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Nitrogen solubility, partitioning, and isotope fractionation in planetary magma oceans - *Shen-su Sun Foundation Medal Lecture*

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The origin of major volatiles nitrogen, carbon, hydrogen, and sulfur in planets is critical for understanding planetary accretion, differentiation, and habitability. However, the detailed process for the origin of Earth's major volatiles remains unresolved. Nitrogen shows large isotopic fractionations among geochemical and cosmochemical reservoirs, which could be used to place tight constraints on Earth's volatile accretion process. The C/N ratio of the bulk silicate Earth (BSE) is superchondritic, which also provides a useful tool for understanding the origin of Earth's volatiles. The Earth accreted largely from differentiated planetesimals and embryos, and the fate of nitrogen and carbon in magma oceans of such rocky bodies is key in shaping the BSE's C/N ratio. I will present recent experimental progress of my group in the determination of the solubility, partitioning, and isotope fractionation of nitrogen and carbon in core-mantle-atmosphere systems of rocky planets. The experiments were performed at 0.3-8 GPa, 1400-2200 °C, and various oxygen fugacities and compositions. I will show that the core/mantle N-isotopic fractionation factors, ranging from −4‰ to +10‰, are strongly controlled by oxygen fugacity. The C/N solubility ratios of the silicate melts are a multi-function of pressure, temperature, silicate melt composition, and mainly oxygen fugacity. The $D_C^{(metal/silicate)}/D_N^{(metal/silicate)}$ ratios are 1.5–1100, which decrease with increasing pressure, fO_2, and the water content in silicate melts. Our results imply that N–C fractionation could occur during core-formation and silicate magma ocean degassing. We find that the N-budget and -isotopic composition of Earth's crust plus atmosphere, silicate mantle, and the mantle source of oceanic island basalts are best explained by Earth's early accretion of enstatite chondrite-like impactors, followed by accretion of increasingly oxidized impactors and minimal CI chondrite-like materials before and during the Moon-forming giant impact. Such a heterogeneous accretion process can also explain the carbon–hydrogen–sulfur budget in the bulk silicate Earth.