MODEL CALCULATIONS FOR EVAPORATION OF AOA AND CAI MelTS: IMPLICATIONS FOR THE BULK CAIs COMPOSITIONS OF CV3 AND CH-CB CHONDRTES, M.A. Ivanova1,2, S.I. Shornikov1, K. M. Ryazantsev1, and O. I. Yakovlev. 1Vernadsky Institute, Kosygin St. 19, Moscow 119991, e-mail: ivanovvama@si.edu; 2Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, DC. 20560, e-mail: MacPhers@si.edu.

Introduction: The most important formation processes of calcium-aluminum inclusions (CAIs) are condensation, melting and evaporation. The bulk compositions of most CAIs record the cumulative effects of these high-temperature and largely volatility-controlled processes during the first 1–2 million years of solar system history [1]. Our previous thermodynamic calculations of evaporation of several pristine CAIs enclosed in the 3N host CAI [2] showed trends obtained for composition changes of their residual melts crystallized after evaporation. CAI 3N from the Northwest Africa (NWA) 3118 CV3 carbonaceous chondrite is a unique ~2 cm-sized compound object, primarily a forsterite-bearing type B (FoB) CAI that encloses at least 26 smaller CAIs of different types, including compact type A (CTA), B, C, and an ultra-refractory inclusion [3, 4]. 3N originated either as an aggregate of many smaller CAIs (mostly types A, B, C) plus accreted Fo-bearing material (resembling an amoeboid olivine aggregate (AOA)) which experienced partial melting of the whole; or else as a FoB melt droplet that collided with and trapped many smaller solid CAIs. Relative to typical type A and B CAIs found elsewhere, the bulk compositions of the A and B CAIs within 3N more closely match the bulk compositions predicted by equilibrium condensation of a gas of solar composition. Being trapped within the FoB host-CAI may have protected them from the melt evaporation that affected most “standalone” CAIs. Therefore the unique 3N CAI contains possibly the most pristine types of refractory material, and their bulk compositions were very important for the investigation of CAI evaporation processes, and our results showed that evaporation of several enclosed CAIs in 3N could result in other known types of CAIs [2].

Here we present results on thermodynamic calculations of evaporation of refractory objects 5aN from NWA 3118 and 52E from Efremovka, CV3 chondrites and discuss the trends obtained for compositions of the residual melts crystallized after evaporation, and compare these trends with bulk compositions of CAIs from CV3 and CH-CB chondrites.

Results: For calculations of the residual melt changes obtained at a constant temperature of 2300 K from evaporation of refractory objects, we used the semi-empirical model of thermodynamic codes developed by [5,6]. This model is based on the theory of associated solutions and experimental data of component activities in molten oxide CaO-MgO-Al2O3-TiO2-SiO2 systems, found by the Knudsen mass spectrometric effusion method in the temperature range of 1600-2500 K. The original chemical compositions of CAI 5aN and AOA 52E are represented in Table 1 and on Fig. 1. These compositions have different contents of the main oxides (CaO, MgO, Al2O3, SiO2 and TiO2, FeO), and variable ratios between them. In texture and mineralogy the CAI 5aN is a pristine fine-grained spinel-rich inclusion with no traces of melting and evaporation. AOA 52E is a pristine amoeboid olivine aggregate consisting of forsterite, Al-diopside, anorthite and spinel. This AOA contains several enclosed CAIs.

During CAI and AOA melt evaporation the most refractory Al2O3 and CaO content in the residual melt material increased. Unlike our previous results [2], we observed different rates of MgO and SiO2 evaporation depending on initial concentrations of oxides and in different activities of the oxides in the melt [7]. We observed inversion of volatilities of the MgO/SiO2 ratios resulting in preferential evaporation of MgO compared to SiO2 from the 52E AOA melt (like all CAIs enclosed in 3N) due to an almost solar initial CaO/Al2O3 ratio of the melt (~1). If the Al2O3 content predominates in the initial melt composition compared to CaO with initial CaO/Al2O3 ratio ~ < 0.3, similar to CAI 5aN, we observe the usual ratio of MgO/SiO2 relative volatilities.

Discussion: Based on the model results, we calculated compositional trends for CAI 5aN and AOA 52E inclusions crystallized from residual melts after evaporation and plotted them on a Ca3SiO4-Al2O3-Mg2SiO4 diagram (Fig. 1). All trends finally lead to CAI compositions corresponding to a Ca-aluminate binary system after FeO, MgO, SiO2 evaporated from the melts.

Evaporation of AOA 52E could result in compositions of Fo-bearing Type B, Type B and hibonite-rich CAIs, and its compositional trend is similar to those of the CAIs enclosed in 3N [2]. All these CAIs and AOA 52E have approximately solar CaO/Al2O3 ratio (~1). The model evaporation of AOA 52E is consistent in general with the experimental work on evaporation of the MgO-rich material of FoB FUN CAIs [8]. Evaporation of CAI 5aN resulted in compositions which have never been observed in CAIs from CV3.
chondrites but have known among CAIs compositions of CH-CB chondrites (Fig. 2). CaO/Al₂O₃ ratio of 5aN is ~0.2 and similar to ratios of the most dominant CAIs from CH-CB chondrites (<0.3, NWA 470, Isheyevo [9]). Based on our observations we can conclude that the final CAI compositions mostly depend on primary bulk chemical compositions of their precursors (mostly from the CaO/Al₂O₃ ratio) and the degree of evaporation processes if evaporation has taken place.


Table 1. Chemical compositions of CAI 5aN and AOA 52E.

<table>
<thead>
<tr>
<th>Oxides, Wt.%</th>
<th>SiO₂</th>
<th>TiO₂</th>
<th>Al₂O₃</th>
<th>Cr₂O₃</th>
<th>FeO</th>
<th>MnO</th>
<th>MgO</th>
<th>CaO</th>
<th>Na₂O</th>
<th>K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>5aN</td>
<td>28.19</td>
<td>0.55</td>
<td>35.05</td>
<td>0.11</td>
<td>7.69</td>
<td>0.02</td>
<td>15.18</td>
<td>9.39</td>
<td>3.21</td>
<td>0.55</td>
</tr>
<tr>
<td>52E</td>
<td>41.34</td>
<td>0.31</td>
<td>6.27</td>
<td>0.21</td>
<td>5.08</td>
<td>0.12</td>
<td>42.56</td>
<td>4.11</td>
<td>n.d.</td>
<td>n.d.</td>
</tr>
</tbody>
</table>

Fig. 1. Trends of chemical compositions of the CAIs enclosed in 3N, CAI 5aN and AOA 52E after evaporation.

Fig. 2. Bulk compositions of CAIs from CV3 chondrites (left) and from CH-CB chondrites (right)