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Nickel isotopes as a tool to study metal-silicate differentiation and the thermal evolution of planetary bodies: a combined approach based on analysis of natural samples, experimental petrology and modeling

GHYLAINE QUITTÉ[1], JÉRÉMY GUIGNARD[2] AND MARC MONNEREAU[3]

[1]IRAP / CNRS
[2]Observatoire Midi Pyrénées, CNRS, IRAP
[3]IRAP, CNRS, Observatoire Midi-Pyrénées

Non-traditional metal stable isotopes have received growing attention over the past decade as powerful tools to trace geochemical processes. Nickel (Ni) is the second most abundant element in the metallic cores of planetesimals and planets, hence an element of major interest to investigate metal-silicate differentiation.

In the present study, high temperature experiments have been performed to determine both kinetic and equilibrium metal-silicate fractionation of Ni isotopes. The results show a strong kinetic fractionation, while no metal-silicate fractionation is observed within uncertainties at equilibrium at temperatures relevant to differentiation, in perfect agreement with first-principles calculations on metal-olivine and metal-pyroxene [1]. It appears that the timescale to reach chemical equilibrium is fO2 dependent and decreases as conditions become more reducing.

In-situ measurements in silicate and metal phases in pallasites and mesosiderites (two types of stony-iron meteorites) show variable fractionation of Ni isotopes. Pallasites exhibit large negative metal-silicate fractionation, whereas mesosiderites display small positive metal-silicate fractionation [2]. The Ni isotope fractionation observed in pallasites is most likely explained by sub-solidus solid-state diffusion of Ni from olivine into metal during cooling, probably due to the increase of the metal-silicate partition coefficient of Ni with decreasing temperature [3]. The large isotope fractionation of Ni between both phases also indicates that the cooling rate of pallasites was relatively low. Modeling provides quantitative discussion on the thermal history and in particularly on cooling rates of the parent body. Contrary to pallasites, the similar behavior of Fe and Ni in mesosiderites has been interpreted as resulting from a limited diffusion of Fe and Ni from metal into silicates due to an evolution of oxygen fugacity conditions in the parent body. Despite their complex multi-stage history, mesosiderites are apparently closer to equilibrium than pallasites in terms of Fe and Ni isotope compositions.

Last but not least, the Ni isotope signature of planets cannot be explained by metal-silicate differentiation at equilibrium but is likely due to other evaporation-related processes.

[1] Guignard J. et al. (2020) *GCA* 269, 238-256. [2] Chernonozhkin S.M. et al. (2017) *GCA*, 217, 95-111. [3] Capobianco C.J. and Amelin A.A. (1994) *GCA* 58, 125-140.