

EVIDENCE OF WATER RETENTION AND LOSS IN MG-SILICATE SMOKES. E. Kohler¹, S. Marcum^{1,2} and J. A. Nuth³. ¹NASA Goddard Space Flight Center, Astrochemistry Laboratory, Code 691, Greenbelt, MD 20771 ²Southeastern Universities Research Association, Washington DC 20005. ³NASA Goddard Space Flight Center, Code 690, Greenbelt, MD 20771 Erika.kohler@nasa.gov

Introduction: The water molecule is arguably the most studied and important molecule to planetary science. Countless studies try to identify where the H₂O formed, where can it be found, and more often than not, where did it go. From a planetary formation perspective, H₂O, along with silicates and metals, are “planet-building materials” [1].

Water ice forms in the interstellar clouds along with preexisting silicate grains forming amorphous structures that sublime and re-condense with temperature changes, developing the precursors to protoplanetary disks [1]. Throughout the formation process, planetesimals inside the snowline tend to outgas any H₂O that may have been trapped in the silicate grains. This leads to a depletion of H₂O in terrestrial planets.

However, the simplicity ends there because planets forming in regions where adsorbed H₂O has been lost, but absorbed water is still locked into the silicate grains, can still contain a significant amount of water. In fact, analysis of basaltic magma shows that H₂O content was at least 3 wt.% H₂O or higher [2]. Knowing the temperatures at which adsorbed, and absorbed, H₂O leaves silicate grains is crucial in understanding planetary formation, transfer of H₂O across the solar system, sequestration of gases, and habitability, amongst others. Laboratory experiments can better constrain the temperatures at which H₂O remains incorporated in planetary formation.

Methods: Amorphous Mg-silicate smokes, similarly synthesized in procedures by Nuth, et al. 2002 [3], was used for this study. These were specifically chosen because the formation for the smokes are indicative of high-temperature processes in the circumstellar outflows. The amorphous Mg-silicate samples were powdered and placed in the sample holder of the AABSPEC cell. The cell was pumped under vacuum to pressures of 9.3×10^{-6} bar and initial spectral measurements were taken at 300 K. Subsequent measurements were taken in 50 K increments up to 1000 K. Each measurement consisted of 1000 scans with a resolution of 4 cm⁻¹ to ensure high resolution data. The data for each sample was normalized and plotted to demonstrate the change in features with increasing temperature.

Spectra was collected at NASA Goddard Space Flight Center using a Mattson RS-10000 Fourier Transform InfraRed (FTIR) spectrometer operating in the near and mid-IR regimes (2 μm – 17 μm). In order

to allow data of the requisite temperatures and pressure to be collected *in situ*, the FTIR was retrofitted with an AABSPEC #2000-A multimode system, that houses samples and allows them to be heated up to temperatures of 1100 K under pressures of 133 bar – 10^{-11} bar.

Results: The preliminary results of this investigation indicate that the solid state H₂O contained within the smokes is removed from the sample between 725 and 750 K. Figure 1 shows the Mg-silicate spectra as a function of temperature. At 700 K the spectra show the H₂O still in the solid-state at around 3 μm and 4.4 μm. In the 750 K measurement, H₂O emission features replace the solid state features. Emission features that were present in the spectra taken at higher temperatures were diminished as the temperature increased, until they disappeared almost completely at 950 K.

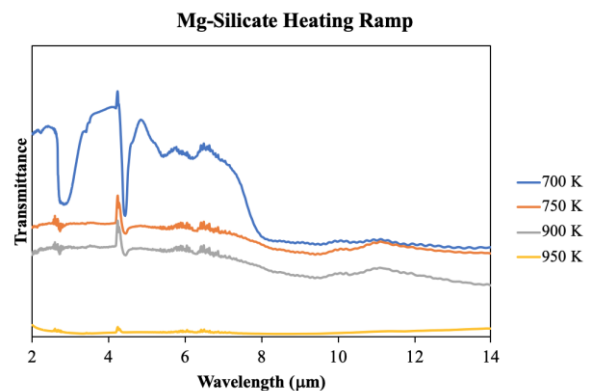


Figure 1. Transmittance spectra of the amorphous Mg-silicate smoke over a range of temperatures. Between 700 and 750 K the H₂O transitions from the solid to the gaseous phase. At 950 K almost all emission features have disappeared. Spectra has been offset by 30%.

Figure 2 shows the initial spectra of the Mg-silicate smoke sample before it was heated up clearly displaying the 3 μm and 4.4 μm water bands. The bands are broad and relatively smooth, indicating that they are solid-state absorption features. The characteristic 10 μm silicate feature is also visible, although it is very weak compared to the intensity of the other bands.

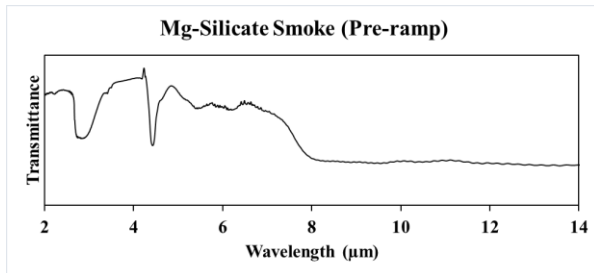


Figure 2. Initial spectra of the Mg-silicate smoke sample taken at 300 K and under pressure of 10^{-6} bar before it was subjected to a heating run.

After the sample was heated up to temperatures of 1000 K and cooled back down to 300 K, the spectra demonstrated clear changes, shown in Figure 3. As the samples cooled down in 100 K increments, the emission features returned, all while retaining the 10 μ m feature.

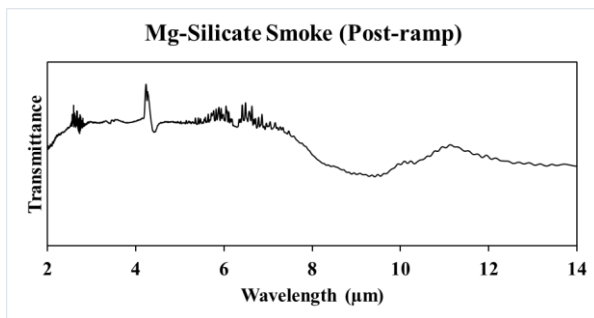


Figure 3. Spectra of the same Mg-silicate smoke at 300 K and 10^{-6} bar after it was heated up and cooled.

Post-ramp spectra (after the sample had been cooled to 300 K) of the silicate smoke after it has been cooled down to 300 K. The spectra shows the water bands in the same position, but after being subjected to heat, the bands are now emission features, indicating that the H_2O being measured is in the gas phase. The 10 μ m silicate feature remains and is more pronounced, suggesting that the chemical integrity of the sample remained intact over the course of the heating run. The solid-state H_2O features did not return, indicating that the H_2O in the samples had been removed completely.

Conclusions & Future Work: Preliminary results from this study suggest that the samples started losing their solid-state H_2O features between 725 and 750 K. This suggests that planetesimals forming within the snow line could have a higher water content. The procedures outlined in this abstract will be repeated in order to clearly quantify the temperature at which water is released from the amorphous smokes. Further work will also involve kinetic studies to determine the activation energy of the H_2O in order to determine

exactly how much water can be released, and how long it would take to release it.

References: [1] Lunine, J. I. (2006). *Meteorites and the early solar system II*, 309-319. [2] Ushioda, M., et al. (2014). *Earth, Planets and Space*, 66, 127. [3] Nuth III, J. A., et al. (2002). *Meteoritics & Planetary Science*, 37(11), 1579-1590.