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Electrolysis with Coin-Shaped Li-MnO_2 Battery as a Student Experiment

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Abstract

A quantitative electrolysis reaction using a coin-shaped Li-MnO_2 battery (CR-2032) was studied to develop a simple, inexpensive, and small-scale experiment. The method and the result of the electrolysis of copper (II) sulfate in aqueous solution will be presented in this paper.

Introduction

High school students learn about electrolysis in chemistry to become familiar with oxidation-reduction reaction and as an example of stoichiometry. Usually, many teachers and chemistry textbooks use "Hoffman Electrolysis Apparatus" as shown in Fig. 1 [1, 2, 3]. But this apparatus is expensive, large-scale, and bulky for storage. In addition, there are other devices we have to prepare for students' lab work of electrolysis *e.g*. DC supply such as large power-supply units or dry batteries connected in series [4].

Fig.1 Hoffman Electrolysis Apparatus

The coin-shaped Li-MnO_2 batteries are commonly used in our daily lives as power supply of remote controllers, backup memories of the appliances, electronic dictionaries, clocks, kitchen alarms and the keyless entry system of cars. The battery is inexpensive and easy to use. The voltage of the Li-MnO_2 battery is 3.0 V, which is advantageous in comparison with 1.5 V of a manganese dry battery and an alkali manganese dry battery. With these advantages, "LED mini light" and new science class activities were developed by Kamata.[5,6].

Fig.2 CR2032

In this study, a coin-shaped Li-MnO_2 battery CR-2032 (ϕ 20.0 mm x 3.2 mm, Fig. 2) was immersed directly into aqueous solution of copper (II) sulfate, and made copper deposited on the surface of the cell.

Theoretical Background

When electrolysis of copper (II) sulfate is conducted in aqueous solution, copper deposits as metal on the surface of cathode, and oxygen gas evolves on the surface of anode as following reaction.

$$2\ CuSO_4 + 2\ H_2O \ \text{--->}\ O_2 + 2\ Cu + 2\ H_2SO_4$$

In high school chemistry, students learn two concepts from electrolysis. One is oxidation-reduction reaction. The other one is stoichiometry.

The phenomenal change in this reaction can be easily observed on the surface of each electrode. Copper deposits on cathode and oxygen gas bubbles evolve on anode as shown below.

$$Cu^{2+} + 2\ e^- \ \text{--->}\ Cu$$

$$2\ H_2O \ \text{--->}\ O_2 + 4\ e^- + 4\ H^+$$

Theoretical molar ratio of O_2 : Cu is 1 : 2. The amount of evolved oxygen can be determined by measuring its volume, and the copper deposited can be determined by measuring the weight change of the anode before and after the reaction.

Experimental Method

1. 30 mL of 1.0 mol / L aqueous solution of copper (II) sulfate was put into a 50 mL beaker.
2. Plastic syringe, medical tap for infusion, silicone tube and plastic funnel were assembled as shown in Fig. 3, which was used to collect bubbles of oxygen evolved in the reaction.
3. Mass of coin-shaped Li-MnO_2 battery (CR2032) was measured using a balance with an accuracy of 0.1mg. When it was put in the beaker containing copper (II) sulfate solution, the reaction started (Fig. 4).
4. The gas-trapping device was placed over the battery. First, drawing the air that filled the silicone tube into the syringe, the silicone tube was filled with the solution. Then, after the valve was closed, the syringe was detached and expelled the air.
   Then the syringe was reattached to the tube and the valve was reopened (Fig. 5).
5. The reaction was kept on for 10 minutes. The funnel of gas-trapping device was placed over CR2032 for this period.
6. The bubbles of oxygen evolved for this 10 minutes were drawn into the syringe(Fig. 6) and the volume of the bubbles was measured.
7. After taking out the battery CR2032 from the solution, it was carefully washed and dried so that the copper deposited on its surface did not come off.
8. The mass of the battery CR2032 after the reaction was measured with an even balance. The mass of the deposited copper was determined by measuring the weight change before and after the reaction.

Fig. 3　Gsa–trapping device

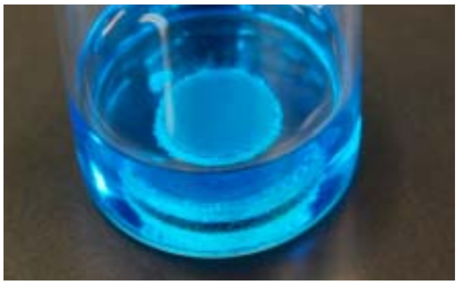

Fig. 4　Aspect of reaction

Fig. 5　Bubble–trapping

Fig. 6　Measuring volume

Fig. 7　Cathode surfaces (before/after reaction)

Table 1　Results obtained by students

group No.	O_2 / mL	O_2 / 10^{-5} mol	Cu / mg	Cu / 10^{-5} mol	molar ratio O_2 / Cu
1	1.07	4.45	6.1	9.6	0.46
2	1.40	5.82	5.1	8.0	0.73
3	1.30	5.40	5.6	8.8	0.61
4	1.25	5.20	5.8	9.1	0.57
5	1.10	4.57	5.1	8.0	0.57
6	1.21	5.03	6.6	10.4	0.48
7	1.20	4.99	5.1	8.0	0.62
Average (except 2)	1.19	4.94	5.7	9.0	0.55

Result and Discussion

While the battery was immersed in the solution, the bubbles were observed on the anode side of battery as shown in Fig. 4. When a burning incent stick was put into the accumulated gas, students were able to recognize that the gas enhanced the combustion and that the gas was oxygen. Deposition of copper was observed on the cathode of the battery as shown in

Fig.7. Each product is identified and the stoichiometry of this electrolysis is discussed.

The experimental results of a certain class are shown in Table 1. When this proposed experiment was carried out by teacher, the ratio of the products agreed with stoichiometry within a small error. When the same experiments were carried out by students, the O_2 volumes were sometimes low. However, after they practiced the experiment, the accuracy of the results was improved.

From these results, it has been demonstrated that the proposed electrolysis experiment is quantitatively available.

Conclusion

This study proposes a new method of an inexpensive and quantitative electrolysis experiment as a simple and small-scale method alternative to the "Hoffman Electrolysis Apparatus." The proposed experiment for students can be useful in high school chemistry.

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