Goldschmidt 2021 Abstract
https://doi.org/10.7185/gold2021.5566

A very early origin of isotopically distinct nitrogen in inner Solar System protoplanets

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Understanding the origin of nitrogen (N) and other life-essential volatiles like carbon and water in the Solar System and beyond is critical to evaluate the potential habitability of rocky planets. Whether the inner Solar System planets accreted these volatiles from their inception or had an exogenous delivery via volatile-rich, carbonaceous material from the outer Solar System is, however, not well understood. Using previously published data of nucleosynthetic anomalies of Ni, Mo, W and Ru in iron meteorites in conjunction with their $^{15}N/^{14}N$ ratios, we show that the earliest accreting protoplanets in the inner and outer protoplanetary disk accreted isotopically distinct N. While the Sun and Jupiter captured N from nebular gas, concomitantly growing protoplanets in the inner and outer disk possibly sourced their N from organics and/or dust - with each reservoir having a different N isotopic composition. Hence the processes that led to the enrichment of ^{15}N in the organics and/or dust relative to the nebular gas either predated or were synchronous with the formation of protoplanets. A distinct N isotopic signature of the inner Solar System protoplanets coupled with their rapid accretion suggests that non-nebular, isotopically processed N was ubiquitous in the growth zone of the inner Solar System rocky bodies within ~0-0.3 Myr of the formation of CAIs. N isotopic ratios of the bulk silicate Earth (BSE) falls between those of inner and outer Solar System reservoirs. Using mass balance calculations with inverse Monte Carlo simulations, we predict that the BSE's N isotopic composition is an admixture of 30-59% carbonaceous (CC) and 41-70% non-carbonaceous (NC) material, depending on the relative N abundance in the two reservoirs.

[1] Grewal, D.S., Dasgupta, R. & Marty, B. A very early origin of isotopically distinct nitrogen in inner Solar System protoplanets. Nat Astron (2021).