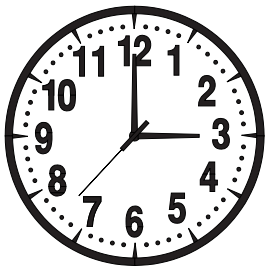
Orange Juice Clock

Electricity from a Chemical Reaction

Introduction

Build an electrochemical cell using orange juice and copper and magnesium metal electrodes. The resulting spontaneous oxidation–reduction reaction will generate enough electricity to power a battery-operated clock. Why does the clock work? How long will the clock run? What happens if the metals are reversed?



Concepts

- Electrochemistry
- Metal activity
- Cell potential
- Anode vs. cathode

Materials

Battery-operated clock
Beaker, 600-mL
Connector cords with alligator clips, 2
Copper foil or sheet, 5 mm × 30 cm
Magnesium ribbon, 30 cm
Orange juice or soda, 400 mL
Pencil
Support (ring) stand and ring
Utility clamp

Safety Precautions

Magnesium is a flammable solid. Avoid contact with flames and heat. Any food-gradeitems 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. Coil one end of the magnesium ribbon around a pencil to form a loose coil about 7 mm in diameter and 5 cm long.
2. Attach the coiled magnesium ribbon to the *negative* terminal of a battery-operated wall clock using a connector cord with alligator clips on both ends.
3. In a similar manner, coil the copper strip and attach it to the *positive* terminal of the clock.
4. Place about 400 mL of orange juice or soda in a 600-mL beaker on the base of a support stand.
5. Attach the clock to the support stand using a ring or a utility clamp and position the clock so that the metal electrodes will fit easily into the orange juice when it is time to start the demonstration (and the clock).
6. Set the time on the clock to correspond with the time the students will arrive.
7. To start the demonstration, immerse the metal electrodes into the orange juice and ask students to record their observations. *(The clock will start running and the orange juice will begin to bubble, froth, and foam.)*
8. At this point, the students will naturally start to ask questions. Use the students' questions to start an open-ended discussion of the reactions that are occurring, how the electricity is generated, etc.

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.

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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
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter, transfer of energy
Content Standard E: Science and Technology
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions, interactions of energy and matter
Content Standard E: Science and Technology

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.
- See the "Electrochemical Clock Kit" available from Flinn Scientific (Catalog No. AP8718) for a wonderful inquiry-based activity using the orange juice clock.
- See "Observations on Lemon Cells," by Jerry Goodisman, in the *Journal of Chemical Education*, Volume 78, No. 4, pp 516–518 (April 2001), for a thorough explanation of the net redox reaction and the cell potential for the orange juice electrochemical cell.

Discussion

The orange juice clock is powered by a spontaneous oxidation–reduction reaction. When the electrodes are incorporated into a closed electrical circuit, electrons flow through the external wire. An electrochemical cell that generates electricity is called a voltaic cell. In a voltaic cell, the anode is the negative electrode and the cathode is the positive electrode.

The magnesium electrode is the *anode* in the orange juice electrochemical cell—magnesium metal is oxidized to Mg^{2+} ions. The copper electrode is the *cathode*. 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 buildup at the electrodes. The clock will not run if the polarity of the magnesium and copper electrodes is switched. (The clock may run backwards, however, if there are no diodes in the circuit.)

Reference

This activity was adapted from *Electrochemistry*, Volume 17 in the *Flinn ChemTopic™ Labs* series; Cesa, I., Editor; Flinn Scientific: Batavia, IL (2005).

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

Catalog No.	Description
AP8718	Electrochemical Clock Kit

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