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Catalog No. AP6467
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# Colorful Electrolysis

## Chemical Demonstration Kit

## Introduction

Demonstrate simple electrolysis in a very colorful and dramatic way on an overhead projector.

## Concepts

- Electrolysis
- Cathode
- Anode
- pH

## Materials (for each demonstration)

Sodium sulfate solution, $Na_2SO_4$, 0.5 M, 40 mL*
Universal indicator solution, 10 mL*
Water, distilled
Battery clip with alligator ends*
Battery, 9-V*
Beaker, 100-mL
Graduated cylinder, 10 mL
Graduated cylinder, 50 mL
Overhead projector
Pencil leads*
Petri dish, disposable*
Stirring rod

**Materials included in kit.*

### *Safety Precautions*

*To extend the life of the battery, avoid touching the positive and negative terminals to each other. 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 Material Safety Data Sheets for additional safety, handling, and disposal information. Wash hands thoroughly with soap and water before leaving the laboratory.*

## Preparation

To prepare the demonstration solution, add 10 mL of universal indicator to 40 mL of 0.5 M sodium sulfate solution and stir.

## Procedure

1. Place the two halves of a Petri dish on the projection stage of an overhead projector.
2. Pour enough demonstration solution into each half of the Petri dish to just cover the bottom of each half dish. Adjust the overhead so that the dishes are in clear focus. Each half dish should appear to be a rich, transparent green color.
3. Break a pencil lead in half. Attach the leads to opposite sides of the Petri dish 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.

4. To start the demonstration, clip the 9-volt battery into the snaps on the battery clip. See Figure 1.

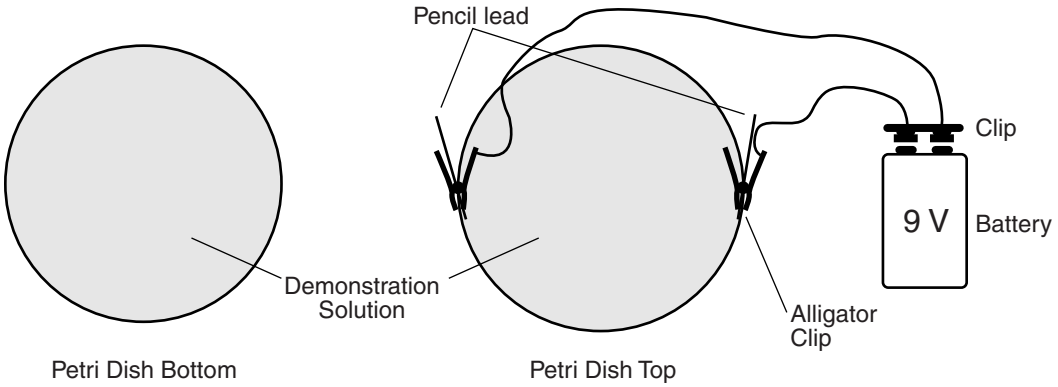



**Figure 1.** Demonstration Setup.

5. Let the demonstration run for 5–10 minutes and note the changing colors over time. (A purple color will appear at the cathode very quickly. An orange color at the anode will appear more slowly. Over time, the entire spectrum of universal indicator colors will appear.)
6. Discuss the results as the demonstration continues. Discuss the various colors as well as why the "extra" dish was included in the demonstration.

## Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. All materials may be disposed of according to Flinn Suggested Disposal Method #26b.

## Tips

- This kit contains enough chemicals to perform the demonstration at least seven times: 9-V battery, battery clip with alligator clips, 100 mL universal indicator, 300 mL of 0.5 M sodium sulfate solution, 12 pencil leads, and a reusable Petri dish.
- Concepts of pH and electrolysis should be discussed prior to this demonstration. Universal indicator colors, as they relate to pH values, should also be discussed. The Flinn Overhead Color Chart (Catalog No. AP5367) would be a nice visual supplement during this discussion.
- The reaction at the anode and cathode seem to proceed at the same pace. There is bubbling at both the anode and the cathode. A deep purple forms immediately at the cathode and an obvious red/orange at the anode. Both of these color changes occur with similar intensity. Purple, blue, green, yellow, and red/orange are all visible after five minutes.
- The demonstration can be repeated using a pH 7 buffer to show the effects of buffering a solution. (When the solution is buffered, no color changes result.)
- The sulfate ion is an extremely weak base (the p$K_a$ for its conjugate acid, $HSO_4^-$, is 2.0). The initial indicator color for the electrolysis solution may be more blue-green rather than green. According to the *Merck Index,* the pH of a sodium sulfate solution is 6.0–7.6. Test a small amount of the sodium sulfate stock solution with bromthymol blue indicator before class—the solution should turn green. If the solution is blue, add one drop of 1 M hydrochloric acid to the stock solution. If the solution is yellow, add one drop of 1 M sodium hydroxide to the stock solution.
- Try the same demonstration procedure using different solutions in the Petri dish as follows:

  *a.* 20 g potassium iodide
  500 mL distilled water
  30 drops phenolphthalein

  *b.* 20 g potassium chloride
  500 mL distilled water
  30 drops bromthymol blue (adjusted green)



- The odor of chlorine may be observed at the anode if sodium chloride is substituted for sodium sulfate as the electrolyte in the electrolysis solution. Based on their standard reduction potentials, oxidation of chloride ion to chlorine ($E^o = -1.36$ V) is less favorable than oxidation of water to oxygen ($E^o = -1.23$ V). However, there is a significant overvoltage for oxidation of water, and oxidation of chloride competes with oxidation of water under typical electrolysis conditions. Although the cause of the overvoltage is poorly understood, it is generally believed to be due to a kinetically slow reaction at the anode.

## Discussion

When an electric current is passed through an aqueous solution containing an electrolyte ($Na_2SO_4$), 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 the hydrogen atoms to elemental hydrogen ($H_2$) occurs at the cathode (–), while oxidation of the oxygen atoms in water to elemental oxygen ($O_2$) occurs at the anode (+). Each half-reaction is accompanied by the production of $OH^-$ or $H^+$ ions as shown below:

$$\text{Cathode: } 4e^- + 4H_2O \rightarrow 2H_2(g) + 4OH^-$$

$$\text{Anode: } 2H_2O \rightarrow O_2(g) + 4H^+ + 4e^-$$

At the cathode the excess $OH^-$ will cause the pH to increase, resulting in a color change of the universal indicator solution from green (neutral, pH 7) to purple (basic, pH ≥ 10).

At the anode the excess $H^+$ will cause the pH to decrease, resulting in a color change of the universal indicator solution from green to an orange/red color (acidic, pH ≤ 4). The electrolysis half-reactions can also be followed by observing the production of gas bubbles at the cathode ($H_2$) and anode ($O_2$).

Universal indicator is an acid–base indicator that is different colors at different pH values. All colors will be visible in the Petri dish as electrolysis progresses and as the pH conditions continually change due to diffusion and neutralization.

| pH | Color |
|---|---|
| 4 | red |
| 5 | orange |
| 6 | yellow |
| 7 | green |
| 8 | blue/green |
| 9 | dark blue |
| 10 | purple |

## Connecting to the National Standards

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

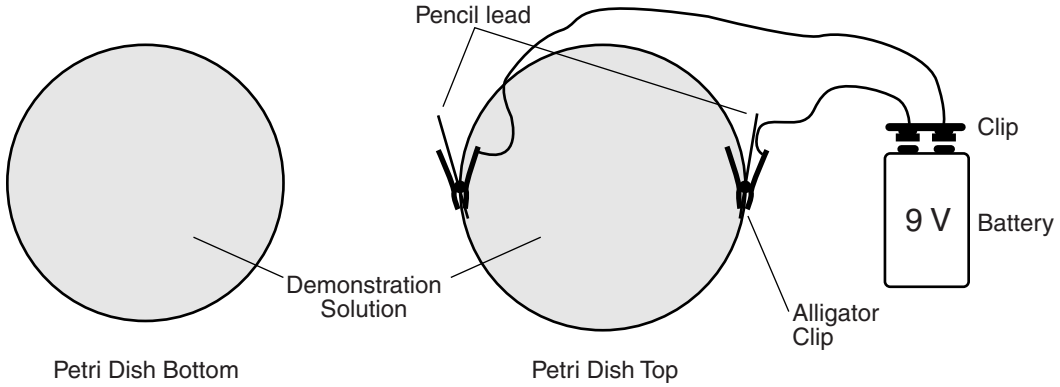
***Unifying Concepts and Processes: Grades K–12***
Systems, order, and organization
Evidence, models, and explanation
***Content Standards: Grades 5–8***
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter, transfer of energy
***Content Standards: Grades 9–12***
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions, interactions of energy and matter



## Answers to Worksheet Questions

1. Draw a diagram of the set-up for this demonstration.




2. Describe the color changes that occurred.

   *The solution around the cathode quickly turned purple. Slowly, the solution around the anode turned orange. A variety of other colors eventually appeared at both ends.*

3. When an electrical current is passed through a solution containing an electrolyte, water molecules are broken down into hydrogen and oxygen. Write a chemical equation for each of independent half-reactions that occurred.

   *a.* At the cathode: water breaks down into elemental hydrogen

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

   *b.* At the anode: water breaks down into elemental oxygen

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

4. In which of the two reactions did oxidation occur? In which did reduction occur? Explain.

   *Oxidation occurred at the anode, where the oxygen atoms in the water released electrons. Reduction, therefore, occurred at the cathode, where the hydrogen atoms in the water gained electrons and became elemental hydrogen.*

5. Which reaction caused the solution around it to become more acidic? Which caused the solution around it to become more basic?

   *The pH of the solution around the cathode increased, becoming more basic due to the excess $OH^-$. Around the anode, the pH of the solution dropped and became more acidic, due to the excess $H^+$.*

## Acknowledgment

Special thanks to Mike Shaw, West Stokes High School, King, NC for this demonstration idea.

## The *Colorful Electrolysis Demonstration Kit* is available from Flinn Scientific, Inc.

| Catalog No. | Description |
|---|---|
| AP6467 | Colorful Electrolysis Demonstration Kit |

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



*Name:* _____

# Colorful Electrolysis Worksheet

## Discussion Questions

1. Draw a diagram of the set-up for this demonstration.

2. Describe the color changes that occurred.

3. When an electrical current is passed through a solution containing an electrolyte, water molecules are broken down into hydrogen and oxygen. Write a chemical equation for each of independent half-reactions that occurred.

   *a.* At the cathode: water breaks down into elemental hydrogen

   *b.* At the anode: water breaks down into elemental oxygen

4. In which of the two reactions did oxidation occur? In which did reduction occur? Explain.

5. Which reaction caused the solution around it to become more acidic? Which caused the solution around it to become more basic?