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Nitrogen in dust, meteorites and planets

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Nitrogen, the fifth most abundant element in the solar system, does not fit the picture of a well-mixed solar nebula. Variations in the ratio $^{14}N/^{15}N$ exceeding a factor of two were observed in solar system matter, and systematic differences are found between graphites, metal and silicates in the same objects (8% in I AB irons, >12 % in Acapulco), which reveal a lack of equilibration. The nitrogen signature in the Sun is currently not known, but solar wind nitrogen is being collected by GENESIS and should provide a clearer picture. Primitive solar nebula signatures ($\delta^{15}N$ = -30‰) were identified in planet Mars [1] and are similar to signatures in enstatite meteorites. Nitrogen isotopic signatures in metals of H- and L-chondrites are identical ($\delta^{15}N$ = -7‰) in petrologic types 4 and 5, and uniform in silicates ($\delta^{15}N$ = +13‰). Distinct signatures in metal of type 3 and of some type 6 chondrites may either document imported presolar matter, or evolutionary processes involving incompletely homogenized parent bodies. A survival was reported[2] of isotopically heterogeneous graphite in the Acapulco meteorite and a wide range of carbon and nitrogen isotopic compositions. Nitrogen possibly was imported in collisional events and also evolved by parent body processes. The signatures observed in metals of the Portales Valley meteorite (a chondrite) suggest mechanisms of this type, as nitrogen ratios are similar to both IAB ($\delta^{15}N$ = -70‰) and IVA ($\delta^{15}N$ = -26‰) irons. Some IAB/IIICD irons show interesting properties: N loss by acid etching and, in stepwise pyrolysis, the release of significant fractions of N at very low temperatures, while usually N is released above 1000°C. A low release temperature suggests either phase changes or nitrogen redistribution, consistent with observed nitrogen redistributions in hot implanted Fe and Fe-Ti films [3] where (acid soluble) iron nitrides (Fe_2N, Fe_4N) were found. These authors concluded that nitrogen atoms were initially bound to Fe and Ti during implantation. The role of nitrides in solar system matter has to be addressed.

References

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Early Earth evolution recorded in lunar soils?

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When did the geomagnetic field first appear? The question is directly relevant to core formation and early Earth evolution. Paleomagnetic studies trace it back only to about 3.5 Ga [1]. The geomagnetic field prevents ion loss from the atmosphere [2], but if it was absent or much weaker in the early Earth, ion escape from the ionosphere would be enhanced and a substantial portion of the atmosphere could have been transported to lunar soils. Close examination of the N isotope composition and lighter noble gases in ancient lunar soils could resolve the evolution of the geomagnetic field and hence impose a constraint on early Earth evolution.

PVO (Pioneer Venus Orbiter) observations suggest the loss of 10^6 – 10^8 O^+ $cm^{-2}s^{-1}$ from the Venus atmosphere [3]. This substantial loss is understood to reflect direct interaction between the solar wind and the upper atmosphere in the absence of a permanent dipole field. For N^+/O^+ of about 0.02 near the ionopause [4], we would expect N^+ loss of about $2x10^5$ $cm^{-2}s^{-1}$. Venus's atmosphere may serve as a proxy for the primitive Earth atmosphere, which probably consisted predominantly of CO_2 [5]. We thus expect that a similar amount of N^+ would escape from Earth if there were no geomagnetic field. Also considering a decreased Earth-Moon separation in the first several hundred Ma [6], we estimate, from simple geometrical considerations, that a few percent of escaping ions from the Earth's ionosphere may have directly hit the lunar surface. Isotopic inventory considerations suggest that this much imported terrestrial N and possibly lighter noble gases could account for non-solar components of these elements that are observed in ancient lunar soils.

Comparing farside ancient lunar soils with those from the nearside can test the hypothesis. We know that Earth-Moon coupling has been so strong that the lunar nearside has remained facing Earth for nearly its entire history [7]. Thus, if our hypothesis is correct, terrestrial N (and possibly lighter noble gases) would only be found on the lunar nearside.

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