

ISOTOPE FRACTIONATION OF MAGNESIUM CHLORIDE DURING CRYSTALLIZATION:

APPLICATIONS TO MARS. S. Gordon^{1,2}, J. Hanley², V. F. Chevrier² and F.-Z. Teng^{2,3}, ¹Department of Physics and Space Sciences, Florida Institute of Technology, 150 W University Blvd, Melbourne, FL 32901, sgordon2008@my.fit.edu. ²Arkansas Center for Space and Planetary Sciences, ³Department of Geosciences, University of Arkansas, Fayetteville, AR 72701.

Introduction: Isotope fractionation functions as a record of the conditions under which a compound was formed. By studying fractionation of magnesium on Earth – in lava lakes, for example [1] – scientists have been able to compile records of the formation of our planet. The factors that cause fractionation to vary include the masses of the isotopes, the temperature at which their crystals form, and the nature of their chemical bonds [2]. Difference in mass (Table 1) and bond strength is theoretically more effective at determining fractionation at low temperatures; lighter isotopes will generally react and crystallize faster than heavier isotopes. However, these differences become less obvious as temperatures rise.

Mg Isotope	Atomic Mass (u)
²⁴ Mg	23.9850419
²⁵ Mg	24.985837
²⁶ Mg	25.982593

Table 1. Stable isotopes of magnesium.

We have been focusing on magnesium in our use of magnesium chloride because it is one of the most abundant elements on Mars. We know there are high concentrations of chloride-bearing salts in some locations on Mars, such as Juventae Chasma [3] and other areas in the southern highlands [4]. Both magnesium and chloride have been found in the Martian regolith [4,5,6]. Because we know that salts form from solutions with water, we can conclude that it is very likely that wherever there are high concentrations of salts on Mars, water had existed in that spot sometime in the past. It is plausible that water once existed on Mars in brine solutions. The present-day conditions of Mars are such that water can only exist in liquid form on the surface if it is mixed with something, like a salt, that will lower its freezing point [7].

The goal of our research is to determine the relationship between fractionation and temperature, if any, for magnesium. With our knowledge of magnesium fractionation, we will be able to analyze the temperature at which magnesium crystallized in any future martian samples, thus shedding light on previous conditions on Mars that may have been conducive to liquid water.

Experimental: To make our stock solution, we made a stability diagram using data compiled from

many experiments on the solubility of magnesium chloride in water [8] (Fig. 1). The diagram shows the equilibrium lines, which a solution will follow as temperature and concentration change. We chose 35.5 wt% for our stock solution (made with 99-102% pure salt) because it is saturated at room temperature and oversaturated at lower temperatures.

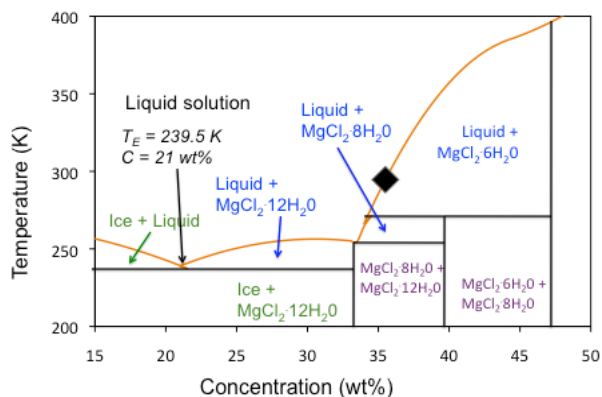


Fig. 1. Stability diagram of magnesium chloride in solution with water. The black diamond shows the mark for our 35.5 wt% solution at room temperature (~298 K).

We have made 13 samples from our stock solution and placed them at different temperatures to crystallize (-22°C, -12°C, 16°C, 26°C, and 50°C). One sample in each group has had the bottom of the sample container scratched to see if it affects the rate of crystallization and fractionation. Once the samples crystallize, we separate the solution from the solid crystals at temperature by passing the sample through a coarse filter. Then we run them through the MC-ICP-MS (multicollector inductively coupled plasma mass spectrometer) in the Space Center. The MC-ICP-MS uses plasma to change our samples into streams of ions, which are then broken into the different isotopes. Each isotope is associated with a different voltage based on its mass-to-charge ratio. The ratio of isotopes in a sample is determined by comparing the different voltages given by the sample.

Results: Over the course of the summer, 2 samples crystallized, both at -22°C. As our 35.5 wt% stock solution was cooled, it followed the equilibrium line (Fig. 1) until its concentration reached 25.25 wt%. Unfortunately, only the crystals from the second sample were dried and prepped in

time to run through the MC-ICP-MS. Figures 2 and 3 below show the results of $\delta^{25}\text{Mg}$ and $\delta^{26}\text{Mg}$ fractionation.

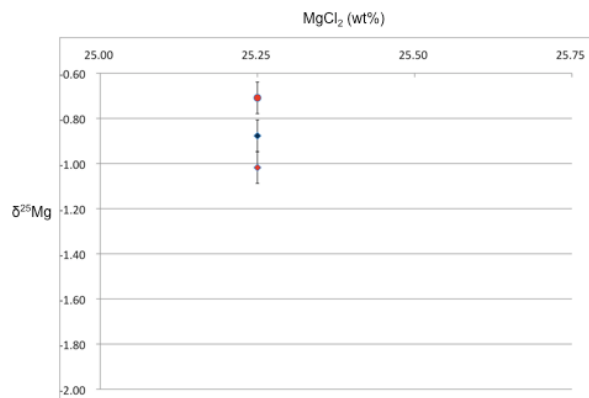


Fig. 2. $\delta^{25}\text{Mg}$ fractionation. Red points are sample 1 and blue point is sample 2. Diamonds are crystals, circle is solution.

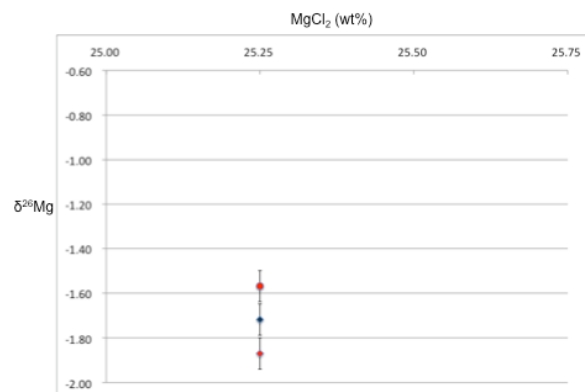


Fig. 3. $\delta^{26}\text{Mg}$ fractionation. Red points are sample 1 and blue point is sample 2. Diamonds are crystals, circle is solution.

Discussion: As seen in the graphs of our results, none of the data are statistically similar. This may have been caused by systematic error with the ICP-MS, or it may have been due to differences in the method of crystal separation. It is clear, however, that the two magnesium isotopes have substantially different fractionation values. Sample 1 was separated a few days after crystallization, while Sample 2 was separated mere minutes after crystallization. It is difficult to directly compare how the time lapse between crystallization and separation affected fractionation between crystal and solution for the samples because Sample 2 only has one data point. As we continue work on this study, we can

acquire data for Sample 2's solution and see if time between crystallization and separation is a factor in the fractionation of our magnesium samples.

Our only samples that have been crystallized so far have been at the same temperature, so we do not yet have enough data to establish whether there is a relationship between fractionation and temperature. Instead, we must review previous studies to get an idea of what results we might find in our study. One study to which we can compare our research focuses on magnesium fractionation at high temperatures. Teng et. al [1] have done an extensive study on magnesium isotope fractionation with samples from all over the world, and their results showed insignificant fractionation of magnesium during terrestrial melting and crystallization processes. This may mean similar results for our study; however, the key difference between their study and ours is temperature. In theory, fractionation should be more significant at lower temperatures, and we expect to see a more drastic difference in fractionation especially at the lowest temperatures.

Conclusions: So far we do not have enough data to tell whether there is a relationship between fractionation and temperature. Once all our samples have been run through the MC-ICP-MS and the fractionation has been calculated, we can compare each sample's results to see if we find a consistent trend. If there is a relationship between fractionation and temperature, our experiment can be repeated at smaller temperature increments and at more extreme high and low temperatures. When martian samples become available for analysis, we hope to use our results to understand the nature of magnesium found on the Red Planet's surface.

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