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-mellite-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 ~0.3. The composition was evaporated in a vacuum furnace at 1900°C and total pressure <10−6 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 CaAl2O3.

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-mellite-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 ~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-basicty 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].