

The application of the XAFS method and oxidative hydrothermal alteration experiments from reproduced I-type cosmic spherules

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The formation mechanism of hematite spherules in Meridiani Planum on Mars was widely discussed by researchers (Misra et al., 2014; Morris et al., 2005; Nie et al., 2020). Misra et al. (2014) proposed a possibility that the hematite spherules may be derived from cosmic spherules. Therefore, we carried out experiments on reproduced I-type cosmic spherules

(Shao et al., 2020) by oxidative hydrothermal alteration experiments. The starting material was oxidized with the oxygen fugacity controlled by $Mn_2O_3 - Mn_3O_4$ solid buffer in the hematite stability field. The sulfuric acid solution and deionized water were used to control pH values to be 4 and 7, respectively. The vessels were heated at 150°C and 200°C for 10 days and 30 days. The detailed experimental conditions are shown in the table.

Exp.	Experimental conditions			
	Tem (°C)	Dur (days)	pH	CO ₂
1	150	10	7	√
2	200	10	7	×
3	150	10	4	×
4	200	10	4	×
5	150	30	7	√
6	150	30	7	×
7	200	30	7	√
8	200	30	7	×

SEM and EDS analysis revealed that the hematite, magnetite, wustite, and Fe-Ni metal were the main mineral of run products. Fe K-edge XAFS measurements were performed using beamline NW-10A in fluorescence mode at the Photon Factory, KEK, Tsukuba, Japan. The shift of the first derivative spectra peak position from low energy to a higher energy value suggests that the oxidation degree increased as follows: 1. Starting material, Exp.1, Exp.3, and Fe metal; 2. Fe_3O_4 and Exp.4; 3. Exp.2, Exp.8, and Fe_2O_3 . It could be inferred that Exp.1 and 3 were nearly not oxidized; Exp.4 contains mainly magnetite; Exp.2 and 8 are almost completely transferred to hematite. According to the above results, the run products from 150°C 10 days show not a big difference from the starting materials both in pH4 or 7. However, when the temperature at 200°C (10 days), the run products were oxidized to be magnetite (in pH4), or hematite (in pH7). At the same time, under 200°C pH7 condition, both 10 days and 30 days are identical spectra to hematite. The oxidation behavior of reproduced I-type cosmic spherules showed that relatively slow oxidation on metallic spherules could progress under around 200°C. Moreover, the run product under the neutral condition could be oxidized to a higher oxidation state than acidic condition (pH4). From our experiments, it is possible to form hematite from extraterrestrial solid Fe-Ni metal spherules by oxidative hydrothermal conditions. Hence, we suggest that the slow oxidation on melted and quenched droplets derived from iron meteorite bodies may also create hematite minerals in a similar process on the Martian surface.

Keywords: Martian hematite, oxidative hydrothermal alteration, XAFS, cosmic spherules

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