Synthesis of Silver Nanoparticle and its Particle Size Analysis using DLS

Aim

Preparation of silver nanoparticle and determination of particle size.

Introduction

Metal nanoparticles are submicron scale entities made of pure metals (e.g., gold, platinum, silver, titanium, zinc, cerium, and, iron) or their compounds (e.g., oxides, hydroxides, sulfides, phosphates, fluorides, and chlorides). They possess unique electronic, optical, and chemical properties compared to the bulk metal crystals. Elemental silver and silver nanoparticles have been used as antimicrobial agents in curative and preventive health care. Silver nanoparticles can continually release silver ions, which may be considered the mechanism of killing microbes. Owing to electrostatic attraction and affinity to sulfur proteins, silver ions can adhere to the cell wall and cytoplasmic membrane. The adhered ions can enhance the permeability of the cytoplasmic membrane and lead to disruption of the bacterial envelope.

Principle

Silver nanoparticles can be chemically synthesized using silver nitrate as a precursor material and trisodium citrate as a reducing agent. The synthesis process possesses two basic steps of particle formation, i.e., nucleation (agglomeration of the atoms) and growth. The shape and size of the nanoparticles are depended on the speed of both processes, which are controlled by parameters such as concentration, temperature, reducing power, and pH. The mechanism of the reaction is as follows:

$$4Ag^{+} + Na_3C_6H_5O_7 + 2H_2O \rightarrow 4Ag^{o} + C_6H_5O_7H_3 + 3Na^{+} + H^{+} + O_2\uparrow$$

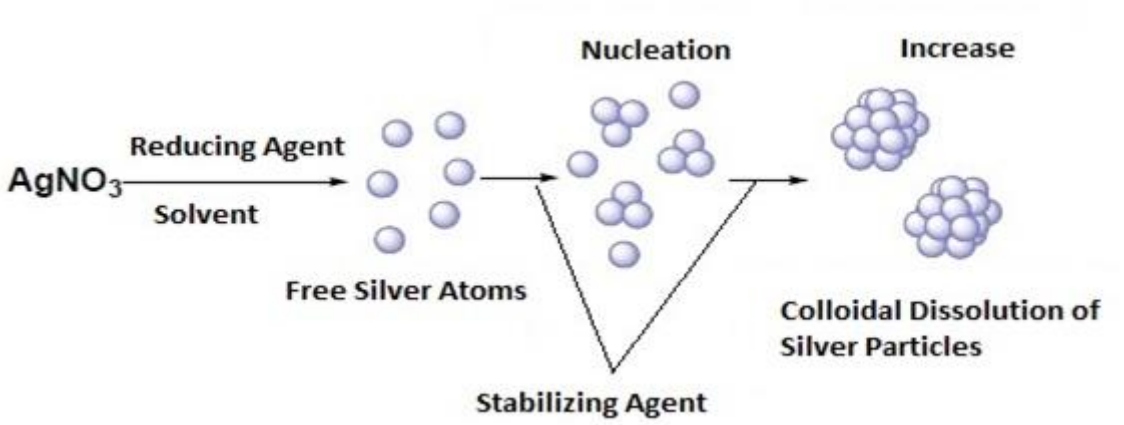

Figure 1: General mechanism of formation of silver nanoparticles from the chemical reduction in solution of AgNO3 salt

The size of the nanoparticle was estimated using a particle size analyzer. The instrument uses the principle of dynamic light scattering (DLS) technique for size-estimation. The sample is illuminated by a laser beam, and the fluctuations of the scattered light are detected at a known scattering angle by a fast photon detector. When particles are dispersed in a liquid, they move randomly in all directions. The principle of Brownian motion is that particles are constantly colliding with solvent molecules. These collisions cause a certain amount of energy to be transferred, which induces particle movement. The energy transfer is more or less constant and therefore has a greater effect on smaller particles. As a result, smaller particles are moving at higher speeds than larger particles. The relation between the speed of the particles and the particle size is given by the Stokes-Einstein equation:

$$D = \frac{k_B T}{6\pi\eta R_H}$$

D Translational diffusion coefficient [m²/s] – “speed of the particles”

k_B Boltzmann constant [m²kg/Ks²]

T Temperature [K]

η Viscosity [Pa.s]

R_H Hydrodynamic radius [m]

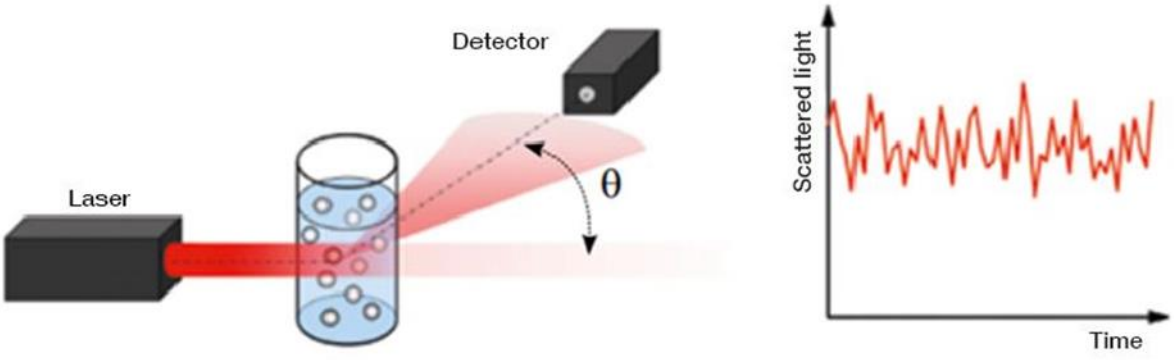

Figure 2: Basic setup of a DLS measurement system. The sample is contained in a cuvette. The scattered light of the incident laser can be detected at different angles.

Materials & Instruments

Silver nitrate ($AgNO_3$), trisodium citrate ($Na_3C_6H_5O_7$), distilled water, beakers, measuring cylinder, hot plate, thermometer, cuvette, and particle size analyser.

Protocol

Synthesis of silver nanoparticle (AgNP)

1. 16.9 mg of $AgNO_3$ and 200 mg of $Na_3C_6H_5O_7$ were weighed. Both were mixed in 1 mL of distilled water individually.
2. $AgNO_3$ solution was then added drop by drop to pre-heated (~80 °C) 50 mL of distilled water.
3. Similarly, $Na_3C_6H_5O_7$ solution was added to the mixture.
4. The mixture was then kept on a hot plate (to maintain the temperature ~80 °C) in stirring condition.
5. The solution was heated until the change of color was evident (pale yellow).
6. Then it was removed from the heating device and stirred until cooled to room temperature.
7. The nanoparticle solution was stored in an aluminum foil-covered container for further use.
8. 2 mL of solution was taken in a cuvette and placed in DLS instrument for size analysis.

Result

1. Pale yellow $AgNO_3$ solution was obtained.
2. The average hydrodynamic diameter of the nanoparticle was 134.4 nm.

Precautions

1. Wear gloves while handling silver nitrate. Repeated applications of silver nitrate may cause a gray or blue-black discoloration of treated skin, sometimes also lead to skin burns.
2. The temperature should not go above 80 °C during the synthesis process. The nanoparticle property will be changed at higher temperature.