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NON-ISOTHERMAL TRANSPORT OF IMMISCIBLE FLUIDS AT LOW CAPILLARY NUMBERS: SURFACE AND LINE CONTRIBUTIONS TO THE DRIVING FORCE

Wednesday, 16 May 2018 11:35 (15 minutes)

We derive the entropy production for transport of heat and two immiscible fluids in an inelastic porous material. The representative volume element (REV) is described by its mass, energy and entropy, and a Gibbs equation from which we define the temperature, pressure and chemical potentials (T,p, µi) of the REV.

The constitutive equations that follow from the entropy production of the REV can be written for a continuous path in state space. There are three independent driving forces with conjugate fluxes, one for transport of heat and two for transport of two immiscible fluids. The forces contain contributions from surface and line energies, contributions that are important at low capillary numbers.

We show how the equations can be used to predict a Soret effect in the porous material or to compute thermal osmosis. They provide an explanation for observations known since long, that there are deviations from Darcy's law at low capillary numbers (1-4), also for single phase flow. This has been observed for transport in clay, soil even through glass beads. We find how the volume flow arises, not only from changes in pressure, but also from changes in porosity or saturation of one of the fluids, in temperature or in chemical potentials. We discuss how the relations can be tested by non-equilibrium molecular dynamics simulations or experiments, and present a first test.

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References

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