

ASPECTS OF EVAPORATION PROCESSES OF CAIs ENRICHED IN SPINEL, MELILITE AND HIBONITE

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Introduction: Ca-, Al-rich Inclusions (CAIs) record the cumulative effects of high-temperature volatility-controlled processes during the first several million years of solar system history [1]. We recently presented results on thermodynamic modeling of evaporation of CAIs with different compositions from CV3 chondrites [2]. The modeling, confirmed by experiments [3], showed that evaporation of a spinel-rich and calcium-poor CAI composition melt (*5aN*) results in a compositional trend that well fits the compositions of refractory hibonite-rich CAIs from CH-CB chondrites [2, 3]. Here we report our observations of chemical peculiarities of experimental run products produced by evaporation of *5aN*-like melts and discuss the results of the thermodynamic modeling of evaporation of two spinel-melilite-hibonite-rich CAIs *54E* (fine-grained; CaO/Al₂O₃ ~0.3) and *48E* (texturally similar to Compact Type As; CaO/Al₂O₃ ~solar) with bulk chemical compositions of typical hibonite-rich CAIs. By comparing both the experimental data and the thermodynamic calculations we discuss the effect of Al₂O₃ content and the CaO/Al₂O₃ ratio on the evaporation process.

Experimental and analytical methods: As a starting material in the experiments we used a CAI *5aN*-like composition prepared by mixing MgO, SiO₂, Al₂O₃ and CaCO₃ with CaO/Al₂O₃ ratio of ~0.3. The composition was evaporated in a vacuum furnace at 1900°C and total pressure <10⁻⁷ bar. Texture and chemical composition of the evaporation residues were studied by SEM and EPMA methods. The thermodynamic calculations were conducted using the theory of associated solutions and experimental data on activities of components in CaO-MgO-FeO-Al₂O₃-TiO₂-SiO₂ melt determined by Knudsen mass spectrometric effusion at 1600 to 2500K [4].

Results and Discussion: Most of the *5aN* evaporation residues consist of intergrowths of quench textured “Christmas tree”-like spinel and glass. As evaporation proceeds the residues become enriched in CaO and Al₂O₃ due to loss of Mg and Si, resulting in formation of non-stoichiometric spinel, which has been reported in natural CAIs [5–7] and in experiments [8] when CAI-like melt was exposed to a reducing gas and lost significant amounts of Mg from the near-surface areas of partially molten droplets by evaporation. The experiments showed that the most evaporated samples, which lost all their Mg and Si, are mostly composed of hibonite and CaAl₂O₄ with minor CaAl₄O₇.

Similarly to the *5aN*-like melt, the compositional trajectory produced by evaporation of CAI *54E*-like melt (14.8 wt% MgO, 52.1 wt% Al₂O₃, 15.8 wt% SiO₂, 17.3 wt% CaO, CaO/Al₂O₃ ~0.3) trends toward the grossite stability field. Evaporation of four hypothetical melts with CaO/Al₂O₃ ~0.3 but different MgO/SiO₂ ratios (0.3; 0.5; 1.0; 1.3) also eventually results in compositions in the fields of hibonite- and grossite-bearing CAIs of CH-CB types. On the other hand, the calculated evaporation trajectory of the hibonite-melilite-rich CAI *48E*-like melt with closer to solar CaO/Al₂O₃ ratio (5.6 wt% MgO, 43.9 wt% Al₂O₃, 20.6 wt% SiO₂, 29.9 wt% CaO, CaO/Al₂O₃ ~0.7) moves away from the compositions of refractory hibonite-rich CAIs from CH-CB chondrites. The latter trend is similar to those obtained for melts with compositions of CAIs from CV3 chondrites [2, 3].

The fact that evaporation of *5aN*-like melt (initial composition within the anorthite stability field) and *54E*-like melt (initial composition within the melilite stability field, close to the melilite-grossite boundary) result in compositions typical for CH-CB hibonite- and grossite-bearing CAIs are probably due to their initial high Al₂O₃ contents and low CaO/Al₂O₃ ratio of ~0.3. As the CaO/Al₂O₃ ratio in starting materials increases (to ~0.7 in *48E*-or to ~1.2 in *CAIB*-melts [9] the evaporation trajectories trend away from the field of refractory CAIs of CH-CBs). We cannot also exclude possible effects of acidity-basicity factor of the melt [10] or melt structure during evaporation. The lack of enrichments in heavy Si and Mg isotopes in CH-CB CAIs [11] might be related to relatively high pressures during evaporation [9].

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