Metal-silicate partitioning of chlorine in a magma ocean: Implications for the origin of chlorine depletion on Earth.

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The chlorine of the Earth is highly depleted relative to other lithophile and volatile elemets [1]. There are two hypotheses for terrestrial missing chlorine; Chlorine incorporation into the core and an erosion of primordial ocean. Here we experimentally investigate the former case. More specifically, the metal-silicate partitioning of chlorine in a magma ocean is experimentally investigated.
In this study, we investigated the effect of pressure and temperature on the metal-silicate partition coefficient of chlorine in order to estimate the core-mantle partitioning of chlorine. Starting materials were a mixture of high-purity oxides (SiO_2, Al_2O_3, CaO, MgO, FeO), metallic iron, and iron sulfide. Chemical compositions in the silicate portion match those of CI- or EH-chondrites. Chlorine was added to the mixture as $FeCl_2$. The starting materials were encapsulated into either a graphite capsule or a single-crystal MgO capsule. The experiments were performed at 4 - 23 GPa and 1923 - 2673 K using multi-anvil presses at the University of Tokyo and Ehime University. The elemental compositions of recovered samples were analyzed with wavelength-dispersive electron microprobe (WDS-EPMA) and secondary ion mass spectrometry (SIMS). Our experimental results show that (1) chlorine is highly lithophile, (2) becomes more siderophile with increasing temperature, and lithophile with increasing pressure. Based on the experimental results and thermodynamic consideration, we estimated the metal-silicate partitioning coefficient of chlorine at the base of a magma ocean. The *P-T* conditions at the base of a magma ocean were estimated from the peridotite melting curve. Calculation results show that the metal-silicate partition coefficients of chlorine at the base of a magma ocean are much lower than the required value for explaining terrestrial missing chlorine. This result strongly suggests that Earth's core is unlikely to account for terrestrial missing chlorine. Given that the fluid-melt partition coefficient of chlorine is above the unity [e.g., 2], chlorine may have been partitioned into primordial ocean. If this is the case, terrestrial missing chlorine may require an extensive loss of primordial ocean during the planetary accretion phase.
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