Is metal stable isotope Geochemistry kinetically approaching equilibrium?

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The production rate of publications using metal and metalloid stable isotope ratios, since the introduction of multicollector ICP-MS in 1995, has increased from ~5/yr in 2000 to ~150/yr in 2013. The periodic table has been colonised so thoroughly that now virtually no element featuring more than one stable isotope has been left untouched by geochemist's favourite mass spectrometers. But has this enormous success been associated by a concomittant increase in scientific insight, or a discovery that would not have been made without these tools?

I will review a non-representative list of some of the "big" discoveries that have been made. Amongst these are the fractional incorporation of Si into Earth's core during early mantle-core differentiation; the oxidation of Earth's mantle over geologic time; its relationship to oxygenation of the atmosphere; the changes of atmospheric CO2 concentration in the latest Cenozoic from paleo-ocean pH proxies; the change in the state of terrestrial weathering over time as recorded in rivers and in marine sediment; the pathways of toxic methyl mercury through marine food webs; approaches for monitoring transition metal reduction in aquifers. Stable metal isotopes have also begun to emerge in other disciplines beyond the Earth sciences. For example, we can now see subtle species-dependent differences in how metals are cycled through higher plants and we are on a path to develop indicators for the onset of severe medical conditions in humans.

Such a review is also the occasion to critically question the way we approach stable metal isotope geochemistry. While good progress has been made on the most important ingredient: the determination of equilibrium fractionation factors from both *ab initio* simulations and experiments, it is (from pure publication statistics) apparent that the field is still lopsided towards empirical surveys of natural systems. Preciously few conceptual models have been developed that provide a framework for the way these complex systems function. Amongst these are the theory of mass- and non mass-dependent fractionation, the competition between kinetic and equilibrium isotope effects, and predictive mass balance and reactive transport models. We need much more such theory to guide the interpretation of data so that its increase generates a true increase in knowledge.