Carbonate Mineral Nucleation Pathways in Geological Carbon Sequestration

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Mineral trapping is expected to be one the key mechanisms ensuring safe and permanent storage of CO_2 in sub-surface environments, in the form of carbonate minerals. However, although carbonates are very common minerals in nature, a large number of unknowns remain to be solved about their nucleation pathways and about how these are affected by the extreme physico-chemical conditions found in CO_2 storage geological reservoirs.

Many of the reservoirs that have been selected as possible hosts for CO_2 sequestration initiatives are geologic formations composed mainly by sandstones. Experiments at the Center for Nanoscale Control of Geologic CO_2 (LBNL) have been designed to study the reactivity of the minerals composing these rocks towards the nucleation of carbonates. Heterogeneous nucleation experiments performed using a synchrotron grazing-incidence small angle X-ray scattering (GISAXS) have shown that quartz, the dominant mineral, is a reactive substrate for the nucleation of $CaCO_3$. Current experiments are being performed to study the reactivity of other phases, including cap-rock minerals and considering the presence of organics –hydrocarbons are expected to be present in depleted oil reservoirs–.

One of the key characteristics of these reservoirs is the presence of a porous media that confines the geological fluid. Experimental and theoretical studies in our Center aim to understand how this confinement affects nucleation, and how these pores are available or not as nucleation sites. Statistical mechanical models of pore nucleation reveal how pore geometries and surface characteristics control the free energy barriers for nucleation within pores and out into the surrounding solution, showing that narrow pores tend to have lower barriers for nucleation than wider ones. On the other hand, neutron and X-ray scattering experiments have shown that nucleation of $CaCO_3$ in model silica nano-pores is prevented, which may indicate that solvent-structuring effects not considered in the statistical models may be adding high kinetic barriers for nucleation to occur.