

**A STUDY OF CAI MELT COMPOSITION CHANGING DURING EVAPORATION.** S. I. Shornikov and O. I. Yakovlev, Vernadsky Institute of Geochemistry & Analytical Chemistry of RAS, Kosygin st., 19, Moscow, 119991, Russia; e-mail: sergey.shornikov@gmail.com.

**Introduction:** Evaporation and condensation are among the key physico-chemical processes that form the meteorite substance composition. These processes played an especially important role at formation of the substance of white inclusions in carbonaceous chondrites (CAI). Despite numerous descriptions of their structure and composition, the problems of the origin and physico-chemical conditions for CAI formation remain the subject of continuous discussions. A weak side of various genetic models of CAI is their construction on a purely theoretical basis without due reliance on experimental data.

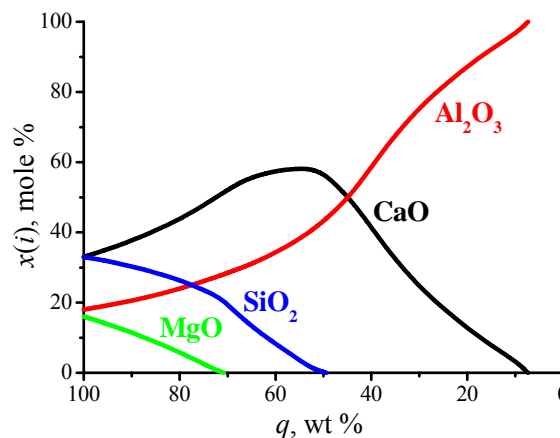
Therefore, of special interest are the results of the study on evaporation of CAI substance from the Yefremovka meteorite obtained by Yakovlev et al. [1]. They identified the gas phase composition and found the partial pressure values of vapor species. The temperature dependence of changes in the CAI substance melt composition was determined at temperature in the range 1300-2600 K. The experiments were performed by the mass spectrometric method at evaporation from a Knudsen cell of the CAI natural substance.

It is known that the evaporation process of oxide compounds is a combination of reactions of simple oxide evaporation and reactions that form gaseous complex oxides. Simple oxides, with a few exceptions, vaporize without changing the composition being either in the region of the solid or the liquid phase. Oxide compounds in the solid phase also vaporize without changing the composition. However, in the liquid state or in a solid solution, oxide compounds and melts, as a rule, change their composition at evaporation.

**Calculations:** Therefore the goal of this work was to study changes in the composition of melts of the CaO–MgO–Al<sub>2</sub>O<sub>3</sub>–FeO–SiO<sub>2</sub> system whose composition is close to that of the CAI substance at temperature range 1600-2300 K. This problem was solved by applying the approach we developed for calculation of the condensed phase composition changes at evaporation [2]. The approach was based on own experimental thermodynamic data [3, 4]. Under consideration were two compositions: 1) average CAI composition [5]: 33 mole % CaO, 16 mole % MgO, 18 mole % Al<sub>2</sub>O<sub>3</sub>, 33 mole % SiO<sub>2</sub> (the content of iron and titanium oxides in this sample was insignificant and thus not taken into account in our calculations) and 2) Ap-16 68415,40 lunar basalt experimentally studied in detail [6]: 19.5 mole % CaO, 7.3 mole % MgO, 18.8 mole % Al<sub>2</sub>O<sub>3</sub>,

4.0 mole % FeO, 50.5 mole % SiO<sub>2</sub> (total content of sodium, potassium and titanium oxides in this sample was as low as 0.8 wt. % and thus was disregarded in the calculations).

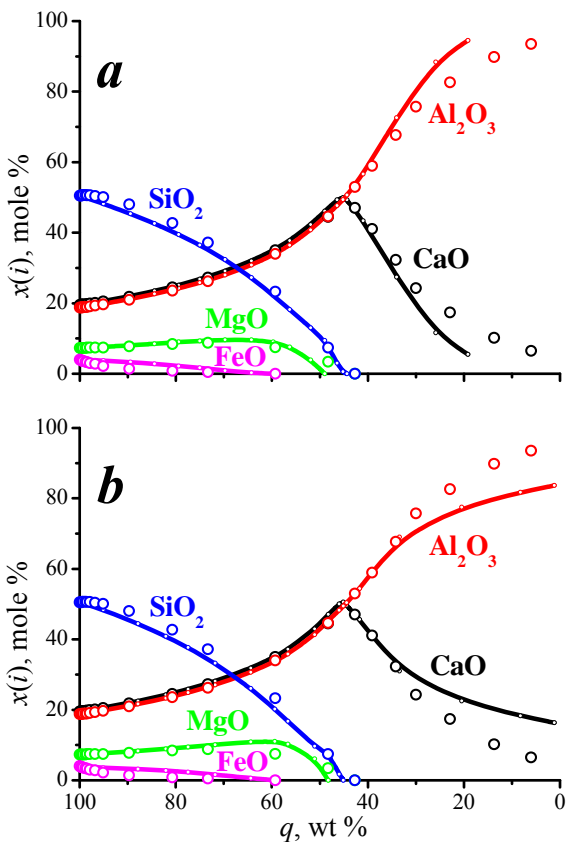
**Results and Discussion:** As follows from Fig. 1, at the first evaporation stage the average CAI composition loses MgO and moves to a region close to the composition of gehlenite Ca<sub>2</sub>Al<sub>2</sub>SiO<sub>7</sub>. Next follows elimination of SiO<sub>2</sub> from the composition of the CaO–Al<sub>2</sub>O<sub>3</sub>–SiO<sub>2</sub> system melt thus formed and the CaO content in the condensed phase, depending on the weight loss  $q$ , achieves its extreme value. The last stage involves evaporation of the CaO–Al<sub>2</sub>O<sub>3</sub> system melt with a sharp decrease in the CaO content down to a level that corresponds to corundum.



**Figure 1:** Calculation of oxide concentration changes in the condensed phase of the CAI average composition melt vs. weight loss during evaporation at temperature in the range 1300-2600 K.

Evaporation of lunar basalt Ap-16 68415,40 (Fig. 2) occurs somewhat differently. At the first stage of evaporation this composition loses FeO and SiO<sub>2</sub>. Simultaneously, the content of calcium, magnesium and aluminum oxides in the condensed phase goes up a little. At a  $q$  value that is about 60 %, iron oxide disappears from the melt. Further evaporation of the lunar basalt melt is characterized by sequential loss of MgO and then SiO<sub>2</sub> from the melt. The last stage, like in the first case, proceeds with predominant evaporation of CaO from the melt composition and reaching the corundum region.

Reliability of the approach developed is shown on the example of the available experimental data. Comparison of the results obtained in the course of this work with the experimental data [6] obtained by the Knudsen spectrometric effusion method shows their satisfactory conformity (Fig. 2). Let us note that changes in the temperature mode do not affect the concentration-weight dependences that characterize melt evaporation.



**Figure 2:** Calculation of oxide concentration changes in the condensed phase of the Ap-16 68415,40 lunar basalt melt vs. weight loss during evaporation at 2300 K in various redox conditions: (a) in chemically neutral conditions; (b) in reducing conditions ( $p(\text{O}) = 1.00 \cdot 10^{-7}$  atm,  $p(\text{O}_2) = 4.13 \cdot 10^{-10}$  atm).

The experimental results obtained by the Knudsen effusion mass-spectrometry method [6] are denoted by symbols. The calculation results obtained in this study are indicated by lines.

A though-provoking conclusion can be drawn from the observed small difference between the experimental dependences and those calculated in this work at the last stage of melt evaporation (Fig. 2). The calculation results of changes in the melt composition

at evaporation in chemically neutral conditions (Fig. 2a) and in preset reducing conditions (Fig. 2b) show that this difference is explained by the conditions under which the experiment was conducted [6]. The samples under examination were placed in a rhenium boat on the bottom of a tungsten container, which did not fully rule out the reducing action of tungsten. It is for this reason that the experimental data are in the interval between the calculated values relating to chemically neutral and preset reducing conditions. From Fig. 2 it also follows that redox conditions of evaporation, which can be characterized by value  $p(\text{O}_2)$  or  $p(\text{O})$ , considerably affect not only the melt evaporation rate but also the residual melt composition.

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**References:** [1] Yakovlev O. I. et al. (1984) *LPS XV*, 945–946. [2] Shornikov S. I. (2009) *Herald Earth Sci. Dept. RAS*, 27, No. 1. [3] Shornikov S. I. (2003) *Herald Earth Sci. Dept. RAS*, 21, No. 1. [4] Shornikov S. I. (2008) *Geochem. Int.*, 46, 724–729. [5] Paque J. M. and Stolper E. (1984) *LPS XV*, 631–632. [6] Markova O. M. et al. (1986) *Geokhimiya*, No. 11, 1559–1569 (in Russian).