Alchemy: A Cross-Curricular Activity



Copper, Silver, and Gold Redox Reactions

Introduction

Turn an ordinary copper penny into "silver" and then into "gold"! Get rich quick by demonstrating this eye-catching and simple procedure!

Concepts

Oxidation-reduction
 Alloys

Materials

Copper pennies, dated 1982 or earlier, 2 Sodium chloride, NaCl, 2.5–3 g Vinegar, 15 mL Zinc chloride solution, ZnCl₂, 1 M, 25 mL Zinc, granular, Zn, 1.0 g Water, distilled or deionized Balance Beakers, 100-mL, 2 Graduated cylinder, 50-mL Hot plate Tongs Towel or paper towel

Safety Precautions

Zinc chloride solution and granular zinc are severe skin irritants. Zinc metal dust can be flammable; dust may be present at the bottom of the bottle of granular zinc. Do not use zinc dust in this procedure. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

- 1. Weigh out and place 2.5–3 g of sodium chloride and 15 mL of vinegar in a clean, 100-mL beaker.
- 2. Clean two pennies by placing them in the sodium chloride/vinegar solution until they are shiny.
- 3. Remove the pennies using tongs and rinse thoroughly with water. Dry thoroughly with a towel. *Note:* Do not handle the clean pennies with your hands. The oils from your skin may interfere with the zinc-plating reaction.

Procedure

- 1. In a clean 100-mL beaker, mix together 1.0 g of granular zinc and 25 mL of 1 M zinc chloride solution. *Note:* Chemical splash goggles must be worn.
- 2. Place the beaker with the $ZnCl_2$ and zinc on a hot plate set to a medium heat setting.
- 3. Carefully and gently heat the mixture until the solution boils.
- 4. Using tongs, immerse two pennies in the mixture until they appear "silver."
- 5. Use tongs to remove the pennies. *Caution:* The pennies will be very hot. Carefully dip the pennies into a beaker of distilled water. Shine the pennies with a towel. Set one treated penny aside to be used for later comparisons.
- 6. Using tongs, place the other treated penny on the hot plate until the penny turns to a golden color. Using a heat-resistant glove or tongs, flip the penny every 30 seconds to avoid burning.
- 7. Use tongs to remove the penny from the hot plate and immediately dip the penny into a fresh beaker of distilled water. The penny will be extremely hot and should be handled with tongs until it has cooled for several minutes. Students will

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enjoy showing their friends their "silver" and "gold" pennies.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The zinc chloride solution may be poured off of the granular zinc and be disposed of according to Flinn Suggested Disposal Method #26b. The granular zinc can either be reused or discarded in the solid waste according to Flinn Suggested Disposal Method #26a.

Tips

- The *Gold Rush—Turning Pennies into Silver and Gold Kit* (Catalog No. AP8895) is available from Flinn Scientific and contains enough materials to perform this demonstration seven times: 10 grams of zinc, 200 mL of 1 M zinc chloride solution, 25 g of sodium chloride, and 110 mL of vinegar. Pennies are needed but not provided in the kit.
- Clean pennies are necessary in this demonstration because a smooth surface is needed for the "silver" and "gold" to plate. Pennies can be cleaned with the salt/vinegar solution as described in the preparation section. Or they can be cleaned by soaking them in dilute hydrochloric acid solution. The pennies can then be scrubbed with steel wool before starting, if necessary.
- Students will likely not believe that "silver" and "gold" were made in this lab. Have them determine what was made.
- Pre-1982 pennies are 95% copper and 5% zinc; post-1982 pennies are 97.6% zinc, coated with a thin electroplating of copper. Either pre- or post- 1982 pennies can be used for this lab; however, pre-1982 pennies have been shown to work better, as long as they are cleaned well and have a shiny, smooth surface. Since post-1982 pennies contain mostly zinc, they tend to warp if overheated (melting point of copper = 1083 °C; melting point of zinc = 420 °C). Also, since there is such a small amount of copper, the brass "gold" alloy formed is not as apparent on new pennies.
- This demonstration has been revised from its original procedure due to safety considerations. The original procedure, which used zinc metal and 3M sodium hydroxide solution presented a possible fire hazard for disposal. The method described herein is safer to perform and eliminates the fire hazard.

Discussion

In this reaction, a penny is placed in a boiling solution of 1 M zinc chloride containing granular zinc. The penny develops a zinc "silver-colored" coating. When removed from the solution and placed on the surface of the hot plate, the brass alloy coating on the penny turns a golden color.

Placing copper, or a copper-coated penny, in a mixture of zinc metal and aqueous zinc chloride causes zinc metal to plate out on the copper surface. This reaction occurs due to electrochemical potential differences that result when different "forms" of zinc solid are contained in a solution of 1M ZnCl_2 . The driving force in this reaction is formation of a brass alloy on the surface of the copper.

$Zn^{2+}(aq) + 2e^{-}$	$\rightarrow Zn_{Cu}$ (alloy)	Note:	Zn_{Zn} = zinc that deposits on the granular zinc
Zn _{Zn}	\rightarrow Zn ²⁺ (aq) + 2e ⁻		Zn_{Cu}^{2n} = zinc that deposits on the copper
Zn _{Zn}	$\rightarrow Zn_{Cu}$		E = +1.0 V

Brass is a copper-zinc alloy. An alloy is a mixture of two or more metals dissolved in each other when molten (or a metal and non-metal fuse together). The percentages of copper and zinc in brass vary depending on the type of brass. These differences allow the penny in this activity to turn several different colors. When a copper penny is added to the zinc solution, the zinc ions migrate to the copper where they are reduced to metallic zinc and deposited. The silver coating on the penny is the gamma-form of the brass alloy with zinc content greater than 45%. This gives the penny its silver coloring. When the zinc-coated penny is heated, the penny becomes gold in color. The gold color is due to the zinc migrating through the copper to convert to the alpha-form of brass alloy which has a zinc content of less than 35%. This form of the brass alloy is a golden color.

Connecting to the National Standards

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

Unifying Concepts and Process: Grades K–12

 Constancy, change, and measurement

 Content Standards: Grades 5–8

 Content Standard B: Physical Science, properties and changes of properties in matter

 Content Standards: Grades 9–12

 Content Standard B: Physical Science, structure and properties of matter, chemical reactions

Sample Data Table

	Penny 1	Penny 2
Year of the penny	Answers will vary.	Answers will vary.
What color did the penny turn when mixed with granular zinc and zinc chloride solution	Silver	Silver
What is the color of the second penny upon heating?	N/A	Golden

Answers to Worksheet Questions

1. Why is it recommended to use pennies that are dated pre-1982 in this activity?

Pennies that were made pre-1982 are 95% copper and 5% zinc. Post 1982 pennies are 97.6% zinc coated with a thin electroplating of copper. Also, the post-1982 pennies that are mostly zinc tend to warp if overheated.

2. Why is it necessary the pennies be thoroughly cleaned before beginning this activity?

A clean smooth surface is needed for the "silver" and "gold" (or brass alloy) to properly plate. When the penny is placed in solution it is necessary that the zinc ions can interact with the copper of the penny so they can be reduced to metallic zinc.

3. After the pennies were dipped in the granular zinc/zinc chloride solution they had a silver colored coating. This was not actually due to the presence of silver, what was the silver coating?

The coating is actually brass which is a copper-zinc alloy. The color of brass is dependent upon its percentage of copper and zinc. The silver coating on the penny is the gamma-form of the brass alloy with zinc content greater than 45%.

4. Unfortunately, the copper pennies were not turned to real gold. What is responsible for the gold coating?

As mentioned previously, the coating is a brass alloy. Upon heating, the brass alloy develops a golden color due to the zinc migrating through the copper to convert to the alpha-form of brass alloy which has a zinc content of less than 35%.

Reference

Szczepankiewicz, Steven H. Journal of Chemical Education; 1995, 72, 386-388.

Flinn Scientific—Teaching Chemistry[™] eLearning Video Series

A video of the *Alchemy: A Cross-Curricular Activity* activity, presented by Kathleen Dombrink, is available in *Copper, Silver and Gold Redox Reactions*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Alchemy: A Cross-Curricular Activity* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in *The Gold Rush—Turning Pennies into Silver and Gold Kit* available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
AP8895	The Gold Rush—Turning Pennies into Silver and Gold
Z0028	Zinc, Granular, 100 g
Z0040	Zinc Chloride Solution, 1 M, 500 mL
S0063	Sodium Chloride, 500 g
V0005	Vinegar, 4 L

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

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Alchemy Worksheet

Data Table

	Penny 1	Penny 2
Year of the penny		
What color did the penny turn when mixed with granular zinc and zinc chloride solution?		
What is the color of the second penny upon heating?		

Questions

- 1. Why is it recommended to use pennies that are dated pre-1982 in this activity?
- 2. Why is it necessary that the pennies be thoroughly cleaned before beginning this activity?
- 3. After the pennies were dipped in the granular zinc/zinc chloride solution they had a silver-colored coating. This was not actually due to the presence of silver, what was the silver coating?
- 4. Unfortunately, the copper pennies were not turned to real gold. What is responsible for the golden coating?