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Partitioning of siderophile elements between molten iron and silicates at high-pressure

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Process and mechanism of the core formation is one of longstanding issues to understand the early evolution of the Earth. Theory for formation of the Solar system and recent Hf-W chronometric studies on the Earth's mantle and various kind of meteorites suggest that the Earth's core first formed from those of already differentiated planetary embryos during accretion and later re-equilibrated with molten silicate in the deep magma ocean. It is kown that bundances of refractory siderophile elements of the silicate part of the Earth are considerably lower than those of of CI chondrite. The depletion of is accepted as a results of partitioning of these elements in the core. We have examined metal/silicate partitioning of Mn, Co, Ni up to 29 GPa and at 2600C to obtain some insight into the core formation.

High-pressure experiments were carried out using the Kawai-type apparatus. Starting materials were powdered mixtures of 3(Mg0.80Fe0.08Mn0.04Ni0.04)2SiO4 + 1Fe (vol. %) and 6Peridotite + 1Fe100Ni16Co5(vol. %), which were capsulated in MgO or graphite tube and heated for 2-3 minutes in a cylindrical Re or LaCrO3 heater embedded in an MgO octahedron. Quenched charges were analyzed by EPMA, focusing on element partitioning for molten lron(MI)/silicate liquid(SL) or magnesiowüstaite(Mw). As the silicate parts of the starting materials do not produce liquidus Mg-Pv up to 29 GPa, the partitioning between MI/Mg-Pv had to be indirectly determined by combining with the partitioning data between Mw/Pv at 26 GPa and 2500C in metal-free olivine composition.

The oxygen fugacities of the charges were estimated to be about two log unites lower than that of the iron-wüstite buffer. The partitioning of Mn, Ni, and Co between MI and Mw or SL was recognized as an exchange reaction and summarized as the exchange partition coefficient, K'M/Fe(MI/Mw or SL)=(XM/XFe)MI/(XM/XFe)Mw or SL, where M represents Mn, Co, or Ni; Xi is the molar fraction of element i of each phase. With increasing pressure, Mn becomes less lithophilic, whereas the siderophile nature of both Ni and Co diminishes. The estimated K'(MI/Pv) values for Ni and Co are large compared to K'(MI/SL) and K'(MI/Mw) but decrease rapidly with pressure. The K'(MI/SL)s of Ni and Co at 29 GPa show clear departures from the trends suggested by the lower pressure data, implying a sign of onset of structural change in SL which strengthen the preference of Ni2+ and Co2+ in SL to MI.

The partition coefficients for Ni and Co between the core and the mantle, K'Ni/Fe(Core/Mantle) and K'Co/Fe(Core/Mantle) are calculated from the abundances of these elements in the mantle and the cosmic abundance to be 1.77 and 1.53, respectively, assuming that no Mg enters in the core. The K'(MI/SL)'s of both Co and Ni determined as function of pressure in the present stuffy require ca. 40 GPa for K's to reach K'(Core/ Mantle) values. In other words, core segregation would have occurred at depths around 1000 km depth, if the MI equilibrated with only SL. As the estimated K'(MI/Pv)'s for Ni and Co are much higher than K'(MI/Mw)'s and K'(MI/SL)s, the Mg-Pv makes the mantle depleted in Ni and Co. In order to make critical evaluation of the core formation models, melting experiments on the mantle-core system at higher pressures are needed.