LABORATORY STUDIES OF THE CONDENSATION AND PROPERTIES OF AMORPHOUS SILICATE SMOKE

Joseph A. Nuth* and Bertram Donn

NASA/Goddard Space Flight Center, Laboratory for Extraterrestrial Physics
Greenbelt, MD 20771

*NAS/NRC Postdoctoral Research Associate

We have constructed a system in which to study the vapor phase condensation of multi-component refractory species as a function of ambient temperature, reactant concentration and total pressure. The apparatus is an improved version of the design originally described by Day and Donn (Ap. J., 222, L45) and in which we can obtain quantitative measurements of the conditions necessary to induce grain formation from a supersaturated vapor. The optical properties of the grains can be studied in situ while suspended in the ambient gas or samples can be removed from the system for infrared or x-ray diffraction studies.

We have measured the critical partial pressure of SiO (Pc) necessary to initiate avalanche nucleation in a SiO-H2 system as a function of ambient temperature (750 K ≤ T ≤ 1000 K) and total pressure (20 torr ≤ P ≤ 50 torr). The condensate produced by this process was found by infrared analysis to be Si2O3 rather than SiO or SiO2. X-ray fluorescence analysis confirmed this stoichiometry, while x-ray diffraction showed only a broad halo. When samples of Si2O3 were annealed in vacuum at 1250 K for 30 minutes the resultant infrared spectrum was characteristic of amorphous quartz.

Measurements of Pc vs T were obtained for a Mg-SiO-H2 system and compared to the results obtained for SiO-H2. The presence of Mg vapor lowers the critical pressure of SiO necessary to induce avalanche nucleation for temperatures less than about 925 K but does not appear to effect the rate of condensation at higher temperatures. Infrared analysis of the condensate shows the presence of some Si2O3 as well as a short wavelength wing added to the 20 micron peak. X-ray diffraction studies reveal the presence of MgO as well as a broad, diffuse unidentified halo corresponding to a "d" spacing of approximately 0.4 nm.
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Annealing of samples of the Mg-SiO-H₂ condensate in vacuo at 1000 K for 1, 2, 4, 8, 16.5 and 30 hours has allowed us to study the gradual recrystalization of this material. The infrared spectra of various stages in the process show remarkable similarities to the infrared spectra of circumstellar shells around oxygen rich stars. In particular, weak peaks near 6.2, 11.5, 12.5, < 18-19, and > 23 microns, observed in the spectrum of OH 26.5 + 0.6, are reproduced in our samples. Further observations to clarify this suggestive similarity, as well as measurements of the spectra of additional amorphous silicates, are needed before the full implications of this work can be evaluated.

Although the temperature range of our nucleation experiments was much too low to be easily extrapolated to the temperatures in a homogeneous model of the primitive solar nebula (T > 2000 K), our work implies that the grains present in the nebula before collapse would be amorphous, unstable silicates. Our observations suggest that these silicates are easily hydrated and thus could be the source of the matrix material of the carbonaceous chondrites provided that these materials were never subjected to temperatures in excess of about 700 K for long periods of time.