**SYNTHESIS OF SILVER NANOPARTICLES**

Nanotechnology deals with processes that take place on the nanometer scale, that is, from approximately 1 to 100 nm. Properties of metal nanoparticles are different from those of bulk materials made from the same atoms. For example, the striking effect of nanoparticles on color has been known since antiquity when tiny metal particles were used to color glass in church windows. Silver particles stained the glass yellow, while gold particles were used to make ruby-colored glass.

 Over the last decades silver nanoparticles have found applications in catalysis, optics, electronics and other areas due to their unique size-dependent optical, electrical and magnetic properties. Currently most of the applications of silver nanoparticles are in antibacterial/antifungal agents in biotechnology and bioengineering, textile engineering, water treatment, and silver-based consumer products. Antibacterial activity of the silver-containing materials is used in medicine in the treatment of severe burns, the treatment of severe chronic wounds, as drug carriers, in diagnosis and prevention.

In performing the experiment described here, students will observe the bright yellow color of silver nanoparticles compared to colorless silver nitrate solution and metallic bulk silver. In designing an experiment involving the synthesis of noble metal nanoparticles for a multi-section general chemistry class, cost was an important consideration. Since the hydrogen tetrachloroaurate(III) trihydrate, HAuCl4x3H2O used to prepare colloidal gold is about 25 times more expensive than silver nitrate; the experiment chosen for development was the synthesis and study of colloidal silver. The synthetic method developed for this experiment consistently produces stable yellow colloidal silver, provided the conditions are properly controlled. The chemical reaction is the sodium borohydride reduction of silver nitrate:

AgNO3 + NaBH4 → Ag + 1/2H2 + 1/2B2H6 +NaNO3

A large excess of sodium borohydride is needed both to reduce the ionic silver and to stabilize the silver nanoparticles that form. Nanoparticles are prone to aggregation. Therefore, the adsorption of borohydride plays a key role in stabilizing growing silver nanoparticles by providing a particle surface charge as shown in the schematic diagram in Figure 1. There must be enough borohydride to stabilize the particles as the reaction proceeds. However, later in the reaction too much sodium borohydride increases the overall ionic strength and aggregation will occur. The aggregation can also be brought about by addition of electrolytes such as NaCl. Nanoparticles are kept in suspension by repulsive electrostatic forces between the particles owing to adsorbed borohydride (Figure 1). Salt shields the charges allowing the particles to clump together to form aggregates. The colloidal silver solution turns darker yellow, violet and then grayish.



Figure 1. Repulsive forces separate Ag nanoparticles with adsorbed borohydride

Reaction conditions including stirring time and relative quantities of reagents (both the absolute number of moles of each reactant as well as their relative molarities) must be carefully controlled to obtain stable yellow colloidal silver. If stirring is continued once all of the silver nitrate has been added, aggregation will occur. Aggregation may also occur if the reaction is interrupted before all of the silver salt has been added.



Figure 2. Change of color of the colloidal silver solution due to aggregation

The distinctive colors of colloidal gold and silver are due to a phenomenon known as plasmon absorbance. Incident light creates oscillations in conduction electrons on the surface of the nanoparticles and electromagnetic radiation is absorbed. The spectrum of the clear yellow colloidal silver from the synthesis above is shown in Figure 3.



Figure 3. UV–Vis absorption spectrum of clear yellow colloidal Ag

The wavelength of the plasmon absorption maximum in a given solvent can be used to indicate particle size (Table 1).

Table 1. Particle Size and Spectral Features of Ag Nanoparticles

|  |  |  |
| --- | --- | --- |
| **Particle size/nm** | **λmax/nm** | **PWHM/nm** |
| 10-14a | 395-405 | 50-70 |
| 35-50b | 420 | 100-110 |
| 60-80c | 438 | 140-150 |

The method used in this experiment produces 12 ± 2 nm particles. The plasmon absorbance is near 400 nm and the peak width at half maximum (PWHM) is 50–70 nm.

**PROCEDURE**

A 10-mL volume of 0.001 M silver nitrate is added dropwise (about 1 drop per second) to 30 mL of 0.002 M sodium borohydride solution that was chilled in an ice bath for 20 minutes. The reaction mixture is stirred vigorously on a magnetic stir plate. The solution turns light yellow after the addition of 2 mL of silver nitrate and a brighter yellow when all of the silver nitrate had been added. The entire addition takes about three minutes, after which the stirring is stopped and the stir bar removed. The clear yellow colloidal silver is stable at room temperature stored in a transparent vial for as long as several weeks or months.

 The effect of NaCl on the stability of the resulting colloidal solution has to be tested by adding a few drops of 1.5 M sodium chloride (NaCl) solution to a smaller amount of the colloidal solution poured into a test tube. After that it is necessary to measure the UV-Vis spectrum of the colloidal solution (or solutions) and compare it to literature data to estimate the size of the obtained nanoparticles.

**LITERATURE**

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