

## Uranium Isotope Fractionation: A Critical Review

SHAUN T BROWN<sup>1</sup>, ANIRBAN BASU<sup>1</sup>,  
JOHN N. CHRISTENSEN<sup>1</sup> AND DONALD J.  
DEPAOLO<sup>1</sup>

<sup>1</sup>Center for Isotope Geochemistry, Lawrence  
Berkeley National Laboratory and UC Berkeley,  
Berkeley CA 94720; stbrown@lbl.gov

Based upon the pioneering work of Weyer and others [1] it is now recognized that small variations in  $^{238}\text{U}/^{235}\text{U}$  exist in many natural and experimental systems. The U isotope system is now applied to a wide array of questions including environmental remediation, paleo seawater anoxia and economic geology.

Our understanding of U isotope fractionation is largely based on the nuclear field shift theory (NFST), observations from laboratory experiments and field studies. NFST predicts that the product phase will be preferentially enriched in  $^{238}\text{U}$ , while the reactant phase is complementarily depleted. Microbial U reduction experiments are largely consistent with the NFST predictions. In contrast, inorganic U reduction experiments show minimal or reverse U isotope fractionation effects, inconsistent with NFST, leading to the idea that certain U isotopic signatures “fingerprint” direct enzymatic reduction.

We review the published data from field studies of groundwater and uranium minerals and conclude that the observed  $^{238}\text{U}/^{235}\text{U}$  can be largely explained by the preferential reduction of the  $^{238}\text{U}$  isotope as predicted by nuclear field shift theory and by isotope hydrology models, not requiring kinetic isotope fractionation favoring  $^{235}\text{U}$  in the product phase.

In light of these findings we re-evaluate the observed isotope fractionation for  $^{238}\text{U}/^{235}\text{U}$  during inorganic reduction. We suggest that solution composition and the aqueous speciation of U(VI) affects the direction and magnitude of  $^{238}\text{U}/^{235}\text{U}$  isotope fractionation in inorganic experiments and that enzymatic  $^{238}\text{U}/^{235}\text{U}$  fractionation may, in fact, be a function of experimental design rather than a unique signature of biotic U reduction.

[1] Weyer, S. *et al* (2008). Natural fractionation of  $^{238}\text{U}/^{235}\text{U}$ . *Geochimica Et Cosmochimica Acta*, 72(2), 345–359.