Constraints on the N isotopic evolution of the solar nebula from volatile analyses of a CAI

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Isotopic analyses of osbornite (TiN), considered as the first solid nitrogen-bearing phase to condensate in the cooling nebula, indicated that the protosolar nebula (PSN) was highly depleted in ^{15}N compared to the terrestrial atmosphere [1]. Results from NASA's Genesis mission confirmed the very low ^{15}N/^{14}N ratio of the Sun and the PSN ($\delta^{15}N_{PSN}$ = -383 ± 8 ‰ [2]). All other Solar System objects (with the exception of Jupiter) are enriched in ^{15}N compared to the PSN, possibly as a result of i) N_2 photochemical self-shielding [e.g., 3] or ii) low temperature isotopic exchanges [4].

Since early-formed solids such as refractory Ca,Al-rich inclusions (CAIs) may retain a record of the nitrogen isotopic evolution of the nebula, we investigate here the N and noble gas (Ne-Ar) abundance and isotopic signature of a large (~4 cm in diameter) coarse-grained type B CAI from a CV3 chondrite by CO_2 extraction-static mass spectrometry analysis. In addition, we determined the O and Al-Mg isotope characteristics of the inclusion by SIMS analysis.

Although the CAI crystallized near "time zero" of Solar System history, as shown by its canonical-like (^{26}Al/^{27}Al)$_i$ value of (5.06 ± 0.50) × 10^{-5}, it experienced later partial isotopic exchange with a ^{16}O-poor reservoir, resulting in large oxygen isotope variations among its constituent minerals. Melilite and anorthite are ^{16}O-poor (Δ^{17}O > -5‰), whereas spinel and fassaite retain the original ^{16}O-rich signature of the solar nebula (Δ^{17}O ≤ -20 ‰). The low ^{20}Ne/^{22}Ne (≤ 0.83) and ^{36}Ar/^{38}Ar (≤ 0.82) ratios rule out the presence of any trapped planetary or solar noble gases, and the abundances of cosmogenic ^{21}Ne and ^{38}Ar are consistent with a cosmic ray exposure age of a few to a few tens of millions of years. Strikingly, the CAI contains 1.4 to 3.4 ppm N_2 with a δ^{15}N value of 8 to 30 ‰. Even after correcting the measured ^{15}N/^{14}N ratios for cosmogenic ^{15}N produced in-situ, the δ^{15}N values resemble the isotopic signatures of chondritic meteorites, suggesting that mixing of the PSN with a ^{15}N-enriched reservoir occurred at very early times.

[1] Meibom *et al* (2007) *ApJ* **656**, L33-L36. [2] Marty *et al* (2011) *Science* **332**, 1533-1536. [3] Lyons *et al* (2009) *GCA* **73**, 4998-5017. [4] Terzieva and Herbst (2000) *MNRAS* **317**, 563-568.