NICKEL STABLE ISOTOPES IN PLANETARY RESERVOIRS.

G. Quitte, F. Poitrasson, and T. Zambardi. Institut de Recherche en Astrophysique et Planétologie (IRAP), Observatoire Midi-Pyrénées, Toulouse, France (Ghylaire.Quitte@irap.omp.eu), Geosciences Environnement Toulouse (GET), Observatoire Midi-Pyrénées, Toulouse, France.

Introduction: The isotope compositions of the three major elements iron, magnesium and silicon have been widely used to trace processes occurring during planetary accretion and differentiation. Nickel is also an element of interest as it is expected to behave similarly to iron, showing comparable condensation temperatures, yet being much less sensitive to redox processes. Thus, a combined set of Fe and Ni isotope data obtained on a suite of planetary materials will permit to disentangle volatility-related processes and redox reactions including planetary core formation. Here we present new Ni isotope data for a variety of samples (meteorites and lunar samples); most of them have been previously studied for Si isotopes [1].

Samples and Methods: Eleven chondrites, 4 lunar samples, 10 martian meteorites, and 3 eucrites have been selected for the present piece of work. All chondrites but one (Tanezrouft 065 – L4) are carbonaceous chondrites.

After crushing of the samples in an agate mortar and after acidic digestion, nickel was separated from the matrix elements thanks to a 4-step ion-exchange chromatography procedure. Nickel isotope measurements were then performed by multi-collection inductively coupled plasma mass spectrometry (MC-ICPMS) using the Neptune instrument in Toulouse. Data are reported as δ values (variations relative to the standard in permil) per mass unit.

Results: Chondrites show a uniform bulk composition, with an average δ value of 0.09‰ per amu, in good agreement with Ni isotopic compositions reported in other studies [e.g. 2]. Similarly, all martian meteorites yield the same isotope composition within uncertainties. The enrichment in Fe and Si heavy isotopes reported for the Earth and the Moon relative to Mars and Vesta [e.g. 1,3 and references therein] is not observed for Ni isotopes: lunar samples, martian meteorites and eucrites are indistinguishable from chondrites.

Discussion: The heavy Fe and Si isotopic composition of Earth’s crust relative to chondrites has been explained by vaporization during the Moon-forming giant impact, equilibrium partitioning between metal and silicate related to core formation, or partial melting and magma differentiation. More recently, it has been shown that equilibrium isotopic fractionation between gaseous SiO and solid forsterite at ≈1370 K in the solar nebula could have produced the observed Si isotope variations and may also explain the absence of Mg isotope fractionation as almost all Mg is condensed as forsterite at that temperature [4]. What about Fe and Ni? Despite their similar geochemical characteristics, both elements show different isotope patterns. Iron isotope fractionation is correlated with Si fractionation [3], while Ni has a behavior similar to that of Mg. If the Fe isotope fractionation was due to vaporization during the Moon-forming impact, Fe and Ni should yield comparable data. Hence the Ni results suggest that the giant impact might not be the major cause of Fe isotope fractionation. Similarly, the effect of core formation cannot be ruled out but is limited if any. In contrast, Ni isotopes seem compatible with an isotope fractionation in the nebula. The carrier phases of Ni (mainly metal + sulfides, spinel) are indeed much more limited than those of Fe and they condensed early over a limited range of temperatures. In this case, the nebular gas is rapidly depleted in Ni, preventing isotope fractionation. Calculations of equilibrium isotope fractionation of Ni in this system would be necessary to further test this hypothesis.

References: