

Pencil Electrolysis

Water is often considered to be a rather stable compound; that is, adding energy in the form of heat only causes a change in its state, but the steam that results is still H₂O. Nevertheless, you can use household materials to decompose water into its elements!

Materials

- 9-volt battery
- 2 wooden pencils
- electrical tape
- 2 4- to 6-inch pieces of small gauge insulated wire (two different colors are preferable)
- masking tape
- marker
- shallow cup or bowl
- table salt or Epsom salt
- water
- 1 of the following combinations (to make an acid-base indicator):
 - red cabbage and either a blender or a stove and pan
 - Ex-Lax® tablet and spoon

Getting Ready

Step 1 Electrolysis apparatus: Sharpen both ends of the pencils. Use electrical or masking tape to attach the battery between the pencils. (See Figure 1.) Strip two centimeters of the insulation from both ends of each of the two pieces of wire. Wrap one end of each piece of wire to a terminal of the battery (Red traditionally goes with positive, and black or green goes with negative). Make sure that the stripped ends are in contact with the terminals, then secure with electrical tape. Wrap the other end of each wire to the sharpened tip of a pencil. Make sure that the stripped ends are in contact with the lead (graphite) of the pencil tips, then secure with electrical tape. With masking tape and a marker, label which wire goes to the positive terminal and which goes to the negative terminal.

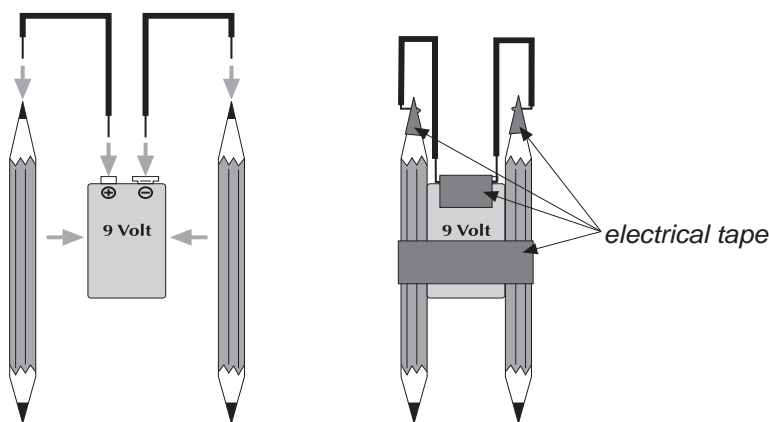


Figure 1: Assemble the pencil electrolysis apparatus.

Step 2 Electrolyte solution: Pour about 1 cm of water into the cup or bowl. Stir in table salt or Epsom salt until no more will readily dissolve.

- Step 3 Acid-base indicator: Red cabbage juice—either boil or blend some of the red cabbage in the smallest possible amount of water until the liquid is dark; discard the solid residue.
Phenolphthalein—crush the Ex-Lax tablet with a spoon.

Exploration

- Step 1 Place the bottom pencil tips of the electrolysis apparatus in the solution.
(See Figure 2.) Look very closely at the submerged pencil tips. If you do not notice something happening, the wire connections are unsuitable or the battery is bad. Readjust the connections and/or try a new battery until you do notice something. Describe what you see at each pencil tip, noting any differences between the two. What is the identity of the bubbles? What is the electrochemical term for each of the pencil tips?

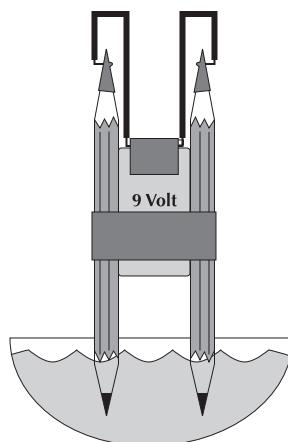
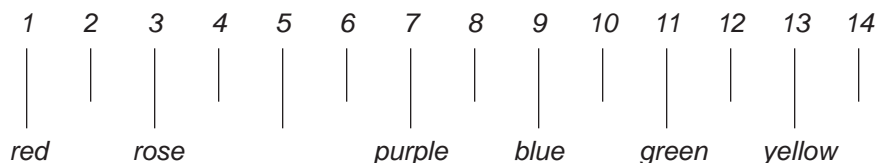


Figure 2: Place the tips of the pencil electrolysis apparatus into the solution.

- Step 2 If using red cabbage juice, add 6–10 drops to the salt solution to give a light purple color; mix. If using Ex-Lax tablet, mix the crushed tablet into the solution. Place the bottom pencil points of the electrolysis apparatus in the solution. Hold it there for several minutes. Record the color of the solution around each pencil tip. The pH scale for red cabbage juice is:



Ex-Lax tablets contain phenolphthalein, which is pink above a pH of 8.5 and colorless below a pH of 8.5.

What is the significance of the colors you see? What other chemical species besides the gas is being generated at each pencil tip? Write the equations for the half-reaction that occurs at each pencil tip. What is the purpose of adding the salt to the water?

Challenge

What happens when water is transformed into its elements by electrolysis?

Pencil Electrolysis

Concepts

electrolysis, decomposition reaction, acid-base indicator

Expected Student Responses to Exploration

- Step 1
- (a) Bubbles should be forming at both pencil tips. However, more bubbles form at the tip of the pencil attached to the negative terminal.
 - (b) Most of the bubbles are hydrogen; a few bubbles are oxygen.
 - (c) The pencil tip where hydrogen is forming is the cathode (negative terminal) and the pencil tip where oxygen is forming is the anode (positive terminal).
- Step 2
- (a) The color at the cathode will be rose in red cabbage juice and colorless in phenolphthalein. The color at the anode will be blue or green in red cabbage juice and pink in phenolphthalein.
 - (b) The solution is basic around the cathode and acidic around the anode.
 - (c) Hydroxide ions must be forming at the cathode and hydrogen ions must be forming at the anode.
 - (d) hydrogen production at the cathode: $4\text{H}_2\text{O} + 4\text{e}^- \rightarrow 2\text{H}_2(\text{g}) + 4\text{OH}^-$
oxygen production at the anode: $2\text{H}_2\text{O} \rightarrow \text{O}_2(\text{g}) + 4\text{H}^+ + 4\text{e}^-$
 - (e) The salt (electrolyte) provides the ions necessary for the liquid to conduct electricity.

Expected Student Answer to Challenge

In the electrolysis of water, oxygen gas, hydrogen ions, and electrons are formed at the anode. The electrons travel through the wire to the cathode and combine with water to form hydrogen gas and hydroxide ions. The hydrogen ions and hydroxide ions combine to reform water.

Acknowledgment

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