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The Study Of The IR Spectra Of The Impregnated Sorbents Before And After The Sorption Of Ag^+ Ions

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Abstract: This study investigates the adsorption of Ag^+ ions by polymer sorbents impregnated with organic ligands using IR spectroscopy. Comparative spectra recorded before and after adsorption show systematic shifts of characteristic vibrational bands, confirming coordination-driven complex formation between Ag^+ and donor functional groups on the sorbent surface. Ligands such as MAB, DEDTK, and DADTFK bind within the polymer matrix and yield stable metal–ligand complexes; diagnostic changes are observed in bands assigned to N–H, C=N, and, for phosphorus-containing ligands, P=S and P–S modes. The polymer matrix exhibits the expected polystyrene signatures, against which new or shifted bands are benchmarked to infer interaction strength and site specificity. The results underscore the decisive role of ligand functionality in designing selective sorbents for silver ion separation and purification.

Keywords: Impregnated sorbents; silver ion (Ag^+); IR spectroscopy; polymer matrix; organic ligands; complex formation; vibrational band shifts; adsorption mechanism; functional groups; selective adsorption; MAB; Dtz; DEDTK; DADTFK.

Introduction

At present, selective sorbents containing active functional groups anchored onto various matrices are well known. These include synthetic and natural polymers, mineral carriers, as well as sorbents obtained through impregnation or other modification methods. Many newly developed sorbents are also recommended for the extraction of valuable components from solutions, wastewater treatment, and other related applications. Numerous theoretical studies have also

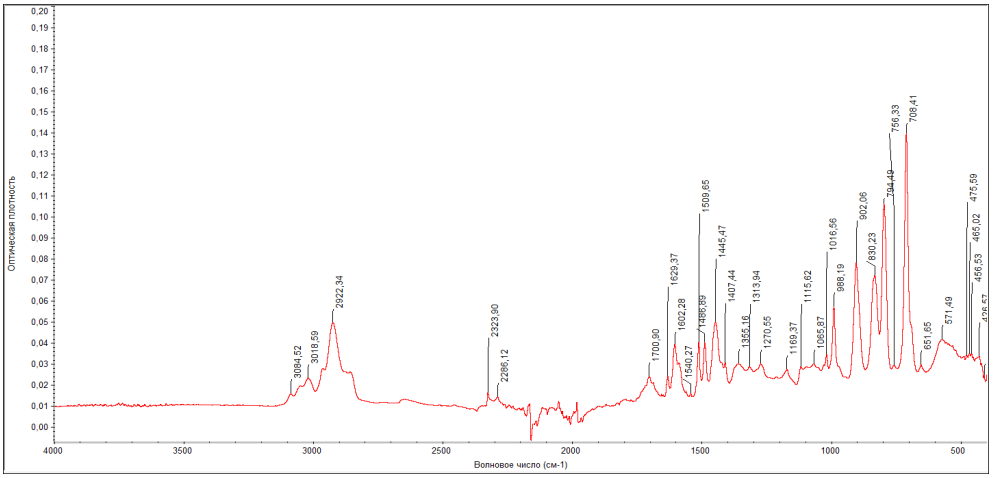
been conducted to investigate the mechanism, kinetics, and characteristics of complex formation during the sorption process. To combine the advantages of extraction and ion-exchange methods, the impregnation of polymer carriers with selective extractants has been proposed. Impregnated resins or sorbents are obtained either by impregnating the extractant into a porous carrier (impregnated resins) or by introducing it into the reaction mixture during the polymerization stage.

Results

The attachment of organic ligands MAV, Dtz, DEDTK, and DADTFK on the matrix surface, as well as the interaction of their functional groups with silver ions leading to the formation of coordination complexes, was confirmed by IR spectroscopy (Figures 1–3) [1-2].

In the IR spectrum of the polymer matrices within the frequency range of 400–4000 cm^{-1}, characteristic absorption bands of polystyrene are observed. The bands in the range of 1600–1700 and 705–795 cm^{-1} correspond to the stretching and deformation vibrations of mono-substituted aromatic hydrocarbons. Meanwhile, the absorption bands at 2925–3081 and 1350–1512 cm^{-1} are characteristic of the symmetric (ν) and asymmetric (ν_a) stretching vibrations of the C–H, CH_2–, and CH_3 bonds in aliphatic hydrocarbons. In the regions of 708, 795, 1605, and 1631 cm^{-1}, characteristic absorption bands of styrene are observed, along with the so-called “five-finger” vibration pattern in the 1700–2000 cm^{-1} range. After the sorption of silver ions by the impregnated sorbents, noticeable shifts (Δ) in the characteristic vibration frequencies are observed, indicating the formation of chemical bonds between the metal ions and the sorbent surface.

Although the presence of intermolecular interactions complicates the interpretation of the spectra, the magnitude of the frequency shift provides insight into the strength of the metal–ligand bonds formed on the surface of the impregnated sorbent. When transitioning to the sorbent containing MAV, in addition to the vibration bands associated with the polymer matrix, new absorption bands appear at 3325 and 3082 cm^{-1}, corresponding to the symmetric and asymmetric stretching vibrations of the $\nu(NH_2)$ group. The $\delta(NH_2)$ bending vibrations are observed in the 1615–1655 cm^{-1} region for primary amine groups and at around 1546 cm^{-1} for secondary amines, showing characteristic bands of moderate intensity. The broad absorption bands corresponding to the ν(NH) group are observed at 3087 cm^{-1}, while the ν(CH) stretching vibrations appear at 3034 cm^{-1}. The characteristic ν(C=N) vibration of the heterocyclic ring is detected at 1654 cm^{-1}. The observed shift of characteristic IR frequencies by 6–9 cm^{-1} indicates that MAV is chemically bonded to the polymer matrix.



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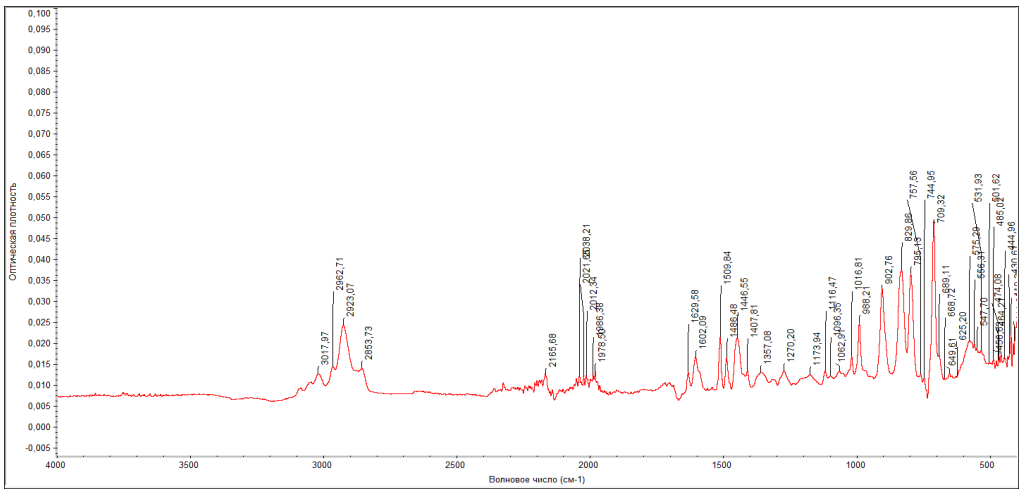

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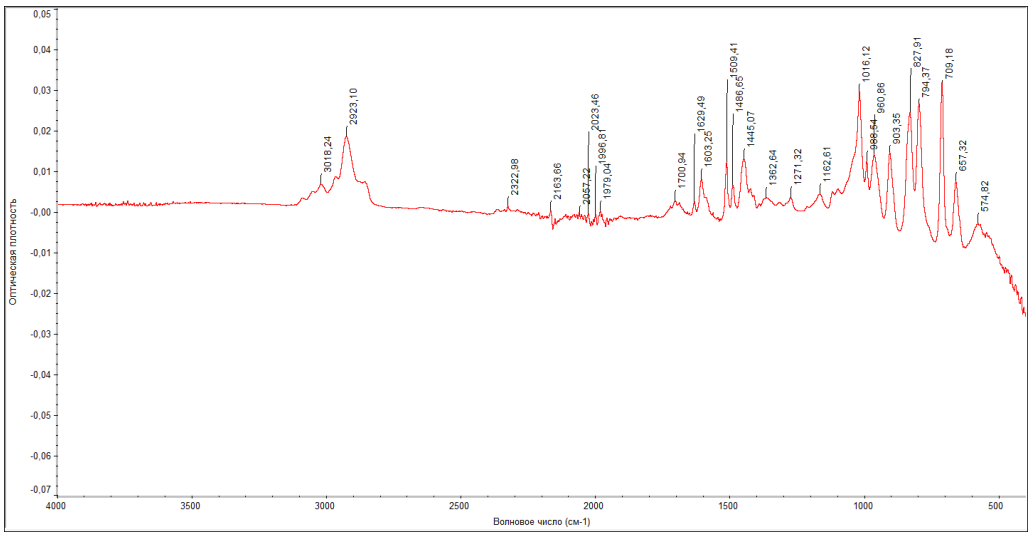

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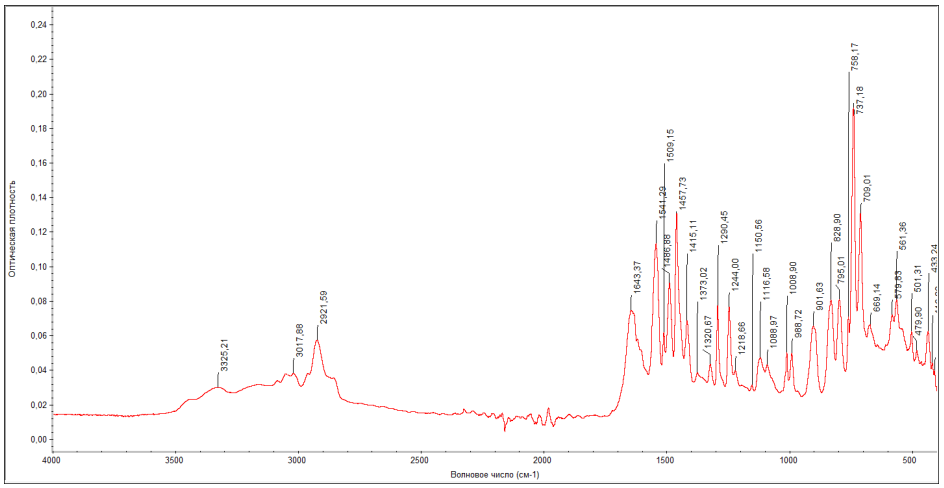
Figure 1. IR spectra: (a) PAD400; (b) PAD600; (c) PAD600 after sorption of the Ag^+ solution.



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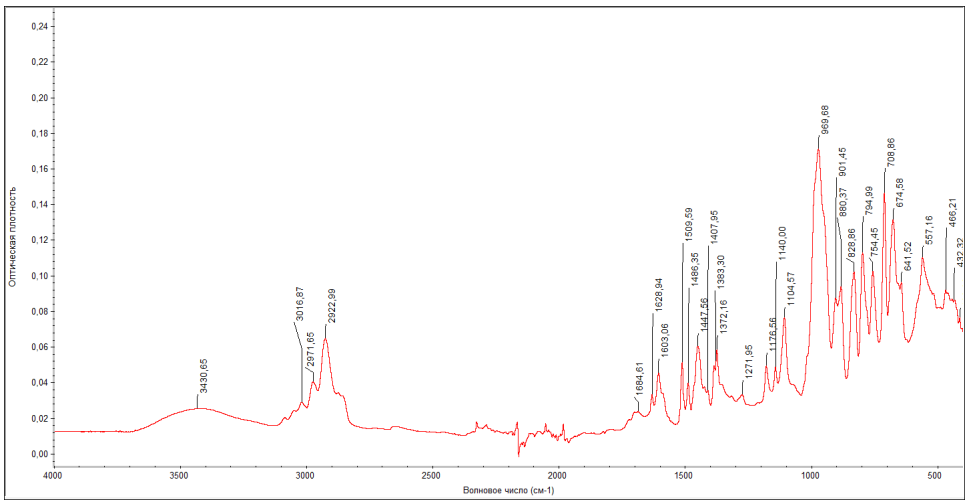

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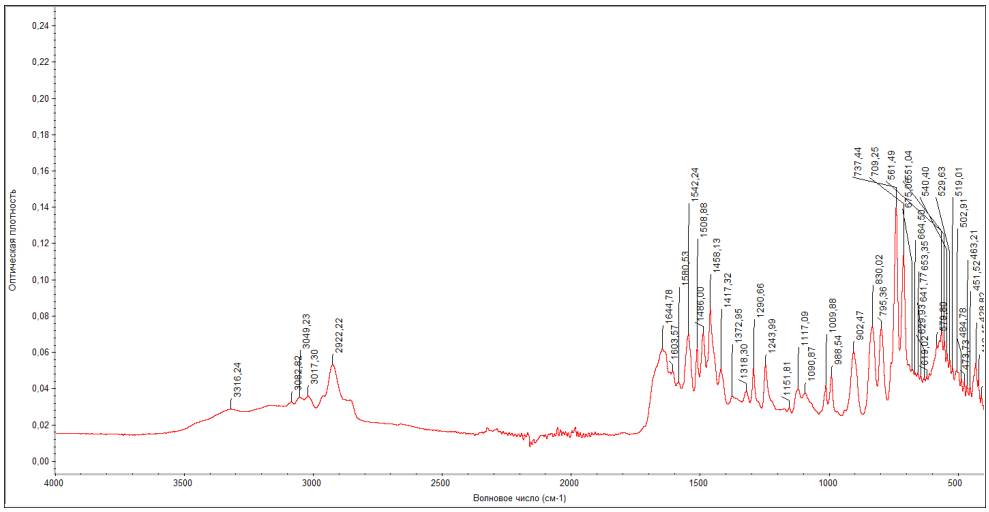
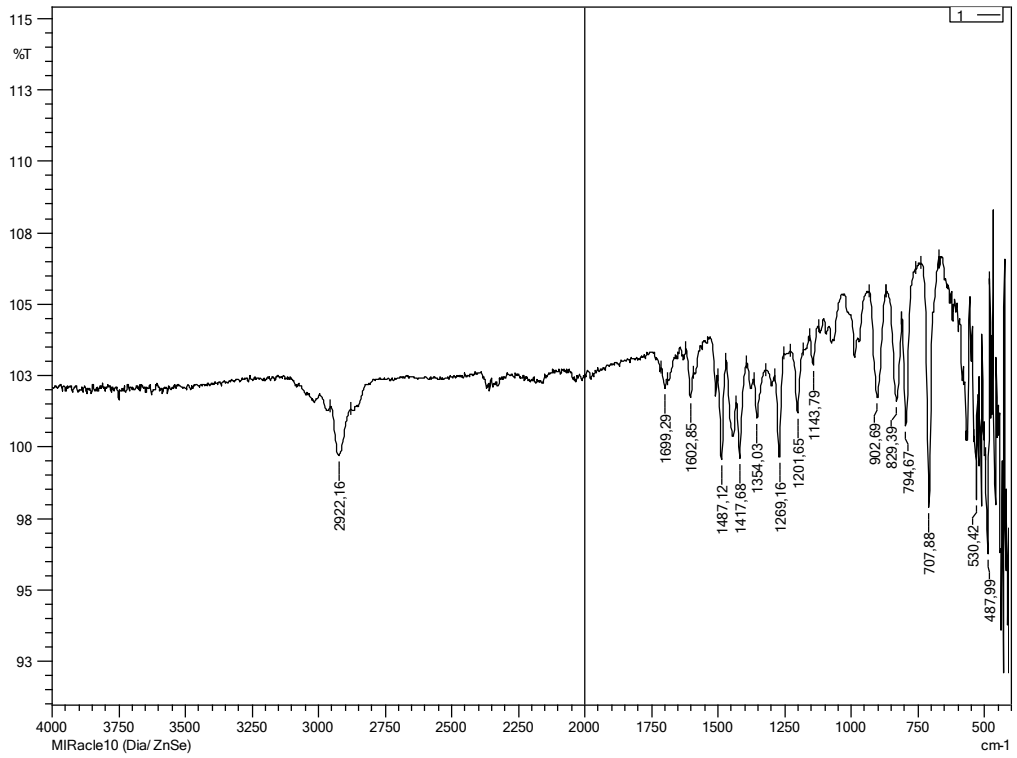


v)

Figure 2. IR spectra: (a) PAD600–MAB–Ag^+; (b) PAD600–DiPDTFK–Ag^+; (c) PAD400–MAB–Ag^+.

The IR spectra of PAD400–MAB and PAD600–MAV sorbents after the sorption of silver ions revealed noticeable changes in the vibration bands of characteristic functional groups. This indicates the occurrence of chemical interactions between the silver ions and the organic ligands on the sorbent surface during the sorption process.

In the PAD400 and PAD600 sorbents impregnated with DiPDTFK, the absorption bands corresponding to P=S stretching vibrations are observed at 676 and 641 cm^{-1}, respectively. The presence of asymmetric bands with maxima at 570 cm^{-1} and 577 cm^{-1} in the PAD400–DiPDTFK and PAD600–DiPDTFK sorbents is associated with the vibrations of the P–S group.



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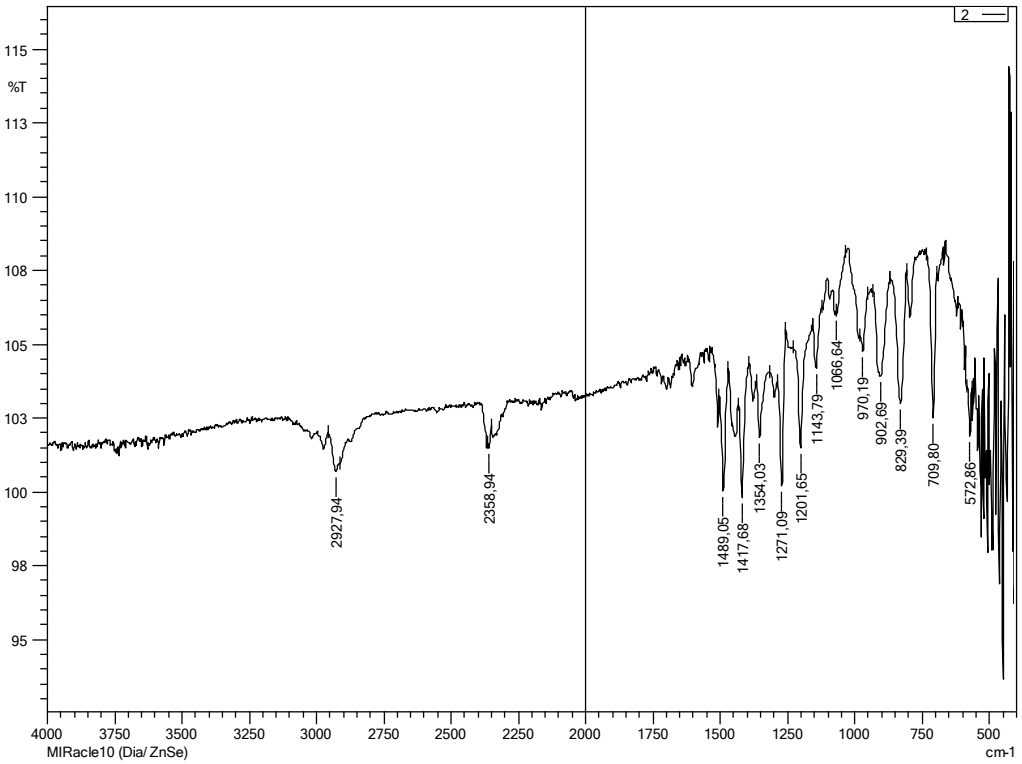

b)

Figure 3. IR spectra: (a) PAD400–DEDTKNA–Ag^+; (b) PAD600–DEDTKNA–Ag^+.

Conclusion

The results of this study indicate that polymer sorbents impregnated with organic ligands possess the ability to selectively sorb silver ions. The shifts observed in the characteristic vibration frequencies of the IR spectra confirm the formation of stable coordination bonds between Ag^+ ions and the surface of the sorbent during

the sorption process. The functional groups of MAB, DEDTK, and DADTFK act as active centers of the sorbent, ensuring the optimal stability of the resulting metal–organic complexes. The differential vibration bands demonstrate that the ligand, being chemically bonded to the polymer matrix, functions as an effective extractant. The obtained results highlight the potential for practical application of these materials in selective metal ion recovery and water purification technologies.

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