STUDY OF THE IR SPECTRAL PROPERTIES OF MAGNETIC IRON OXIDE (FE₃O₄) NANOMATERIALS

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Abstract. *This study is devoted to the infrared (IR) spectral analysis of Fe_3O_4-based magnetic nanomaterials, focusing on the vibrational characteristics of molecular bonds, structural features, and physicochemical parameters. Infrared spectroscopy is used to identify the internal structure, functional groups, and lattice bonding of the nanoparticles. The IR spectrum of Fe_3O_4 is highly sensitive to particle size, crystal structure, temperature, and synthesis conditions, and these factors determine the material's potential for practical applications. Therefore, the spectral characteristics of Fe_3O_4 samples obtained under different conditions were comparatively analyzed in this work.*

Keywords: *infrared spectroscopy, IRAffinity-1S, Fe_3O_4, magnetic nanomaterials, pharmaceutical applications.*

Introduction. The synthesis of Fe_3O_4-based magnetic nanoparticles using saponins as surfactants represents an important research direction in nanotechnology and materials science. Saponins are natural glycosides characterized by high emulsifying ability, biocompatibility, and low toxicity, which provide favorable conditions for nanoparticle synthesis. Fe_3O_4 nanoparticles produced with the help of these substances exhibit a narrow particle size distribution and a high degree of monodispersity, which significantly enhances their magnetic properties.

Saponin-based Fe_3O_4 magnetic nanomaterials have wide application potential in biomedicine, environmental protection, and electronics. In particular, they are promising for cancer diagnosis and therapy, removal of heavy metals from water, and the development of high-density data storage devices. Therefore, the synthesis

of magnetic nanomaterials using environmentally friendly and efficient saponins remains a scientifically relevant and promising research area.

Main Part. Infrared (IR) spectra are an important tool for determining the structure and composition of chemical compounds. They provide information about the vibrational motions of molecules, which makes it possible to identify the functional groups present in a molecule. In IR spectra, absorption bands corresponding to different types of molecular vibrations can be observed. For example, bands related to the vibrations of hydrogen atoms indicate the presence of functional groups such as alkanes, alkenes, and alcohols. Bands associated with the vibrations of oxygen and nitrogen atoms may indicate the presence of functional groups such as carbonyl compounds (e.g., aldehydes and ketones) and amines.

In addition, IR spectra provide information about the degree of saturation of molecular bonds, the conformation of molecules, and other physical properties of substances. All of this information can be used to identify unknown compounds and determine their molecular structure. Furthermore, IR spectroscopy can be applied to determine the concentration of individual components in a mixture, which is especially useful in the analysis of petroleum products and other complex mixtures where the amounts of different components must be quantified. Another important application of IR spectra is quality control at various stages of production. For example, in the pharmaceutical industry IR spectroscopy is used to verify the composition of drugs, while in the food industry it is applied to monitor product quality.

Overall, IR spectra provide comprehensive information about chemical compounds and serve as an essential tool for analyzing molecular composition and structure. The IR spectra of Fe_3O_4-based magnetic nanomaterials were recorded using an IRAffinity-1S IR spectrometer. The IRAffinity-1S instrument is widely used for analyzing chemical compounds in various samples and is applied in many scientific and industrial fields, where it enables rapid and accurate determination of chemical composition.

Figure 1. IRAffinity-1S IR Spectrometer

The IR spectra of Fe_3O_4-based magnetic nanomaterials obtained using the IRAffinity-1S instrument are presented in Figures 3.10 and 3.11.
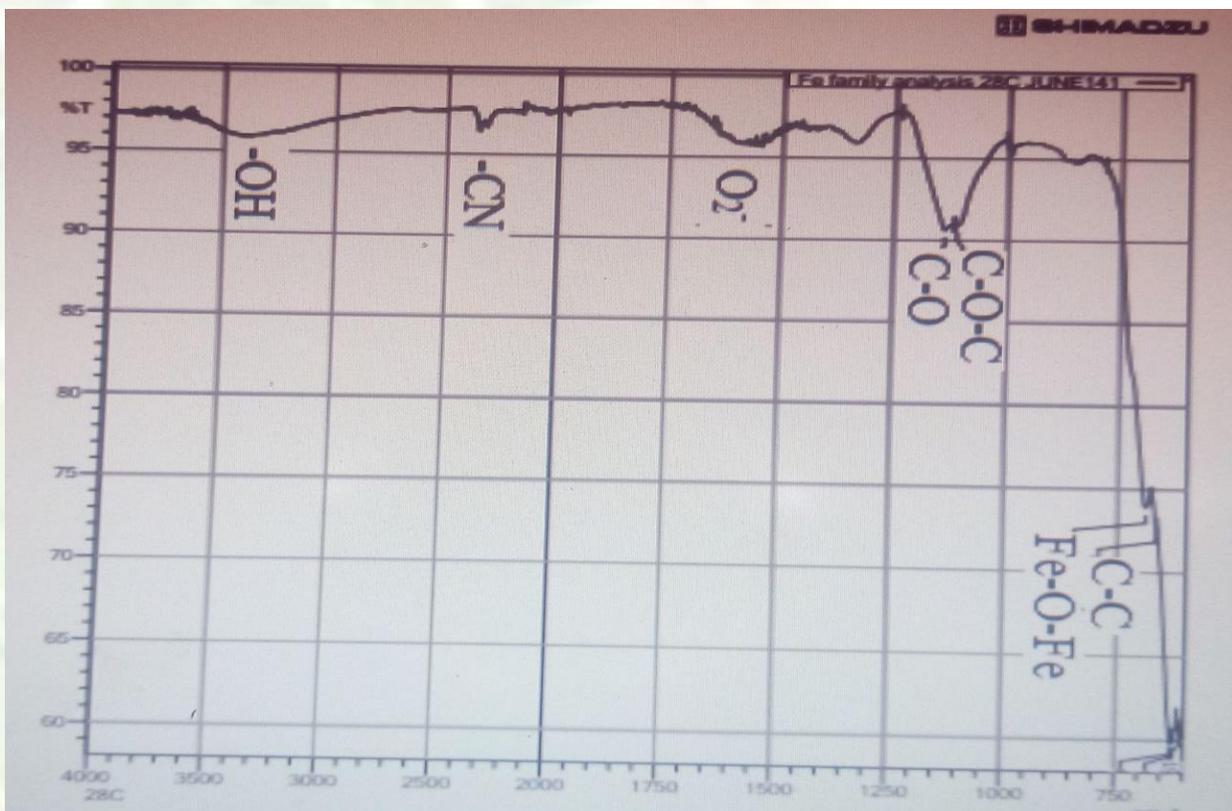
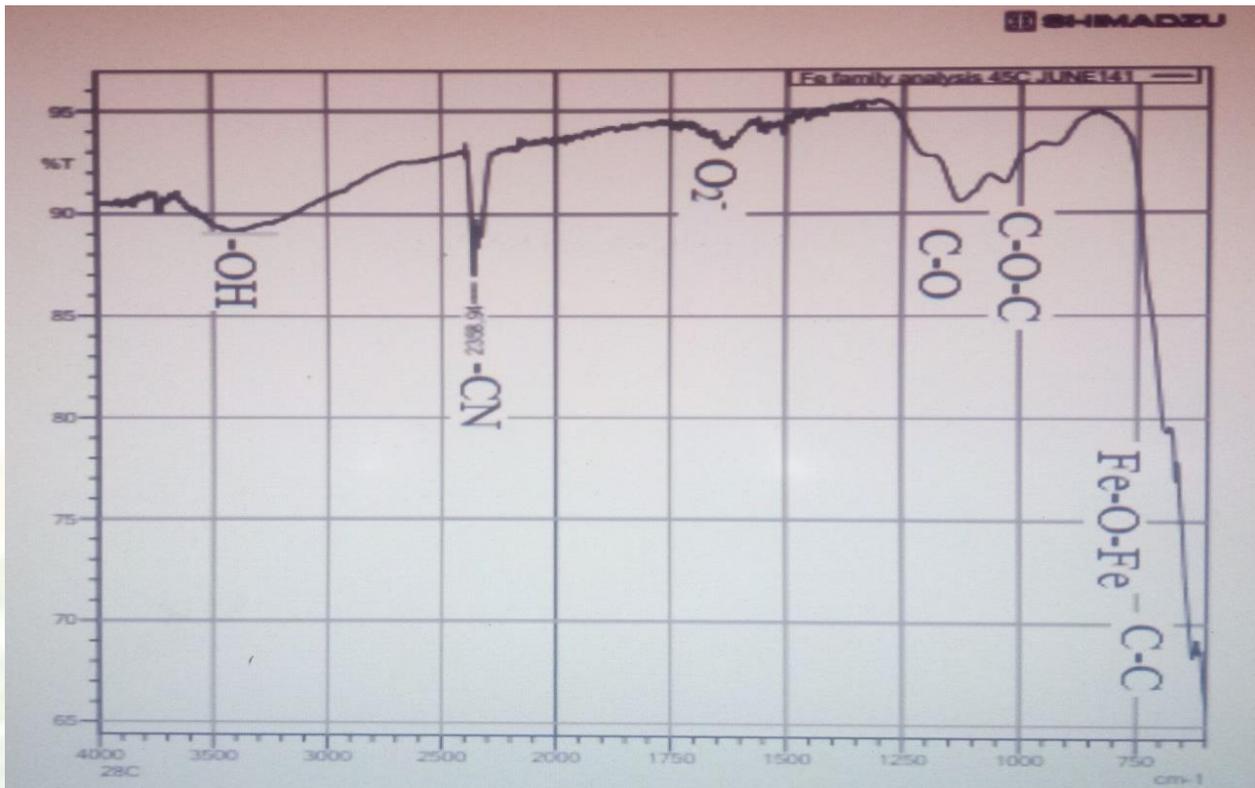Figure 2. IR spectrum of Fe₃O₄-based magnetic nanomaterial obtained at 28 °C

Figure 3. IR spectrum of Fe₃O₄-based magnetic nanomaterial obtained at 45 °C

The IR spectral characteristics of Fe_3O_4 include the following peaks:

570 cm^{-1}: This peak corresponds to the vibration of iron–oxygen (Fe–O) bonds.

400–500 cm^{-1}: These peaks indicate the vibrations of metal–metal bonds between iron ions (Fe–Fe).

3000–3600 cm^{-1}: These peaks are associated with the vibrations of O–H groups present on the surface of Fe_3O_4 nanoparticles.

In addition, the following peaks may also be observed in the IR spectrum of Fe_3O_4:

690 cm^{-1}: This peak corresponds to the vibrations of iron–oxygen–iron (Fe–O–Fe) bonds within the crystal lattice of Fe_3O_4.

1500 cm^{-1}: This peak is related to the vibrations of O^{2-} anions (oxide ions) that are part of the Fe_3O_4 crystal lattice.

Furthermore, the IR spectrum of Fe_3O_4 may vary depending on the structure, particle size, temperature, and other experimental conditions of the sample. Therefore, to fully understand the spectral properties of Fe_3O_4, all these factors must be taken into account and the material should be analyzed under well-defined experimental conditions. These spectral features can be used to identify Fe_3O_4 in samples as well as to study its structure and physicochemical properties.

Conclusion. In this study, Fe_3O_4-based magnetic nanomaterials were synthesized using saponins, and their structural and functional properties were evaluated by modern analytical methods. The obtained nanoparticles were characterized by atomic force microscopy, energy-dispersive X-ray fluorescence spectrometry, and infrared spectroscopy. The results demonstrated that Fe_3O_4 possesses a highly crystalline structure and an active surface, which makes these nanomaterials promising candidates for applications in biomedicine and environmental technologies.

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