C/N fractionation during mantle-core differentiation

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The origin of the particularly high and non-chondritic C/N ratio of the bulk silicate Earth (BSE) is the topic of a vigorous debate. It may reflect large-scale differentiation events such as sequestration in Earth's core or massive blow off of Earth's early atmosphere, or alternatively the characteristics of a late-added volatile-rich veneer. As the behavior of N during early planetary differentiation processes is poorly constrained, we determined together the partitioning of N and C between Fe-N-C metal alloy and a terrestrial and a martian basalt in piston-cylinder experiments run at 1, 2 and 3 GPa, 1400ºC and 1600ºC, and fO_2 ranging from IW-0.7 to IW-3.6. Major element and N concentrations in silicate glasses and metals, and C in metals were measured by EPMA. Carbon and N in silicate glasses were analysed on the Cameca IMS 6f SIMS at Arizona State U.

N partitioning between Fe-N-C alloy and silicate melts depends chiefly on fO_2, with lower values of $D_N^{metal/silicate}$ under more reducing conditions. Partition coefficients also decrease with increasing temperature and pressure at similar fO_2, though the effect is subordinate. In contrast, C partition coefficients display no pressure effect but are influenced by temperature. At 1400ºC, C partition coefficients increase linearly with decreasing fO_2. However at 1600ºC, they increase from IW-0.7 to IW-1.8 and decrease from IW-1.8 to IW-3.6. Enhanced C in melts at high temperatures under reduced conditions may result from stabilization of C-H species. No compositional dependence for either N or C partitoning is evident, perhaps owing to the comparatively similar basalts investigated.

At modestly reduced conditions (IW-0.7 to -2), N is more compatible in core-forming metal than in molten silicate ($1 \leq D_N^{metal/silicate} \leq 20$), while at more reduced (IW -2 to IW -3.6) conditions, N becomes more compatible in the magma ocean than in the core-forming metal phase. In contrast, C is highly siderophile at all conditions investigated ($100 \leq D_C^{metal/silicate} \leq 2000$). Therefore, sequestration of volatiles in the core affects C more than N, and lowers the C/N ratio of the bulk silicate Earth (BSE). Consequently, the high C/N ratio of the BSE is more likely a result of loss of a massive atmosphere and/or the accretion of a high C/N late veneer, perhaps similar in volatile inventory to the ureilite parent body.