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UV-Vis spectroscopic study of the stability of Silver nanoparticles in monovalent and divalent electrolyte solutions

ABSTRACT

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Nanotechnology has been advanced since the last decades. Among all nanomaterials that have been developed, nanosilver is the most frequently used nanoparticles. Its release into natural water bodies is inevitable due to its broad applications. Nanosilver (nAg) was prepared via Tollens method using. The morphology, size distribution and average size of the obtained nAg was characterized using Transmission electron microscope (TEM) and Dynamic light scattering (DLS) technique. Stability of nanosilver was determined using UV-Vis spectroscopic method. Additionally, a time-resolved DLS technique was applied to confirm the UV-Vis spectroscopic results

Keywords: *Nanosilver; Natural water; Tollens method; Transmission Electron Microscope (TEM); UV-Vis spectroscopy.*

INTRODUCTION

Nanotechnology has been greatly advanced in recent years. Currently, there are over 1000 varieties of nanomaterials present in market. Nanosilver has been widely applied as an excellent antimicrobial agent [1-10]. It is inevitable to be released into the natural water body undeliberately or deliberately. As the antimicrobial ability of nanosilver is closely associated with its physicochemical properties, it is important to study its physicochemical properties in different water conditions. Currently, nanosilver can be synthesis and prepared using different approaches such as physical, chemical and biological approaches. Among all the approaches, Tollens' method within the chemical approaches provides a simple and environmental-friendly way to synthesize nanosilver by reducing the silver ion to its elementary state using reducing agents such as polysaccharides [1, 4-6]. The antimicrobial ability of nanosilver has been well studied. However, to the author's knowledge, physicochemical properties of nanosilver in different salt solutions were not reported.

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This study applied Tollens' method for nanosilver preparation. The obtained nanosilver was characterized using UV-Vis spectroscopy, TEM and dynamic light scattering (DLS). Its stability was conducted using UV-Vis spectroscopy in monovalent and divalent cationic solutions.

EXPERIMENTAL

nAg was synthesized using Tollens method. The concentrations of the reactants were $1 \times 10^{-3} \text{ mol} \cdot \text{L}^{-1}$, $1 \times 10^{-2} \text{ mol} \cdot \text{L}^{-1}$ and 5×10^{-3} for AgNO_3 , maltose and ammonia, respectively [2]. PH value of the reaction system was adjusted to 11.5 using NaOH. Then, the obtained nanosilver was ultrafiltrated using a 3000 ultrafiltration membrane and passed through DI water for cleaning and pH neutralization. Concentration of the cleaned nanosilver was measured using ICP-OES.

Ten mmol/L NaCl and CaCl_2 solutions were prepared for the stability study. The stability of nAg was determined using UV-Vis spectrometer with the wavelength ranges from 300-800 nm. A time-resolved DLS technique was also applied to confirm the UV-Vis spectroscopic observation.

RESULTS AND DISCUSSION

As can be observed in Figure 1, the shape and morphology of nAg was spherical. Figure 2 presents the UV-Vis spectrum of nanosilver in DI water. It shows that the characteristic peak of the spectrum is around 408 nm. This observation is in agreement with other published data [6].

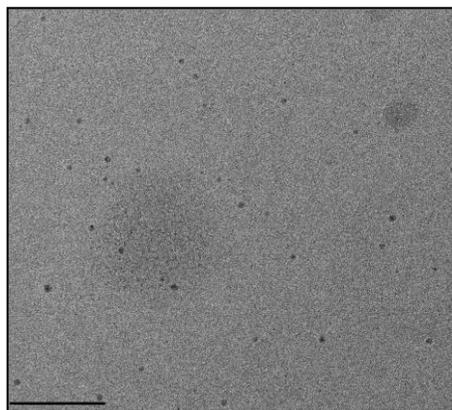


Fig. 1. TEM image of nAg in DI water (Black line=200 nm).

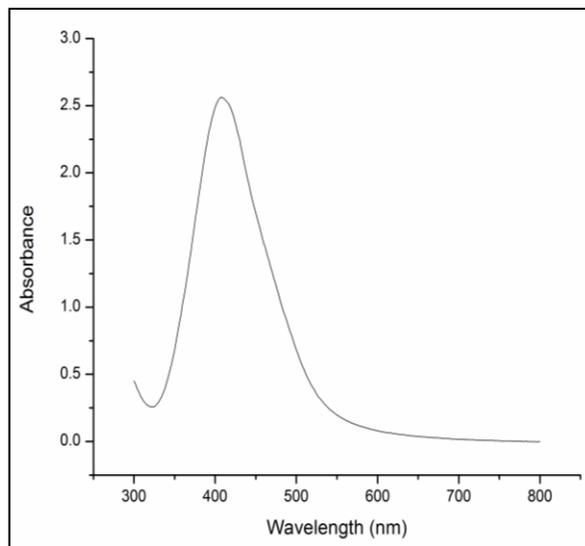


Fig. 2. UV-Vis spectrum of nAg in DI water.

The stability studies using UV-Vis spectroscopy were shown in Figures 3-5. As shown in Figure 3, it shows that the characteristic peak of the nAg in NaCl and CaCl_2 was the same as measured in DI water, which is located at 408 nm. A increase in absorbance was observed for nAg in NaCl solution. This might be because of the slow dissolution process of nAg due to the oxidation of nAg by oxygen and further reaction with Cl^- anion [4,5, 8]. On the contrary, it was observed that the absorbance at the characteristic peak of nAg in CaCl_2 decreased, which is attributed to the aggregation process of nAg. As indicated by DLVO theory, the stability of a colloidal system is dependent on the concentration and valence of counter ion against the colloids [1, 4, 5]. In our case, as the zeta potential measurement of nAg shows a negative value, cations present in the electrolyte solution could adsorb onto the nanoparticle surface and neutralize their surface charge to reduce the electric repulsion forces between nanoparticles [4,5, 8]. As big aggregates tend to precipitate, there are fewer nanoparticles present in the suspension, which result in a decreasing absorbance at 408 nm.

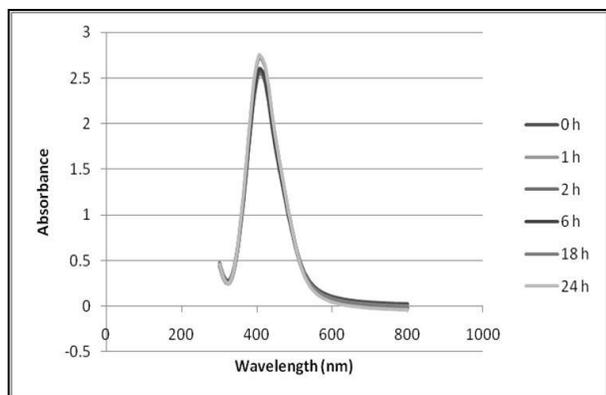


Fig. 3. UV-Vis spectrum of nAg in NaCl solution for 24 h.

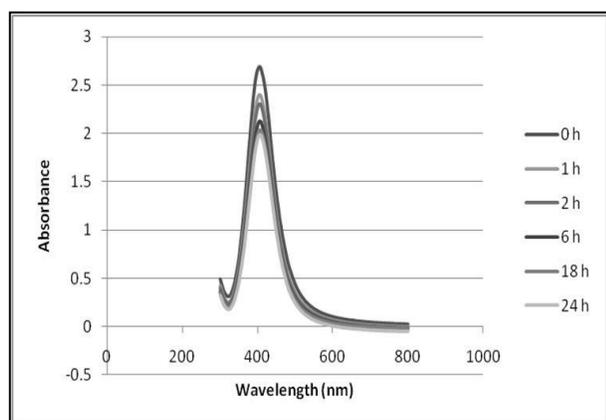


Fig. 4. UV-Vis spectrum of nAg in CaCl₂ solution.

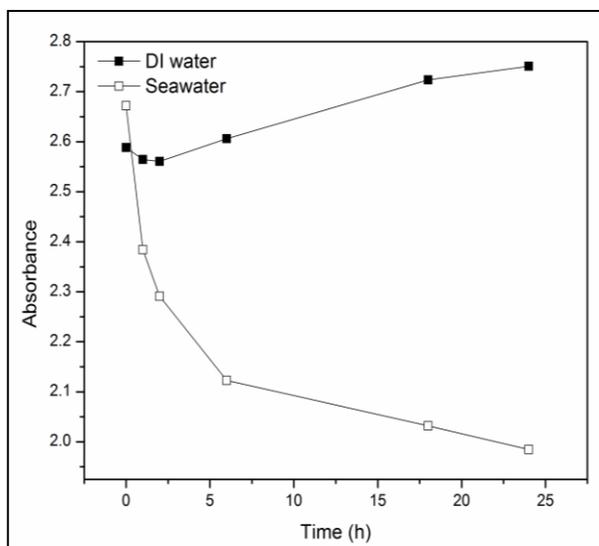


Fig. 5. Change of UV-Vis characteristic peak of nAg at the wavelength of 408 nm in NaCl and CaCl₂ solutions.

A time-resolved DLS measurement was carried out to confirm the nanoparticle aggregation process (Figure 6). Figure 6 shows that the aggregate size of nAg in CaCl₂ kept growing over time [11]. However, particle size of nAg in NaCl solution was stable, indicating a more stable state in NaCl in comparison with nAg in CaCl₂ solution.

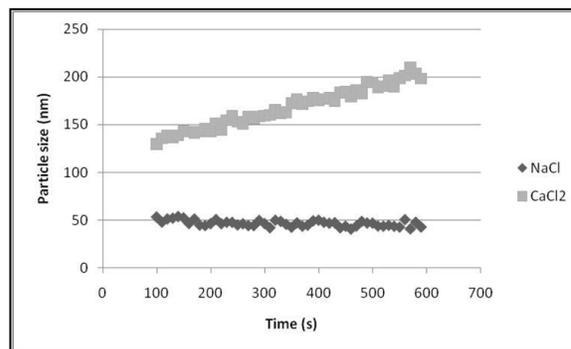


Fig. 6. Aggregation kinetics of nAg in NaCl and CaCl₂ solutions.

CONCLUSIONS

This study has demonstrated that: 1) UV-Vis spectrum has shown that the characteristic peak of nAg is around wavelength at 408 nm; 2) nAg in CaCl₂ is less stable than that in NaCl solution; 3) aggregation behavior of nAg in CaCl₂ is more intense compared with nAg in NaCl solution.

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