Simple Electrolysis

Decomposition of Water

FLINN SCIENTIFIC CHEM FAX!

Introduction

Demonstrate the decomposition of water in simple but colorful fashion on an overhead projector using just a 9-volt battery and alligator clips. No need for expensive power supplies or fancy glassware. Color changes produced in universal indicator solution reveal the pH changes that occur at the positive and negative electrodes as the reaction proceeds.

Concepts

- Decomposition reaction
- Oxidation–reduction
- Electrolysis
- pH

Materials

Sodium sulfate solution, Na_2SO_4, 1 M, 40 mL	Beaker
Universal indicator solution, 2–3 mL	Overhead projector
Water, distilled	Pencil lead, 0.9 mm
Battery cap with alligator clip leads	Petri dish
Battery, 9-V	Stirring rod

Safety Precautions

Universal indicator is an alcohol-based solution and is flammable; do not use near an open flame. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

1. Place the two halves of a Petri dish on the projection stage of an overhead projector. Pour enough sodium sulfate solution into each half of the Petri dish to just cover the bottom of each half dish.
2. Add 2–3 mL of universal indicator to each solution to give each a rich, transparent green color.
3. Break a pencil lead in half. Attach the leads to opposite sides of the Petri dish bottom with the alligator clips. Make sure the tip of each lead is submerged in the green solution and the alligator clips remain out of the solution. *Note:* The solution in the Petri dish top will serve as a control.

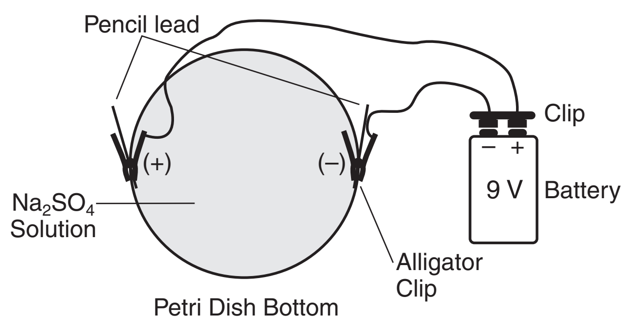

Figure 1.

4. To start the demonstration, clip the 9-volt battery into the snaps on the battery cap (Figure 1).
5. Let the demonstration run for 5–10 minutes and note the changing colors over time and the production of gases (bubbling) at each electrode. A deep purple color forms immediately at the negative electrode, while at the positive electrode a red-orange color appears more slowly. Over time, a wider range of universal indicator colors—purple, blue, green, yellow, and red—may develop.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The waste solutions may be disposed of down the drain with excess water according to Flinn Suggested Disposal Method #26b.

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Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation

Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter, transfer of energy

Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, chemical reactions, interactions of energy and matter

Tips

- Sodium sulfate is used as a source of dissolved ions to increase the current flow through the solution. In the absence of added electrolyte, no reaction will occur when the battery is connected to the pencil leads—there are no ions to "carry" the current through the solution. The rate of electrolysis increases as the concentration of sodium sulfate increases.
- The sulfate ion is an extremely weak base. The initial indicator color for the electrolysis solution may be more blue-green rather than green. Test a small amount of sodium sulfate stock solution with universal indicator—the solution should turn green. If the solution is teal-colored, add one drop of 0.1 M hydrochloric acid to the stock solution.

Discussion

When an electric current is passed through a solution of water containing an ionic salt, such as sodium sulfate, the water molecules break apart or decompose into their constituent elements, hydrogen and oxygen. The overall reaction occurs as two separate, independent half-reactions. Reduction of hydrogen atoms in water to elemental hydrogen (H_2) occurs at the negative electrode (the cathode), while oxidation of the oxygen atoms in water to elemental oxygen (O_2) occurs at the positive electrode (the anode). Each half-reaction is accompanied by the production of OH^- or H^+ ions, as shown below:

$$4e^- + 4H_2O \rightarrow 2H_2(g) + 4OH^- \qquad \textit{Reduction}$$

$$2H_2O \rightarrow O_2(g) + 4H^+ + 4e^- \qquad \textit{Oxidation}$$

The overall reaction is the decomposition of water (Equation 1).

$$2H_2O(l) \rightarrow 2H_2(g) + O_2(g) \qquad \textit{Equation 1}$$

Universal indicator is an acid–base indicator that is different colors at different pH values (Table 1). Excess OH^- ions produced at the cathode cause the pH to increase, resulting in a color change of the universal indicator solution from green (neutral, pH 7) to purple (basic, pH $\geq$ 10). Excess H^+ ions produced at the anode cause the pH to decrease, resulting in a color change of the universal indicator solution from green to orange-red (acidic, pH $\leq$ 4). The electrolysis half-reactions can also be followed by observing the production of gas bubbles at each electrode.

Table 1. Universal Indicator Color Changes

pH	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Color	Red	Orange	Yellow	Green	Blue/green	Dark blue	Purple

Materials for *Simple Electrolysis—Decomposition of Water* are available from Flinn Scientific, Inc.

Catalog No.	**Description**
A0352	Sodium Sulfate Solution, 1 M
U0001	Universal Indicator Solution, 100 mL
GP3019	Petri Dish

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.