

## LESSON: Making a Better Nail

**Summary:** Students conduct an experiment using iron nails, a lantern battery, and zinc acetate solution to galvanize a nail. Then they read an article about the hazards associated with electroplating chromium.

**Lesson Type:** Experiment—Students collect, manipulate, and/or summarize data from an experiment or activity they conduct.

**EHP Article:** “Shiny Science: A New Substitute for Hexavalent Chromium”  
*EHP Student Edition*, November 2006, p. A482–A485  
<http://www.ehponline.org/members/2006/114-8/innovations.html>

**Objectives:** By the end of this lesson, students should be able to

1. explain the process of chemical electroplating; and
2. describe the benefits and health problems associated with electroplating chromium.

**Class Time:** 60 minutes

**Grade Level:** 9–12

**Subjects Addressed:** Environmental Sciences, Chemistry, General Science, Physical Science

### ► Prepping the Lesson (15 minutes)

#### INSTRUCTIONS:

1. Download the entire November 2006 *EHP Student Edition*, or download just the article “Shiny Science: A New Substitute for Hexavalent Chromium” at <http://www.ehponline.org/members/2006/114-8/innovations.html>.
2. Review the Background Information, Instructions, and Student Instructions.
3. Decide whether students will use reference books, the Internet, or printouts of information to help them answer the questions in Steps 9 and 12. Websites that may be useful for printouts are included in the Resources section.
4. Read the article “Shiny Science: A New Substitute for Hexavalent Chromium.”
5. Assemble the materials needed for the laboratory activity.
6. Review the material safety data sheet for zinc acetate dehydrate (a website link is in the Resources section).
7. Make copies of the *EHP Student Edition* article, Student Instructions, and Internet printouts as necessary.

#### MATERIALS

##### per student:

- 1 copy of *EHP Student Edition*, November 2006, or 1 copy of “Shiny Science: A New Substitute for Hexavalent Chromium”
- 1 copy of the Student Instructions
- Safety goggles

##### per group:

- 1 alkaline lantern battery (6 volt)
- 1 clear 10-oz plastic cup or 250-mL beaker
- 1 piece of emery cloth (medium or fine) or steel wool
- 1 100-mL graduated cylinder
- 1 galvanized nail
- 2 iron nails, 3.5” (16 penny) or larger
- Paper towels
- 1 stand



- 2 clamps
- 1 spatula or plastic knife
- 1 stirring rod
- 1 triple beam balance or equivalent
- 2 wires (each approximately 1' long) connected by alligator clips
- 2 g zinc acetate dehydrate

**VOCABULARY:**

- anode
- cathode
- electrons
- electroplating
- galvanizing
- hexavalent chromium
- ion
- nanostructures
- oxidation
- permissible exposure limit (PEL)
- reduction
- trivalent chromium

**BACKGROUND INFORMATION:**

Electroplating is a chemical process used to coat an item made of one type of metal with another metal. Many different metals can be used as the plating metal, including gold, silver, palladium, chromium, zinc, and copper. No matter what metals are used, the process involves connecting an external direct current supply of electricity to two electrodes in a solution of the metal to be plated. The metal object to be plated is always one of the electrodes and is connected to the cathode (positive terminal) of the power supply. This results in the metal in the solution being reduced to its elemental form and being deposited on the surface of the metal object being coated.

**RESOURCES:**

*Environmental Health Perspectives*, Environews by Topic page, <http://ehp.niehs.nih.gov>. Choose Metal Toxicity, Occupational Health Agency for Toxic Substances and Disease Registry (ATSDR) ToxFAQs™ for chromium, <http://www.atsdr.cdc.gov/tfacts7.html>

Finishing.com, Electroplating—how it works, <http://www.finishing.com/faqs/howworks.html>

New Jersey Department of Health and Senior Services, Hazardous substance fact sheet for zinc acetate, <http://www.state.nj.us/health/eoh/rtkweb/2022.pdf>

Occupational Safety and Health Administration, Hexavalent chromium, <http://www.osha.gov/SLTC/hexavalentchromium/index.html>

U.S. Environmental Protection Agency, Toxicological Reviews and Support Documents, Chromium(IV), <http://www.epa.gov/IRIS/toxreviews/0144-tr.pdf>

Wikipedia Online Encyclopedia

Electroplating, <http://en.wikipedia.org/wiki/Electroplating>

Galvanization, <http://en.wikipedia.org/wiki/Galvanization>

Redox, <http://en.wikipedia.org/wiki/Redox>

## ► Implementing the Lesson

---

**INSTRUCTIONS:**

1. Tell students that they are going to investigate the chemical process called electroplating.
2. Divide students into groups and pass out the lab materials, Student Instructions, website printouts (if needed), and a copy of the article “Shiny Science: A New Substitute for Hexavalent Chromium.” Have students complete the activity.
3. Have the students discuss their answers and the health problems associated with electroplating chromium.

**NOTES & HELPFUL HINTS:**

1. Depending on the background knowledge of the students, they may need to be introduced to oxidation–reduction (redox) reactions, electrons, and ions. Conducting the experiment first and then discussing the chemical and physical processes that occurred may be more engaging for the students and provide a hands-on visual reference for concepts that may otherwise be very abstract.
2. Wire and alligator clips can be purchased at electrical supply houses or hardware stores and assembled as needed.



3. The cleanliness of the surface of the nail is critical in having the zinc bond with the surface of the nail. Some electroplating procedures suggest cleaning with a strong acid (such as sulfuric acid), a strong base (such as sodium hydroxide), and a solvent (such as acetone) to remove all surface impurities. These steps were not included because of the hazards associated with these chemicals. If the nails are carefully cleaned with emery cloth or steel wool, the zinc will bond with the surface of the nail. If the zinc coating on the nail is easily wiped off, then there are problems with surface contamination that is preventing the bonding.
4. This experiment could be used as an introduction to galvanic or electrochemical cells.
5. Many other metal salts can be dissolved into solution and electroplated to other metal surfaces using this procedure; copper sulfate is often used to form a copper coating. Zinc acetate was chosen for this experiment because it is less hazardous to people and the environment than many of the other metals and their salts that might be used.
6. The zinc acetate solution used in the experiment is approximately 0.1 molar. This solution would not normally be classified as hazardous waste and could be poured down the drain. Follow your school waste disposal procedures, and contact your state department of environmental protection to verify any specific disposal restrictions.
7. The experiment could also be done as a demonstration.
8. The experiment could be expanded by having the students compare cleaned and uncleaned nails and then explain why they think one worked better than the other.
9. The nails could be held by hand in the solution rather than using a stand and clamps. Between the low direct voltage of the battery (6 volts) and the resistance of the skin (100,000 ohms dry skin or 1,000 ohms wet skin) there is little danger of electrical shock or burns. It is possible, however, given the right circumstances (wet hands with skin broken), that students might feel or perceive a current. For this reason, a stand and clamp have been recommended for holding the nails.

## ▶ Aligning with Standards

---

### SKILLS USED OR DEVELOPED:

- Communication (note-taking, oral, written)
- Comprehension (listening, reading)
- Critical thinking and response
- Experimentation (conducting)
- Manipulation
- Observation
- Technological design

### SPECIFIC CONTENT ADDRESSED:

- Electroplating
- Environmental health
- Oxidation–reduction reaction

### NATIONAL SCIENCE EDUCATION STANDARDS MET:

#### Science Content Standards

##### Unifying Concepts and Processes Standard

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

##### Science as Inquiry Standard

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

##### Physical Science Standard

- Structure of atoms
- Structure and properties of matter
- Chemical reactions
- Interactions of energy and matter

##### Science and Technology Standard

- Abilities of technological design
- Understandings about science and technology



**Science in Personal and Social Perspectives Standard**

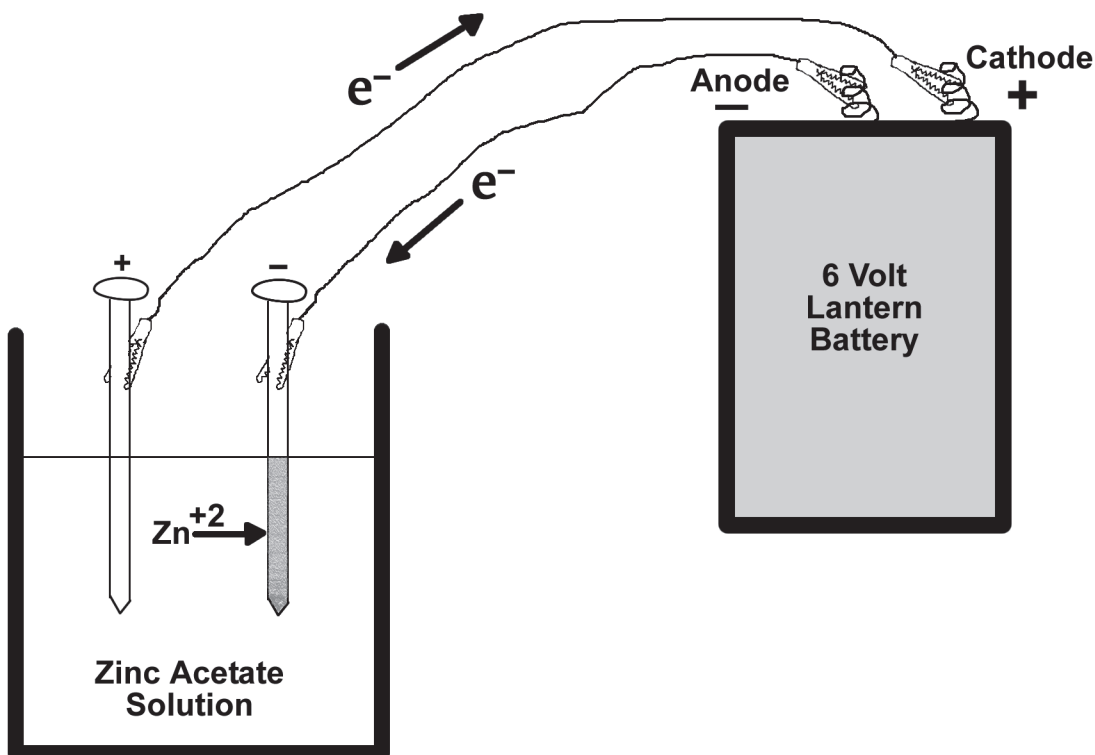
- Personal and community health
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

**History and Nature of Science Standard**

- Nature of scientific knowledge

**▶ Assessing the Lesson**

**Step 9:** Draw a diagram of the connected apparatus at the conclusion of the experiment showing the battery, wires, and what the nails looked like in the solution. Label the terminals of the battery positive (cathode) and negative (anode). Using arrows, show the direction of the flow of the electrons on your diagram. Indicate which nail has a negative charge (i.e., more electrons = reduction in charge) and which nail has a positive charge (i.e., loss of electrons). Use books, the Internet, or materials provided by your teacher to help you as needed.



**Step 10:** Describe what you observe, and explain what happened. Be sure to discuss changes in atomic charge (what was oxidized and what was reduced) and bonding that occurs.

The nail connected to the negative pole of the battery became coated with a gray substance. Zinc ions ( $Zn^{+2}$ ) in the solution moved toward the nail connected to the negative pole of the battery and got reduced to zinc metal (no charge) from the excess electrons, bonding with the surface of the nail. The iron nail connected to the positive terminal of the battery also got darker in color, probably because iron in the nail got oxidized to iron ions ( $Fe^{+2}$  and  $Fe^{+3}$ ) and dissolved into solution. The color of the water turned slightly orange, probably indicating the formation of iron compounds in solution.



**Step 11:** Wipe the ends of the nails with the paper towel. Describe what you observe, and explain what happened. Be sure to explain any errors that may have occurred to produce your result.

Some or all of the coating on the nail connected to the negative terminal of the battery may wipe off, indicating the zinc did not bond with the surface of the nail. This happens because the surface of the nail is contaminated with impurities such as dirt, oil, rust (i.e., oxidized iron), or another substance that prevents the zinc from bonding.

**Step 12:** Examine the galvanized nail. Explain what it means to be galvanized and why some nails are galvanized.

Galvanized means that the nail is coated with zinc. The zinc coating shields the iron from the atmosphere and prevents rusting. The zinc coating oxidizes first, before any iron will oxidize, providing what is called cathodic or sacrificial protection.

**Step 12:** Read the article “Shiny Science: A New Substitute for Hexavalent Chromium” and answer the following questions.

a. How does the chemical process to electroplate chromium described in the article compare to the process used in the experiment to electroplate zinc?

The process used to electroplate chromium is similar to that used in the experiment. Electroplating chromium involves a solution of chromium trioxide dissolved in water and sulfuric acid. As in the experiment, a direct current is passed through the solution, which results in chromium ions being reduced to chromium metal on the metal object being electroplated.

b. What health concerns are raised in the article about the process of electroplating chromium?

The electroplating process involving chromium releases a hazardous mist containing hexavalent chromium. This mist can be inhaled by workers, increasing their risk of cancer, kidney damage, and liver damage. Contact with chromium compounds can also cause dermal irritation.

c. According to the article, how are people trying to resolve health concerns with respect to electroplating chromium?

Students may provide any of the following answers:

- By reducing the permissible exposure limit (PEL) for workers in the chrome plating industry.
- By using trivalent chromium instead of hexavalent chromium.
- By using other metals such as tungsten, nickel, and cobalt.
- By reducing the overall use or production of “chrome” products.

## ► Authors and Reviewers

**Authors:** Barry Schlegel and Laura Hemminger, University of Medicine and Dentistry of New Jersey–School of Public Health

**Reviewers:** Susan Booker, Erin Dooley, Stefani Hines, Liam O’Fallon, Kimberly Thigpen Tart, and Joseph Tart

**Give us your feedback!** Send comments about this lesson to [ehpscienced@niehs.nih.gov](mailto:ehpscienced@niehs.nih.gov).



# STUDENT INSTRUCTIONS: Making a Better Nail

**Step 1:** Carry out the following experiment, and record your observations and conclusions. You will use these materials:

- alkaline lantern battery (6 volt)
- 1 clear 10-oz plastic cup or 250-mL beaker
- 1 piece of emery cloth (medium or fine) or steel wool
- 1 100-mL graduated cylinder
- 1 galvanized nail
- 2 iron nails, 3.5" (16 penny) or larger
- Paper towels
- Safety goggles
- 1 stand
- 2 clamps
- 1 spatula or plastic knife
- 1 stirring rod
- 1 triple beam balance or equivalent
- 2 wires (each approximately 1' long) connected by alligator clips
- 2 g zinc acetate dehydrate

**Step 2:** Put on safety goggles and review classroom safety procedures. Zinc acetate dehydrate is an irritant to the eyes, nose, throat, and skin.

**Step 3:** Thoroughly clean two iron common nails using emery cloth or steel wool. Wash off any residual dust with soap and water.

**Step 4:** Measure out 100 mL of water into the cup or beaker.

**Step 5:** Mass 2 g zinc acetate dehydrate, and dissolve it in the water.

**Step 6:** Connect the two wires to the positive and negative terminals of the battery. Connect the other ends of the two wires to the two nails near the head of the nails. **Be careful not to have the two nails come in direct contact with each other as this will short-circuit the battery.** Make sure you can identify which nail was connected to the positive terminal of the battery and which nail was connected to the negative terminal of the battery.

**Step 7:** Using a stand and clamps, place the bottom half of both nails in the zinc acetate solution for a couple of minutes until you see visible changes to the surface of the nails. Again, be careful not to have the two nails come in direct contact with each other while in the solution, as this will short-circuit the battery.

**Step 8:** Get two paper towels and mark a plus (+) on one towel and a minus (-) on the other. Remove the nails from the solution and disconnect the wires. Make sure you know which nail was connected to the positive terminal of the battery and which nail was connected to the negative terminal of the battery. Place the nails on the corresponding + or - paper towel.

**Step 9:** On the next page, draw a diagram of the connected apparatus at the conclusion of the experiment showing the battery, the wires, and what the nails looked like in the solution. Label the terminals of the battery positive (cathode) and negative (anode). Using arrows, show the direction of the flow of the electrons on your diagram. Indicate which nail has a negative charge (i.e., more electrons = reduction in charge) and which nail has a positive charge (i.e., loss of electrons). Use books, the Internet, or materials provided by your teacher to help you as needed.



**Step 10:** Describe what you observe, and explain what happened. Be sure to discuss changes in atomic charge (what was oxidized and what was reduced) and bonding that occurs.

**Step 11:** Wipe the ends of the nails with the paper towel. Describe what you observe, and explain what happened. Be sure to explain any errors that may have occurred to produce your result.

**Step 12:** Examine the galvanized nail. Explain what it means to be galvanized and why some nails are galvanized.



**Step 13:** Read the article “Shiny Science: A New Substitute for Hexavalent Chromium” and answer the following questions.

- a. How does the chemical process to electroplate chromium described in the article compare to the process used in the experiment to electroplate zinc?
  
  
  
  
  
  
  
  
  
  
- b. What health concerns are raised in the article about the process of electroplating chromium?
  
  
  
  
  
  
  
  
  
  
- c. According to the article, how are people trying to resolve health concerns with respect to electroplating chromium?

