JOURNAL OF CHEMICAL EDUCATION

Laboratory Experiment

pubs.acs.org/jchemeduc

An Easy-To-Assemble Three-Part Galvanic Cell

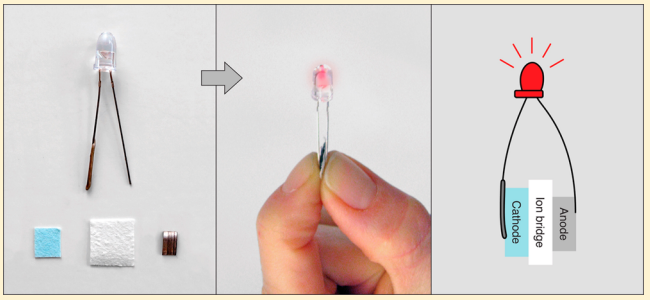
Per-Odd Eggen*,† and Brit Skaugrud‡

†Programme for Teacher Education, Norwegian University of Science and Technology, 7491 Trondheim, Norway

‡Department of Chemistry, University of Oslo, 0315 Oslo, Norway

Supporting Information

ABSTRACT: The galvanic cell presented in this article is made of only three parts, is easy to assemble, and can light a red light emitting diode (LED). The three cell components consist of a piece of paper with copper sulfate, a piece of paper with sodium sulfate, and a piece of magnesium ribbon. Within less than 1 h, students have time to discuss the function of the main battery parts, construct the cell, and test it with a LED. This low cost laboratory activity is suited to most general chemistry curricula.



KEYWORDS: *High School/Introductory Chemistry, Hands-On Learning/Manipulatives, Laboratory Instruction, Student-Centered Learning, Electrolytic/Galvanic Cells/Potentials, Electrochemistry*

Homemade batteries demonstrate how chemical energy can be converted to electrical power, and many such batteries or single galvanic cells have been designed for educational purposes.[1−5] This article describes how students can make a simple galvanic cell and use it to light a light emitting diode (LED). This galvanic cell, which contains only three parts, can be assembled in a few minutes. Most students will also be able to draw a cross-section of this cell in their reports.

Galvanic cells consist of three main parts: (1) the anode or negative electrode, (2) the cathode or positive electrode, and (3) the ionic conductor or the electrolyte that separates the electrodes.[6] Despite its simplicity, students struggle to understand how such cells work.[7−9] To support understanding, we have designed a cell consisting of only these three items, which can easily be built by a student. When assembled correctly, the battery will light a LED. The three components of the cell are a piece of magnesium metal and two pieces of soaked filter paper, one containing copper ions and one containing an inert salt solution.

EXPERIMENTAL OVERVIEW

In this lab, students assemble a working galvanic cell. A student handout and instructor notes are available (see Supporting Information). Students in groups of three or four should perform the exercise, and the experiment can be run in a 1 h laboratory session. Besides constructing the cell, the main purpose is to initiate discussion and reasoning about the function of each cell component. Within 1 h, each student can make several attempts to construct the cell and discuss their results with the group members or the teacher.

EXPERIMENTAL DETAILS

Preparations and Assembly

To make the cell components, one piece of filter paper is soaked with sodium sulfate solution and another with copper sulfate solution and then dried. The dried filter papers can be cut into pieces between $^1/_2$ and 1 cm^2. The third part of the cell is a piece of magnesium ribbon. The sodium sulfate paper piece is used to make the ion bridge and should be larger than the piece of copper sulfate paper to avoid inadvertent contact between the galvanic cell components, as can be seen in Figure 1.

The positive terminal of the LED used for testing the cell should be covered with an inert, conductive material to avoid a reaction between the terminal metal and the copper sulfate. An easy way of coating the terminal is using conductive glue or tape. We prefer conductive epoxy glue with silver, but other types have also shown to work well. The cell should be assembled as shown in the abstract graphic and to the right in Figure 1. The battery can be assembled by squeezing it gently between two fingers. An alternative way of assembling the battery is shown in in the instructor notes (Supporting Information). Notice that the positive LED terminal must be attached to the battery cathode, which is the copper sulfate paper, and the negative terminal must be attached to the magnesium anode. LEDs only light with correct electrical polarity, and to distinguish the terminals, the positive terminal is made longer. More details for how to construct this cell are given in the instructor notes of the Supporting Information.

DOI: 10.1021/ed500726y
J. Chem. Educ. XXXX, XXX, XXX−XXX

Figure 1. Three galvanic cell components and a LED shown separate (to the left) and oriented for assembly (to the right). The three cell components are (from the left) a piece of paper with copper sulfate, a piece of paper with sodium sulfate, and a piece of magnesium ribbon. Notice that the positive terminal of the LED is coated with a conductive glue.

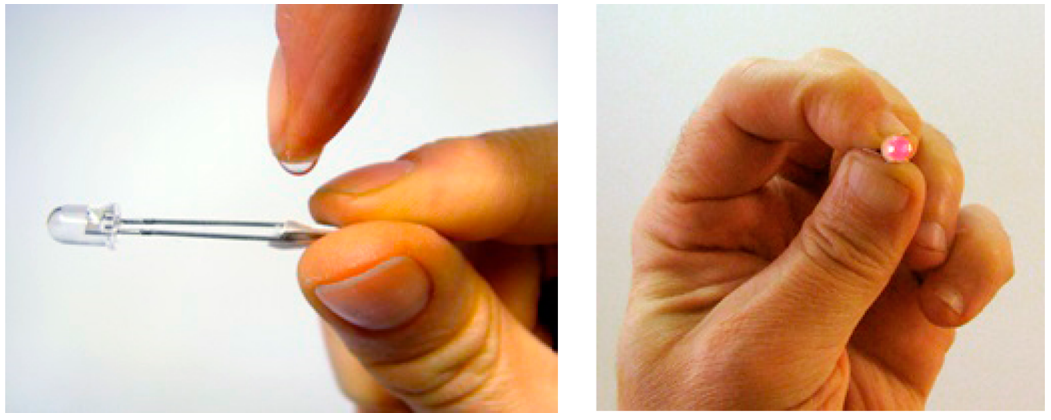


Figure 2. When a drop of water is added, the LED will glow.

Testing the Cell

When the cell is assembled and connected to the LED, one drop of water must be added to make the cell work and the LED glow. A convenient way of wetting the cell is to dip a finger into water and then transfer a drop from the fingertip to the filter paper as shown in Figure 2. Adding too much water will damage the cell.

To see the light of the LED clearly, one should look directly toward the end of the bulb as seen in Figure 2.

■ HAZARDS

Copper sulfate is a respiratory irritant and harmful if swallowed.

■ RESULTS AND DISCUSSION

Since this galvanic cell is made of very simple and cheap materials, students have the opportunity to make several attempts if they struggle to assemble it correctly. This also allows time to discuss the function of the battery components. We recommend letting the students figure out about how to assemble the battery instead of giving a detailed description, but with one warning that adding more than one drop of water may "drown" the battery.

The anode of this cell is magnesium, which reacts spontaneously with water. This can of course be discussed in class, but in our opinion, only the main cell reaction (where copper ions are reduced) needs to be dealt with at introductory courses. At higher levels, the competing reactions occurring can be discussed.

When a drop of water is added, the voltage of this cell is typically 2.0−2.1 V, which is sufficient to make a red LED glow, but the voltage may be too low for other LED colors. We therefore recommend using clear, red LEDs in this experiment.

Many illustrations of modern batteries show the three-layer construction with a separator between the anode and the cathode. The cell presented in this article has a similar structure, which might be an advantage when learning about modern batteries. The chemistry involved in this experiment is not discussed in detail as this can be found in any general chemistry book, but some comments to possible reactions are given in the instructor notes (Supporting Information).

■ SUMMARY

This laboratory experiment can be used as an uncomplicated, low cost starting point when introducing students to galvanic cells. The time saved compared to conducting more sophisticated experiments may be used to reason about the function of the cell components and compare with illustrations of modern batteries. The limited waste makes it an environmentally preferable experiment, and the materials used make few demands on classroom and safety precautions.

■ ASSOCIATED CONTENT

Supporting Information

Instructor notes and student handouts. This material is available via the Internet at http://pubs.acs.org.

DOI: 10.1021/ed500726y
J. Chem. Educ. XXXX, XXX, XXX−XXX

AUTHOR INFORMATION

Corresponding Author

*E-mail: per.eggen@plu.ntnu.no.

Notes

The authors declare no competing financial interest.

ACKNOWLEDGMENTS

The authors are grateful to Kjersti Hansen Eggen for contributions to the graphical abstract.

REFERENCES

(1) Furian, P. Y.; Krupa, T.; Naqiv, H.; Anderson, K. An Open-Ended Project: Building a High Performance, Yet Simple, Household Battery. *J. Chem. Educ.* **2013**, *90*, 1341−1345.

(2) Smith, M. J.; Fonseca, A. M.; Silva, M. M. The Lead−Lead Oxide Secondary Cell as a Teaching Resource. *J. Chem. Educ.* **2009**, *86*, 357−359.

(3) Muske, K. R.; Nigh, C. W.; Weinstein, R. D. A Lemon Cell Battery for High-Power Applications. *J. Chem. Educ.* **2007**, *84*, 635−638.

(4) Tamez, M.; Yu, J. H. Aluminum−Air Battery. *J. Chem. Educ.* **2007**, *84*, 1936A−1936B.

(5) Grønneberg, T.; Kvittingen, L.; Eggen, P. Small-Scale and Low-Cost Galvanic Cells. *J. Chem. Educ.* **2006**, *83*, 1201−1203.

(6) *Linden's Handbook of Batteries*, 4th ed.; Reddy, T. B., Ed.; McGraw-Hill, Inc.: New York, 2011; p 1.3.

(7) Sanger, M. J.; Greenbowe, T. J. Students' Misconceptions in Electrochemistry: Current Flow in Electrolyte Solutions and the Salt Bridge. *J. Chem. Educ.* **1997**, *74*, 819−823.

(8) Özkaya, A. R. Conceptual Difficulties Experienced by Prospective Teachers in Electrochemistry: Half-Cell Potential, Cell Potential, and Chemical and Electrochemical Equilibrium in Galvanic Cells. *J. Chem. Educ.* **2002**, *79*, 735−738.

(9) *Chemical Education: Towards Research-Based Practice*; Gilbert, J. K., De Jong, O., Rosaria, J., Treagust, D., Van Driel, J. H., Eds.; Kluwer Academic Publishers: Dordrecht, The Netherlands, 2002; pp 317−337.

DOI: 10.1021/ed500726y
J. Chem. Educ. XXXX, XXX, XXX−XXX