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Impact of Crystal Structure on Methanol Vapor Adsorption in MFI-Type Zeolites: Equilibrium Isotherms and Kinetic Insights

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Porous materials stand at the forefront of adsorption research, offering versatile applications in separation processes and catalysis for both fundamental research and industrial purposes. Among the numerous applications, methanol separation through adsorption mechanisms is an interesting topic due to the high-value accessible derivatives (purified methanol, hydrocarbons, olefins). Therefore, as a first approach, this study focused on the adsorption behavior of methanol vapor on synthesized MFI-type zeolites. Through a meticulous characterization process, including ill-crystalized (IC), fully crystalized (FC), and hierarchical (HZ) zeolites, we aimed to unveil the influence of material properties on methanol adsorption capacity and accessibility. Equilibrium adsorption experiments conducted at 313.15 K provided critical insights by elucidating the distinctive adsorption behavior across the zeolite samples. The observed isotherm pattern was accurately fitted with the Dubinin–Astakhov model. Notably, the synthesized zeolites exhibited varying adsorption capacities, with hierarchical structures demonstrating superior methanol adsorption over fully and ill-crystalized counterparts, which was also confirmed by calorimetry immersion analysis. Furthermore, our investigation focused on the kinetics of the methanol accessibility within MFI-type zeolites, employing three models: Elovich, Weber-Morris, and Boyd. Estimation of kinetic parameters allowed for a comprehensive evaluation of the adsorption behavior at different loading conditions. The findings showcased distinct kinetic behavior and exposed the influence of material composition on the adsorption kinetics, finally elucidating the methanol-vapor interaction with MFI-type zeolites. Overall, there is an evident and intricate interplay between material chemical properties, adsorption capacity, and vapor accessibility. These insights emphasize the prospect of customizing materials to optimize their performance in diverse adsorption applications.

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