Silver Holiday Ornaments

Introduction

Create a beautiful silver ornament to demonstrate a practical application of an oxidation–reduction chemical reaction. The process "reflects" the way silver mirrors are actually produced!

Concepts

- Oxidation–reduction
- Reducing sugars

Background

In 1835, the German chemist Justus von Liebig invented a silvering process to plate a sheet of glass with a thin layer of silver metal by reducing silver ions with dextrose. This chemical method of lining glass with a "silver mirror" ushered in the modern era of producing mirrors for common household uses. The silver mirror reaction invented by Liebig will be used in this lab to make a silver holiday ornament. The overall reaction is a classic *oxidation–reduction reaction* between silver complex ions and dextrose in ammonia solution. Dextrose or glucose ("blood sugar") is a simple carbohydrate. It is an example of a *reducing sugar*, so-named because it is capable of reacting with and reducing mild oxidizing agents such as Ag^+ or Cu^{2+} ions. In this experiment, dextrose molecules reduce $Ag(NH_3)_2^+$ complex ions to form silver metal, which plates out as a thin coating on the inside of the glass ornament (Equation 1). The aldehyde [R–C(H)=O] functional group in dextrose (see Figure 1) is oxidized to a carboxylate functional group in the process.

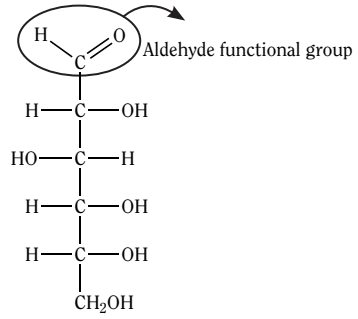

Figure 1. Structure of Dextrose.

$$R\text{–}CHO(aq) + 2Ag(NH_3)_2^+(aq) + 2OH^-(aq) \rightarrow R\text{–}COO^-(aq) + 2Ag(s) + NH_4^+(aq) + 3NH_3(aq) + H_2O(l) \quad \textit{Equation 1}$$

Aldehyde — *Carboxylate*

Materials

Acetone, 5 mL

Ammonium nitrate solution, NH_4NO_3, 1.5 *M*, 2.5 mL

Dextrose solution, $C_6H_{12}O_6$, 5% solution, 5 mL

Silver nitrate solution, $AgNO_3$, 0.5 *M*, 2.5 mL

Sodium hydroxide solution, NaOH, 10%, 5 mL

Balance, centigram (0.01-g precision)

Beaker, 50-mL

Glass ornament, 2⅝"

Graduated cylinder, 10-mL

Marking pen

Metric ruler

Parafilm®, 2 cm square

Pipet, Beral-type

Stirring rod

String

Wash bottle and distilled water

Waste beaker

Safety Precautions

Sodium hydroxide solution is a corrosive liquid and is especially dangerous to the eyes. Ammonium nitrate solution is toxic by ingestion. Silver nitrate solution will stain skin and clothing. The mixed solution in the flask may form a potentially explosive material if left standing and allowed to dry. Do NOT mix the solutions beforehand—add them together in the glass ornament ball and follow the instructor's directions for disposing of the leftover solution immediately after use. Rinse with copious amounts of water. Wear chemical splash goggles and chemical-resistant gloves and apron. Please review current Safety Data Sheets for additional safety, handling, and disposal information. Wash hands thoroughly with soap and water before leaving the lab.

Publication No. 11174
013018

Procedure

1. Obtain a plain glass ornament. Wrap string around the circumference (widest part) of the ornament and mark the length of string.
2. Using a metric ruler, measure the marked off length of string to the nearest 0.1 cm and record the length.
3. Gently grasp the "ornament holder" and carefully remove it from the top of the ornament ball. Set the ornament holder aside. *Caution:* The glass ornament is fragile—do not exert pressure.
4. Measure and record the mass of the glass ornament ball.
5. Using a Beral-type pipet, add about 2 mL of acetone to the ornament ball and swirl the liquid inside the ornament.
6. Pour the acetone into a waste beaker and allow the ornament ball to dry completely in air.
7. Measure 2.5 mL of silver nitrate solution using a graduated cylinder and pour the solution into a clean, dry 50-mL beaker.
8. Rinse the graduated cylinder with distilled water and pour out the rinse water.
9. Measure 2.5 mL of ammonium nitrate solution using the graduated cylinder and pour the solution into the beaker containing silver nitrate. Mix the combined solution using a stirring rod.
10. Rinse the graduated cylinder with distilled water and pour out the rinse water. Measure 5 mL of dextrose solution using the graduated cylinder and pour the dextrose into the completely air-dried ornament ball.
11. Rinse the graduated cylinder with distilled water and pour out the rinse water. Measure 5 mL of sodium hydroxide solution into the graduated cylinder.
12. Add the combined silver nitrate/ammonium nitrate solution from the beaker to the ornament ball, followed *immediately* by the sodium hydroxide solution.
13. Gently cover the opening of the ornament with Parafilm and swirl the solution. Keep rotating the ornament so the solution covers the entire inside surface of the ball. A shiny silver coating will appear.
14. Carefully remove the Parafilm and pour the remaining solution into a labeled waste container. *Note: Rinse the ornament thoroughly with distilled water.*
15. Using a Beral-type pipet, add about 2 mL of acetone to the ornament and swirl gently to cover the interior surface. Pour the acetone into a waste beaker and allow the ornament to dry completely in air.
16. Measure the mass of the air-dried silver ornament.
17. Carefully replace the ornament holder back on top of the silver holiday ornament.

Questions

1. Using the measured circumference of the glass ornament, calculate the radius (in cm) and the surface area (cm^2) of the ornament. (The formula for the circumference of a sphere is $2\pi r$. Surface area = $4\pi r^2$.)
2. Calculate (a) the mass and (b) the number of moles of silver lining the inside of the glass ornament.
3. The density of silver is 10.5 g/cm^3. What is the volume of silver metal lining the inside of the glass ornament?
4. Assume that the volume of silver in the ornament can be approximated by the following equation: Volume = Surface area × thickness. Calculate the approximate thickness of the silver lining in centimeters, and convert the answer to micrometers (1 $\mu m = 1 \times 10^{-6}$ m) and nanometers (1 $nm = 1 \times 10^{-9}$ m).

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The mixture remaining in the glass ornament after the silver mirror reaction is complete may become unstable or explosive when concentrated or heated and must be rinsed with excess water into a waste beaker or flask set up in a central location. Test the combined waste solution for the presence of left-

over silver ions by adding 1 M hydrochloric acid. If a cloudy, white precipitate of silver chloride is observed, continue adding hydrochloric acid in small amounts until no further precipitation is evident. Filter the mixture—the silver chloride should be identified as a toxicity characteristic hazardous waste according to Flinn Suggested Disposal Method #27f. The filtrate may be neutralized and rinsed down the drain with excess water according to Flinn Suggested Disposal Method #24b.

Lab Hints

- Glassware must be scrupulously clean for the silver mirror to adhere to the glass surface. Check ornaments for dust or debris and rinse as needed. Do not use ornaments that appear iridescent.
- Silver ornaments may be protected from oxidation by coating the inside with clear nail polish.
- The risk of explosion for disposal of Tollens' reagent is attributed to the potential formation of "fulminating silver" due to the formation of solid silver imide. **This hazard may be avoided by following the safety precautions and disposal instructions—rinse with copious amounts of water**. Do not concentrate and never heat the solution or leftover reaction mixtures.

Answers to Questions *(Student answers will vary.)*

1. *Circumference = 20.8 cm. Radius = 3.3 cm.*

   Surface area $= 4\pi r^2 = 138\ cm^2$.

2. *Mass of silver = 0.22 g. Number of moles = 0.22 g/107.9 g/mole = 0.0020 moles*
3. *Volume of silver* $= 0.22\ g/10.5\ g/cm^3 = 0.021\ cm^3$
4. *Thickness of the silver lining* $= V/SA = 0.021\ cm^3/138\ cm^2 = 1.5 \times 10^{-4}$ *cm. 1.5* μm *or 1500 nm.*

Acknowledgement

We are grateful to Edmund Escudero, Summitt Country Day School, Cincinnati, OH, for providing Flinn Scientific with the idea and instructions for this activity.

Silver Ornaments is available as a Student Laboratory Kit from Flinn Scientific, Inc.

Catalog No.	Description
AP7189	Silver Ornaments—Holiday Laboratory Kit

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