

Determination of noble gas partition coefficients between metal and silicate melts under high-pressure and high-temperature conditions

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Noble gas isotopes have been a strong argument for the presence of primordial geochemical reservoir characterized by unradiogenic noble gas signatures (e.g., high $^3\text{He}/^4\text{He}$ and low $^{40}\text{Ar}/^{36}\text{Ar}$ ratios) in the deep earth. There has been much debate about the area holding the primordial noble gases deep in the Earth [1], including that the primordial noble gases have been retained in the deepest region of the mantle since 4.4 Ga [2], or in the core since the core-mantle separation [3,4]. However, recent understanding of mantle dynamics has revealed difficulty with the isolation within the mantle. On the other hand, the validity of the core as the source of primordial noble gases strongly depends on the quantity of noble gases the core incorporates during its segregation in the magma ocean. Although a few experiments reported partition coefficient of noble gases between liquid iron-rich metal and silicate melt under high pressure and high temperature [4,5], there are still several uncertainties. For a better understanding of the primordial noble gas reservoir, we conducted new experiments to determine noble gas partition coefficients between molten metal and silicate.

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, recovered, and analyzed for noble gas concentrations. Sample synthesis was performed at the Geodynamics Research Center, Ehime University. Noble-gas doped silicate glass, which was prepared by using a hot isostatic pressing equipment at the Earthquake Research Institute of University of Tokyo, and iron were melted and equilibrated under high pressure and temperature (3-28 GPa, 1700 and 2400 °C) using a multianvil apparatus. The sample capsule was cut and the polished surface of the section was investigated with scanning electron microscope and Raman spectroscopy. The chemical compositions of silicate and metal phases were determined with electron microprobe. And then, the noble gases in the silicate phase were extracted by an ultraviolet laser ablation apparatus and analyzed using a noble gas mass spectrometer at the University of Tokyo.

We determined the partition coefficient D , where $D = (\text{noble gas in metal phase})/(\text{noble gas in silicate phase})$, of Ne, Ar, Kr, and Xe at pressures between 3 and 8 GPa. The D values ranged from orders of 10^{-6} to 10^{-3} , which is consistent with the previous work [5]. Although we confirmed that the silicates obtained with higher pressures than 10 GPa contain a sufficient amount of noble gas, we have not determined amount of the noble gas in the metals because they are too small to be selectively analyzed with the laser ablation system for noble gas extraction. Moreover, we have not determined He partition coefficient in the all pressure range as it was difficult to retain enough amount of He in high-pressure and temperature apparatus during the experiments. However, the D values are highest for Ar, and lower for in order of Ne, Kr, and Xe, suggesting the D value of 10^{-4} or less for He, which is lower than the previously reported values by two orders of magnitude [4]. Since this estimate is close to the lower limit with which the core holds enough primordial He to supply the present-day degassed mantle [3], further experiments are

necessary to determine the partition coefficients at higher pressures, at least 30 GPa with which the elemental partition between iron and silicate melt would have occurred during core formation [6].

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