tube. If the splint glows then oxygen is present.

Option 2

1. Fill one of the beakers approximately three quarters full of the salt solution. The presence of the salt, an electrolyte, will help conduct the electric current. This will be Beaker A and will be the cathode (site of reduction).

   Add a few drops of phenolphthalein to the water. If the solution appears red after adding the indicator (because the water is too basic), add a few drops of vinegar until the red colour disappears.

2. Fill the second beaker approximately three quarters full of the salt solution. This will be Beaker B and will act as the anode (site of oxidation).

3. Place the beakers next to one another. Connect the wires to the battery as follows:
   Beaker A (salt solution + phenolphthalein) – connect to the negative post of the battery or power source.

   Beaker B (salt solution only) – connect to the positive post of the battery or power source.

4. Fold the coffee filter and place one end in Beaker A and the other in Beaker B, forming a bridge between the two solutions.

   The electrolysis will not begin until the filter paper becomes fully wet.

RESULTS

Option 1: Brownlee Electrolysis Apparatus

1. Describe what you observe occurring at the two electrodes. Make special note of the relative amounts of gas that form in each of the two test tubes – are they equal amounts? If not, indicate which test tube is attached to which post of the power source or battery.

2. Describe any colour changes that occurred after the addition of phenolphthalein.

Option 2

1. Record your observations for the two beakers. Carefully observe the ends of the wire. Watch for any colour changes that occur.

CONCLUSIONS AND QUESTIONS

Option 1: Brownlee Electrolysis Apparatus

1. Why does more gas form in one test tube than in the other? Explain in terms of the half-reactions that occur in each test tube, identifying each test tube by which post they are attached to at the power source.

   Also identify each test tube half-reaction as either the anode or the cathode.

   Finally explain the flow of electrons through the system.

2. Explain the colour changes that occurred after the addition of phenolphthalein.

Option 2

1. What gas was formed in Beaker A? Write the half-reaction that occurred in this beaker, identify it as either oxidation or reduction, and label it as the anode or cathode.

2. What gas was formed in Beaker B? Write the half-reaction that occurred in this beaker, identify it as either oxidation or reduction, and label it as the anode or cathode.

3. Explain the flow of electrons through the system.

4. What was the purpose of adding phenolphthalein to the solution in Beaker A?