Experimental studies on carbon isotope fractionation in the deep Earth
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Carbon is the fourth most abundant element in the solar system. It has an important role in the melting phase relations of mantle rocks (Dasgupta & Hirschmann, 2006) and metallic core (Wood et al., 2013). Carbon further acts as an agent of mass transfer in the form of mobile carbonate-rich melts. Carbon isotopic composition has been used as an efficient tool to understand the carbon cycle, both in the shallow and deep Earth environments. However, our understanding of carbon isotopic composition of deep Earth is very limited. Here we review the recent results of experimental determination of partitioning of carbon isotopes at high-pressure high-temperature conditions, in systems analogous to the core formation environment and carbonate melting in the mantle conditions.

High-pressure experiments were performed using a Kawai type multi-anvil high-pressure apparatus at the ISEI, Okayama University, Misasa, Japan. Two types of starting materials were used. First type is a mixture of Fe + 9.0 wt% C with known carbon isotopic composition. Second series of experiments were carried out in the Mg(-Fe)-Si-C-O system, where natural enstatite and San Carlos olivine was mixed with graphite and magnesite. Experiments were carried out at a pressure of 5 and 10 GPa at temperature conditions between 1200 ºC and 2100 ºC. Carbon isotope measurements were carried out using an IRMS.

The distribution of carbon isotopes between Fe-C melt and graphite/diamond at various pressure-temperature conditions shows the presence of large and measurable carbon isotope fractionation in the Fe-C system, consistent with the carbon isotope distribution between graphite and cohenite (Fe3C) in iron meteorites. A temperature-dependent fractionation of carbon isotopes between iron carbide melt and graphite/diamond, as reported in Satish-Kumar et al. (2011), is believed to have created a “^12C-enriched core” with a significant difference in the distribution of carbon isotopes between the carbon core and bulk silicate Earth during accretion and differentiation of early Earth.

In order to further characterize the carbon movement in the mantle, the carbon isotope systematics in carbonated mantle in the presence of graphite/diamond were investigated in the Mg-Si-C-O system. Experimental results indicate that carbon isotopes show considerable partitioning between graphite/diamond and carbonate melt at temperatures and pressures corresponding to upper mantle conditions. Below the solidus an equilibrium temperature dependent fractionation between graphite and magnesite is observed and this equilibrium is sharply disturbed by the onset of carbonate melting. Moreover, the onset of carbonated silicate melting is found to result in an isotopic crossover between graphite and carbonated silicate melt. We infer that the isotopic crossover is caused by the change in speciation from CO2 to CO3^2- in the dissolved melt. Thus, the isotope fractionation process during partial melting need to be examined in detail to understand the cycling of material based on carbon isotopic behavior, its inventories, including the core.


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