



# Spectroscopic Study Of Metal Nanoparticles Stabilized By Biopolymers

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## ABSTRACT

In this paper, we study silver, copper, and gold nanoparticles stabilized with natural biopolymers chitosan, sodium alginate, and gelatin using infrared spectroscopy (IR). The interaction of the biopolymer functional groups with the surface of metal nanoparticles obtained by the "green synthesis" method was studied. The obtained IR spectra showed a shift of the bands corresponding to the stretching vibrations of the OH, -H, and C=O groups, indicating the formation of coordination bonds between the metal atoms and the active centers of the polymers. It was found that the efficiency of nanoparticle stabilization depends on the chemical nature of the biopolymer, as well as on the pH and reaction temperature. Additional methods, UV spectroscopy and dynamic light scattering (DLS), confirmed the formation of stable nanocomposites with a particle size of 20-80 nm. The results demonstrate that biopolymers can act as both a reducing agent and a stabilizer, ensuring the environmentally friendly synthesis of metal nanoparticles. The obtained materials are promising for use in biomedicine, catalysis, and sensorics.

## Keywords:

IR spectroscopy; metal nanoparticles; biopolymers; green synthesis; stabilization; surface interaction; chitosan; alginate; gelatin; nanomaterials.

**Introduction.** Metal nanoparticles (Ag, Au, Cu, etc.) are one of the most actively developing classes of nanomaterials due to their unique optical, catalytic, and antibacterial properties. They are widely used in electronics, pharmaceuticals, photocatalysis, medicine, and sensor technologies [1-3]. However, the main problem remains the aggregation of nanoparticles, leading to a loss of activity and a change in properties. To solve this problem, stabilizers are used, forming a protective shell around the nanoparticles [4].

In recent years, particular attention has been paid to "green" synthesis methods based on the use of natural biopolymers. Materials such as chitosan, sodium alginate, and gelatin not only prevent aggregation, but are also capable of converting metal ions into nanoparticles due to hydroxyl, carboxyl, and amino groups [5-7]. Infrared spectroscopy (IR) is a powerful tool for determining the nature of interactions between a biopolymer and a nanoparticle. Changes in the vibrational frequencies of functional groups before and after synthesis indicate the

mechanism of binding and formation of coordination complexes [8,9].

The aim of the work is to study the interaction of biopolymers with metal nanoparticles (Ad. Au, Cu) using the IR method and to determine the influence of synthesis conditions on the structure and stability of the obtained nanocomposites.

**Materials and methods.** Reagents The following analytical grade chemicals were used: silver nitrate ( $\text{AgNO}_3$ ), gold chloride ( $\text{HAuCl}_4 \cdot 3\text{H}_2\text{O}$ ), copper sulfate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ), biopolymers: chitosan (85% deacetylated), sodium alginate and gelatin. The solutions were prepared in distilled water and the pH was adjusted with a solution of NaOH or acetic acid. UV spectroscopy measures the plasmon maxima of nanoparticles

Methodology for the synthesis of nanoparticles A solution of metal salt ( $1 \times 10^{-3}$  M) was mixed with a solution of biopolymer (0.5-1%).

The reaction mixture was heated at 60-80°C with stirring. During the reaction, a color change in the solution was observed, indicating the formation of nanoparticles (yellow AgNPs, red-violet AuNPs, blue CuNPs).

The synthesized nanoparticles were separated by centrifugation, washed with water, and dried at 40°C. The resulting powders were used for IR analysis.

Research methods. IR spectroscopy, range 4000-400  $\text{cm}^{-1}$ , resolution 4  $\text{cm}^{-1}$  (Bruker Tensor 27 spectrometer). (Ad ~ 420 nm, Au ~ 530 nm, Cu - 580 nm). DLS (dynamic light scattering) determines the average particle size and polydispersity index. pH-metry monitors the acidity of the environment

**Results and discussion.** IR spectra of biopolymers. Electrostatic interactions between oppositely charged drugs (insulin and benzoic acid) and chitosan were studied using FTIR spectroscopy. No ionic interactions between the carboxyl group and the amino group of chitosan were detected. There was a slight change in the FTIR spectra of insulin-chitosan microparticles prepared from different insulin concentrations [11]. For the original biopolymers, using amino acids as an example, the following characteristic absorption bands were observed: 3400-3420

$\text{cm}^{-1}$  stretching vibrations O-H and Na-H; 1650  $\text{cm}^{-1}$  C=O vibration (amide I); 1550  $\text{cm}^{-1}$  Na-H vibrations (amide II); 1030  $\text{cm}^{-1}$  C-O-C vibrations in polysaccharide chains. IR spectra of nanoparticles. After the synthesis of nanoparticles, these functional groups are potentially involved in complexation with metal ions.

Characteristic changes in the spectra were observed: a shift of the O-H and Na-H bands to lower frequencies (3400-3360  $\text{cm}^{-1}$ ); a decrease in the intensity of the C=O and Na-H bands, indicating the participation of these groups in the coordination; the appearance of new bands in the 450-600  $\text{cm}^{-1}$  region, related to vibrations of the Me-O and Me-Na bonds. Thus, the IR data confirm the formation of coordination bonds between the metal atoms and the functional groups of the biopolymer when compared. The effectiveness of chitosan stabilizers ensures the strongest interaction with nanoparticles due to the amino groups ( $-\text{NH}_2$ ) that form coordination bonds with metal ions. Sodium alginate binds nanoparticles through carboxyl groups ( $-\text{COO}^-$ ), forming a dense polymer network. Gelatin acts as a physical barrier and forms weak hydrogen bonds with the particle surface. Under varying synthesis conditions, the optimal pH for the synthesis of silver and gold nanoparticles was 6-7, at which minimal aggregation was observed. At pH < 5, protonation of the chitosan amino groups and loss of stabilizing ability occurred. Increasing the temperature to 70-80°C accelerates the reduction process and leads to a reduction in particle size (to 25-40 nm). Further confirmation: UV spectra show plasmonic peaks for AgNPs at 420 nm, AuNPs at 530 nm, and CuNPs at 580 nm, confirming the formation of nanoparticles. DLS analysis showed that the average particle size varied from 20 to 80 nm, and the polydispersity did not exceed 0.25. The IR spectra show band shifts that correlate with the intensity of plasmonic absorption. In studying the mechanism of stabilization. Obtained data, the biopolymers based on the following stabilization mechanism can be proposed:

1. Metal ions interact with the functional groups of the biopolymer.

2. Hydroxyl and amino groups act as mild reducing agents, converting ions into a metallic state.
3. The formed nanoparticles are coated with biopolymer chains, preventing aggregation.
4. As a result, stable metal-biopolymer nanocomposites are Formed.

This mechanism explains the presence of characteristic changes in the IR spectra and the high stability of the synthesized systems.

**In conclusion**, the green synthesis of silver, copper, and gold nanoparticles using natural biopolymers (chitosan, sodium alginate, gelatin) was confirmed by spectral analysis. IR analysis confirmed the formation of coordination bonds between metal atoms and the functional groups of the biopolymers (-OH, -NH<sub>2</sub>, -COOH). Chitosan proved to be the most effective stabilizer due to its high density of donor sites.

The authors propose optimal synthesis conditions: pH 6-7, temperature 70°C, polymer concentration 0.5-1%, as the resulting nanocomposites are characterized by particle sizes of 20-80 nm and high colloidal stability. Interest in biopolymer nanoparticles is currently growing rapidly across many different industries. are particularly promising for use in biomedicine, catalysis and environmental technologies.

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