

ADSORPTION–DESORPTION ISOTHERMS OF AN INORGANIC POLYMER SORBENT DERIVED FROM LOCAL CLAY

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Abstract

The porous structure of an inorganic polymer aluminosilicate sorbent synthesized from local clay via the sol–gel method was investigated by low-temperature nitrogen adsorption–desorption at 77 K. The specific surface area was determined using the Brunauer–Emmett–Teller (BET) method. According to the IUPAC classification, the isotherm is close to Type IV and is characterized by a broad hysteresis loop, including hysteresis in the low-pressure region. The specific surface area of the material was approximately $32 \text{ m}^2 \text{ g}^{-1}$, and the total pore volume was $0.0186 \text{ cm}^3 \text{ g}^{-1}$.

Keywords

inorganic polymer, aluminosilicate sorbent, nitrogen adsorption, BET, porous structure, hysteresis, specific surface area.

Introduction. The specific surface characteristics, porosity parameters, and specific pore volume of an inorganic polymer sorbent derived from local raw materials are among the principal factors governing its sorption properties [1]. Pore size and pore-size

distribution determine the diffusion rate of substances within the porous structure, whereas analysis of the specific pore volume is important for evaluating the physicochemical properties of inorganic polymer sorbents [2].

To prepare the inorganic polymer sorbent, the initial local clay was first treated with 1 M sulfuric acid at room temperature at a solid-to-liquid ratio of 1:5 for 2 h and subsequently washed with distilled water until neutral. The material was then treated with 3 M NaOH solution at room temperature at a ratio of 1:3 for 4 h [3]. The textural properties of the initial clay and the resulting sorbent were investigated using nitrogen (N₂) adsorption–desorption isotherms at 77 K. Prior to measurement, a 0.0882 g sample was degassed under vacuum at 120 °C for 2 h 56 min. The adsorption and desorption isotherms were recorded over the relative-pressure range $P/P_0 = 0.03–0.99$.

The specific surface area (S_{BET}) was calculated using the Brunauer–Emmett–Teller (BET) equation from the adsorption-branch data in the relative-pressure range $P/P_0 = 0.05–0.30$ [4]:

$$P / [V (P_0 - P)] = 1 / (V_m C) + [(C - 1) / (V_m C)] (P/P_0), \quad (1)$$

where V is the volume of nitrogen adsorbed at the relative pressure P/P_0 , cm³ g⁻¹ (STP); V_m is the monolayer capacity, cm³ g⁻¹ (STP); and C is the BET constant related to the energy of adsorbate–adsorbent interactions. Taking the cross-sectional area of a nitrogen molecule as 0.162 nm², the specific surface area was determined as follows:

$$S_{\text{BET}} = 4,353 \cdot V_m. \quad (2)$$

The total pore volume (V_{total}) was determined by converting the volume of nitrogen adsorbed at a relative pressure of $P/P_0 = 0.99$ to the corresponding volume of liquid nitrogen:

$$V_{\text{total}} = 0,001547 \cdot V_{0,99}, \quad (3)$$

where 0.001547 is the conversion factor from the volume of gaseous nitrogen at STP to the volume of liquid nitrogen at 77 K. The average pore diameter was calculated

using the cylindrical-pore model:

$$D = 4V_{\text{total}}/S_{\text{BET}}. \quad (4)$$

Results and Discussion.

The nitrogen adsorption–desorption isotherms of the inorganic polymer sorbent at 77 K are shown in Figure 1. The adsorption branch does not exhibit a sharp increase in the low-relative-pressure region ($P/P_0 < 0.1$), indicating the absence of a distinct stage associated with volumetric filling of micropores. As the relative pressure increases, the volume of adsorbed nitrogen increases almost linearly and reaches approximately $8 \text{ cm}^3 \text{ g}^{-1}$ at $P/P_0 \approx 0.9$, after which it approaches saturation. The maximum adsorption value ($\approx 8.1 \text{ cm}^3 \text{ g}^{-1}$) is relatively low, indicating limited overall porosity of the material.

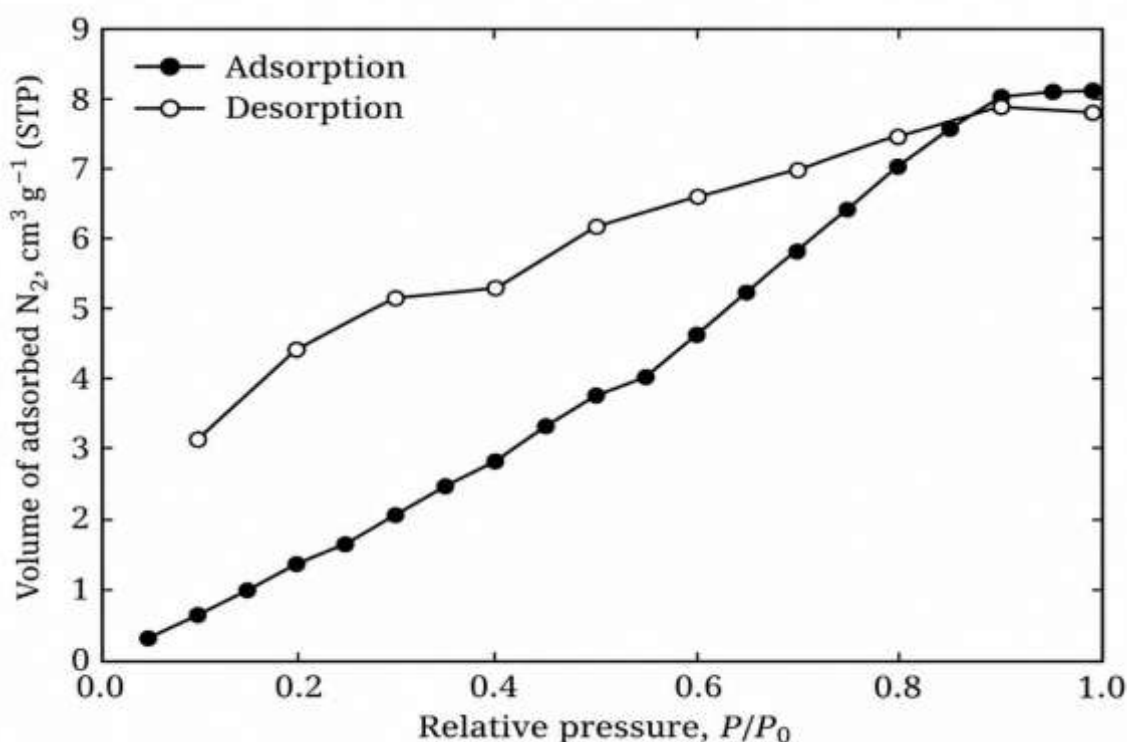


Figure 1. Nitrogen adsorption (●) and desorption (○) isotherms of the inorganic polymer sorbent at 77 K

The saturation behavior at high relative pressures and the presence of a broad hysteresis loop indicate that the isotherm is close to Type IV according to the IUPAC

classification [4]. The hysteresis loop extends over $P/P_0 \approx 0.1-0.9$, and the desorption branch does not rejoin the adsorption branch even at low relative pressures (low-pressure hysteresis). Such behavior is commonly attributed to incomplete equilibration caused by slow diffusion of nitrogen molecules through narrow pore entrances, partially irreversible retention of nitrogen within the pores, or deformation of the material framework during adsorption [4].

CONCLUSION

The most pronounced retention of mesopores was observed in the 15–20 nm range, which is considered favorable for ion-exchange and diffusion processes. The modification promotes the formation of active ion-exchange sites while preserving the total pore volume. The predominance of mesopores in the 10–20 nm range provides a structural basis for the enhanced sorption properties of the inorganic polymer sorbent.

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