Steam catalytic cracking of fuel oil over a novel composite nanocatalyst: Characterization, kinetics and comparative perspective

A novel composite nanocatalyst (CNM) was fabricated and identified using XRD, NH₃-TPD, FTIR, SEM, EDX, and N₂ physisorption, and was further assessed for the catalytic cracking of a heavy feedstock to value-added chemicals, including light alkenes and liquid fuels. Multiple phases (MEL, MFI, CHA, and AlPO) and a moderately tuned acidity different from those in FCC and ZSM-5 catalysts were identified for the investigated catalyst. More than 80 wt% of the dry gas stream was occupied by light olefins (ethylene, propylene, and butenes) with the remarkable propylene-to-ethylene ratio of 2.18, surpassing the two benchmark ZSM-5 and FCC samples. Meanwhile, the total yield of gasoline and diesel fuel amounted to ~46wt%. The influence of operating conditions including reaction temperature and contact time on the catalytic performance of CNM was further investigated. The results indicated that a temperature of 823 K was most promising for obtaining notable yields of light olefins, particularly propylene, while at lower temperatures (723 K), the yield of liquid products became almost three times the gaseous species. The observed activation energy was about 36.7 kJ/mol with the CNM catalyst. Interestingly, by increasing the space velocity by a factor of five, the productivity to light olefins increased by 11.4% on a feed basis, indicating the high potential of the new catalyst for the catalytic conversion of heavy hydrocarbons to light olefins. An eight-lump kinetic model with varying orders of reaction successfully described the obtained results. The overall reaction order for the conversion of fuel oil on CNM was 1.47, whereas a negative reaction order for coke formation was observed in reasonable agreement with the phase separation theory.