

Sensitivity of mass-independent Sn isotope fractionation to UV radiation and magnetic fields

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Mass-independent isotope fractionation (MIF) enables powerful tracing for various geochemical and planetary problems [1], yet the mechanisms driving MIF for tin (Sn) remain enigmatic [2-4]. Here we report that photolysis of Sn species under UV irradiation and sunlight conditions results in distinct Sn isotope fractionation signatures. We demonstrate through controlled photolysis experiments that UV irradiation induces pronounced Sn-MIF in all odd Sn isotopes ($\Delta^{115}\text{Sn}$ up to 21.82‰, $\Delta^{117}\text{Sn}$ up to 23.16‰, $\Delta^{119}\text{Sn}$ up to 24.01‰), with their ratios ($\Delta^{117}\text{Sn}/\Delta^{115}\text{Sn} = 1.069$; $\Delta^{119}\text{Sn}/\Delta^{115}\text{Sn} = 1.099$; $\Delta^{119}\text{Sn}/\Delta^{117}\text{Sn} = 1.028$) conclusively aligning with the magnetic isotope effect (MIE) [5], rather than nuclear volume effects. Crucially, we experimentally demonstrate that the magnitude of Sn-MIF is non-monotonically dependent on the strength of magnetic field. Methyl radicals ($\bullet\text{CH}_3$) are detectable during the photolysis experiments, and the magnitude of MIF was suppressed by an electron spin trapping agent (DMPO) for radicals, supporting that the pronounced Sn MIF originated from radical-mediated singlet-triplet transitions of Sn species. Interestingly, Sn-MIF was absent under natural sunlight despite significant mass-dependent fractionation. These findings underscore that significant Sn-MIF can be induced by the magnetic isotope effect on radicals of Sn species when activated by UV radiation, particularly under suitable magnetic field conditions. Consequently, Sn-MIF signatures hold promise as a tool for investigating photochemical reactions in Archean Earth systems.

References:

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