Determination of the noble gas partition coefficients between metal-silicate melts using laser microprobe analysis

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Analyses of ocean island basalts (OIBs) reveal a geochemical reservoir characterized by unradiogenic, "primordial" noble gas signatures (e.g., high $^{3}He/^{4}He$ and low $^{40}Ar/^{36}Ar$ ratios), likely residing in the deep mantle. There has been much debate about the area holding the "primordial" noble gases deep in the Earth (Porcelli & Ballentine, 2002), including that the "primordial" noble gasses have been retained in the deepest region of the mantle since 4.4 Ga (Mukhopadhyay, 2012) or in the core since the core-mantle separation (Trieloff & Kunz, 2005). However, the validity of latter strongly depends on the quantity of noble gases the core incorporates during accretion and can hold in the present day.
In this study, in order to investigate noble gas partitioning behavior between the core and mantle, noble gases were dissolved into metal-silicate melts under high temperature and pressure conditions, and then the samples were quenched. Two series of sample synthesis were performed at different pressure-temperature ranges and experimental approaches. At the Geophysical Laboratory, Carnegie Institute of Washington, Ar partitioning experiments were conducted using a piston cylinder apparatus. Temperatures were 1700 °C, and pressures were 1 GPa. Experimental samples were contained by a double capsule: Pt outer capsule and graphite inner capsule. A Fe metal-silicate mixture was packed into the graphite capsule. Argon was added to the Pt outer capsule as a liquid, and the Pt capsule was welded shut while held in a bath of liquid N_2. At the Geodynamics Research Center, Ehime University, noble-gas doped hydrous silicate glass and iron were melted and equilibrated under high pressure and temperature (~ 30 GPa, 1700 °C) using a laser-heated diamond anvil cell. After that, the noble gas concentrations contained in the each phase were analyzed using an ultraviolet laser ablation apparatus and a noble gas mass spectrometer at the University of Tokyo.
Preliminary results for argon showed that the partition coefficient D, where D = (noble gas in metal phase)/(noble gas in silicate phase), is in the order of 10^{-4}, which is three orders of magnitude lower than the previous work (Matsuda *et al.*, 1993). However, the apparent noble gas concentrations in the metal phase seem significantly controlled by contaminant phases, such as metal inclusions and micro- or nano-noble gas bubbles. Further experiments are necessary to distinguish noble gases dissolved in metal and retained in the contaminants to better constrain noble gas behaviors between silicate and metal.

References: Matsuda *et al.*, *Science* **259**, 788-791, 1993; Mukhopadhyay, *Nature* **486**, 101-104, 2012; Porcelli & Ballentine, *Rev. Mineral. Geochem.* **47**, 411-480, 2002; Trieloff & Kunz, *Phys. Earth Planet. Inter.* **148**, 13-38, 2005.

Keywords: core, mantle, noble gas, partition coefficient, high P-T experiment

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