Redistribution of Argon by Lower Mantle Phases During Magma Ocean Crystallization

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Recent measurements of Xe isotopes place the formation of high $^{3}He/^{4}He$ mantle to within the first 80 Ma of solar system history. This timeframe coincides with Earth's accretion, leading to the hypothesis that a magma ocean concentrated materials that now comprise the high $^{3}He/^{4}He$ source. We report the Ar contents of bridgmanite, periclase, and stishovite synthesized in the presence of Ar-rich fluids at lower mantle pressures. Experiments were conducting using diamond anvil cells (DAC) and multi-anvil (MA) apparatus and were analyzed by a microprobe. These data are needed to evaluate the behavior of noble gases during magma ocean crystallization, and thus, which materials are suitable precursors to high $^{3}He/^{4}He$ mantle.

The Ar contents of the large majority of bridgmanite, periclase, and stishovite analyses in the MA experiments were below delectability by WDS microprobe. Detection limits are calculated from counting statistics and nominally approached 20 ppm Ar for longer analyses. Saturation of an Ar-rich fluid in the MA experiments was confirmed by high Ar concentration blebs throughout the recovered samples. The Ar contents of samples from DAC experiments were more variable, but large areas of laser heating spots on bridgmanite contain Ar contents at or below the detection limit by EDS microprobe (~100 ppm Ar). Bridgmanite disproportionated to (Mg,Fe)O and SiO_2 in some higher temperature heating spots. These phases also had undetectable Ar concentrations. Combined, our results indicate that Ar is relatively insoluble in the major lower mantle minerals compared to silicate liquids under similar pressures, i.e. Ar is incompatible during magma ocean crystallization. This suggests 1) a basal magma ocean will become progressively enriched in noble gases with crystallization and 2) trapped liquids have the potential to control the noble gas budget of any early-forming reservoir. Noble gas elemental fractionations in magma ocean liquids are not expected until high crystallinity is reached.

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