

What can we learn from stable isotope fractionation about the mechanisms controlling solid-fluid interactions?

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The last decade has seen important advances in the theoretical and experimental investigations of the chemical physics of the mass-dependent fractionation of metal stable isotopes during solid-fluid interactions. These studies have allowed establishment of a rigorous theoretical framework for using stable isotope tools in geosciences, for example in estimating the environmental conditions that occurred during mineral growth in the past. Another precious and somewhat unexpected outcome of these fundamental studies is to provide new insights onto the elementary paths and mechanisms that control the kinetics and thermodynamics of solid-fluid interactions.

Combining *ab initio* and experimental modeling with spectroscopic observations, we analyze the impact of reaction kinetics and fluid speciation on the mass-dependent fractionation of metal isotopes during sorption, dissolution and growth processes, as well as the effect of the formation of transient amorphous phases during precipitation. New and recent results on the Ca-Mg-CO₃-fluid (in the presence of Mg, Zn, Ni, B,...), SiO₂-fluid, and α -FeOOH-fluid (in the presence of Ge, Ga) systems provide information on a) the aqueous metal species involved in the exchange reactions occurring at the solid-fluid interface at chemical equilibrium, b) the rate controlling steps during carbonate minerals crystal growth and the nature of the aqueous species incorporated in the growing crystallized phase and its amorphous precursors, c) the near equilibrium rate constants and the validity of the principle of detailed balancing.

Such information derived from stable isotopes should improve both our ability to model natural water-rock interactions and to interpret the isotopic signatures of sedimentary minerals.