Implications of Fe and Ni stable isotope ratios for the formation of the pallasite parent body

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Metal-rich achondritic materials such as iron meteorites and main group pallasites (PMG) exhibit a fractionations of up to 0.6 ‰ for $\delta^{56/54}$Fe and ~2 ‰ for $\delta^{60/58}$Ni between coexisting metal and silicate phases. By comparing the magnitude and sign of the Fe and Ni stable isotope ratios shifts between different meteorite groups and fractions, it becomes clear that these isotopic signatures result from unique combinations of distinct planetary processes, including metal segregation and fractional crystallization during core formation, primary equilibration between planetary reservoirs, evaporation during collisional disruption, diffusive re-equilibration during re-accretion on secondary parent bodies, and subsequent diffusion during prolonged cooling histories. For iron meteorites and PMGs, Fe and Ni isotope ratios reveal kinetically controlled isotope fractionation, resulting from sub-solidus diffusion, which can be used for cooling rate estimation. The observed relation between $\delta^{56/54}$Fe and Ir concentration in the metal fractions of PMGs and IIIAB irons indicates that Fe isotopes fractionated during the crystallization of the metal core of the parent asteroid. The Fe isotopic compositions show resolvable differences between the metal and olivine of PMGs, with only a hint of Fe isotope zoning within the olivine, suggesting efficient Fe isotope equilibration. If the Fe isotopes did achieve equilibrium, the wide range of equilibration temperatures (340-1300˚C based on the Fe isotope thermometer), and skewed Fe isotope distributions suggest that the Fe isotopic compositions cannot result from a single event of core-mantle segregation of an initially chondritic body, but represent later re-equilibration in a secondary parent body. The light Ni isotopic signatures previously found for PMG metal are associated with heavier Ni in the PMG schreibersite, compared to irons. Such Ni distribution between metal and schreibersite potentially highlights new relations between formation histories of these meteorites.