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Phosphorus-Modified Catalysts in the Dehydrogenation of n-Heptane as a Model Compound for Pyrolysis Oil Upgrading

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The recycling of plastic waste is a key component in the transition towards a circular carbon economy. In particular, pyrolysis enables the conversion of complex plastic waste streams into hydrocarbon-rich feedstocks. Such pyrolysis oils typically contain significant fractions of linear mid-chain alkanes, which are energetically valuable but of limited utility as chemical intermediates [1]. In this context, catalytic dehydrogenation of n-alkanes to linear olefins represents an attractive upgrading route, since linear olefins are important platform chemicals for the production of, e.g., detergents and polymers.
However, due to high temperatures required for alkane dehydrogenation, conventional Pt/Al_2O_3 catalysts are prone to deactivation caused by coke deposition and metal particle sintering. In order to tailor catalytic selectivity and improve stability, catalyst modification represents a promising approach. Among other promoter elements, phosphorous (P) has gained interest due to its capability to alter both steric and electronic properties of active metal clusters as well as the support material's surface characteristics [2]. Previous studies on different dehydrogenation systems have already demonstrated benefits of P-modification, including improved olefin selectivity and stability against sintering [3][4]. Therefore, P-modified Pt-based catalysts are investigated in this study for the dehydrogenation of n-heptane, serving as a model compound representative of linear alkanes present in plastic pyrolysis oils. The synthesized catalysts are evaluated in a continuous fixed-bed reactor setup.
In comparison to an unmodified Pt/Al_2O_3 catalyst, initial variations in phosphorus loading already indicate improvements in heptane conversion and olefin selectivity by 11% and 15%, respectively. In addition, parameter studies are being performed for both unmodified Pt/Al_2O_3 and P-modified catalysts aiming to identify differences in activity, selectivity, and deactivation behavior under varying reaction conditions. Furthermore, Pt-catalysts supported on SiO_2 will be employed in order to examine the influence of the support material and its interaction with the P-promoter. By combining of extensive characterization and catalytic testing, this work aims to provide fundamental insights into structure-performance relationships of phosphorus-modified dehydrogenation catalysts for the upgrading of plastic-derived hydrocarbon feedstocks.

References:

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