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ZEOLITES FOR SELECTIVE CO₂ ADSORPTION

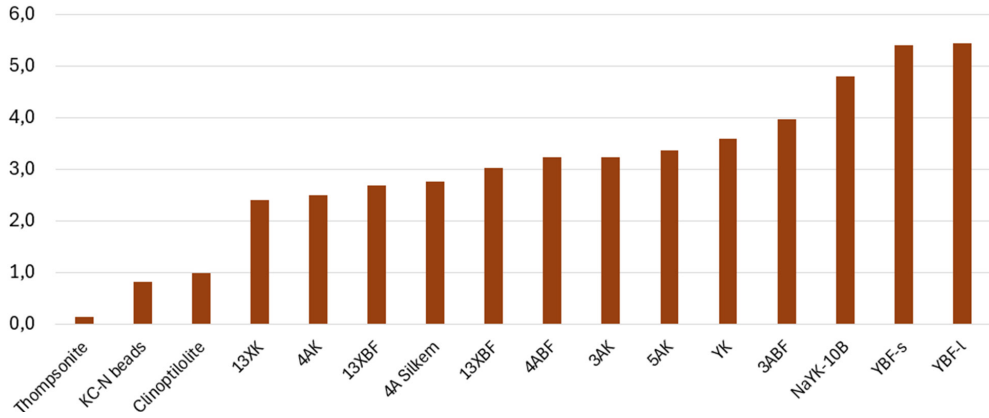
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Abstract – This work investigates the selective CO₂ adsorption behaviour of various synthetic zeolites and provides a comparative assessment of their sorptive performance and regeneration characteristics under controlled conditions. CO₂ capture in zeolites plays an essential role in gas purification, sorption-enhanced reaction processes, and decentralized renewable energy systems, where efficient adsorption–desorption cycles directly impact process energy demand and operational stability. In this study, several zeolite types – including Faujasite-based materials (YBF, YK, 13XBF, 13XK) and LTA-type zeolites (4A, 5A, 3A) – were evaluated for their CO₂ uptake capacity under an applied pressure of 1 bar gauge (2 bar absolute). To ensure reproducibility, all samples were fully desorbed at 250 °C prior to CO₂ loading. The measured CO₂ adsorption capacities ranged from 2.5 to 5.4 mmol/g, with Faujasite-type zeolites exhibiting the highest uptake. The maximum capacity of 5.4 mmol/g, corresponding to approximately 25 wt% CO₂, was observed for binder-free Y-type zeolite (YBF). The preferred adsorption of water relative to CO₂ – rooted in the significantly higher dipole moment and adsorption enthalpy of H₂O – means that CO₂ adsorption is strongly affected by the hydration state of the zeolite. Consequently, complete removal of moisture is essential to achieving maximum CO₂ uptake. The experiments confirm that CO₂ remains in the gaseous state within the pores during adsorption due to its low critical temperature (31 °C), resulting in a lower reaction enthalpy compared to water and enabling rapid, low-energy desorption. Desorption studies demonstrate that CO₂ can be released either through exposure to ambient air, where water vapour displaces the adsorbed CO₂, or via controlled thermal treatment, which is more energy-efficient for subsequent reloading. Overall, the results highlight strong material-dependent differences in CO₂ capacity, fast and low-enthalpy regeneration behaviour, and the suitability of Faujasite-type zeolites – particularly binder-free variants – for cyclic CO₂ adsorption processes. The findings contribute to the optimization of zeolitic sorbents for gas-separation, methanation, and renewable energy applications, where rapid and energy-efficient CO₂ handling is essential.

Keywords – *Gas adsorption; renewable gas purification; sorbent regeneration; zeolites*



CO₂ adsorption in different sorptive materials contained within a pressurized vessel at 1 bar gauge pressure

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