CHEMICAL EFFECTS OF HIGH-TEMPERATURE PROCESSING OF SILICATES. M. V. Gerasimov⁷, E. N. Safonova⁷, Yu. P Dikov⁷, and O. I. Yakovlev⁷. ¹Space Research Institute, RAS, Prosfoyuznaya, 84/32, Moscow, 117997, Russia, mgerasim@mx.iki.rssi.ru, ²Institute of Ore Deposits, Petrography, Mineralogy and Geochemistry, RAS, Moscow 109017, Staromonetny per., ³Vernadsky Institute of Geochemistry and Analytical Chemistry, RAS, Moscow 117975, GSP-1, Kosygin st., 19

Introduction: Hypervelocity collisions is a fundamental process which affect the evolution of solid material in the universe. Collisions of particles occur in dust clouds or protoplanetary disks. Planetesimals or meteorites impact large planetary bodies through the geological history. Solid material during an impact is subjected to high-temperature flash heating at highly compressed state which is followed by release of the pressure while temperature can remain rather high to cause vaporization of some portion of the material. The main reason of chemical differentiation here is the selective character of volatility of different elements, which can result in sufficiently different compositions of impact products (melted residua, vaporized/condensed stuff, etc.) while the bulk composition of the whole system remains unchanged. The process of star bursts also have some similarity to the evolution of initially high temperature and high-pressure impact-produced plumes. This supports the validity of the investigation of chemical differentiation of siliceous material during impact-related high-temperature flash processes. Here we present some basic results of our experimental investigation of evaporative chemistry under impact-simulated conditions.

Experimental technique: The simulation of impact-related high-temperature processing was performed using a laser pulse (LP) technique [1]. The Nd glass laser had the following parameters: the wavelength - 1.06 μm, the energy of a pulse 400÷600 J, the power density 10⁶÷10⁷ W/cm², and a pulse duration ~10⁻³ s. Typical temperature under such condition is 4000÷5000 K. The experiments were performed by vaporizing samples in a sealed cell which was usually filled by gas (helium, air, H₂, CH₄, etc.) at 1 atm. The laser beam was focused into a spot with diameter 3÷5 mm producing melting, evaporation, and dispersion of melted droplets into expanding plume. A copper foil was placed in the path of spreading of the vapor plume at a distance ~7 cm from the sample to collect condensed material. The glass spherules with diameters ranging from around one to several tens of microns were found on the surface of the condensed film. Chemical analysis of the spherules were performed using FESEM/EDS microprobe analyses.

Experimental results: High-temperature impact-related treatment results in fundamental chemical changes of siliceous materials.

Formation of refractory compositions. Experimental investigation of differentiation of mafic melts shows that spherules in the beginning of a mass loss process are loosing Si, Fe, alkalis, and their composition enriches in Mg, Ca, Al, and Ti. With a developed mass loss spherules looses Mg while Si is still present in the system [2]. Even Na is not totally lost. Greater mass loss results in the enrichment of Ca, Al, and Ti in the system (Fig. 1). The end members of the mass loss process depends on the temperature of volatilization. Volatilization under 3000 K results in Al-rich spherules and volatilization at temperatures over 3000 K results in Ca-rich spherules.

Reduction of iron. An important effect of high-temperature processing is the reduction of iron. Two main mechanisms are responsible for the reduction: thermal and chemical. Thermal mechanism produces metallic iron nanoparticles through the body of high-temperature siliceous melts due to direct dissociation of iron oxide

$$\text{FeO} \rightarrow \text{Fe} + \text{O}$$

while chemical mechanism involve reducing components (C, H, etc.) in exchange reactions

Fig. 1. Chemical composition (wt. %) of starting augite and of dispersed melted droplets which were produced in LP experiment. The field of droplets compositions indicate the trend of compositional changes of the augite melt during successive mass loss.

FeO + C → Fe + CO

Fig. 2 shows metallic iron nanoparticles (white points) inside the melt which were formed in LP experiment with olivine. Gray uniform body under the melt is the not melted starting olivine. Reduction of iron in olivine is a result of only thermal mechanism since no reducing components were present in the system. Generally both mechanisms are working in a multicomponent system making reduction rather efficient. Fig. 3 shows a melted spherule from LP experiment with Murchison. Its surface is heavily covered by Fe-metal and FeS particles. Due to immiscibility metallic particles are concentrated on the surface of melted droplets but some metallic particles can be present inside the melt. Siderophile elements have a noticeable trend of enrichment in the formed metallic particles.

Fig. 2. SEM view of a cross-section of a piece of melt over a not melted olivine (gray) after a LP experiment. White points in the melt are iron-metal nanoparticles.

Fig. 3. SEM view of a melted spherule produced in LP experiment with Murchison. Its surface is covered by Fe-metal (small) and FeS (large) particles.

Synthesis of complex organics. We performed systematic experiments with samples containing inorganic carbon and hydrogen. In one set of experiments, carbon and hydrogen were incorporated into the sample in inorganic phases, in another, carbon and hydrogen free samples were vaporized in CO₂+H₂O or CH₄ atmospheres. Experiments show the synthesis of a rather complex organic components (mainly hydrocarbons) even at oxidized conditions only if hydrogen and carbon is present in the system [3]. The possible mechanism here can be the Fischer-Tropsch-type of synthesis on the surface of forming condensed particles. Fig. 4 shows chromatograms of organic compounds obtained at oxidized conditions in LP experiment with a composite sample in atmosphere of air. Synthesis of organics at reduced conditions is sufficiently high [4]. Extracted organics were mainly PAHs with degree of polymerization up to C₂₀. X-ray photoelectron spectroscopy of obtained condensates indicate much higher concentration of carbon bound in C-C and C-H bonds than the amount of organic components extracted by solvents. It is probable that some organics are present in the form of a kerogen-like material.


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