

**MASS SPECTROMETRIC STUDY OF EVAPORATION OF NATURAL CAIs MELTS (TYPES A AND B) IN EFREMOVKA CHONDRITE.** S. I. Shornikov<sup>1</sup> and O. I. Yakovlev<sup>1</sup>, <sup>1</sup>Vernadsky Institute of Geochemistry & Analytical Chemistry of RAS, Kosygin st., 19, Moscow, 119991, e-mail: [sergey.shornikov@gmail.com](mailto:sergey.shornikov@gmail.com), [yakovlev@geokhi.ru](mailto:yakovlev@geokhi.ru).

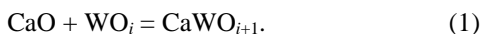
**Introduction:** Ca–Al–Inclusions of chondrites (CAIs) are unique objects of geochemistry. CAIs represent the most primitive substance of the Solar System with an age of 4.567 billion years. They consist of high-temperature minerals (corundum, hibonite, perovskite, spinel, melilite, fassaite, anorthite). Most researchers believe that CAIs were formed by condensation of solar composition gas. According to modern concepts [1, 2], high-temperature evaporation processes also played a significant role in CAIs formation. There are two main stages in CAIs evolution: the stage of formation of CAIs primary condensates and the stage of heating, melting and partial evaporation of substance. The evaporation of CAIs natural samples of type A and B in a wide temperature range is investigated at the present study.

**Experimental:** The studied samples were natural inclusions in Efremovka chondrite (CV3) of types A and B (Table 1). They contained also some oxides of potassium, sodium, sulfur, iron, titanium, chromium and nickel.

**Table 1.** CAIs initial compositions (wt %)

Oxide	A	B
CaO	36.2	27.6
MgO	5.0	11.4
Al <sub>2</sub> O <sub>3</sub>	38.3	32.3
SiO <sub>2</sub>	20.5	28.7

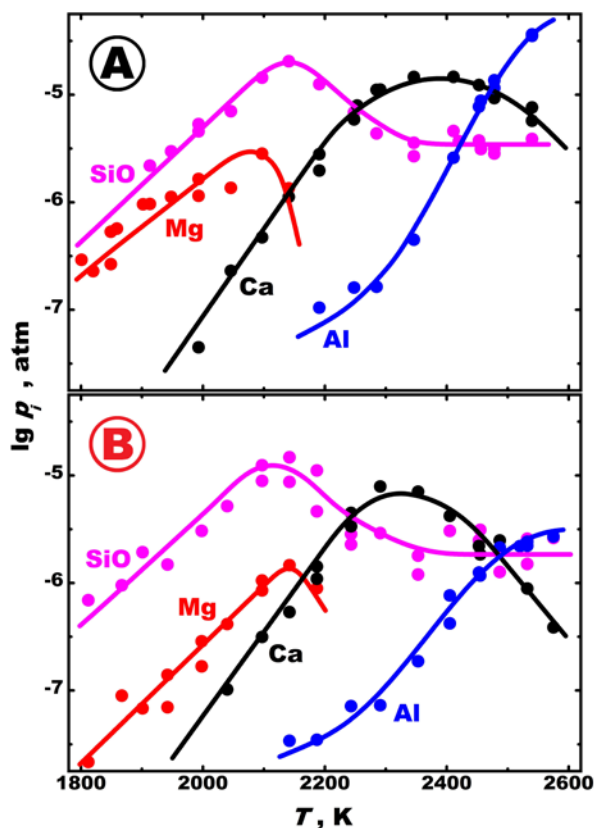
Experimental data on the evaporation of CAIs melts were obtained by the Knudsen effusion mass spectrometric method at 1300–2600 K. Samples weighing 10–15 mg in rhenium foil were placed in a tungsten effusion cylindrical cell heated by electron bombardment. The ionization of the molecular beam from the effusion cell was carried out at ionizing electron energy equal to 28 eV. The following ions were detected in the vapor mass spectra over the melts: Ca<sup>+</sup>, Mg<sup>+</sup>, Al<sup>+</sup>, AlO<sup>+</sup>, Al<sub>2</sub>O<sup>+</sup>, SiO<sup>+</sup>, SiO<sub>2</sub><sup>+</sup>, O<sub>2</sub><sup>+</sup>, as well as K<sup>+</sup>, Na<sup>+</sup>, SO<sub>2</sub><sup>+</sup>, Fe<sup>+</sup>, Ni<sup>+</sup>, Cr<sup>+</sup>, TiO<sup>+</sup>, TiO<sub>2</sub><sup>+</sup>. The WO<sub>2</sub><sup>+</sup> and WO<sub>3</sub><sup>+</sup> ions corresponded to gaseous tungsten oxide formed due to the interaction of oxygen in the gas phase with the material of the tungsten effusion cell. The presence of CaWO<sub>3</sub><sup>+</sup> and CaWO<sub>4</sub><sup>+</sup> ions in the mass spectra is due to the gas phase reaction:



**Results and Discussion:** Partial pressures of vapor species ( $p_i$ ) over CAIs melts (types A and B) were calculated using data of the partial pressure of gold [3] as a standard substance ( $p_s$ ) according to the equation [4]:

$$p_i = \frac{I_i T_i}{I_s T_s} p_s \times \frac{\sigma_s \eta_s}{\sigma_i \eta_i} = K \frac{I_i T_i}{\sigma_i \eta_i}, \quad (2)$$

where  $I_i$  and  $I_s$  are the intensities of the ion currents of the studied and standard substance,  $\sigma_i$  and  $\eta_i$  are the effective cross-sections of ionization and the isotopic distribution coefficient of the  $i$ -th vapor species, respectively. The partial pressures of gaseous Ca, Mg, Al and SiO over CAIs melts during evaporation calculated by the equation (2) are shown in Fig. 1.

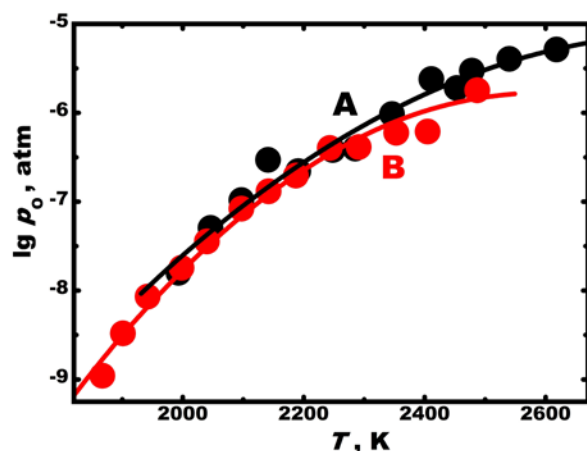


**Fig. 1.** The partial pressures of vapor species (Ca, Mg, Al and SiO) over CAIs melts of type A and B during evaporation at 1800–2600 K.

The partial pressure of atomic oxygen was calculated based on the following reaction:



The obtained  $p_{\text{O}}$  values (Fig. 2) satisfactorily corresponded to those determined on the basis of similar reactions involving atomic oxygen:



**Fig. 2.** Partial pressure of oxygen over CAIs melts of type A and B during evaporation at 1800–2600 K.

The correspondence of the calculated  $p_{\text{O}}$  values for reactions (3) – (8) testified to the molecular origin of the recorded ions.

The comparison of the temperature dependences of partial pressures of vapor species over CAIs melts of types A and B (Fig. 1 and 2) shows their approximate similarity. Note that the CaO and  $\text{Al}_2\text{O}_3$  content in the condensed phase of CAIs type A is higher than in type B. At the same time there are some differences in the  $p_i$  temperature dependences of CAIs melts of types A and B. It can be seen that in CAIs type A melts MgO is the first to leave the melt, ahead of  $\text{SiO}_2$  that it follows from the position of the  $p_{\text{Mg}}$  and  $p_{\text{SiO}}$  maxima (Fig. 1). On the contrary the MgO and  $\text{SiO}_2$  simultaneous exit from the melt that is specific for CAIs melts of type B.

An interesting feature of the evaporation of CAIs melts of types A and B is the presence of SiO vapor specie in the gas phase to high temperatures exceeding

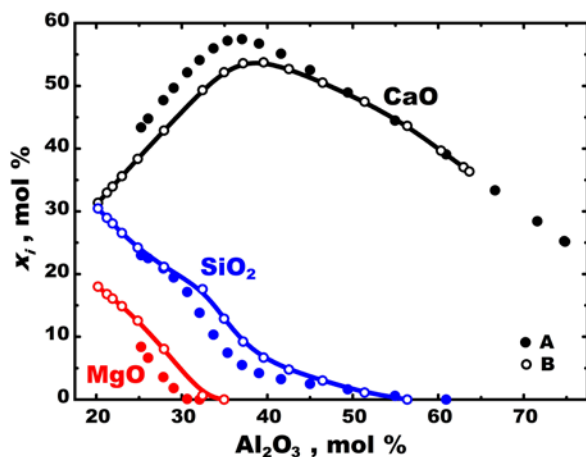
2500 K (Fig. 1). This indicates the presence of silicon dioxide in the condensed phase of CAIs melts.

Using the  $p_i$  values, we can calculate the amount of vaporized oxide from CAIs melts ( $\Delta q_i$ ) at a temperature  $T$  according to the Hertz-Knudsen equation:

$$\Delta q_i = \alpha_i p_i / \sqrt{2\pi RT/M_i} \quad (9)$$

where  $M_i$  is a molecular weight of oxide. The partial evaporation coefficients ( $\alpha_i$ ), characterizing the change in the structure of a molecules during its transition to the gas phase, in this case are equal to 1 [5].

The calculated changes in CAIs melt compositions of types A and B during evaporation at 1800–2600 K are shown in Fig. 3. The interesting feature of CAIs melt evaporation is the similarity of changes in the compositions of residual melts of types A and B.



**Fig. 3.** The changes of CAIs melt compositions of types A and B during evaporation at 1800–2600 K.

**References:** [1] Grossman L. et al. (2000) *GCA*, 64, 2879–2894. [2] Grossman L. et al. (2008) *GCA*, 72, 3001–3021. [3] Paule R. C. and Mandel J. (1972) *J. Pure Appl. Chem.*, 31, 371–394. [4] Semenov et al. (1976) *Application of Mass Spectrometry in Inorganic Chemistry*, Leningrad, Khimiya [in Russian]. [5] Shornikov S. I. (2015) *Geochem. Int.*, 53, 1080–1089.