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Missing nitrogen of the bulk silicate Earth established by deep core-mantle differentiation

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Nitrogen is one of the most significant volatiles in the Earth, an essential element for life, and the primary component of the atmosphere. The Earth's missing nitrogen problem is manifested by an extremely low nitrogen concentration and a super-chondritic C/N ratio of the bulk silicate Earth (BSE). Understanding the nitrogen depletion in the BSE is a key to the storage and isotopic features of nitrogen in Earth's deep reservoirs as well as the delivery process of volatiles to the early Earth. Core-mantle differentiation is one of the most significant processes controlling the initial distribution of elements in the early Earth. Knowledge of the partitioning behavior of nitrogen during the core-mantle differentiation is therefore of fundamental importance to the Earth's nitrogen budget and subsequent evolution. In this study, we perform *ab initio* molecular dynamics combined with the thermodynamic integration method to calculate partition coefficients of nitrogen between iron and silicate melts to 135 GPa and 5000 K. Our results demonstrate that nitrogen basically remains siderophile under high-pressure and temperature condition irrespective of its different chemical speciation, and predict a positive but nonlinear effect of pressure on nitrogen partitioning, which is primarily caused by the structural modification of the silicate melt upon compression. Combining first-principles calculations with geochemical modelling, we find that the BSE can be extremely depleted in nitrogen if nitrogen undergoes deep core-mantle differentiation. These results provide important constraints on the distribution of nitrogen in the deep Earth and offer new insights into the delivery of volatiles during the proto-Earth growth.