Impact-induced redox reactions of silicates with metal iron. *D.D.Badjukov[1], T.L. Petrova[2], and S.V.Pershin[3]; 1 - Vernadsky Institute, Kosygin St., 19, Moscow, 117975, Russia, 2- Institute of Lithosphere, Moscow, Russia; 3 - Insitute of Chemical Physics, Chernogolovka, Russia*

Shock-induced transformations of valent state of elements can be an important process during early stages of the solar system history when practically all matter undergone an impact reworking [1]. However, a little is known about the redox impact reactions [2]. Recently we have assumed a possibility of the reactions in strong shock waves [3,4]. The goal of this work is to study shock-induced redox reactions between coexisting metal and silicate phases.

Specimens for the experiments were powder mixtures of kamacite (5.87 wt.%Ni, 0.4 wt.%Co) of the Sikhote-Alin meteorite with quartz, albite, oligoclase (An_{18}), enstatite (Fs_8), and olivine (Fa_{12}). The mixtures were pressed in cylindrical steel containers and shocked as described by [5]. Parameters of the shock loading are listed in the Table.

Table

Silicate component of the mixture	quartz (Q)	albite (Ab)	oligoclase (Olg)	enstatite (En)	olivine (Ol)
Porosity, vol.%	24	24	26	27	24
Pressure(GPa)[a]	84	81	84	86	93

[a]The shock wave velocity in the all experiments was 7.9 km/s.

Material located near a long sample axis was studied by EMP. In order to avoid a possible influence of the silicate matrix on the microprobe analyses of the metal phase, we picked out pure metal particles from the silicate material. A preliminary Mossbauer spectral study of a shocked Q-kamacite (Me) mixture was carried out. Experiments on Q-, Ab- ,and Olg-Me mixtures yield fluidal colored melt glasses containing numerous metal spherules. Most of the metal spherules in Q- and Ab-Me targets has rounded microcavities. Shocked En- and Ol-Me mixtures demonstrate distinct quenched texture, and contain metal spherules and drops embedded in a crystalline matrix. Quartz and feldspar glasses show a contamination with FeO (up to 3-4 wt.%). No Ni traces are detected in the glasses. Mossbauer spectral measurements show a presence of Fe^{+2} in the quartz glass. Some metal spherules obtained in experiments on Q-, Ab-, Olg-, and En-Me mixtures are enriched in Si (Fig. 1). Interestingly, that a number of Si-bearing spherules and Si contents in silicate components of the mixtures show a positive correlation. Average Si contents in Si-bearing spherules are 4.38, 2.84, 2.44, and 0.77 for shocked Q-, Ab-, Olg-, and En-Me mixtures respectively. No Si-containing metal particles were found in the shocked Ol-Me mixture.

The Si presence in the metal melted particles and contamination with Fe of quartz and feldspar glasses found in Q-, Ab-, and Olg-Me targets indicate that there should be a redox reaction between metal and silicate phases. The same reaction is assumed also for metal and enstatite, although we were not able to detect any enrichment of Fe in shocked enstatite. A scheme of the reaction can be written as:

$$2Fe_{met} + [Si]^{IV} = 2[Fe]^{II} + [Si]^{0}$$

where $[Si]^{IV}$ is silicon in oxygen-silicon tetrahedra , $[Fe]^{II}$ is ferrous ions in a silicate, and $[Si]^{0}$ is silicon dissolved in the metal. Figure 2 illustrates the Si reduction by the oxidation of Fe. The dotted line on this plot is a simple silicon-iron mixture line. The one lies above the trend of the metal spherule compositions. The dashed line shows the spherule compositions calculated according to the redox reaction. This line coincides practically with the regression line of data points. Significantly that there is a some enrichment of the metal spherules in Ni (Fig. 3). It supports our conclusion because Ni is a more siderophile element than Fe. Concentrations of Si in the metal phase in the shocked specimens should be controlled by both pressure-temperature and kinetic parameters. Unfortunately, we can not estimate a theoretical equilibrium Si concentrations in the metal due to absence of necessary thermodinamical data for the phases by the P-T conditions in the experiments.

Thus, the experimental data show there should be redox reactions between metal iron and silicates under a shock. Traces of the reactions can be found in some impactites and heavily shocked meteorites. It is also possible that the reactions could be important during accretion of planetary bodies.

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References: [1] Bischoff A. and D.Stoffler (1992), Euhr. J. Mineral., 4, 707. [2] Yakovlev O.I. et al., (1992), Geochimiya, N12, 1359. [3] Badjukov D.D. and T.L.Petrova (1991), LPSC, 22, 41. [4] Badjukov D.D., (1990), LPSC, 21, 36. [5] Pershin S.V. et al., (1972), Dep. VINITI N1446-70

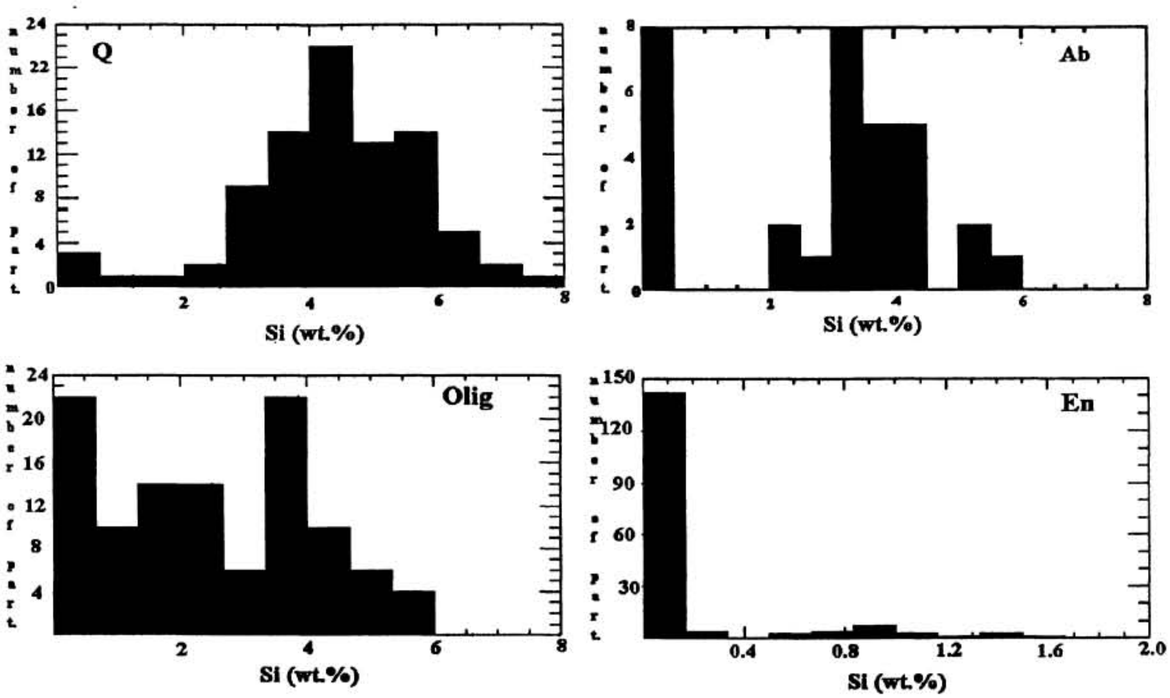

Fig. 1. Distributions of Si contents in metal particles in shocked quartz-, albite-, oligoclase-, and enstatite-kamacite mixtures.

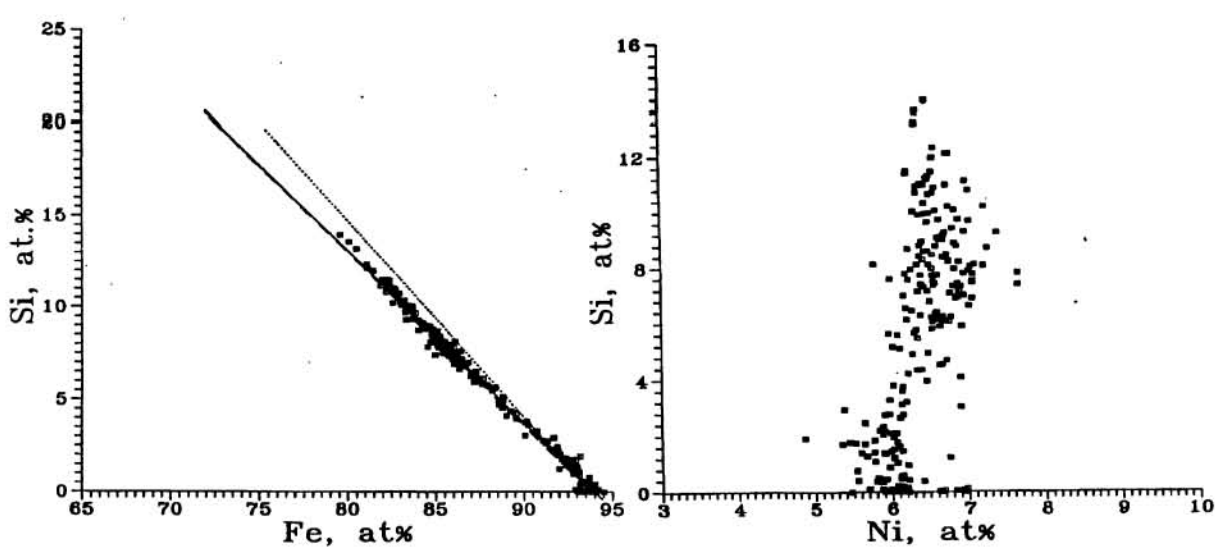

Fig. 2. Fe - Si diagramm for metal particles from experiments on quartz-, albite-, oligoclase-, and enstatite-kamacite mixtures. The dotted (upper) line represents a line of simple Fe-Si mixing. The dashed line shows spherule compositions calculated according to the redox reaction.

Fig. 3. Ni - Si diagramm for metal particles from experiments on quartz-, albite-, oligoclase-, and enstatite-kamacite mixtures.