# SYNTHESIS AND FTIR SPECTROSCOPIC CHARACTERIZATION OF NaP-TYPE ZEOLITE: CONFIRMATION OF THE GIS ALUMINOSILICATE FRAMEWORK

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**Abstract:** *This study presents the synthesis and Fourier-transform infrared (FTIR) spectroscopic characterization of NaP-type zeolite (GIS framework type, $NaAlSi_2O_6 \cdot H_2O$) obtained by hydrothermal crystallization using pure chemical reagents - sodium silicate and sodium aluminate. Unlike conventional methods based on the activation of natural clay minerals, this approach yields a purer product with a more controllable composition. The FTIR spectrum of the synthesized sample, recorded in the 4000-400 $cm^{-1}$ range, exhibits characteristic absorption bands confirming the formation of a crystalline aluminosilicate framework, including an intense band at 991 $cm^{-1}$ assigned to the asymmetric stretching vibration of Si-O(Al) bonds, together with bands in the 700-450 $cm^{-1}$ region associated with secondary building units. The results confirm that the applied synthesis method produces phase-pure NaP zeolite with spectral features characteristic of the GIS structural type.*

**Keywords:** *NaP zeolite; GIS framework; FTIR spectroscopy; aluminosilicate;*

*hydrothermal synthesis; pure chemical reagents.*

## INTRODUCTION

Zeolites are crystalline microporous aluminosilicates widely used as adsorbents, molecular sieves, ion exchangers, and catalysts due to their well-defined pore systems, high thermal and chemical stability, and structural selectivity [1-3]. Among synthetic zeolites, NaP zeolite (also designated Na-P1), belonging to the GIS framework type, is of particular interest because of its one-dimensional channel system with a small pore diameter of about 3.1 Å, which makes it effective for the adsorption of small molecules and promising for ion-exchange and catalytic processes [4].

NaP zeolite is conventionally synthesized by the hydrothermal treatment of natural aluminosilicate materials such as kaolin; however, the use of natural raw materials is associated with variability in composition and the presence of impurity phases. An alternative approach is the synthesis of the zeolite from pure chemical reagents - sodium silicate and sodium aluminate - which allows the molar ratios of the starting gel to be set precisely and promotes a more homogeneous, phase-pure product [5, 6].

Fourier-transform infrared spectroscopy (FTIR) is widely used to confirm the phase composition and structural features of synthesized zeolites, identifying the characteristic vibrations of Si-O-Si, Si-O-Al and T-O bonds in the aluminosilicate framework. The aim of this study was to synthesize NaP-type zeolite by a hydrothermal method using pure chemical reagents and to characterize it by FTIR spectroscopy in order to confirm the formation of an aluminosilicate framework corresponding to the GIS structural type.

## METHODOLOGY AND MATERIALS

NaP zeolite was obtained by a hydrothermal method using pure chemical reagents at a fixed molar ratio of the components $SiO_2$:$Al_2O_3$:$Na_2O$ = 2.0:1.0:3.0 (modulus ratios $SiO_2/Na_2O$ = 0.415 and $SiO_2/Al_2O_3$ = 2.43). Solutions of NaOH, sodium silicate

($Na_2SiO_3$) and sodium aluminate ($NaAlO_2$) were prepared and combined with stirring at 50-60 °C to form a homogeneous aluminosilicate gel.

The gel was transferred into a Teflon-lined autoclave and subjected to hydrothermal crystallization at 100 °C for 48 hours. The solid product was then separated by filtration, washed three times with distilled water and dried at 80 °C for 6 hours.

Infrared spectra of the synthesized sample were recorded directly on the powder by the attenuated total reflectance (ATR) technique, without KBr pellet preparation, on a Bruker spectrometer in the 4000-400 $cm^{-1}$ wavenumber range in transmittance mode.

**RESULTS AND DISCUSSION**

The FTIR spectrum of the synthesized NaP zeolite (Figure 1) exhibits a series of clearly defined absorption bands confirming the formation of a crystalline aluminosilicate framework. A broad, intense band with a maximum at 3444 $cm^{-1}$ is due to the O-H stretching vibrations of structural silanol groups and water molecules coordinated with the exchangeable $Na^+$ cations located within the zeolite channels. The band at 1638 $cm^{-1}$ corresponds to the bending vibration of adsorbed water, confirming the hydrated state of the material consistent with the formula $NaAlSi_2O_6 \cdot H_2O$ [7, 8].

The most diagnostically significant feature of the spectrum is the intense band at 991 $cm^{-1}$, representing the asymmetric stretching vibration of Si-O(Al) bonds within the tetrahedral framework. Its high intensity and comparatively narrow shape indicate the formation of an ordered crystalline framework. The position of this band near 990-1000 $cm^{-1}$, rather than in the 1050-1090 $cm^{-1}$ region characteristic of zeolites with a higher Si/Al ratio, is consistent with the relatively low $SiO_2/Al_2O_3$ modulus set in the synthesis (2.43), which is typical of NaP zeolite of the GIS structural type [4, 6].

Additional bands at 700 and 608 $cm^{-1}$ are associated with vibrations of secondary building units (double rings) and bending vibrations of Si-O-Si / Si-O-Al bonds, while the band at 455 $cm^{-1}$ is attributed to the bending vibration of T-O-T bonds. Their presence provides further confirmation of the crystalline, rather than amorphous,

nature of the synthesized product. Weak bands at 2923, 2854, 1448 and 1405 $cm^{-1}$, corresponding to vibrations of $CH_2$ groups, are attributed to trace organic contamination on the sample surface rather than to the aluminosilicate framework itself.

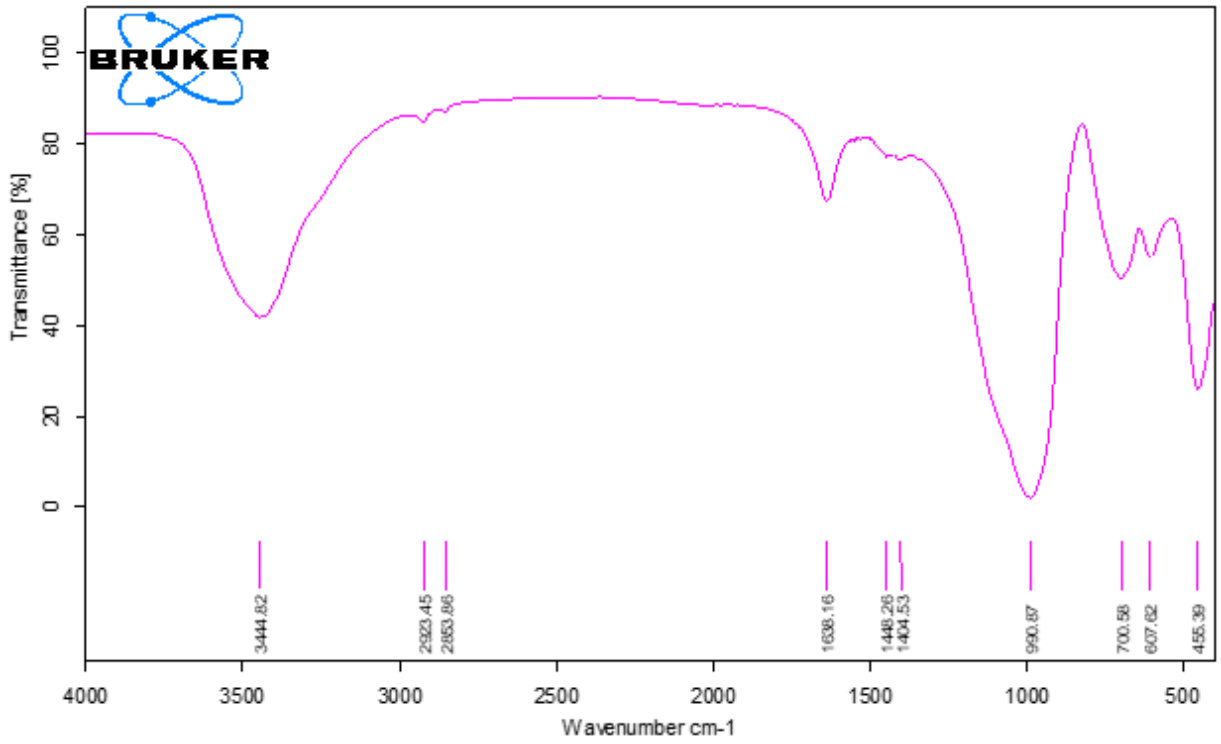



**Figure 1. FTIR spectrum of the synthesized NaP zeolite showing the positions of the main absorption bands ($cm^{-1}$).**

Overall, the set of absorption bands obtained - above all the intense band at 991 $cm^{-1}$ together with the bands in the 700-450 $cm^{-1}$ region-confirms the formation of a crystalline aluminosilicate framework characteristic of NaP zeolite (GIS structural type), consistent with literature data on GIS-type zeolites obtained both from natural raw material and from pure chemical reagents [4, 6].

## CONCLUSION

NaP-type zeolite (GIS structural type) was successfully synthesized by hydrothermal crystallization at 100 °C for 48 hours using pure chemical reagents. FTIR spectroscopy confirmed the formation of a well-defined aluminosilicate

framework, with the most intense band at 991 $cm^{-1}$, assigned to the asymmetric stretching vibration of Si-O(Al), confirming an ordered crystalline structure typical of NaP zeolite.

The results demonstrate that a synthesis method based on pure chemical reagents makes it possible to obtain NaP zeolite with clearly defined structural features consistent with literature data, providing a basis for further investigation of its adsorption, ion-exchange and catalytic properties.

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