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Experimental determination of stable Ni isotope fractionation between metal and sulfide

HELEN M. WILLIAMS[1], MR. JULIEN BOULLIUNG, PHD[2], GUANGLIANG WU[1,3] AND BERNARD J WOOD[2]

[1]University of Cambridge

[2]University of Oxford

[3]China University of Geoscience Beijing

Presenting Author: hmw20@cam.ac.uk

Several studies have demonstrated that silicate Earth is depleted in the light stable isotopes of Ni ($d^{60}Ni$) relative to chondrites by ~ 0.13‰ [1,2]. This difference is diffcult to explain: it is opposite to what would be expected for Ni isotope fractionation during volatile loss and experimental studies have demonstrated that there is no appreciable Ni isotope fractionation between silicate melt and molten Fe-Ni metal [3,4].

Nickel is a siderophile and chalcophile element that partitions stronly into sulfide phases. One possibility is that the subchondritic $d^{60}Ni$ of the Earth relates to Ni partitioning into a late-stage Fe-S ‘matte’ that exsolved from the cooling mantle after the Moon-forming giant impact [5,6]. Another is that the Earth acquired its subchondritic $d^{60}Ni$ during the giant impact via collision with a highly reduced impactor with a sulfur-rich, light $d^{60}Ni$ mantle [2].

Knowledge of Ni isotope partitioning between solid metal and sulfide is essential to evaluating the scenarios above. We investigated Ni isotope fractionation between Fe-Ni metal and liquid Fe-Ni-S alloys in 1-atmosphere furnace experiments at temperatures and oxygen fugacities (relative to the iron-wüstite buffer, IW) between 1100-1200°C and IW-2 and IW+3. Equilibrium was evaluated by running duplicate experiments for different durations (2 to 48 hours). Metal and sulfide fractions were separated from mounted and sectioned experimental charges by microdrilling. Sample dissolution, Ni purification and isotopic analysis followed established procedures [1,2]. In the IW -2 to +0.8 experiments we find that sulfide is isotopically light relative to metal by 0.10 to 0.20‰, with the expected inverse dependence on temperature. In the more oxidised experiments (IW +3) sulfide is also enriched in the light isotopes of Ni but the magnitude of fractionation is reduced to ~ 0.10‰ at 1100°C and <0.04‰ at 1200°C. Our observations suggest that neither the formation of a Hadean matte nor collision with an impactor planet with a S-rich, light-$d^{60}Ni$ mantle can explain the subchondritic $d^{60}Ni$ of the silicate Earth. Other scenarios must therefore be considered.

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