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Conventional cubic equation-of-state modeling of the phase behavior of bitumen and solvents

J. Modaresghazani, M.A. Satyro, H.W. Yarranton*

Department of Chemical and Petroleum Engineering, University of Calgary
Calgary, Alberta, Canada, T2N1N4
(corresponding author: hyarrant@ucalgary.ca)*

The application of cubic equations of state (CEOS) to conventional oils is well established. The use of CEOS for heavy oils and solvent mixtures is more challenging and not well tested because characterization data are not available for the non-distillable fraction of the heavy oil, which can make up more than 40 wt% of the fluid. In this study, simulated distillation data obtained from the distillable fraction of a bitumen are extrapolated over the non-distillable fraction. Fluid characterizations are constructed from different extrapolations and phase behavior predictions based on these characterizations are compared with data for the bitumen mixed with several different solvents.

The experimental data set included vapor-liquid (VL), liquid-liquid (LL), and vapor-liquid-liquid (VLL) phase boundaries for two pseudo-binary systems (propane and Athabasca bitumen; carbon dioxide and Athabasca bitumen) and three "ternary" mixtures of propane, carbon dioxide, and Athabasca bitumen [1,2]. Asphaltene yields from n-heptane diluted Athabasca bitumen were also available.

The distillable fraction of the bitumen was characterized based on the simulated distillation data of maltenes using standard methods to cut the distillation curve into pseudo-components. Physical and critical properties were assigned to each pseudo-component using existing correlations. A variety of characterizations were developed for the non-distillable fraction, some based on linear and probability extrapolations of the simulated distillation data, and some based on a molecular weight distribution from a Gamma function.

The Peng-Robinson equation of state (EoS) was adapted to either fit or predict the saturation pressure and phase boundaries for binary and ternary mixtures of Athabasca bitumen with propane and carbon dioxide. For each model, the binary interaction parameters between the solvent and each bitumen pseudo-component were regressed to fit experimental saturation pressure data.

Each characterization was successfully fitted (within 200 kPa) to the saturation pressure data for all of the mixtures using a self-consistent set of interaction parameters. The characterizations that included a distribution of high molecular weight material (representing asphaltene nano-aggregates) successfully predicted the appearance and disappearance of a second light liquid phase for all of the binary and ternary mixtures, Figure 1. These models also predicted plausible onsets and compositions of a second heavy liquid phase formed in propane diluted bitumen (data were not available for verification).

However, while all models could be tuned to match the onset of asphaltene precipitation from n-heptane diluted bitumen, they significantly underestimated the yield at high dilutions. It appears that a simple CEOS is sufficient for VLL modeling of heavy oils and solvents except when asphaltene precipitation occurs.

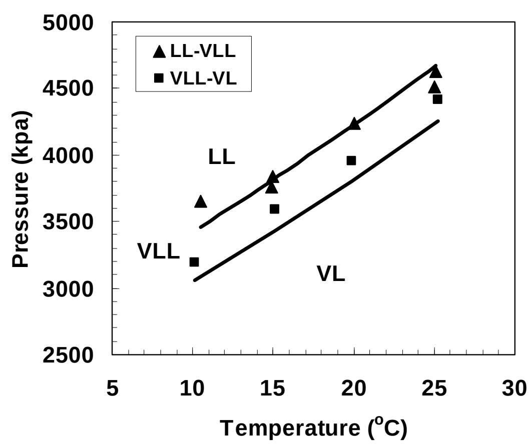

Fig. 1. Experimental and modeled phase boundaries for Ternary A (19.2% carbon dioxide, 13.1% propane and 67.7% Athabasca bitumen). LL/VLL boundary was fitted and VLL/VL boundary was predicted.

References

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[2] Mehrotra, A.K. and Svrcek, W.Y. (1985) *AOSTRA J. Res.,* 1, 4, 215-229