



Contribution ID: 417

Type: Oral Presentation

## A Thermodynamically Consistent Model for Compositional Multiphase Flows

*Monday 22 May 2023 11:20 (15 minutes)*

While irreversible thermodynamics has proven his relevance in modelling of flows through porous media, explicit and usable formulations based on thermodynamics remain few and hard to extend. Yet thermodynamics offers powerful concepts to achieved the coupling of the wide variety of processes occurring in porous media. This work proposes to apply the principles of irreversible thermodynamics to compositional multiphase flows through porous media and to derive from them a formulation that encompasses the most usual models.

Starting from a clean decomposition of the porous media system between the volume of matrix, the volumes of fluids and the interfaces, the entropy is assumed to be a Euler homogeneous function of first order of the total internal energy, the total mole numbers of each component, the volumes of each fluid, the areas of each interface. The entropy balance equation is then derived from the energy and mole balance equations.

The local entropy production brings out a term that summarizes the exchanges of mechanical work between fluids and interfaces. Such a dissipation term, counting for the interface displacements and deformations, gives a proper definition for the interface equilibrium assumption : interface dissipation is zero, interface transformations are reversible. We show how that interface equilibrium assumption is foundational for the common idea of capillary pressure curve. Indeed, it appears that all the capillary pressure curves in a given porous media derive from a unique convex potential. Although the two phase case is trivial, for three and more phases, this result is strongly structuring, possibly conflicting with some capillary models proposed in the litterature.

The other entropy production terms are related to energy and mass transfers. They come in the form of flow-force products and are compatible with usual laws like Darcy's law for the fluid velocities and Fourier's law for the thermal conduction. The exception is the molecular diffusion where the more classical Fick's law (driven by the gradient of concentration) is not compatible with the positivity of entropy production expected by the second principle. Instead, we have to consider generalizes Fick's laws or Maxwell-Stefan diffusion that are driven by the gradients of the chemical potentials.

In order to ensure the usability of such of modeling, we conclude by proposing a closed formulation, based on a fixed set of primary variables related to the temperature and the chemical potentials. The data of the model are the coefficients for flux-gradient laws, the equations of state for the fluids and the "capillary" potential. The total entropy of the local system is provided and the entropy balance equation derivation is natural thanks to the choice of primary variables.

### Participation

In-Person

### References

Smaï, 2020. A thermodynamic formulation for multiphase compositional flows in porous media (preprint) - <https://hal.archives-ouvertes.fr/hal-02925433v1>

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**Session Classification:** MS06-A

**Track Classification:** (MS06-A) Physics of multiphase flow in diverse porous media