Synthesis of Ruby Red Colloidal Gold Nanoparticles

Procedure modified from A. D. McFarland, C. L. Haynes, C. A. Mirkin, R. P. Van Duyne and H. A. Godwin, "Color My Nanoworld," *J. Chem. Educ.* (2004) **81**, 544A and Flinn Scientific, "Ruby Red Colloidal Gold", https://www.flinnsci.com/media/622223/95032.pdf
The electrolyte analysis of sports drinks was developed by Andrew Greenburg.
Procedure posted at http://education.mrsec.wisc.edu/nanolab/gold/index.html
Additional information and procedure added by David A. Katz, Chemist, Educator and Consultant, Tucson, AZ, USA

Introduction

The colors of stained glass windows and of glasses such as Murano glass from the Venetian island of Murano are obtained by adding small amounts of minerals, oxides, and chemical derivatives to the base composition of the glass powder. Such glasses, dating from before 8th-century Rome, with significant Asian and Muslim influences, are early examples of nanotechnology. The colors were produced using recipes passed from Master to apprentice and were never recorded.

cobalt copper chromium iron manganese gold

In this experiment Au^{3+} ions, in the form of $AuCl_4^+$, are reduced by citrate ions to gold atoms in dilute solution. The gold nanoparticles are stabilized by the citrate ions adsorbed on surface of the particles. The citrate ions act as both a reducing agent and a capping agent (i.e., a strongly adsorbed monolayer, usually of an organic compound, that aids stabilization of nanoparticles in a colloidal solution). The resulting particles have a negative charge that is responsible for the formation of a stable colloid.

The color of gold nanoparticles will vary with the size of the particles. If the nanoparticles are less than 100 nm, the solution has an intense red color. When NaCl solution is added to the colloid, the electrostatic repulsions of the colloidal particles are disrupted and the gold nanoparticles aggregate into large particles. Larger particles are blue/purple.

Materials Needed

1.0 mM hydrogen tetrachloroaurate ($HAuCl_4$) solution. (Dissolve 1.0 g $HAuCl_4 \cdot 3H_2O$ in 250 mL distilled water. This makes a 10.0 nm solution of gold(III) ions. The solution, stored in a brown bottle is stable for years. To make a 1.0 nM solution, dilute 25 mL of 10.0 nM solution to 250 mL)
1% trisodium citrate solution. Dissolve 0.5 g sodium citrate, $Na_3C_6H_5O_7 \cdot 2H_2O$, in 50 mL distilled water.
1 M sodium chloride (NaCl) solution. Dissolve5.8 g NaCl in 100 mL distilled water. (Note: A saturated solution of NaCl can be used.)

NOTE: A kit consisting of 150 mL 1.0 mM hydrogen tetrachloroaurate ($HAuCl_4$) solution, 25 mL 1% trisodium citrate solution, and 50 mL 1 M sodium chloride (NaCl) solution is available from Flinn

Scientific Inc., Catalog no. AP7117 (This is enough for 7 demonstrations or about 2 classes of students working in groups.)

Flask, Erlenmeyer, 125 mL
Dropper
Magnetic stir bar
Stirring hotplate
Laser pointer or bright flashlight
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Safety Precautions

Wear approved eye protection at all times in the laboratory.

Dilute hydrogen tetrachloroaurate solution may be irritating to the eyes, skin, and the gastrointestinal tract.

The potential health effects of nanoparticles have not been fully identified.

Disposal

Dispose of all materials in the proper waste containers.

The colloidal gold solution is very stable and may be stored indefinitely. (A brown bottle is recommended.) To dispose of the solution, add 6 M hydrochloric acid to precipitate the gold. Recycle the gold (about 0.0079 g) or dispose of solid gold in the trash. The remaining solution can be disposed of down the drain with running water.

Procedure

Rinse all glassware with distilled or deionized water.

Measure 20 mL of 1.0 mM $HAuCl_4$ solution into a 125 mL flask on a stirring hotplate. Add a magnetic stir bar and bring the solution to a boil.

Add 2 mL of 1% trisodium citrate, $Na_3C_6H_5O_7$, solution to the boiling solution.

Continue to heat until the solution has turned deep red or 10 minutes, whichever comes first.

Remove the flask and solution from the hot plate. Allow to cool to room temperature.

Use a laser beam to demonstrate the presence of a colloidal suspension (Tyndall Effect).

Pour some of the solution into a cuvette. Record the visible spectrum of the solution. If the solution is too dark, dilute it with distilled water to obtain the spectrum.

Pour a small amount of the red gold nanoparticle solution into two test tubes. Keep one test tube as a color reference. Add 5 to 10 drops of 1 M NaCl solution to the second test tube. Report your results.

Questions

You will need to use the Internet to answer these questions. Reference the sources for your answers.

1. How much gold is in 20 mL of 1.0 mM $HAuCl_4$ solution?

2. What is the current cost of gold?

3. How much is the gold in question 1 worth?