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From natural gas storage to hydrogen storage: Microscopic flow dynamics of hydrogen versus methane in fractured reservoir rock

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Underground hydrogen storage offers a promising solution for addressing seasonal renewable energy fluctuations. While converting natural gas storage facilities to hydrogen storage leverages existing infrastructure, the differences in flow behavior between hydrogen-brine and methane-brine systems, particularly through fractures and sealing caprock, remain poorly understood. This study investigates the pore-scale two-phase flow dynamics of hydrogen, methane, and their mixtures in fractured limestone from the Loenhout natural gas storage facility in Belgium. Controlled primary drainage (gas injection) and imbibition (withdrawal) experiments were conducted at typical reservoir conditions (10 MPa and 65℃) on three different rock samples, revealing the impact of fracture geometry on fluid invasion patterns and recovery efficiency. Our results show that H_2 and CH_4 exhibit similar gas saturations after primary drainage, but H_2 forms larger numbers of smaller ganglia compared to CH_4 due to more discontinuous invasion in rough fractures. The flow through fracture is influenced by variable aperture and roughness on flow dynamics, gas trapping, and recovery efficiency. Furthermore, steady-state relative permeability experiments on fractured carbonate rock from Loenhout show that the relative permeability for hydrogen is similar to methane but significantly lower than for nitrogen, implying that nitrogen cannot serve as a reliable proxy for hydrogen in typical reservoir conditions. This study emphasizes the need for accurate pore-scale modeling to inform field-scale predictive models for underground hydrogen storage in fractured reservoirs.

Country

Belgium

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References

Sojwal Manoorkar, Gülce Kalyoncu Pakkaner, Hamdi Omar, Soetkin Barbaix, Dominique Ceursters, Maxime Latinis, Stefanie Van Offenwert, and Tom Bultreys. From underground natural gas to hydrogen storage in fractured reservoir rock: comparing relative permeabilities for hydrogen versus methane and nitrogen. arXiv preprint arXiv:2411.14122, 2024

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