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Heavy halogen geochemistry of martian shergottite meteorites and implications for the halogen composition of the depleted shergottite mantle source

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Abstract

Volatile elements (e.g., H, C, N) have a strong influence on the physical and chemical evolution of planets and are essential for the development of habitable conditions. Measurement of the volatile and incompatible heavy halogens, Cl, Br, and I, can provide insight into volatile distribution and transport processes, due to their hydrophilic nature. However, information on the bulk halogen composition of martian meteorites is limited, particularly for Br and I, largely due to the difficulty in measuring ppb-level Br and I abundances in small samples. In this study, we address this challenge by using the neutron irradiation noble gas mass spectrometry (NI-NGMS) method to measure the heavy halogen composition of five olivine-phyric shergottite meteorites, including the enriched (Larkman Nunatak LAR 06319 and LAR 12011) and depleted (LAR 12095, LAR 12240, and Tissint) compositional end-members. Distinct differences in the absolute abundances and halogen ratios exist between enriched (74 to136 ppm Cl, 1303 to 3061 ppb Br, and 4 to 1423 ppb I) and depleted (10 to 26 ppm Cl, 46 to 136 ppb Br, and 3 to 329 ppb I) samples. All halogen measurements are within the ranges previously reported for martian shergottite, nakhlite, and chassignite (SNC) meteorites. Enriched shergottites show variable and generally high Br and I absolute abundances. Halogen ratios (Br/Cl and I/Cl) are in proportions that exceed those of both carbonaceous chondrites and the martian surface. This may be linked to a volatile-rich martian mantle source, be related to shock processes or could represent a small degree of heavy halogen contamination (a feature of some Antarctic meteorites, for example). The differences observed in halogen abundances and ratios between enriched and depleted compositions, however, are consistent with previous suggestions of a heterogeneous distribution of volatiles in the martian mantle. Depleted shergottites have lower halogen abundances and Br and Cl in similar proportions to bulk silicate Earth and carbonaceous chondrites. Tissint in particular, as an uncontaminated fall, allows an estimate of the depleted shergottite mantle source composition to be made: 1.2 ppm Cl, 7.0 ppb Br, and 0.2 ppb I. The resultant bulk silicate Mars (BSM) estimate (22 ppm Cl, 74 ppb Br, and 6 ppb I), including the martian crust and depleted shergottite mantle, is similar to estimates of the bulk silicate earth (BSE) halogen composition.

Keywords: Mars, shergottites, meteorites, halogens, noble gas, volatile, geochemistry, planetary habitability; Halogens in Planetary Systems