

**Synthesis and Characterisation of Conventional and Hierarchical BEA Catalysts with
Varying $\text{SiO}_2/\text{Al}_2\text{O}_3$ Ratios**

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STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.



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ABSTRACT

SYNTHESIS AND CHARACTERISATION OF CONVENTIONAL AND HIERARCHICAL BEA WITH VARYING Si₂/AL₂O₃ RATIOS

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The rising demand for middle distillate fuels and the production of heavy waxes during low-temperature Fischer-Tropsch synthesis justifies the search for catalysts capable of converting these waxes into usable fuel fractions through dewaxing. Zeolite Beta has been identified as a promising catalyst for dewaxing processes due to its three-dimensional channel system composed of 12-membered rings. However, the exclusively microporous nature of conventional zeolite Beta restricts the diffusion of long-chain paraffinic molecules, which are too large to readily enter the micropores, thereby limiting catalytic activity toward the Fischer-Tropsch wax fraction. To address this limitation and increase the accessibility of active acid sites to long-chain paraffins, hierarchical zeolites incorporating both micropores and mesopores were synthesised and characterised at SiO₂/Al₂O₃ ratios of 50 and 150. Conventional zeolite Beta was synthesised using tetraethylammonium hydroxide (TEAOH) as the sole structure-directing agent (SDA). Hierarchical zeolite Beta was synthesised using both TEAOH and cetyltrimethylammonium bromide (CTAB) as SDAs, where CTAB acts as a mesopore-directing surfactant. The synthesised materials were characterised using X-ray diffraction (XRD), N₂ physisorption, and inductively coupled plasma optical emission spectroscopy (ICP-OES). Conventional zeolite Beta was successfully synthesised at both SiO₂/Al₂O₃ ratios, yielding BET surface areas of 690 and 698 m²/g for the ratio-50 and ratio-150 samples respectively, and measured Si/Al ratios of approximately 18 and 24, both considerably lower than the targeted gel ratios due to the preferential incorporation of aluminium into the zeolite framework under alkaline synthesis conditions. Hierarchical zeolite Beta was successfully synthesised at a SiO₂/Al₂O₃ ratio of 50, as confirmed by XRD. However, synthesis at a SiO₂/Al₂O₃ ratio of 150 predominantly yielded MFI-type zeolite rather than BEA. This outcome was attributed to the reduced Al₂O₃ content used to achieve the higher ratio, which

raised the TEA₂O/Al₂O₃ ratio and diminished the availability of Al-TEA ion pairs required to stabilise the forming BEA nuclei. These findings demonstrate that the dual-templating process for hierarchical BEA formation is viable at a SiO₂/Al₂O₃ ratio of 50 but requires further optimisation at higher ratios. Consequently, conventional BEA has been identified as a viable support for platinum-containing dewaxing catalysts, while the hierarchical form requires additional characterisation and synthesis optimisation prior to catalytic evaluation.

Keywords: Zeolite Beta, Hierarchical zeolite, Dual templating, hydrocracking, Fischer-Tropsch



DEDICATION

For my mother, whose sacrifices made this possible.
And for South Africa, may this work, however small, be one step toward the energy future and
the country you deserve.



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