Shock-induced devolatilization and isotope behavior of hydrogen of Murchison meteorite

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[Introduction]

Shocks are very ubiquitous phenomena in the universe and affect materials in there. The Murchison meteorite is one of carbonaceous chondrites, which are acknowledged as primitive materials that provide information on the early solar system. Shock experiments of the Murchison meteorite are very significant to know about the evolution of the solar system. Tyburczy et al. (2001) carried out shock experiments of the Murchison meteorite at shock pressures from 30.5 to 38.6 GPa and reported that the shock causes the devolatilization and isotopic fractionation of hydrogen. Scott et al. (1992) reported that carbonaceous chondrites had suffered various shock pressures up to 35 GPa. Thus it is necessary to carry out the shock experiments at wide range of pressure, in order to discuss the shock-induced devolatilization and hydrogen isotope behavior of meteorites. In this study we performed the shock experiments on the Murchison meteorite at pressures of 6 to 37 GPa. Moreover, we impacted main sources of hydrogen in the Murchison meteorite and discussed the contributions of these sources to the dehydrogenation from the meteorite.

[Experiments]

The sources of hydrogen in the Murchison meteorite are serpentine and organic matter. The main component of the organic matter is an acid-insoluble phase called macromolecular carbon (MC). We used three types of starting materials in this study, the Murchison meteorite, terrestrial serpentine and MC extracted from the Murchison meteorite.

The powder of starting material was pressed into a shock apparatus. The apparatus was impacted with a flyer plate and starting material suffered shock pressure. The recovered samples were sealed with CuO in Vycor tubes under vacuum and heated at 900 degrees Celsius to generate gasses including H2O. After collecting the generated H2O in a tube in which Indiana Zinc was placed, the tube heated at 500 degrees Celsius to reduce H2O to H2. Then hydrogen isotopic ratios were analyzed by mass spectrometer and were expressed in the delta notation relative to the international SMOW standard. Concentrations of hydrogen in samples were analyzed by manometric analysis. The percentages of dehydrogenation (deH) by shock were calculated by comparing the concentrations of hydrogen of starting materials with those of shocked samples.

[Results and Discussion]

The deH increased with increasing shock pressure for all starting materials. The deltaD values of shocked Murchison samples increased from the value of starting material (+11.7 permil) to +59.6 permil with increasing deH and decreased simply to -87.6 permil at higher deH. All deltaD values of shocked serpentine samples were higher than that of starting material at any given shock pressure. The values increased in the range of low deH and remained constant at higher deH. On the contrary, all deltaD values of shocked MC samples decreased simply with increasing deH and were lower than that of starting material.

We discuss the contributions of several sources to dehydrogenation and hydrogen isotope behavior of the Murchison meteorite. The deltaD values of shocked Murchison samples should be explained by the abundance of two sources and their deltaD values. The dehydrogenation and isotope behavior of the Murchison meteorite are estimated using the dehydrogenation and isotope behavior of serpentine and MC at any shock pressure. These estimation cannot, however, explain our results of the isotope behavior for shocked Murchison. This conflict may be attributed to the difference of mechanism for dehydrogenation. The behavior of dehydrogenation from each source which exists in a mixture of volatile materials (e.g. carbonaceous chondrites) may be different from that of the source which exists as a single item.