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Metal-silicate partitioning of chlorine: Implications for the origin of terrestrial missing chlorine

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The chlorine abundance of the bulk silicate Earth may be depleted relative to the predicted values from various types of primitive materials, such as chondrites (Sharp & Draper, 2013). Such terrestrial missing chlorine would have been caused by planetary accretion processes. There are two hypotheses for the depletion of terrestrial chlorine; Incorporation into the Earth's core and primordial ocean blow off. The latter case is due to the high hydrophilic nature of chlorine. Here we experimentally examine the possibility of the former case. More specifically, metal-silicate partitioning of chlorine in a magma ocean is investigated.

Metal-silicate partitioning behavior of elements is controlled mainly by temperature, pressure, and oxygen fugacity of magma oceans. In this study, we first investigated the oxygen fugacity dependency for the partitioning coefficient of chlorine. Starting materials were prepared from a mixture of high-purity oxides (SiO_2, Al_2O_3, CaO, MgO) and metal (Fe). The relative abundances of each component in the mixture were assumed to be CI chondrite. Chlorine was added to the mixutre as $FeCl_2$(2wt.%). Oxygen fugacity was controlled by adding metallic Si to the samples. The starting materials were enclosed in graphite capsules. The experiments were performed at 4GPa and 1900K for 15 min using multi-anvil high pressure apparatus at Institute for Solid State Physics, The University of Tokyo. The sample was quenched by turning off the power to the heater. The elemental composition of recovered samples were analyzed by wavelength-dispersive electron microprobe at Atmosphere and Ocean Research Institute, The University of Tokyo.

The metal-silicate partitioning coefficient of chlorine in recovered samples was within the range between 0.001∼0.01, suggesting that chlorine is a highly lithophile element. In addition, oxygen fugacity dependence on the partitioning coefficient was not observed. If such a highly lithophilic behavior of chlorine observed in our study does not depend significantly on pressure, terrestrial missing chlorine might require primordial ocean blow off during the main-accretion phase.

Reference: Sahrp, Z.D. and D.S. Draper, 2013, Earth Planet. Sci. Lett. 369-370, 71-77.

Keywords: Chlorine, Partitioning of elements, Primordial oceans, Core composition