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ABSTRACT:

Concentration Dependent Diffusion Coefficients in Complex Systems

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Mass transfer is important in multiple industries involving solvent processes where time delays are critical (carbon sequestration, enhanced oil recovery, food industry, medicine, plastics etc.). In this work we present non-invasive techniques such as X-ray Tomography and Magnetic Resonance for monitoring of mass transfer in complex fluid systems as well as analysis of the observed concentration profiles in those systems. The fluids of choice are bitumen and heavy oils and liquid or gaseous hydrocarbon solvents. In some cases, we also examine mass transfer in nanofluids.

In typical fluid/fluid or fluid/gas systems, bitumen and solvent components are brought into contact in x-ray transparent containers where the two liquids are allowed to mix through molecular diffusion. Mixing is monitored using a CT X-ray system and the images obtained are translated into density profiles. Density data is plotted in terms of depth as well as distribution functions over time. Based on the density profiles developed over time, we calculate the solvent-in-bitumen and bitumen-in-solvent concentration profiles. From the concentration profiles, complex function of diffusion coefficients can be calculated, based on models developed in our group. The results of the analysis of concentration profiles also provide unique information on partial miscibility of solvent and solute, solute swelling and shrinkage, precipitation and settling of solids (e.g., asphaltenes), and the effects of adding accelerants for settling of solids in the original mixture.

It was further observed that not every solvent solute system resulted in partial miscibility. This was influenced by solvents and solutes being mixed at certain solvent fractions. When partial miscibility exists, it was observed that the solute is the controlling factor in the diffusion process. All experiments were designed with minimal convection contribution. The mass transfer calculations did not consider convection related to solid settling.

When dealing with nanofluids, the same techniques can be used to calculate accumulation or entrainment of solids and the results can be analyzed in the same fashion as with miscible tracers in porous media. Results of such entrainment studies in sand packs are presented.

Modeling of solvent-solute systems was conducted using concentration dependent diffusion equations. Different approaches for estimation of the concentration dependent diffusion coefficient

as well as adsorption or advection parameters developed by the group include new and improved slope and intercept geometrical techniques and polynomial methods.