Mechanical Valorisation of Asphaltene using Ball Milling

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Abstract

Asphaltenes, the heaviest and most complex fraction of crude oil, are increasingly critical in the global energy landscape as conventional light oils decline. Their intrinsic heterogeneity, strong aggregation tendencies, and refractory nature, however, present major challenges for efficient conversion and utilisation. A deeper understanding of asphaltene thermal behaviour and strategies to enhance its reactivity are therefore of significant industrial and academic interest. This study aims investigates the impact of ball milling treatment on asphaltene thermophysical properties. The results show that asphaltene underwent mechanochemical oxidation with ~3.7% higher oxygen content while preserving the overall elemental composition of other atoms. The average molecular assemblies became more uniform, as indicated by a reduced dispersion value, and Raman spectroscopy revealed an increase in both D and G band integrals (from 44.6 and 16.3 to 67.8 and 22.9, respectively), signifying greater aromatisation accompanied by structural disorder. The average aromatic sheet length decreased from 16 to 14.86 Å, evidencing edge defects in the aromatic core. The kinetic analysis further demonstrated that ball milling reduced reduces activation energy at early stages, to facilitate an earlier onset of decomposition, while. Meanwhile, in the refractory zone, molecular modifications sustained higher conversion and lowered kinetic barriers relative to the virgin sample. Overall, ball milling emerges as a green and scalable strategy for asphaltene oxidation and molecular modification, offering potential benefits for both chemical processing and oil industry optimisation.

Keywords

Asphaltenes, Ball Milling, Oxidisation, Aromatisation, Edge Defects, Reactivity.