Aluminum Air Battery

Introduction

Batteries provide electricity for nearly every small electrical device in the home—from flashlights to power tools. The composition of a battery depends on the purpose for which it will be used. Some batteries, such as those in an artificial pacemaker, need to operate for a very long time. Other batteries need to be reliable and ready to supply electricity at any time, even after several years of storage.

Concepts

- Battery
- Oxidation–Reduction
- Voltage
- Current

Background

A battery is an electrochemical cell known as a *galvanic cell*. In a galvanic cell, a spontaneous chemical reaction releases energy in the form of electricity (moving electrons). The chemical reaction that generates electricity in a battery is known as an oxidation–reduction reaction. *Oxidation* is a term used to describe when a substance loses electrons. *Reduction* describes a process in which a substance gains electrons. When a substance is oxidized and loses electrons, the resulting oxidized species becomes more positive. In a typical "wet cell" battery, the oxidized substance is converted from a neutral metal atom into a metal cation, or an ion with a positive charge. During reduction, a substance gains electrons and becomes more negative. Again, using the "wet cell" battery example, the reduced substance is a metal cation that gains electrons to become a neutral metal atom.

To create a battery that provides electrical energy, a galvanic cell must be produced. The battery must have a substance that will be oxidized at one electrode, a substance that will be reduced, and a "salt bridge" that separates the two substances. The salt bridge contains an electrolyte (dissolved ions) that allows for the flow of ions between the two substances. When the two electrodes are connected together with a conductive wire, the electrons generated at the oxidized electrode (also known as the *anode*) flow toward the reduced electrode (known as the *cathode*) along the conductive wire. In the process of moving through the wire, the electrons can provide energy to materials connected between the two electrodes. This "electron energy" is more commonly referred to as electricity. During the spontaneous oxidation–reduction reaction, excess positive and negative charges can build up on the anode and cathode side, respectively. The "salt bridge" prevents the buildup of excess charge at the two electrodes. Without the salt bridge, the charge buildup at the electrodes would prevent the oxidation–reduction reactions from continuing (see Figure 1).

The name "dry cell" battery is a slight misnomer since this type of battery is not entirely dry. A modern 1.5-volt "alkaline" battery consists of a zinc anode (a granulated zinc mixture), and a moist cathode paste consisting of carbon (graphite), manganese dioxide (MnO_2), and sodium hydroxide (NaOH). The anode and cathode are separated by a paper sheath soaked in a concentrated sodium hydroxide solution. This mixture provides a spontaneous electrochemical reaction when zinc is oxidized to generate electrons, and the manganese dioxide is reduced. The carbon electrode provides a surface on which reduction occurs. Carbon is called an inert electrode because it is not consumed during the reactions.

The dry cell battery constructed during this lab is an aluminum–air battery. Aluminum foil will be oxidized at the anode, while oxygen from the air is reduced at the cathode. Activated charcoal provides the surface for reduction to occur (just as in an "alkaline" battery), and because of its very finely divided nature, resulting in many air pockets, it also supplies the oxygen. In order for the reactions to proceed, an aqueous (water) environment is needed, so the materials must be damp. A piece of electrolyte-soaked paper towel will be used as the "salt bridge" to separate the anode from the cathode and allow for the flow of ions.

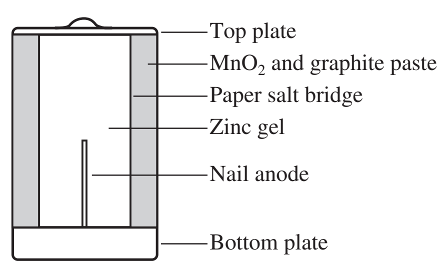

Figure 2. Typical Dry Cell (alkaline) Battery Diagram

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Materials

Aluminum foil, 15 cm × 15 cm piece
Charcoal, activated, 10–15 g
Graphite rod, 1
Sodium chloride solution, NaCl, saturated, 50 mL
Beaker, 100-mL
Connector cords with alligator clip leads, 2
DC motor
Forceps
Gloves, disposable
Multimeter
Paper towel
Pipet, disposable
Scoop or spatula
Weighing dish

Safety Precautions

Charcoal is a flammable solid. Keep away from flames. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Be sure all circuit connectors and work surfaces are dry before conducting the experiments. Do not touch any part of the circuit with wet hands. Wash hands thoroughly with soap and water before leaving the laboratory. Please follow all laboratory safety guidelines. Please review current Safety Data Sheets for additional safety handling and disposal information.

Dry Cell Construction

1. Obtain a paper towel, pipet, and a 15 cm × 15 cm sheet of aluminum foil.
2. Place the aluminum foil sheet flat on the tabletop. Fold the paper towel into quarters and center it on the aluminium foil.
3. Obtain approximately 50 mL of saturated sodium chloride solution in a 100-mL beaker.
4. Using the disposable pipet, add the saturated sodium chloride solution to the paper towel. Wet the entire paper towel.
5. Obtain the red connector cord with alligator clips and the graphite rod. Attach the red alligator clip to the graphite rod.
6. Place the graphite rod in the center of the wet paper towel. See Figure 3.
7. Obtain approximately 10–15 g of activated charcoal from the chemical dispensing station. Place the activated charcoal into a weighing dish or 400-mL beaker. *Note:* Be careful! Activated charcoal powder will easily create a black mess on skin, clothing, and the tabletop. Scoop and pour this material slowly and in small quantities.
8. Using a scoop or spatula, carefully cover the graphite rod in the center of the paper towel with the activated charcoal (see Figure 3).

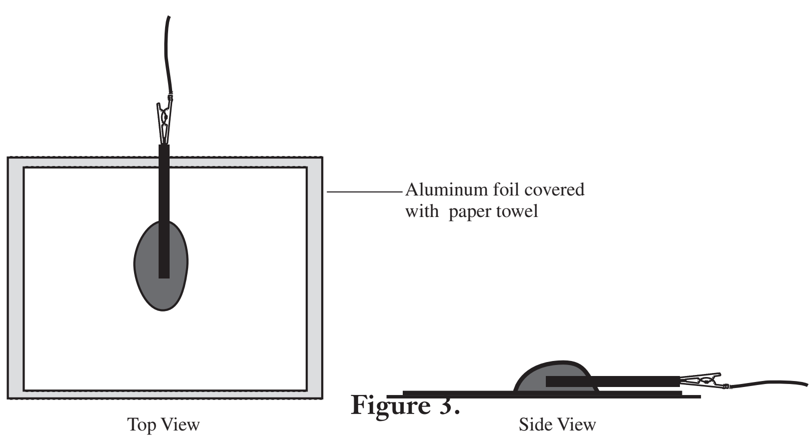

Figure 3.

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9. Carefully fold the aluminum foil and paper towel in half as shown in Figure 4. *Note:* Be sure the paper towel stays between the aluminum foil and the activated charcoal.

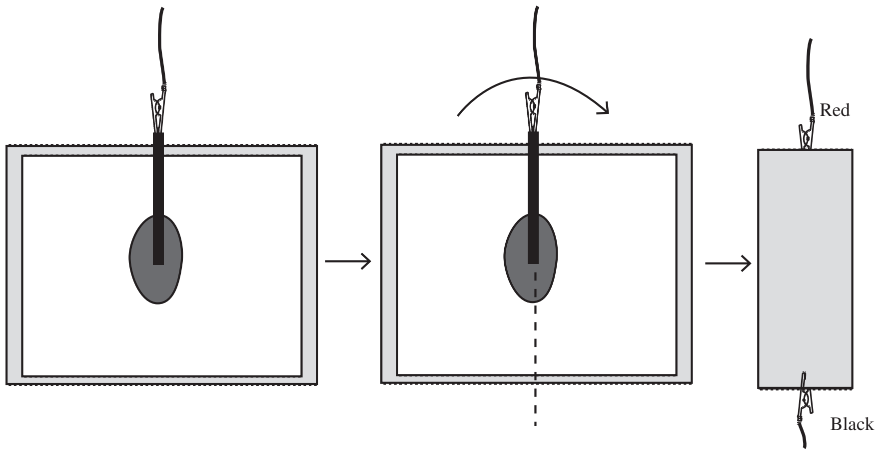

Figure 4.

10. Obtain the black connector cord.
11. Clip one end of the black connector cord to the aluminum foil. (See Figure 4.)
12. Using a multimeter, the voltage and current can be recorded.

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. Sodium chloride solution may be disposed of according to Flinn Suggested Disposal Method #26b. Activated charcoal may be disposed of in the trash according to Flinn Suggested Disposal Method #26a. The graphite rod may be rinsed with water, dried and stored for future use.

Teaching Tips

- If lightbulbs and sockets are available, have students attempt to light them with the aluminum air battery. Some questions for the students: How many batteries will it take to light the lightbulb? What is the best battery configuration (series or parallel) of lighting the lightbulb with the fewest batteries? What seems to be the most important factor to get a lightbulb to glow—the voltage or the current?
- The half reactions for the aluminum–air battery are as follows:

  $Al(s) \rightarrow Al^{3+}(aq) + 3e^-$; $E^o = 1.66$ V (oxidation half-reaction)

  $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$; $E^o = 0.40$ V (reduction half-reaction)

  The overall cell potential is positive, which means the electron transfer reaction will be spontaneous, with a theoretical value of 2.06 V.
- Do not store the aluminum air batteries. The reactions will continue and slowly dissolve the metal alligator clip. Be sure to disassemble the batteries after the lab.
- *Build a Dry Cell Battery—Student Laboratory Kit* (Flinn Catalog No. AP6925) is a great extension to this activity.

References

Aluminum Air Battery, Foiled Again. Web. 17 July 2002. <http://www.exo-net/~pauld/activities/AlAirBattery/alairbattery.html>.

Tamez, Modesto and Julie H. Yu. “Aluminum-Air Battery.” Journal of Chemical Education December 2007: 1936A–1936B.

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The *Build a Dry Cell Battery—Student Laboratory Kit* is available from Flinn Scientific, Inc.

Catalog No.	Description
AP6925	Build a Dry Cell Battery—Student Laboratory Kit
C0047	Charcoal, Powder, Activated, 500 g
A0019	Aluminum, Foil, 120 wide × 259 long Roll
S0236	Sodium Chloride Solution, Saturated, 500 mL
AP6321	Connector cords, Alligator Clips, Both Ends, Red
AP6041	Motor, DC
AP9248	Lightbulb, Miniature, 1–2V
AP9058	Receptacles, Lamp, Plastic
AP4639	Multimeter, Student

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