Experimental analysis of multi-scale oil shale pyrolysis

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Oil shale is a complex material that contains organic matter, mineral matrix and a small amount of bound and/or unbound water. The decomposition of the organic matter generates liquid and gaseous products. During decomposition several coupled processes occur simultaneously and regulate the distribution of the products. The yield and desired quality of the liquid (shale oil) is controlled by the operational condition to which the raw oil shale is exposed. Pyrolysis of a small amount of finely powdered oil shale provides a chemically controlled intrinsic kinetic rate of organic decomposition. Pyrolysis of large size blocks or core provides distribution of temperature and product generation profiles across the sample. Heat and mass transfer considerations influence the distribution of products. Secondary reactions, coking and cracking, in liquid and vapor phases are important and alter the yield and quality of the desired product. In this paper, we report experimental studies on multi-scale oil shale pyrolysis. Oil shale in the Mahogany zone of the Green River formation was used in all experiments. Experiments were performed at four scales, powdered samples (100 mesh) and core samples of ¾″, 1″ and 2.5″ diameters. Batch, semi-batch and continuous flow pyrolysis experiments were designed to capture the effect of temperature (300 to 500°C), pressure (ambient and 500 psi) and of the use of samples of different sizes on product formation. Comprehensive analyses were performed on feed and products - liquid, gas and spent shale, to quantify the elemental distributions and mass balances. TGA analysis on spent shale was used to measure the amount of coke formed under different conditions. Compositions of liquid and gas products were analyzed using gas chromatography. Increase in the size of the core sample results in the formation of more coke and lighter oil. Experiments under high pressure also generated more coke and lighter oil. Mechanistic models, addressing multi-scale issues were developed to represent the elemental and mass distribution of oil shale pyrolysis products under different conditions. The multi-scale experimental data generated and the models developed provide an understanding of the simultaneous effects of chemical kinetics, heat transfer, mass transfer and pressure on oil quality and yield.