CONDENSATION EXPERIMENTS IN THE SYSTEM Mg-Si-O-H;
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Condensation is the most important process to produce solids in the solar nebula as well as in circumstellar regions, and played an important role in fractionation in the solar nebula. In this point of view, many thermochemical calculations of solid-gas equilibria have been performed [e.g.,1] and several condensation experiments have been carried out [e.g.,2-5] . However, non of the experiments have been compared directly with the calculation, and thus understanding of the condensation has been limited. In the present study, condensation experiments were carried out in the simplest but most important system Mg-Si-O-H, and the results were compared with the phase diagram in the system Mg-Si-O-H constructed independently with the thermochemical calculation [6].

A new condensation furnace was built for the experiments [7] by taking following points into consideration; (1) low hydrogen pressures similar to conditions in the solar nebula is obtained, (2) high temperatures up to about 2000K is obtained for vaporization and condensation of silicates, (3) condensation can takes place under controlled redox conditions and temperatures, and (4) a large amounts of condensates can be recovered for characterization of the condensates. In the furnace, condensation takes place from a steady-state gas flow derived by heating a vaporization source. Condensates on a cold finger with different temperatures were recovered. The present experiments are different from smoke experiments [e.g.,2] in which gas is quenched immediately after vaporization. Similar experiments have been done [4,5], but a large condensation crucible was used in the present furnace to clear the points (3) and (4) mentioned above.

Forsterite was chosen as vaporization source for the experiments because it vaporized congruently. The experimental conditions were follows; vaporization temperature = about 1630^{o}C, condensation temperature = 1455^{o}C - room temperature, duration = 14.8-96.0 hrs, and $p(H_2) = 1.4 \times 10^{-7} - 1.4 \times 10^{-5}$ bar. Oxidized and reduced conditions were obtained by using the condensation crucible of Mo and Ta, respectively. Condensation took place only at 1.4×10^{-5}bar. Under this condition the mean free path of H_2 molecules is shorter than the crucible size and the molecules (H_2 and Mg, SiO, H_2O from forsterite) were collided with each other. The condensates were examined with SEM/EDX, TEM/EDX, and XRD.

Phases and average chemical composition of the condensates were determined mainly by the redox conditions and the condensation temperature. Condensation sequences with the temperature are follows; forsterite (1200-900^{o}C) -> forsterite + enstatite (900-600^{o}C) -> Mg-rich amorphous material (<600^{o}C) under the oxidized condition, and forsterite (1200-930^{o}C) -> forsterite + silicon (930-700^{o}C) -> Si-rich, O-poor amorphous material (<700^{o}C) -> Mg-rich, O-poor amorphous material (room temperature) under the reduced condition. Fractionation of the gases took place in the furnace, and the amorphous materials at room temperature can be explained as the quenched materials of the residual gases. These sequences are exactly the same as those predicted by the phase diagram [6]. This is essentially important for further experimental studies on condensation. Furthermore, large amounts of condensates (>100mg) recovered in the furnace under controlled conditions will available for further studies on condensates. Preliminary measurements of Mg-isotopes of the condensates with a SIMS show that isotope fractionation took place in the experiments; the heavy isotope (^{26}Mg) is enriched in the solid phases [8].

Condensation of olivine and pyroxene have already reported in the previous experiments [4,5], but the pressures and the (Mg+Si)/H ratio of the gas were quite different from those expected in the solar nebula. The present experiments were performed under more similar condition to the nebula and is applicable to the natural condensation although the (Mg+Si)/H ratio (about 1×10^{-2}) is slightly higher than that of the solar abundance. Most of the silicates were dendrites or whiskers in the present experiments. In fact, pyroxene whiskers were reported as candidates of natural condensates in the nebula [9].

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