



Size and Zeta Potential Characterization of Chemically Synthesized Silver Nanoparticles

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Abstract: -

Silver nanoparticles (AgNPs) were synthesized via a chemical reduction method using water as the solvent. The characterization focused on particle size and stability, assessed through zeta potential measurements. The nanoparticles exhibited sizes ranging from 24.8 nm to 28.2 nm, confirming the successful synthesis of nanoscale particles. Zeta potential values of -43.49 mV, -41.43 mV, -31.9 mV, and -32.4 mV indicated good stability due to sufficient electrostatic repulsion. These results highlight the favourable properties of the synthesized AgNPs, making them suitable for potential applications in biomedical, environmental, and catalytic fields.

Keywords: Silver nanoparticles, zeta potential, particle size, stability, chemical reduction.

1. Introduction

Nanotechnology, a rapidly advancing field that involves the manipulation of materials at the nanoscale (typically within the range of 1 to 100 nm), has sparked a paradigm shift across numerous scientific disciplines, including medicine, electronics, energy, and environmental science [1]. The ability to engineer materials at such small dimensions unlocks a host of novel properties, such as enhanced surface area, increased chemical reactivity, and improved mechanical strength, which do not manifest in bulk materials. These distinctive attributes render nanomaterials particularly advantageous for a broad spectrum of cutting-edge applications.

Among the various classes of nanomaterials, silver nanoparticles (AgNPs) have garnered considerable attention due to their remarkable antimicrobial properties, biocompatibility, and catalytic capabilities [2]. Silver, renowned for its long-standing antimicrobial effects, exhibits significantly enhanced activity in its nanoparticulate form. This is primarily due to its increased surface-to-volume ratio and its capacity for interacting with biological systems at the molecular level, which endows AgNPs with remarkable efficacy in a variety of



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applications, ranging from medical treatments, such as drug delivery, wound healing, and diagnostic imaging, to industrial and environmental uses, including water purification and catalysis.

The synthesis of silver nanoparticles has been a focal point of extensive research, with numerous methods developed to control the size, morphology, and stability of the nanoparticles [3]. Among these, chemical reduction methods are widely employed due to their simplicity and effectiveness. However, challenges persist in achieving monodisperse nanoparticle distributions and maintaining stable dispersions without the use of toxic chemicals. As a result, there has been a growing interest in the development of sustainable and eco-friendly synthesis routes, particularly those utilizing water as a solvent, which offer a more environmentally benign alternative [4].

In this study, we present a cost-effective, water-based chemical reduction method for the synthesis of silver nanoparticles. The aim is to produce stable, uniformly sized nanoparticles that are suitable for diverse applications, while minimizing the environmental impact typically associated with conventional synthesis techniques. This method demonstrates considerable potential for the large-scale production of highly stable silver nanoparticles with broad applicability across various fields.

2. Research Objective

This study aims to characterize the size and stability of silver nanoparticles synthesized via a chemical reduction method. By employing particle size analysis and zeta potential measurements, we explore how nanoparticle size and surface charge influence stability [5]. The findings provide essential insights into the relationship between these properties and the practical applications of AgNPs, offering guidance for their design and use in various fields such as medicine, catalysis, and environmental science.

3. Materials & Method

Synthesis of silver nanoparticles by chemical reduction method

Silver nitrate (AgNO_3), sodium borohydride (NaBH_4) was obtained from Sigma-Aldrich, sodium citrate ($\text{Na}_3\text{C}_6\text{H}_5\text{O}_7$), nitric acid (HNO_3), and sodium hydroxide (NaOH) were obtained from biotechnology department of Maharaja Ranjit Singh College of Professional Sciences, Indore. All of the chemicals were used without additional purification. Milli-Q grade deionized water was used for the preparation of the solutions.

Silver nitrate was used as the metallic precursor, while tribasic sodium citrate served as the stabilizing agent. Sodium borohydride was used as the reducing agent, and hydrogen



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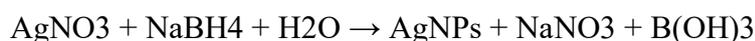
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peroxide was employed as the oxidizing agent. Milli-Q deionized water was used to prepare the aqueous solution.

The use of water as a solvent in this chemical reduction method ensures environmental sustainability. The method produces silver nanoparticles with high colloidal stability and consistent particle size distribution, making it simple, cost-effective, and scalable.[6]

The chemical equation for the synthesis of silver nanoparticles (AgNPs) using silver nitrate (AgNO₃) and sodium borohydride (NaBH₄) can be represented as follows:



In this reaction, silver nitrate (AgNO₃) which serves as the silver precursor, providing the silver ions (Ag⁺) necessary for nanoparticle formation. Sodium borohydride (NaBH₄) acts as the reducing agent, responsible for reducing the silver ions to silver nanoparticles. Water (H₂O) is typically used as the solvent.

During the reaction, the silver ions are reduced by sodium borohydride, leading to the formation of metallic silver nanoparticles (AgNPs). Sodium nitrate (NaNO₃) and boric acid (B(OH)₃) are byproducts formed in the process.

Measurements taken for synthesis of silver nanoparticles-

30 millimole of AgNO₃ =0.255 gram of AgNO₃ in 50 ml distilled water

30 millimole of sodium citrate Na₃C₆H₅O₇=0.451 gram of Na₃C₆H₅O₇ in 50 ml distilled water

100 millimole of NaBH₄= 0.190 gram of NaBH₄ in 50 ml distilled water

Typically, 30 mL of deionized water and 1.5 mL of sodium citrate (SCT) was added into a 100 mL beaker under vigorous stirring. The amounts of the chemical's reagents added were modified as follows:

Table-1: The concentration of AgNO₃, H₂O₂ and NaBH₄ for preparation of Ag Nanoparticles [7].

Sample NO.	AgNO ₃ in μL	H ₂ O ₂ in μL	NaBH ₄ in μL
1	30	40	175
2	30	60	175
3	30	50	150
4	30	50	200



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4. Characterization Techniques

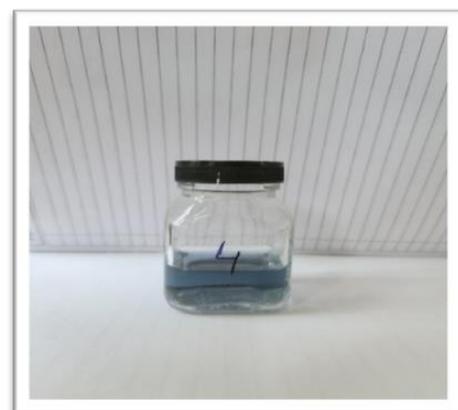
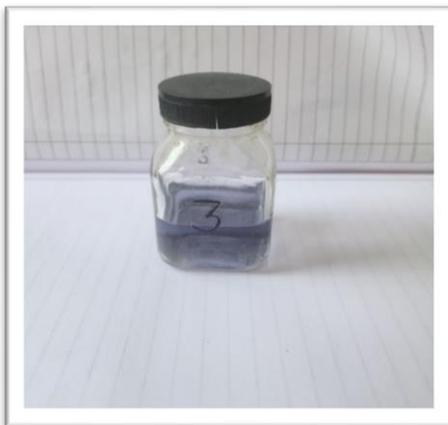
Particle Size Measurement

The particle size of the silver nanoparticles was determined using the Nano Plus Zeta/Nanoparticle Analyzer. Measurements were performed at room temperature on a diluted nanoparticle solution. The analyser utilizes dynamic light scattering (DLS) to measure the hydrodynamic size and provide the size distribution.

Zeta Potential Measurement

The zeta potential of the silver nanoparticles was also measured using the Nano Plus Zeta/Nanoparticle Analyzer. A sample of the nanoparticle solution was placed in a cuvette, and the measurements were conducted at room temperature. The zeta potential values, recorded in millivolts (mV), were used to assess the electrostatic stability of the nanoparticles.

5. Results and Discussion





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Colour of samples

Sample NO.	Colour of silver nanoparticles
1	Indigo
2	Blue
3	Dark blue
4	Blue

Particle Size Measurement

The diameter of silver nanoparticles was determined using Dynamic Light Scattering (DLS). The particle size distribution of the synthesized silver nanoparticles is presented in Table 2. The results show that the range of particle size is between 24.8-28.2 nm.

The size of silver nanoparticles is-

Sample NO.	Particle Size in nm
1	25.4
2	24.8
3	27.0
4	28.2

These results indicate a narrow particle size distribution, with minimal variation among the samples, suggesting that the synthesis process is both reproducible and uniform. The small and consistent particle size is advantageous for applications requiring precise control over nanoparticle dimensions, such as in drug delivery systems, catalysis, and antimicrobial coatings.[6]

Zeta Potential Measurement

The stability of the silver nanoparticles synthesized using the chemical reduction method was assessed through zeta potential measurements. The measured zeta potential values for the four samples ranged from -43.49 mV to -31.9 mV. These negative zeta potential values indicate that the nanoparticles possess high colloidal stability, primarily due to electrostatic repulsion between particles, which prevents aggregation. The specific values observed were:

Sample 1: -41.43 mV



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Sample 2: -43.49mV

Sample 3: -31.9 mV

Sample 4: -32.4 mV

A zeta potential magnitude greater than ± 30 mV is generally considered indicative of stable nanoparticle dispersions, as it suggests sufficient electrostatic repulsion to counteract the van der Waals forces that promote aggregation. The relatively consistent zeta potential values across all samples suggest that the synthesized silver nanoparticles exhibit robust stability, which is crucial for their performance in various applications.

The zeta potential of silver nanoparticles was determined using Dynamic Light Scattering (DLS).

The zeta potential of silver nanoparticles is –

Sample NO.	Zeta Potential in mV
1	-41.43
2	-43.49
3	-31.90
4	-32.40

The results of this study demonstrate the successful synthesis of silver nanoparticles using a water-based chemical reduction method. A key finding is the high colloidal stability of the nanoparticles, as indicated by the zeta potential values ranging from -43.49 mV to -31.9 mV. These values suggest that the nanoparticles possess sufficient electrostatic repulsion, preventing aggregation and ensuring long-term stability. The consistency of the zeta potential across the four samples highlights the reliability of the synthesis method, which is essential for the reproducibility of nanoparticle-based applications.[8]

The observed narrow particle size distribution—ranging from 24.8 nm to 28.2 nm—further reinforces the uniformity and precision of the synthesis process. This consistency is critical, as uniform particle size can significantly influence the physicochemical properties of nanoparticles, such as their surface reactivity, biocompatibility, and optical properties. Smaller, uniformly sized nanoparticles are particularly advantageous for drug delivery systems and biomedical applications, where precise control over particle characteristics is essential for effectiveness.

The use of water as the solvent in this method is a notable advantage over conventional nanoparticle synthesis techniques, which often rely on toxic organic solvents. This not only



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enhances the environmental sustainability of the process but also reduces the risk of harmful by-products, making the method eco-friendlier and more scalable. Additionally, water is a cost-effective and widely available solvent, further improving the economic feasibility of this synthesis approach.

When compared to other common methods of silver nanoparticle synthesis, such as physical vapor deposition (PVD) or biological synthesis, the water-based chemical reduction method stands out due to its simplicity and low cost. Unlike other methods that require specialized equipment or complex procedures, this approach offers a straightforward and accessible means of nanoparticle production. The scalability of the process further supports its potential for industrial applications, where large quantities of nanoparticles are required.

Moreover, the particle size range observed in this study—while small enough to be used in high-performance applications—can also be fine-tuned by adjusting the reaction parameters (such as precursor concentration, temperature, or pH). This flexibility is a key strength of the method, allowing for customizable nanoparticle features tailored to specific needs across diverse fields, including catalysis, electronics, and environmental remediation.

In summary, the findings from this study suggest that the water-based chemical reduction method is a promising, scalable, and sustainable approach for the synthesis of stable and uniformly sized silver nanoparticles. The high stability, narrow size distribution, and eco-friendly nature of the process position it as a superior alternative to traditional methods, offering significant potential for future applications in nanomedicine, sensor development, and environmental technologies.

6. Conclusion

In summary, the water-based chemical reduction method offers an effective and sustainable approach for synthesizing stable and uniformly sized silver nanoparticles. The zeta potential values and particle size distribution confirm the high stability and consistent quality of the nanoparticles produced. The simplicity, low cost, and eco-friendly nature of this method make it an attractive alternative to traditional nanoparticle synthesis techniques.

Given its reproducibility and scalability, this method holds significant potential for a wide range of applications, particularly in drug delivery, antimicrobial treatments, and catalysis. Future work could focus on optimizing this approach for different nanoparticle sizes and exploring its potential in other fields, such as sensor development and environmental remediation.



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