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Redox control on nitrogen isotope fractionation during planetary core formation

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The origin and evolution of Earth's nitrogen is often discussed by comparing the large variation of N isotopic compositions among Earth's building blocks (chondrites) to the signatures of various terrestrial reservoirs. Here, we demonstrate that planetary differentiation processes, such as core formation, may have significantly modified the N isotopic composition of the proto-Earth.

We experimentally determined N isotopic fractionation during metal-silicate partitioning (i.e., planetary core formation) over a large range of oxygen fugacities ($\Delta IW -3.1 < \log fO_2 < \Delta IW -0.5$) at 1 GPa and 1400 °C using a piston cylinder apparatus. We developed an *in-situ* analytical method to measure the N elemental and isotopic compositions of experimental run products composed of Fe-C-N metal alloys and basaltic melts by ion probe. Our results show substantial N isotopic fractionations between metal alloys and silicate glasses, i.e., from –257 ± 24‰ to –49 ± 1‰, over three log units of fO_2. These large fractionations under reduced conditions can be explained by the large difference between N bonding in metal alloys (Fe-N) and in silicate glasses (as molecular N_2 and NH complexes). We show that the $\delta^{15}N$ value of the silicate mantle could have increased by ~20‰ during core formation due to N segregation into the core as the fO_2 of the magma ocean increased.

This study shows that the magnitude of N isotopic fractionation varies significantly as a function of the redox history of the early Earth. Therefore, distinct N isotopic ratios among Earth's reservoirs or between planetary bodies may reflect different planetary evolution processes as opposed to different N sources.