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Experimental determination of Si, Mg, and Ca isotope fractionation during enstatite melt evaporation

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Abstract

Evaporation of silicate materials from Earth or its precursors may be important in shaping their primordial compositions represented by undifferentiated meteorites, e.g., enstatite chondrites; however, the conditions under which evaporation occurs and the extent of evaporation-induced elemental and isotope fractionation remain uncertain. Here, we experimentally determine the volatility and isotope fractionation of Si, Mg, Ca, Nb, and Ta during enstatite melt evaporation at 2423–2623 K using a high-temperature conical nozzle levitator. Homogenous glasses are recovered after experiments; then we use EPMA and LA-ICP-MS to measure the elemental compositions, MC-ICP-MS to measure the Si and Mg isotopes, and TIMS to measure the Ca isotopes. Our results show that the evaporation rates of Si are larger than Mg, and the mean vapor/melt isotope fractionation factors ($\alpha = R_{vapor}/R_{melt}$; R = isotope ratio) are 0.99585 ± 0.00002 for $^{29}Si/^{28}Si$ and 0.98942 ± 0.00130 for $^{25}Mg/^{24}Mg$. However, neither evaporative loss of Ca, Nb, and Ta nor Ca isotope fractionation was observed within analytical uncertainty. In conjunction with previous studies, we find that in an evaporation experiment the saturation degree (partial vapor pressure/equilibrium vapor pressure) of Si (S_{Si}) is larger than S_{Mg} when Si is more volatile than Mg, and vice versa. If the Mg/Ca and Si/Ca ratios and isotopes in the bulk silicate Earth are attributed to the evaporation of enstatite chondrite-like precursors, evaporation temperatures >5000 K and $S_{Si} < S_{Mg}$ are required.

Keywords: Enstatite, planetary evaporation, high-temperature experiments, isotopic fractionation, Earth's composition