Electrochemical Clock

Scientific Method Demonstrations

Introduction

Build a simple electrochemical cell using orange juice and copper and magnesium metal. The resulting spontaneous oxidation–reduction reaction will generate enough electricity to power a battery-operated clock. What makes the clock work? How long will the clock run? What happens if the metals are reversed? Use this demonstration to promote inquiry, inspire wonder, and highlight the process of scientific discovery.

Concepts

- Scientific method
- Electrochemistry
- Metal activity

Materials

Electrochemical Clock Kit—each kit contains the following components:

Clock face with element symbols in order of atomic number 1–12

Pizza-type delivery box

Plastic cup

Electrical leads with alligator clips, 2

Clock assembly hardware (brass washer and nuts, 1/4″ and 1/8″, rubber washer)

Orange juice

Double-sided tape (1 roll)

Set of clock hands (hour hand, minute hand, second hand)

Electrodes: rectangular copper foil, zinc foil, magnesium ribbon (coiled on a craft stick)

Safety Precautions

Magnesium is a flammable solid. Avoid contact with flames and heat. Any food-grade items that have been brought into the lab are considered laboratory chemicals and are for lab use only. Do not taste or ingest any materials in the laboratory and do not remove any remaining food items after they have been used in the lab. Wear chemical splash goggles, chemical-resistant gloves, and chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

1. Assemble the clock according to the kit instructions.
2. Position the clock so that the metal electrodes will fit easily into a plastic cup or beaker.
3. Hook the rectangular piece of copper foil over one end of the cup and place the craft stick with the coiled magnesium ribbon into the other side. Do not allow the metals to touch.
4. Using a connector cord with alligator clip leads, attach the coiled magnesium ribbon to the *negative* terminal of the battery compartment in the clock.
5. In a similar manner, attach the copper strip to the *positive* terminal of the clock.
6. Set the time on the clock to correspond with the time the students will arrive.
7. To start the demonstration, pour about 250 mL of orange juice into the plastic cup or beaker.
8. Ask students to record their observations. *(The clock will immediately start running and the orange juice will begin to bubble, froth, and foam.)*
9. At this point, the students will naturally start to ask questions. Acknowledge all questions, but do not answer them. The purpose of this activity is to illustrate how these questions can lead to potential experiments, that is, to start the students on the pathway of the scientific method. The only questions you should answer are the following:
   - Can you drink the juice? Emphatically NO! You cannot eat or drink any laboratory materials.

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- What are the metals in the plastic cup?
- Is there a battery in the back of the clock?

10. Encourage students to continue asking questions until you have at least 25 questions listed on the board. Have different groups of students design an experiment to try to answer one of the questions in the list. Provide materials for this purpose, but be sure to check all students' procedures and review the safety precautions with students before allowing them to perform any experiments.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The magnesium ribbon should be left in the orange juice (or a similar acidic solution, such as 1 M hydrochloric acid) until it has completely dissolved. The orange juice waste solution may then be rinsed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Tips

- For best results, polish the magnesium and copper metal with sandpaper or steel wool before use. Rinse well with distilled water and pat dry. Alternatively, the metals may be cleaned by dipping them (briefly, in the case of magnesium) into 1 M acetic acid or vinegar.
- The zinc electrode can be used to see what difference it makes if it is used in place of either copper or magnesium in the orange juice clock.
- The orange juice clock will not run backwards; the leads must be connected correctly.

Discussion

Some of the questions that are most frequently asked by both teachers and students are:

1. Will the clock work?
2. Why does the clock work?
3. What was in the cup before the orange juice was added?
4. What are the electrodes?
5. What are the electrodes connected to?
6. Is there a battery inside the box?
7. What is inside the box?
8. Can I drink the juice after the experiment? Answer - No! (In a very loud voice)
9. How long will the clock run?
10. Does the clock keep good (correct) time?
11. Can other juices be used to run the clock?
12. Can other liquids (other than juices) be used to run the clock?
13. What is the effect of increasing/decreasing the temperature of the liquid?
14. What is the effect of increasing/decreasing the concentration of the juice?
15. What happens if the electrical connections are reversed?
16. Can other metals be used as the electrodes?
17. Can nonmetals be used as the electrodes?
18. Can more than one clock be operated, at the same time, off the same cup of juice?

19. What voltage is being generated?
20. Should the extra clocks be connected in parallel or in series?
21. Can other appliances (pieces of equipment) be operated by the cell?
22. What is the foam on top of the orange juice?
23. Has the orange juice been changed during this process?
24. What is the significance of the letters on the clock face?
25. Are the symbols of the elements arranged in any particular pattern?
26. Why are we doing this exercise?
27. Where can I get one of those clocks?
28. Where can I get a copy of the clock face?

The following explanation of the mechanism of the orange juice or electrochemical clock is provided for the teacher's information only. The magnesium electrode is the anode (negative electrode) in the orange juice electrochemical cell—magnesium metal is oxidized to Mg^{2+} ions. The copper electrode is the *cathode* (positive electrode). The copper electrode is an inert electrode—hydrogen (H^+) ions from the citric acid solution are reduced to hydrogen gas (H_2) on the surface of the electrode.

Oxidation half-reaction (anode) $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$

Reduction half-reaction (cathode) $2H^+(aq) + 2e^- \rightarrow H_2(g)$

Net reaction $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$

The magnesium ribbon dissolves over the course of the electrochemical reaction. The reaction is spontaneous and the cell is irreversible. Copper has a higher electrical potential than magnesium. When the metal conductors are connected by means of an external wire circuit (the clock), there is a positive current flow from the copper to the magnesium. *Electrons flow in the opposite direction (from the magnesium to the copper).* Within the electrochemical cell, ions carry the current through the solution. Anions move toward the anode, cations toward the cathode, to prevent charge build-up at the electrodes. The clock will not run if the polarity of the magnesium and copper electrodes is switched.

Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of mater, interactions of energy and matter
Content Standard G: History and Nature of Science, nature of scientific knowledge

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Electrochemical Clock* activity, presented by Irwin Talesnick, is available in *Scientific Method Demonstrations* and in *Using Demonstrations to Promote Inquiry*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Electrochemical Clock* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the Electrochemical Clock Kit available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
AP8718	The Electrochemical Clock Kit
C0182	Copper Strips, Pkg/6 strips
M0001	Magnesium Ribbon, 25 g

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