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• ***Учебни опити и демонстрации*** •
• ***Teaching Chemical Experiment*** •

ELECTROCHEMICAL WRITING AND PRINTING: OVERHEAD PROJECTOR DEMONSTRATION

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Abstract. One of the most difficult subjects for students is the concept of oxidation-reduction. The terms "oxidizing" and "reducing agent" are hard to understand and usually mixed-up by students. Electrochemistry experiments could be helpful in making easier to understand this subject. There are many experiments that demonstrate electrolysis phenomena. However, the experiments we propose are simple, cheap and could be applied in any level of chemical education starting from a kindergarten up to the university level. Electrochemical writing is an electrolysis experiment which shows writing with an electrode (metal) on a paper soaked with an appropriate electrolyte solution in a close current circuit. For performing electro-printing experiments, various coins and other metallic objects are collected. Then, a square piece of aluminum foil is cut and placed on the top of a rubber surface (rubber sheet). Quantitative (smooth) filter papers are placed on the aluminum foil and soaked with different kinds of solutions: aqueous solutions of ammonia, potassium hexacyanoferrate(II), potassium tiocyanate, potassium iodide or solutions of sodium sulfate with different acid-base indicators (including natural red cabbage indicator).

Keywords: electrochemical writing; colors electrochemical experiments.

Introduction

The concept of oxidation-reduction is found to be one of the main difficult subjects especially for high school students. Therefore, many electrochemical experiments are proposed as educational tools in variety of articles [1,2] and textbooks [3-6].

Many times it has been proven that an interesting experiment is a strong tool which reinforces chemistry lectures and keeps student's attention focused on the topic. To the best of our knowledge, there is one electrochemical writing experiment published by Harris [7] and its Internet version [8]. This experiment describes writing on a paper soaked with an aqueous solution of KI and phenolphthalein and taped to a backing of Al foil. Using a copper wire hooked up to a battery, one can write on the filter paper. Switching the wire causes the writing to become another color. In addition to well-known experiments, our work presents an experiment of electrochemical reactions on overhead projector as a demonstration experiment.

Opportunities for inventing new reactions as demonstration experiments of the electrochemical writing are given and are limited with two groups. The first group reactions are characterized with a colored product of the reaction. The second group of chemical reactions is the one followed by changes in concentration of hydrogen ions and which results in color change of acid — base indicator.

Experimental

Equipment and chemicals. The following equipment and chemicals are needed for the demonstration:

- an overhead projector
- a Petrie dish (Fig. 1a)
- electric cords with crocodile clips (Fig. 1b)
- electric power source of direct current with variable voltage or battery Fig. 2
- aluminum foil
- filter paper
- different coins
- metallic objects (keys etc.)
- gelatine
- aqueous solution of hexacyanoferrate (0,1 mol dm^{-3})
- aqueous solution of tiocianate (0,1 mol dm^{-3})
- aqueous solution of potassium iodide (0,1 mol dm^{-3})
- aqueous solution of sodium sulfate (0,1 mol dm^{-3})
- ethanol solution of phenolphthalein
- different indicators

The equipment is presented on Fig. 1 and 2.

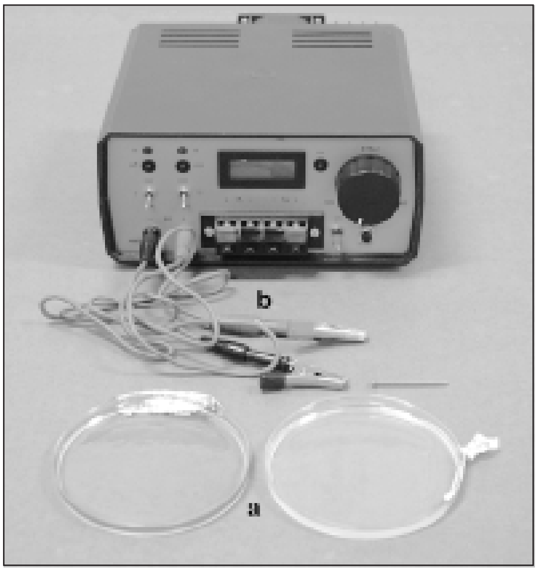

Figure 1. Apparatus for performance of the experiment with electric power source of direct current with variable voltage: Petrie dishes with gel (a); electric cords with crocodile clips (b)

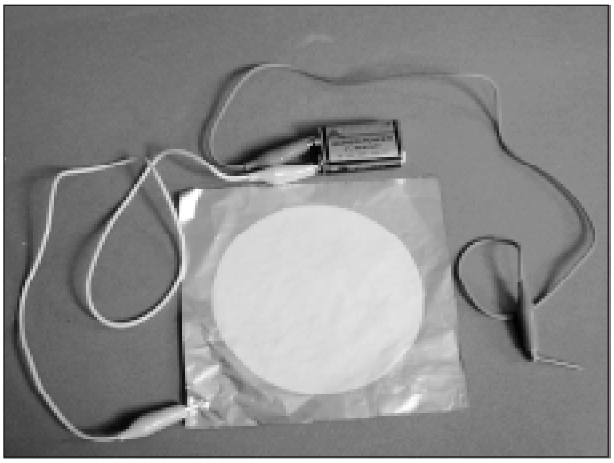

Figure 2. Apparatus for performance of the experiment with a battery

Experimental work includes two parts:

a) Development of experiments for overhead projector demonstrations

For preparation of gels: 25 mL of aqueous solutions and 2 grams of gelatin are used. This mixture is left in a beaker for about ten minutes and then heated for preparation of a transparent liquid. Stirring is applied during the heating. The liquid is placed in a Petrie dish with a piece of aluminum, covered and left for at least three hours in a fridge. Solutions that were used for gel preparations are: a solution of potassium hexacyanoferrate(II) and sodium chloride (c = 0,1 mol.dm^{-3}; a solution of potassium tiocianate (c = 0,1 mol M dm^{-3}), citric acid and sodium chloride; a solution of sodium sulfate (c = 0,1 mol M dm^{-3}) and 0,1% ethanol solution of phenolphthalein.

The setup is shown on the Fig. 3.

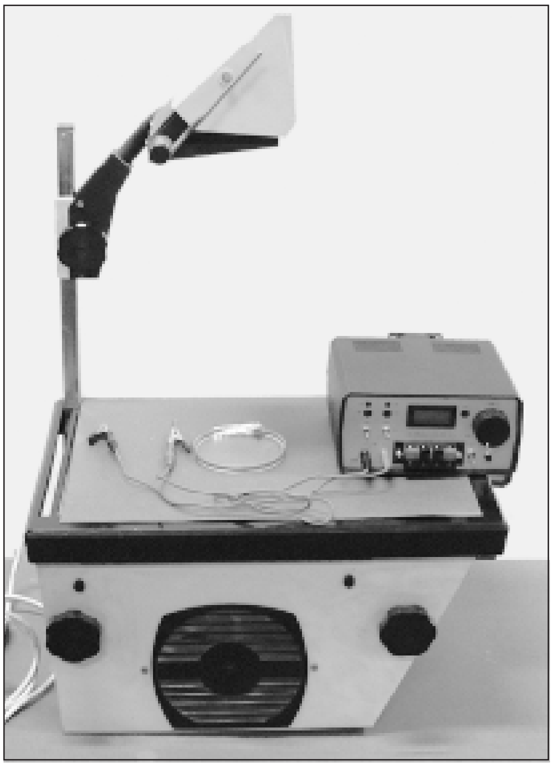

Figure 3: Set up for demonstration of the experiment on overhead projector

Iron nail and aluminum electrode are connected to the electrical power source. Iron nail is connected as anode and aluminum as a cathode. Stain appears after a gentle touch of the gel surface.

Instead of iron nail metal objects like keys, coins, and others can be used and the result will be printing on the surface of the gel. In the case of coins printing mirror feature is the result.

b) Research part

Filter papers are soaked in following solutions: potassium hexacyanoferrate(II), potassium tiocyanate, potassium iodide, potassium dichromate, ammonium hydroxide or in solutions of sodium sulfate with different acid-base indicators.

One can write on the filter paper by using different metals such as copper, iron, cobalt, nickel, and bismuth hooked up to the power source or can print metal textures according to the previously explained method.

Discussion

A) Writing on:

Potassium hexacyanoferrate(II) gel with iron anode leaves a blue mark which is a result of formation of ferric hexacyanoferrate(II) known as Prussian blue.

Potassium tiocianate gel with iron anode leaves a red mark that is a result of formation of ferric hexatiocyanate ions;

Phenolphthalein gel with iron anode leaves a red mark that is a result of formation basic media (Fig 4).

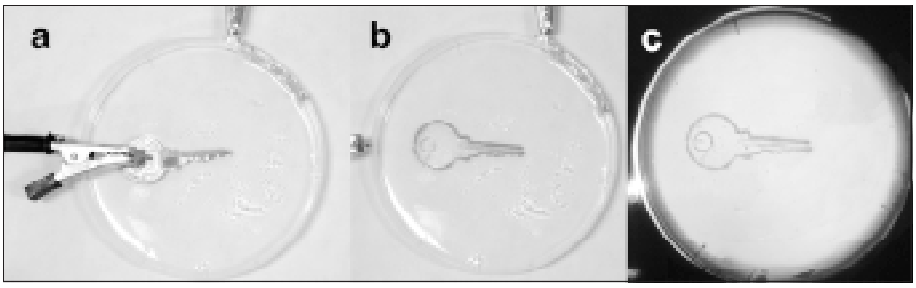

Figure 4. Experiment with phenolphthalein gel: key anode (a), mark obtained after some time (b), projection (c)

In general, metal anode generates cations as a result of oxidation process.

(1) $$M \rightarrow M^{x+} + xe^{-}$$

Generated cations react with salt anions and gives colored compounds.

In another case, electrolysis of the solutions occurs and thus pH value is changed which results in indicator color change.

B) Different colored marks appear by writing chemical symbols of used metals on filter papers soaked in appropriate solutions (Fig. 5, 6 and Fig 7).

Marks of different colors on filter paper soaked with different kind of indicators are observed and are given in the following table:

Table 1

Observed color changes are due to the pH changes.

Prints of different coins are shown on Fig. 8. The filter paper is soaked with a solution of potassium iodide. The marks of iodine are result of oxidation

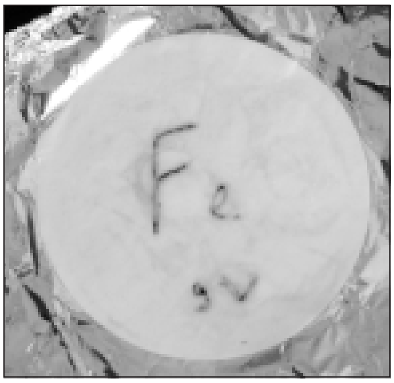

Figure 5. Marks on filter paper soaked with potassium hexacyanoferrate(II), writen with iron and copper anode

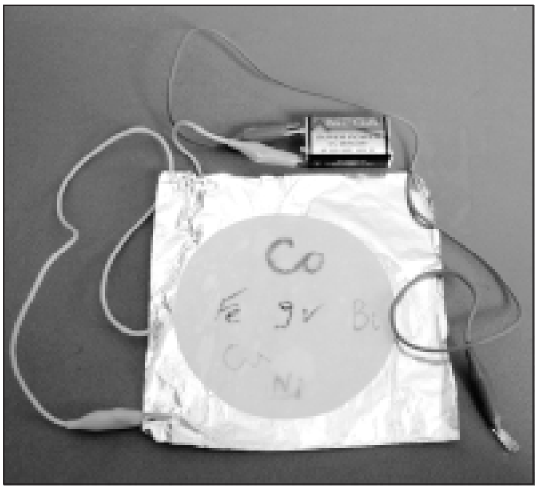

Figure 6. Marks on filter paper soaked with potassium tiocianate, writen with Fe, Cu, Ni, Co and Bi anode

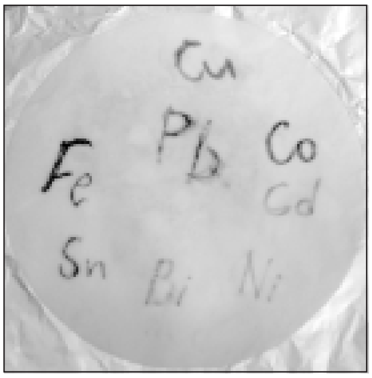

Figure 7. Marks on filter paper soaked with sodium sulfide, writen with Cd, Sn, Fe, Pb, Cu, Ni, Co and Bi anode

of iodide ions on the coins surface that has a role of anode.

Figure 8. Prints of coins (anode) on filter paper soaked with solution of potassium iodide

Conclusions

These experiments can be performed with different gels that are able to produce variety of colors. The research part allows teachers to perform research experiments together with students or to give an idea for student projects.

Due to simplicity of these experiments, chemistry teachers who are short on resources can find it very useful. Other advantages of the proposed experiments are the fact that they are fast and easy to perform, and are visible in a large auditorium.

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ЕЛЕКТРОХИМИЧНИ ОПИТИ И ДЕМОНСТРАЦИИ

Резюме. Окислително-редукционните химични процеси са трудни за преподаване и обучение. Термините „окислител“ и „редуктор“ не се разграничават лесно от учениците. С подходящи и ефектни електрохимични опити и демонстрации овладяването на тази сложна материя може да се улесни. Експериментите, описани в настоящата статия, са прости, евтини и приложими на всички образователни нива — от детската градина до висшето училище.

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