
Over the past several decades, the presence of sulfur in martian soils and rocks has been detected by a number of missions using X-ray spectroscopy [1-3]. Optical spectroscopy has also provided evidence for widespread sulfates on Mars [4,5]. The ubiquitous presence of sulfur in soils has been interpreted as a widely distributed sulfate mineralogy [6]. However, direct confirmation as to the identity and solubility of the sulfur species in martian soil has never been directly obtained.

One goal of the Wet Chemistry Laboratory (WCL) [7] on board the 2007 Phoenix Mars Lander [8] was to determine soluble sulfate in the martian soil. The WCL received three primary samples. Each sample was added to 25 mL of leaching solution and analyzed for solvated ionic species, pH, and conductivity [9,10]. The analysis also showed a discrepancy between charge balance, ionic strength, and conductivity, suggesting the presence of unidentified ionic species.

Figure 1 shows the data for WCL cell-2 on sols 107 and 116 that, along with a blank, was one of two cells used to determine total soluble sulfate, \((\text{SO}_4^{2-})_T\), present in the soil by addition of \(\text{BaCl}_2\) as \(\text{BaSO}_4\). The \(\text{Ba}^{2+}\) remained relatively constant until the end of sol 116 when it rapidly increased, indicating that it was no longer being precipitated by the \(\text{SO}_4^{2-}\). At that point (\(\text{SO}_4^{2-})_T = \Delta C \times 2\)). The \(\text{SO}_4^{2-}\) in solution = 5.9 (±1.5) mM, equivalent to 1.4 (±0.5) wt % \(\text{SO}_4^{2-}\) in the soil.

Several sulfate mineral phases are plausible candidates for the soluble sulfate, including K-, Na-, Fe-, Mg-, and Ca-sulfate. The Fe was eliminated due to sensor responses. The concentrations of the K and Na were too low and would account for only a minor fraction of any mineral phase. Only \(\text{MgSO}_4\) and \(\text{CaSO}_4\) remain as the most likely phases present in the soil.

Calculations show that addition of \(\text{BaCl}_2\), coupled with dissolution of \(\text{SO}_4^{2-}\), would result in an increase of \(\text{Mg}^{2+}\) and a decrease of \(\text{Ca}^{2+}\) only if a \(\text{MgSO}_4\) phase were added. This was observed during the sol 107 analysis [10]. The addition of soluble \(\text{CaSO}_4\) would have caused an increase in \(\text{Ca}^{2+}\) and no change in \(\text{Mg}^{2+}\), which was not observed. This suggests the major fraction of \(\text{SO}_4^{2-}\) was added as a \(\text{MgSO}_4\) phase. If the soil was once wet, then salts from evaporating the WCL solution could act as a guide to minerals present in the soil. Such models, when run over temperature ranges of 0-25°C and partial pressures of \(\text{CO}_2\) of 0.004-1 atm, show that epsomite exceeds gypsum precipitation by 3 times to 3 orders of magnitude.

The level of dominant salts also has a direct bearing on the question of whether, under appropriate conditions, water activity on Mars could have been sufficient to support life. Newly derived WCL solution ion concentrations and evaporation models, suggest that if only a small portion of the landing site’s ice had been converted to liquid water in the past, brine pockets with the WCL derived salt speciation would have had water activity above the threshold for habitability.

**Acknowledgments:** The Phoenix Mission was led by the University of Arizona, Tucson, on behalf of NASA, and was managed by NASA’s Jet Propulsion Laboratory, Pasadena, CA. The spacecraft was developed by Lockheed Martin Space Systems, Denver, CO.

**References:**