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A molecular cloud origin for the ^{15}N enrichment of planetary materials

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The ^{15}N depletion of the solar wind (Marty et al. 2011) and the massive enrichment of N-containing hotspots (Busemann et al. 2006) span a range in $d^{15}N$ of -400 to +5000 ‰ relative to Earth atmosphere. But what processes are principally responsible for this enormous range in $^{15}N/^{14}N$ in solar system materials? Both N_2 self-shielding (Chakraborty et al. 2013) and low temperature ion-molecule reactions (Rogers and Charnley 2008) have been proposed. Ion-molecule reactions are viable in the parent cloud but were found to be negligible in the coldest regions of a protoplanetary disk model (Visser et al. 2018). N_2 self-shielding experiments produced very large ^{15}N enrichment for an implausible 1:1 N_2:H_2 gas. I address these issues with a photochemical model of N_2 self-shielding in the solar nebula.

The N isotope model has 700 reactions and includes vertical mixing. Initial N_2/H_2 is $2x10^{-5}$ and solar $^{15}N/^{14}N$ is used for the initial N_2 reservoir. Results for the outer nebula at a temperature ~ 50 K are as follows: 1) ^{15}N-enriched amines consistent with meteoritic amino acids are formed by reactions on dust grains; 2) a $d^{15}N$ enrichment of 400 to 600 ‰ in bulk amine-containing compounds is possible but only if the fraction of amine-containing N inherited from the parent cloud is $< 10^{-6}$ which is 10-100 times lower than expected from observations of protostellar cores. I conclude that ^{15}N-enriched material in the solar nebula is primarily inherited from the parent cloud. The proportion of N_2 self-shielding and ion-molecule chemistry depends on the temperature of dust grains, which is determined by the local radiation field. Formation of the solar nebula in a cloud rich in star formation would imply a UV radiation field more favorable to N_2 self-shielding than to low-temperature ion-molecule ^{15}N enrichment, consistent with the small amount of highly enriched material seen in hot spots.

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