SAND 2013-8449 C

Nanogeochemistry: Nanostructures, emergent properties, and their implications to chemical reactions and mass transfers

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Nanostructures and nanometer mineral phases, both widely present in geologic materials, can potentially affect many geochemical processes. It is known that at nanometer scales a material tends to exhibit chemical properties distinct from the corresponding bulk phase. Understanding of this size-dependent property change will help us to bridge the existing knowledge gap between the molecular level understanding and the macro-scale laboratory/field observations of a geochemical process. In this presentation, I will review of the recent progresses in nanoscience and provide a perspective on how these progresses can potentially impact geochemical studies. My presentation will be focused the following areas: (1) the characterization of nanostructures in natural systems, (2) the study of fluids and chemical species in nanoconfinement, (3) the effects of nanopores on geochemical reaction and mass transfers, and (4) the use nanostructured materials for environmental management. I will demonstrate that the nanopore confinement can significantly modify geochemical reactions in porous geologic media. As the pore size is reduced to a few nanometers, the difference between surface acidity constants of a mineral ($pK_2 - pK_1$) decreases, giving rise to a higher surface charge density on a nanopore surface than that on an unconfined mineral-water interface. The change in surface acidity constants results in a shift of ion sorption edges and enhances ion sorption on nanopore surfaces. This effect causes preferential enrichment of trace elements in nanopores. I will discuss the effects of emergent nanometer-scale properties on shale gas disposition and release in unconventional reservoirs.

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