**EVAPORATION RATES OF BRINE ON MARS.** D. W. G. Sears[1, 2], J. Chittenden[1, 2], S. R. Moore[1, 2], A. Meier[1, 2], M. Kareev[1], and C. B. Farmer[1, 3, 4] and, [1]Arkansas-Oklahoma Center for Space and Planetary Sciences, [2]Department of Chemistry and Biochemistry, [3]Department of Geosciences, University of Arkansas, Fayetteville, Arkansas 72701, USA. [4]Jet Propulsion Laboratory, Pasadena, California 91109.

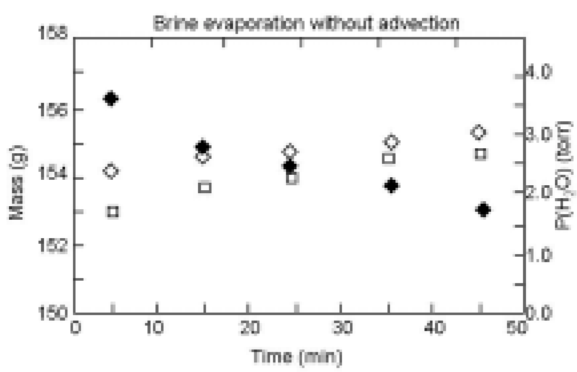
**Introduction:** While Mars is now largely a dry and barren place, recent data have indicated that water has flowed at specific locations within the last ~$10^6$ y [1]. This had led to a resurgence of interest in theoretical and experimental work aimed at understanding the behavior of water on Mars [2-4]. There are several means whereby the stability of liquid water on Mars could be increased, one being the presence solutes that would depress the freezing point [5]. Salt water on Earth is about 0.5M NaCl, but laboratory experiments suggest that martian salt water is quite different [6]. We recently began a program of laboratory measurements of the stability of liquid water, ice and ice-dust mixtures under martian conditions [4,7] and here report measurements of the evaporation rate of 0.25M brine.

**Experimental:** Our measurements were performed in a 61 cm diameter, 208 cm tall stainless steel cylinderical vacuum chamber whose walls and atmosphere were maintained at $0^oC$ while containing an atmosphere similar to that of Mars. Eleven thermocouples, three pressure gauges and two hygrometers monitor conditions in the chamber, one hygrometer being at 2.5 and the other 20 cm from the surface of the sample.

Our experimental set-up consisted a beaker containing 0.25 M brine and ice cubes made from the same solution with a gauze holding the ice in the lower half of the beaker. The chamber was filled with $CO_2$, cooled down, the beaker placed on the balance, and the chamber pumped down to 5.25 Torr (7 mb). After a few minutes to settle down, mass, temperatures, pressures and humidity were recorded every 10 minutes. After about sixty minutes, an ice layer formed on the surface of the water and the present run was assumed to come to an end. Advective conditions were achieved by suspending a cloth bag containing dry ice in the chamber to condense the water vapor on its surface. The $CO_2$ evaporating from the dry ice was occasionally pumped away to maintain the desired pressure. This dynamic method of achieving advective conditions will soon be replaced with a static method of a liquid nitrogen cooled cold finger.

**Results:** Examples of some of our measurements are shown in Figs. 1 and 2. Without advection, brine evaporates at 0.40 mm/h in the example and water vapor pressure increases from 1.5-2.5 torr 20 cm from the sample and 2.5-3 torr 2.5 cm from the sample. Thus for much of the experiment water constitutes a significant fraction of the atmosphere in the chamber. Evaporation of brine under advective conditions is shown in Fig. 2. The evaporation rate is 1.45 mm/h and the atmosphere 2.5 cm about the sample is also rich in water in this example. We do not have data for the water content of the atmosphere 20 cm from the sample during this experiment.

To date, we have completed six experimental runs for brine evaporation and the results of these are compared in Fig. 3. Also shown are data for the evaporation of distilled water under martian conditions from a companion study reported elsewhere at this meeting [7]. We find evaporation rates for liquid water of 1.15±0.22 in the case of no advection, while for two measurements of brine evaporation with advection we obtained values of 1.45 and 0.85 mm/h.



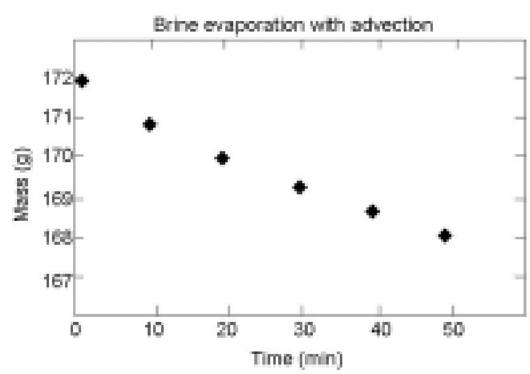




Fig. 1 (upper) and Fig. 2 (lower). Mass (filled symbols) and $P(H_2O)$ measurements (open symbols) at 10-minute intervals during the experiment. The P(H2O) measurements were made 2.5 cm (diamonds) and 20 cm (squares) from the surface of the sample in Fig. 1.

**Discussion of data:** *Mechanism of evaporation of brine.* There are two effects that lead us to expect that brine should evaporate more slowly than pure water. First, the presence of solute ions reduces the surface area of the solution occupied by water molecules. Secondly, the presence of ions reduces the freezing point of the solution which lowers the fraction of water mole-

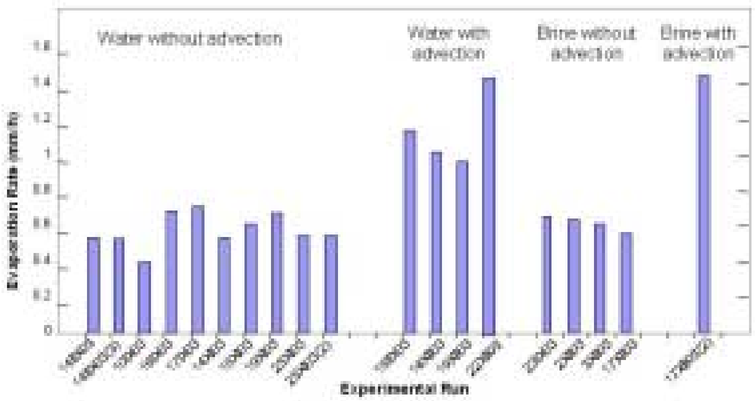



Fig. 3. Evaporation rates for water and brine with and without advection as determined in a planetary simulation chamber under Mars conditions.

molecules with sufficient kinetic energy to leave the surface. The relevant expression is:

$$E = \beta_{evap} A(VP' - PP)\,(2\pi mRT')^{-1/2}$$

where E is the evaporation rate in untis of mass/time, $\beta_{evap}$ is the evaporation coefficient, A is the surface area, VP' and PP are the vapor pressure (modified by for solute ions by Roault's Law) and partial pressure of water, m is molecular weight, R is the gas constant and T' is temperature (modified by the presence of solute). Thus the present data are surprising in that they indicate great similarity between the evaporation rate of brine and water, with perhaps brine even evaporating a little more rapidly.

However, the evaporation process is very complicated, and is affected not only by the release of molecules from the surface but also by processes occurring in the solution and in the atmosphere. These processes are represented in the expression by $\beta_{evap}$ which could be as small as $10^{-4}$. In the solution there is the possibility of compositional zoning so that a layer at the surface of the brine solution, perhaps even a monolayer, is pure water. In the atmosphere, the evaporation rate is governed by the diffusion of water molecules away from the surface and this is strongly dependent on the amount of water vapor in the atmosphere over the surface, which in turn is dependent on advection. This will not be affected by the presence of ions in solution.

*Evaporation of brine on Earth.* Two recent measurements of evaporation rates on Earth suggest that rates are similar for the two planets and that the present of dissolved salts do not materially affect evaporation rates. The Salton Sea, California, one of the most saline lakes in the US (salinity, ~40 g/L or 0.70M) while Mirror Lake, is a fresh water lake in New Hampshire (salinity <3 g/L or <0.05M) have evaporation rates of 0.20 mm/h and 0.19 mm/h, respectively [8,9]. Thus the rate of evaporation of brine on Mars is a factor 2-5 higher than these two measurements for Earth. Recent laboratory measurements for the evaporation rate of pure water on Earth are ~0.36 mm/h, comparable with the present values [10].

**Implications for Mars:** The existence of solute ions in the water does not decrease evaporation rates so this is not a mechanism for increasing the stability of water on Mars. However, the suppression of the freezing point caused by the presence of solute in the water does enlarge the stability field of water. Haberle et al. showed that, if sufficiently concentrated, brine could exist over most of Mars depending on the availability of ice and a heat source, and the evaporation rate [5].

These data also have implications for modeling the water and energy budget of Mars, since evaporation rate plays a role in these issues. This will be pursued elsewhere.

Several authors have suggested that carbonates and other hydrated minerals observed in martian meteorites were deposited from brine solutions [e.g. 11]. The present data offer the possibility of insights into the timescale for the formation for such evaporites.

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