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## Pore-scale simulation of H<sub>2</sub>-brine system relevant for underground hydrogen storage: A lattice Boltzmann Investigation

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Underground hydrogen (H<sub>2</sub>) storage in saline aquifers is a viable solution for large-scale H<sub>2</sub> storage. Due to its remarkably low viscosity and density, the flow of H<sub>2</sub> within saline aquifers exhibits strong instability. Therefore, it is crucial to understand the flow processes of H<sub>2</sub> and brine at the pore-scale, which can be translated into constitutive relations at continuum-scale to guide field-operations. For the first time, we develop a lattice Boltzmann model tailored for pore-scale simulations of the H<sub>2</sub>-brine system under typical subsurface storage conditions. The model captures the significant contrast of fluid properties between H<sub>2</sub> and brine, and it offers the flexibility to adjust the contact angle to suit varying wetting conditions. The developed model is employed to investigate the pore-scale dynamics of two-phase flow composed of H<sub>2</sub> and brine. We show that the snap-off is enhanced in a system with a higher capillary number and a smaller contact angle. These conditions lead to a reduced connectivity of the gas phase, which is unfavorable for H<sub>2</sub> production from the aquifer. Moreover, the relative permeability curves, computed from the simulation results, exhibit distinct behaviors for H<sub>2</sub> and brine. In the case of the wetting phase, the relative permeability can be quantified solely using the phase saturation, whereas for the non-wetting phase, the phase saturation and Euler number appear to contribute equally to the relative permeability. This implies that different formula, compared to the typically used saturation-based functions, should be considered for continuum-scale simulations.

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### References

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