

ON THE FORMATION OF HASP AND GASP PARTICLES. O. I. Yakovlev^{1,2}, M. V. Gerasimov¹, Yu. P. Dikov^{1,3}. Russian Academy of Sci.: ¹Space Research Inst., Profsoyuznaya st., 84/32, Moscow, 117997, yakovlev@geokhi.ru; ²Vernadsky Inst. of Geochem. and Analytical Chemistry; ³Inst. of Ore Deposits, Petrography, Mineralogy and Geochemistry; Moscow, Russia.

Introduction: Warren [1] has reported about composition of HASP glasses and condensates which were identified in Apollo 14 regolith breccias 14076. Condensates were discovered in the form of small (<10 μm) spherules and aggregates and were named - GASP (Gas-Associated Spheroidal Precipitate) condensates. GASP condensates were separated into Fe-rich FeGASP and Si-rich SiGASP condensates. We have compared composition of HASP and GASP particles with experimental data of Markova et al. [2] on experimental evaporation of aluminum-rich basalt 68415,40 delivered by Apollo-16 and calculations of residua melt and complementary vapor compositions at different temperatures. The aim of our investigation was to evaluate temperatures and mass losses which are related to the origin of HASP glasses and GASP condensates.

Experiment: The sample of aluminum-rich basalt 68415,40 (starting composition (wt.%): SiO_2 45.5; TiO_2 0.3; Al_2O_3 28.7; FeO 4.3; MgO 4.4; CaO 16.4; Na_2O 0.4 K_2O < 0.1) was evaporated using effusive Knudsen technique with mass-spectrometric analysis of the vapor phase [3]. Experimental setup permitted to measure equilibrium temperature and partial pressure of vapor components over melts in the range of temperature up to $\sim 2600^\circ\text{C}$. Peculiarity of the method was the possibility of simultaneous measurement of ion current intensities of the sample and of a standard sample in the same chamber. Temperature of evaporation was measured by pyrometer with accuracy of $\pm 1^\circ\text{C}$. Evaporation was performed in a tungsten effusive cell. The sample with a mass of 15 g was placed in Re-cap to reduce direct interaction between the melt and tungsten. Evaporation from a Re-cap sufficiently inhibits reductive action of tungsten. Experiment was performed with stepped increase of temperature on $\sim 50^\circ\text{C}$. The duration of each step was ~ 15 min what was necessary to gain all the mass-spectrum range. Stepped heating in experiment permitted to keep molecular outflow regime at given sample mass and optimally decrease duration of the experiment. All the duration of the experiment started at $T \sim 900^\circ\text{C}$ and to the total sample evaporation was 5-7 hours. Measured partial pressure of components permitted to calculate their velocities of evaporation based on Hertz-Knudsen formula. Velocities of evaporation permitted to calculate chemical composition of residua melts and corresponding vapor at different temperatures and mass loss rates. Composition of residua melts was calculated at all time

and temperature intervals until its total escape from the Knudsen cell. Elements masses in the melt residua at each temperature step were recalculated to oxide forms and adjusted to 100%. Chemical composition of the vapor was defined as the difference between starting sample and actual residua melt composition. It was also recalculated to oxides form and adjusted to 100%.

Experimental results: Fig. 1 shows chemical composition of residua melt vs. temperature and Fig. 2 shows composition vs. temperature of complementary vapor. Experimental data reveals that the main components of the residua melts were SiO_2 , Al_2O_3 and CaO , and the main components of the vapor were FeO and SiO_2 . It is worth to note that the increase of SiO_2 in the vapor goes only up to $T \sim 1855^\circ\text{C}$ and than it steadily decreases due to its loss from the system and enrichment of the vapor with Al_2O_3 and CaO .

Discussion: Experimental compositions of the residua melts and complementary vapor were compared with compositions of HASP glasses and GASP [1] particles, which originated during vaporization-condensation process in impact-produced plumes on the Moon. Temperature of HASP formation was evaluated as $>1600^\circ\text{C}$ with respective mass loss about one forth to one third of starting mass [1]. Compositional trends of melts and vapor on Al_2O_3 - SiO_2 and FeO - SiO_2 diagrams respectively are informative for evaluation of temperature and mass loss of evaporating material. Fig. 3 shows the sequence of experimental data with defined temperature of evaporation and mass losses. Black circles shows compositions of HASP glasses which have good coincidence with experimental compositional trend. All HASP glasses correspond to temperatures in the range ~ 1750 - 1870°C and mass loss in the range ~ 20 - 50% . The dispersion in HASP glasses composition is a result of individual thermal trend of each particle caused by temporal and spatial unhomogeneity of temperature in impact-generated vapor plume.

Fig. 4 shows composition of vapor in the experiment with related temperatures and mass losses and composition of FeGASP and SiGASP particles. Condensation from FeO and SiO_2 rich vapor was considered [1] to be the most efficient at late stages of expansion of a vapor cloud when evaporation was terminated by cooling. Condensation of FeGASP particles according to Fig. 4 occurred at temperatures in the range ~ 1860 - 1650°C . Higher enriched in iron FeGASPs were formed at lower condensation temperatures. SiGASP particles have compositions

beside the experimental data, but on the same trend of enrichment of SiO_2 concentration in the vapor up to $T \sim 1855^\circ\text{C}$ (see Fig.4). We can admit that SiGASP particles were condensed at higher than that for FeGAS temperatures. High concentration of SiO_2 can be a result of high temperature, which is not sufficient for FeO condensation, and termination of condensation at this high-temperature stage. Dispersion of composition of SiGASP particles also is a result of individual thermal history of particles in a vapor plume.

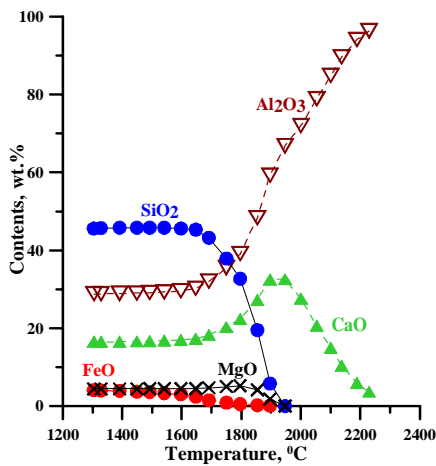


Fig. 1. Concentration of main elements in the residua melt of basalt sample 68415,40 (Apollo 16) vs. temperature.

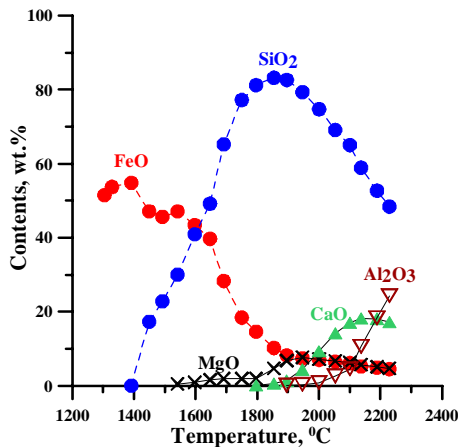


Fig. 2. Concentration of main elements in the vapor phase during evaporation of basalt sample 68415,40 (Apollo 16) vs. temperature.

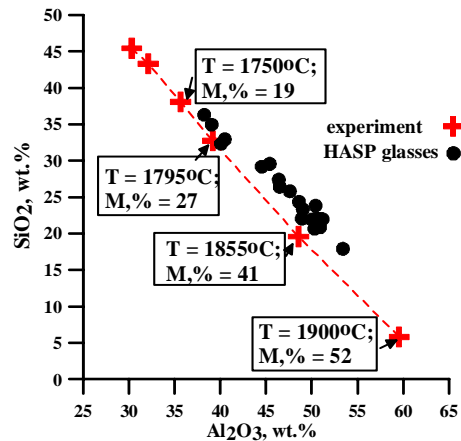


Fig.3. Compositions of HASP glasses and experimentally derived residua melts of basalt sample 68415,40 (Apollo 16). Labels indicate corresponding temperature and starting basalt mass loss for respective composition of the melt.

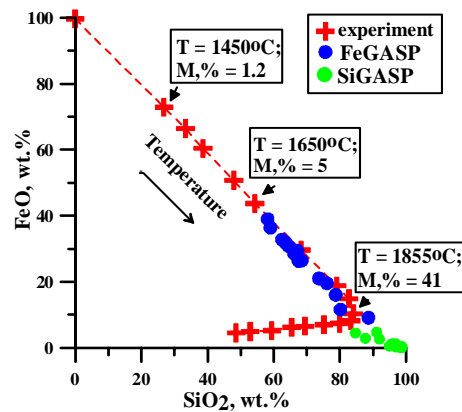


Fig.4. Compositions of FeGASP and SiGASP condensates and experimentally derived vapor compositions of basalt sample 68415,40 (Apollo 16). Labels indicate corresponding temperature and starting basalt mass loss for respective composition of the vapor.

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References: [1] P. H. Warren (2008) *GCA*, 72, p. 3562-3585. [2] Markova O. M., Yakovlev O. I., et al. (1986) *Geokhimiya*, No 11, p.1559-1569 (in Russian). [3] Semenov G. A., et al. Mass-spectroscopy in Chemistry (1976), L. Nauka. 150 p. (in Russian).