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Exploring Ca isotope systematic in the Earth's mantle

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Ca is a highly refractory element with 50% condensation temperature of 1517 K. Ca isotopic compositions of terrestrial and extraterrestrial materials may preserve records of early events of the formation and evolution of the Earth, Mars, and the Moon. For better application of Ca isotope geochemistry, a sound understanding of the Ca isotope systematic in the Earth's mantle is important. Here we combine analyses on a variety of mantle rocks and first-principles calculations, to constrain (1) the Ca isotopic composition of the Bulk Silicate Earth (BSE); (2) equilibrium fractionation factors among major Ca-bearing minerals and silicate melts; (3) the behavior of Ca isotopes during partial melting and metasomatism in the upper mantle.

Mantle peridotites and minerals from Siberia, Eastern China, and Mongolia were analyzed by TIMS or MC-ICP-MS using the double spike method. These samples include pristine, melt-depleted, metasomatism, spinel and garnet phase peridotites. Based on the data of pristine peridotites, we define the $\delta^{44/40}$Ca of the BSE to be 0.94±0.05‰ (2SD, n=14, relative to NIST SRM 915a). $\delta^{44/40}$Ca in refractory peridotites are elevated, which may be induced by partial melting, while metasomatism by carbonate materials can dramatically lower $\delta^{44/40}$Ca of peridotites.

Using first-principles calculations, we estimated the equilibrum fractionation factors of Ca isotopes of the common Ca-bearing minerals in the crust and mantle. We further investigated the compositional effect on equilibrium fractionation between the clinopyroxene and orthopyroxene [1, 2]. For the first time, we quantitatively calculated equlibrium fractionation factor of Ca isotope between clinopyroxene and silicate melt which is negligible relative to current analytical error. This study sets up a benchmark to investigate Ca isotope fractionation during planetary evolution.

[1] Feng et al. (2014) GCA 143: 132-142. [2] Kang et al. (2016) GCA 174: 355-344.