

LIQUID WATER AND FERRIC SULPHATE ON MARS. V.F. Chevrier¹ and T.S. Altheide¹, ¹W.M. Keck Laboratory for Space Simulation, Arkansas Center for Space and Planetary Science, MUSE 202, University of Arkansas, Fayetteville, AR, 72701, vchevrie@uark.edu, talthei@uark.edu.

Introduction: Numerous geomorphologic features are seen on the martian surface which indicate fluvial activity, both ancient and recent [1,2]. In addition, abundant hydrated minerals have been found across Mars, suggesting a wet past [3,4]. However, given the conditions existing at the surface, liquid water should not have been stable on Mars for any significant period of time.

Yet this only holds true for pure liquid water. Brines involving chlorides would allow liquid water to exist for much longer periods under the harsh surface conditions [5,6]. Concentrated halide solutions involve may remain liquid down to around -50°C , which is approximately the average temperature on Mars. But unlike the surface of Earth, chlorides and other halogens are quite scarce on Mars, making such solutions unlikely to have existed in sufficient quantities to cause the observed structures.

The opposite holds true for sulphate minerals. Magnesium sulphates, such as kieserite, are abundant in the martian soils [7]. Other sulphates, including gypsum, have also been found primarily in equatorial regions and in the northern polar regions [8]. However, these minerals are not extremely soluble and can only lower the freezing point of water by less than 5 K [9]. Thus, these solutions are not liquid at temperatures appropriate to Mars.

We suggest that ferric sulphates are an important component in martian fluids. Both iron and sulphate are found in abundance on Mars, so solutions of ferric sulphate should not be rare over geologic history. Indeed, jarosite has been detected in Meridiani Planum [10], and other ferric sulphates have been found in concentrations of up to 30% by weight in some soils in Gusev Crater [11].

Here, we present data demonstrating the stability of ferric sulphate solutions under simulated martian conditions.

Materials and Methods: The following solutions were made using DI water and dried ferric sulphate ($\text{Fe}_2(\text{SO}_4)_3$): 30, 35, 40, 45, 50, 55, and 60 wt%. Ferric sulphate n-hydrate was dried in an oven for 48 – 72 hours at 110°C under a total pressure of 0.04 bars. The dried sulphate was analyzed using XRD to confirm nature of original phase (composed of amorphous $\text{Fe}_2(\text{SO}_4)_3$, rhomboclase, mikasaite and coquimbite). Weight loss measurements at 400°C showed that the originally dried ferric sulphate contained ~ 15 wt% H_2O , and this was allowed for in calculating concentrations of solutions made from the salt.

The evaporation rate of each solution was measured in our Mars Simulation Chamber, where it was exposed to 7 mbar of CO_2 for 0.5 to 3 hours. The average temperature of the atmosphere inside the chamber was 264K. The temperature of each solution tested ranged from 274 to 257K. Humidity inside the chamber was kept from around 1% by carefully injecting CO_2 and pumping. The density of each solution was also determined.

Samples were observed over a range of low temperatures in an attempt to observe any potential crystallization. For the 50 and 60 wt% solutions, CO_2 ice and liquid nitrogen were used to achieve temperatures of 195K and lower.

Results: The evaporation rate for each ferric sulphate solution was determined from the mass loss at low pressure (Fig. 1). Two observations can be noted from these experimental data: first, the evaporation rate strongly decreases at lower temperature. This has been demonstrated under similar conditions for brine solutions of NaCl and CaCl_2 [6]. Second, we observe that increasing concentrations decrease the evaporation rate at constant temperature. The 60 wt% concentration demonstrated an evaporation rate 20 times slower than that of pure liquid water at the same temperature.

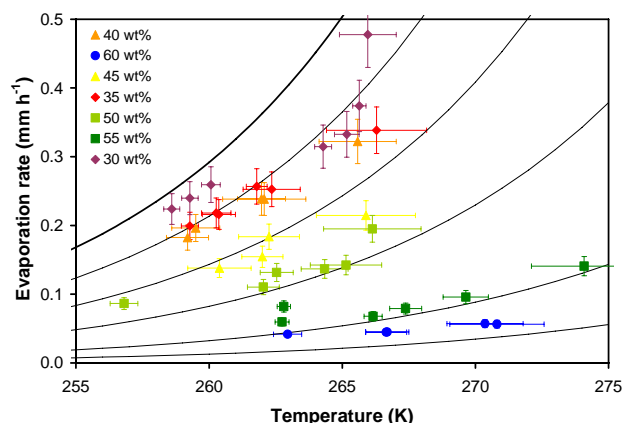


Figure 1: Evaporation rate of ferric sulphate solutions as a function of the sample temperature for various concentrations: 30, 35, 40, 45, 50, 55 and 60 wt %. The top black line indicates the evaporation rate of pure water calculated using Ingersoll (1970) equation.

The observed eutectic seems to be around 201K for an initial concentration of 65 wt% (or 55.3 wt% $\text{Fe}_2(\text{SO}_4)_3$). When exposed to very low temperatures, these solutions exhibited a strong increase in viscosity

with decreasing temperature. This effect was particularly obvious for high concentrations (above 50 wt%) [12].

Discussion: It has been shown before through experiments and theory that the saturation vapor pressure controls the diffusion of water molecules in the CO_2 atmosphere [6,13]. However, in the case of strongly concentrated solutions, the saturation pressure is affected by the lower water activity resulting from interactions between water and ions in the solution. Using our evaporation data we determined the corresponding water activity in the solution (Fig. 2). As expected the activity strongly decreases with increasing $\text{Fe}_2(\text{SO}_4)_3$ concentrations.

The Pitzer ion interaction model for the $\text{Fe}_2(\text{SO}_4)_3$ - H_2SO_4 - H_2O system was used as an independent model to recalculate the water activity [14,15] at very high ionic concentration. The results show that the Pitzer model perfectly fits our data within the error bars (Fig. 2), confirming our approach to the evaporation process and the validity of the Pitzer model at very high concentration.

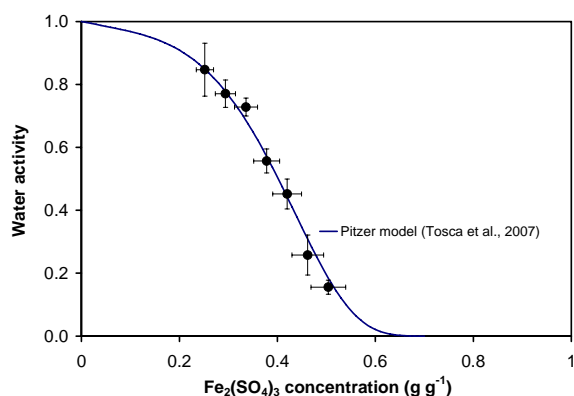


Figure 2: The Pitzer model applied to our kinetic evaporation data. The data fit the model within the margins of error.

The data obtained from each simulation run was used to build a three dimensional model detailing the relationship between concentration and temperature of solution, and the resulting evaporation rate (Figure 3). From this model we were able to determine that at temperatures ranging from 190 – 210 K, a one meter deep pond of 60 wt % ferric sulphate solution would last more than 300,000 years.

Conclusions: Depending on the concentration of these solutions, a freely flowing liquid is still achieved at temperatures dominating the surface of Mars today. The very low evaporation rates of these solutions at such temperatures and concentrations make them perennial at geologic times. We suggest that such solutions should have formed quite easily, and subse-

quently, may be responsible for formation of liquid-related geomorphologic features on the surface today.

The flow characteristics of these solutions need to be determined in order to access their potential in forming features like gullies. This may be especially relevant to northern latitudes from 30° to 60° , where extensive gully formations are found, where the temperature range allows liquid ferric sulphate solutions to exist and where these solutions would remain quite stable for geologically relevant periods of time.

Reflectance measurements of the viscous states of these solutions at low temperatures should be investigated to determine if indeed they exhibit any spectral properties. This knowledge would be most important for determining the presence of these ferric sulphates within areas demonstrating fluid activity.

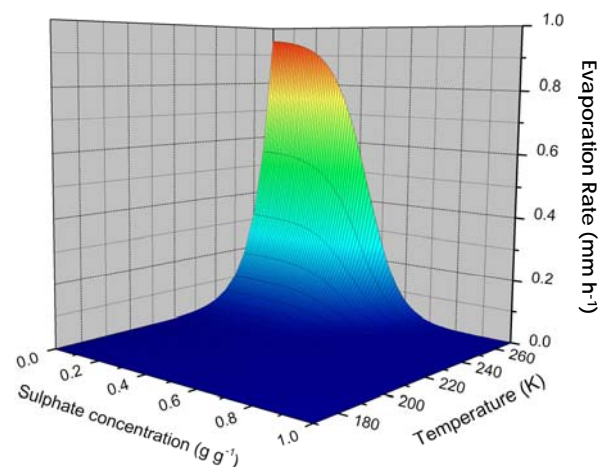


Figure 3: Three dimensional model of ferric sulphate stability under martian surface conditions. Dark blue areas represent most stable conditions.

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