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BUILDING PLANETS: THE DYNAMICS AND GEOCHEMISTRY OF CORE FORMATION

Carbon as the dominant light element in the lunar core

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Abstract

Geophysical and geochemical observations point to the presence of a light element in the lunar core, but the exact abundance and type of light element are poorly constrained. Accurate constraints on lunar core composition are vital for models of lunar core dynamo onset and demise, core formation conditions (e.g., depth of the lunar magma ocean or LMO) and therefore formation conditions, as well as the volatile inventory of the Moon. A wide range of previous studies considered S as the dominant light element in the lunar core. Here, we present new constraints on the composition of the lunar core, using mass-balance calculations, combined with previously published models that predict the metal–silicate partitioning behavior of C, S, Ni, and recently proposed new bulk silicate Moon (BSM) abundances of S and C. We also use the bulk Moon abundance of C and S to assess the extent of their devolatilization. We observe that the Ni content of the lunar core becomes unrealistically high if shallow (<3 GPa) LMO scenarios are assumed, and therefore only deeper (>3 GPa) LMO scenarios are considered for S and C. The moderately siderophile metal–silicate partitioning behavior of S during lunar core formation, combined with the low BSM abundance of S, yields only <0.16 wt% S in the core, virtually independent of the pressure (P) and temperature (T) conditions during core formation. Instead, our analysis suggests that C is the dominant light element in the lunar core. The siderophile behavior of C during lunar core formation results in a core C content of ~0.6–4.8 wt%, with the exact amount depending on the core formation conditions. A C-rich lunar core could explain (1) the existence of a present-day molten outer core, (2) the estimated density of the lunar outer core, and (3) the existence of an early lunar core dynamo driven by compositional buoyancy due to core crystallization. Finally, our calculations suggest the C content of the bulk Moon is close to its estimated abundance in the bulk silicate Earth (BSE), suggesting more limited volatile loss during the Moon-forming event than previously thought.

Keywords: Moon, lunar, core, siderophile, volatiles