
Diffusiophoretic transport induced by mineral dissolution in porous media

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Résumé

In the context of climate change, many key environmental engineering applications rely on transport and reactive processes in porous media, including CO₂ storage in geological formations and the remediation of contaminated soils and aquifers. Ensuring the integrity of geological containment barriers and improving groundwater quality requires the development of effective engineering strategies, particularly to seal caprock fractures and to treat polluted aquifers. One promising approach involves the injection of colloidal particles into subsurface reservoirs (3, 6). Given its strong potential, this strategy motivates the development of approaches to control colloid transport to efficiently target damaged or contaminated regions, a challenge that remains largely unresolved (8).

In underground reservoirs used for CO₂ storage, water acidification can lead to the dissolution of minerals constituting the reservoir and caprock matrix. In this study, we focus on calcite dissolution upon contact with an acid solution. We aim to investigate the transport of colloidal particles under the influence of concentration gradients generated by this dissolution process. In particular, we examine the role of diffusiophoresis – a transport mechanism that drives colloids along solute concentration gradients (2) – in controlling particle migration. Diffusiophoresis represents a promising yet underexplored mechanism in particle transport models for reactive porous media, especially in reactive systems involving mineral dissolution. A key challenge lies in accurately capturing both the evolving concentration gradients and their impact on colloid transport within porous structures.

We develop a pore-scale numerical simulator based on OpenFOAM to model the transport of colloidal particles driven by diffusiophoresis. The diffusiophoretic velocity – accounting for both electrophoretic and chemiphoretic contributions (4, 7) – is incorporated into an advection-diffusion framework (1). A first-order kinetic reaction boundary condition is imposed at the calcite-fluid interface to model mineral dissolution. This approach enables us to track the evolution of hydrogen chloride concentration gradients, dissolution products (calcium and bicarbonate ions), as well as the resulting diffusiophoretic velocities of both the fluid and the particles. The simulated particle velocities are in agreement with microfluidic experimental observations (5). Furthermore, we systematically investigate the influence of diffusiophoresis around dissolving calcite surfaces as a function of several dimensionless numbers, including the ionic Péclet number, the particulate Péclet number, the diffusiophoretic Péclet number, and the diffusiophoresis number

*Intervenant

This work provides new insights into the influence of diffusiophoresis on colloid transport in reactive porous media.