

EXPERIMENTAL INVESTIGATION OF DELIQUESCENTE-DRIVEN LIQUID BRINE FORMATION WITH CALCIUM PERCHLORATE IN A MARS-LIKE ENVIRONMENT. R. A. Slank¹ and V. F. Chevrier¹; ¹Arkansas Center for Space and Planetary Science, University of Arkansas, 346 Arkansas Ave., Fayetteville, AR 72701, rslank@uark.edu.

Introduction: Variability in the parameters of Mars' orbit allows for mass transport of seasonal water vapor from the equatorial regions to the poles. The stability of this water ice on Mars is largely due to the diffusive and thermal properties of the regolith. While diffusion can explain this process over large timescales, the dynamics of water vapor at shorter timescales (day to year) remains largely unknown. Local effects, mostly related to phase changes of water, including adsorption [1], melting of ice [2], interaction with hygroscopic salts, like perchlorates [3, 4, 5] through hydration, deliquescence, and dissolution [2, 5, 6], and the presence of an ice layer [1], can all be attributed to this uncertainty. Experimental work thus far has focused on defining the phase space for Mars-relevant brines [7], but not much work has been done to define the stability of these brines under Mars-like conditions [8]. Therefore, deliquescence experiments were conducted in a simulation chamber that can mimic Martian pressure, temperature, and atmospheric composition. These experiments are vital to understanding how the water vapor diurnal or seasonal cycle can allow for the creation of liquid water on the surface of Mars.

A series of experiments were conducted, which focused on determining water vapor transfer and deliquescence by weight, temperature, and relative humidity between the atmosphere and a layer of JSC Mars-1 regolith simulant with varying concentrations of $\text{Ca}(\text{ClO}_4)_2$ (0-10 wt.%).

Methodology: A series of fourteen experiments were conducted in the Ares Mars simulation chamber, at the University of Arkansas. Six of the experiments were considered controls. At -20°C (from liquid nitrogen) and 5°C (from chiller) a control was conducted with an empty petri dish, a petri dish filled with 2 mm of JSC Mars-1 regolith simulant, and a petri dish filled with 64.5 grams of pure calcium perchlorate ($\text{Ca}(\text{ClO}_4)_2$). Each of these controls was run in duplicate. Six deliquescence experiments were run at temperatures ranging from -23°C to 5°C for 3-7.5 hours. An additional two deliquescence experiments were run for longer time frames: one at 24 hours and the other at 50 hours. All deliquescence experiments were conducted with 2 cm of JSC Mars-1 and varying abundances of calcium perchlorate (1-10 wt. %).

There were two sets of temperature processes. The first was a set cooled with liquid nitrogen, traveling through

a coils system around the sample petri dish, along with a chiller helping maintain the temperature in the chamber. Those experiments ranged from -23°C to -12°C . The liquid nitrogen was manually let into the chamber, to maintain a specific temperature. The second set of experiments were cooled with just the chiller system. Those experiments ranged from 3°C to 5° . A lithium chloride humidity buffer was placed in the chamber, near the sample, creating a stable humidity in the chamber (maintaining a theoretical average humidity of $11.2\% \pm 0.5$ at 0°C in the atmosphere). Experiments were ran at a pressure of ~ 6 mbar. JSC Mars-1 was baked for 24 hours above 100°C , placed in a desiccator, pulled to vacuum, and then placed in a freezer to cool to -25°C . The calcium perchlorate salt was placed in a desiccator, pulled to vacuum, and then placed in a freezer. The calcium perchlorate was weighed at the proper weight percent amount and then evenly mixed within the regolith. Although there was a short exposure to the atmosphere while the sample was removed from the desiccator and placed in the chamber, the chamber was filled with CO_2 to help prevent water contamination. The entire exposure time was less than 120 seconds.

Results and Discussion: Three deliquescence experiments were conducted using the liquid nitrogen cooling system. The trends varied with the experiments. With the coldest experiment (-23°C) the mass stayed roughly identical. The mass decreased by 0.24g in the experiment run at -20°C , and the mass increased by 0.16g in the experiment run at -12°C (Fig. 1, A). The humidity of the sample also varied in the experiments. In the -23°C experiment, the sample's humidity oscillated between 20-17%, while in the -20°C experiment it started out at 24% before decreasing to 18.5%. In the -12°C experiment the sample humidity started at 16.5% and increased over the entire experiment, ending with a humidity of 21% (Fig. 1, B). The sample temperature was the lowest in the chamber for the -23°C and -20°C experiments, but in the -12°C experiment the atmosphere was the colder location (Fig. 1, C).

Five experiments were conducted with only the chiller cooling the system, the trends were all similar. The sample's mass increased in every experiment. In the case of the 50hr experiment, the mass increased by 3.6g (Fig. 2, A). The sample's humidity ranged from 20-22%

(Fig. 2, B) in all experiments but one, which had a humidity around 10%. The sample temperature followed a similar trend in every experiment. The sample started at a lower temperature and heated up until it was about the same temperature as the upper atmosphere ($\sim 4.5^\circ\text{C}$) (Fig. 2, C).

Relative humidity plays a key role in deliquescence, as it controls water vapor availability in the atmosphere. For most of the experiments, the sample had the highest humidity and was almost double what the humidity of the lithium chloride buffer at 0°C . We believe the JSC Mars-1 regolith mixed with the calcium perchlorate locally controls the humidity, allowing for a higher humidity in the generalized area of the sample. This suggests that deliquescence might occur, even in moderately low humidity environments.

Typically, visible wetness is the best way to identify deliquescence. However, we observed no visible wetness during or immediately after the experiments. This does not mean that water isn't being absorbed into the salt. Mass increase is a great way to help identify water uptake by deliquescence or adsorption. Of the six experiments with increased mass, five of them were experiments conducted in the warmer conditions. (Fig. 1; Fig. 2). Three of the experiments had visible wetness shortly after the experiment, when left in a terrestrial environment. This leads us to believe that water was being absorbed into the regolith and/or salt, but was not fully saturated. This is especially true with the longer run time, where more water was able to be absorbed increasing the mass by 1.14 and 3.71g respectively.

Conclusion: It is important to note that the duration the sample was in the chamber had no impact on surface deliquescence. No matter if the sample was in for 5 hours or 50 hours, there was no visible wetness on the surface. We believe deliquescence did not occur under these conditions. More experiments are needed to understand under which conditions deliquescence occurs (high temperature and/or humidity). Additional experiments are being conducted at cooler temperatures, to better characterize the potential of deliquescence at various humidities under ideal Martian conditions. Exposing complex subtleties in diffusion, adsorption/desorption cycles, and deliquescence processes on Mars, specifically the limits to which this liquid formation is possible, has important implications for liquid stability and habitability near the surface, liquid brines, future missions to Mars, and the continuing search for liquid water.

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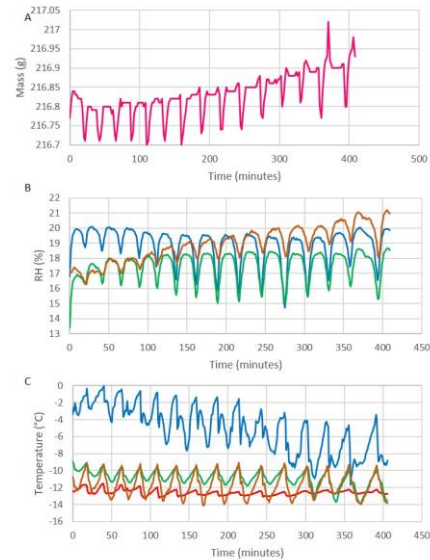


Figure 1: 2cm JSC Mars-1, 1.3 wt% $\text{Ca}(\text{ClO}_4)_2$, -12°C , 7hrs. A: Mass, B: Relative Humidity, C: Temperature. Blue represents the upper atmosphere; red the lower atmosphere; green the humidity buffer; orange the sample.

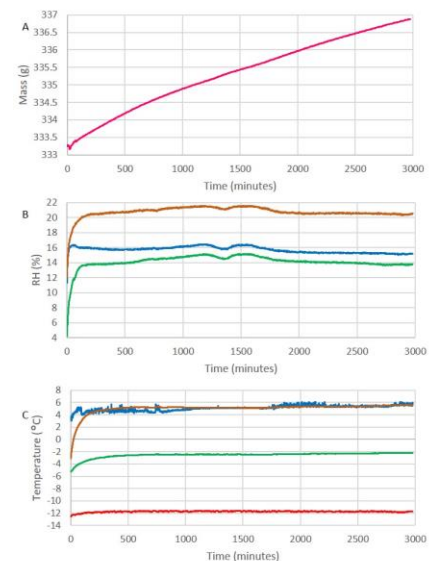


Figure 2: 2cm JSC Mars-1, 5.3 wt% $\text{Ca}(\text{ClO}_4)_2$, 4°C , 50hrs. A: Mass, B: Relative Humidity, C: Temperature. Blue represents the upper atmosphere; red the lower atmosphere; green the humidity buffer; orange the sample.

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