EPSC Abstracts
Vol. 8, EPSC2013-841, 2013
European Planetary Science Congress 2013

The Mars Chemical Analysis Laboratory (MCAL) for in-situ analysis of martian aqueous geochemistry.

Samuel P. Kounaves (1), Joseph Bauer (2), and Kyle M. McElhoney (1)
(1) Tufts University, Medford, MA, USA, (samuel.kounaves@tufts.edu), (2) Draper Laboratory, Cambridge, MA, USA.

1. Introduction

The 2007 Phoenix Mars Lander [1] included four Wet Chemistry Laboratory (WCL) units [2] for performing the first wet chemical analysis of soil on another planet. Each WCL (Figure 1) consisted of electrochemical sensors for analyzing the aqueous geochemical properties of the soil. These included sensors for Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, NH_4^{+}, Cl^{-}, Br^{-}, I^{-}, NO_3^{-}, pH, and $SO_4^{=}$; electrodes for measuring electrical conductivity; determining redox potential (E_h), for independent determination of halides, and for identifying redox couples.

Three ~1 cm^3 soil samples were successfully added to 25mL of water and analyzed. The soil/water mixture had a pH of 7.7(±0.3), conductivity of 1.4(±0.5) mS/cm, with $[Ca^{2+}]$ = 0.5(±0.5) mM, $[Mg^{2+}]$ = 2.9(±1.5) mM, [Na+] = 1.4(±0.6) mM, soluble sulfate SO_4^{2-} = 5.9 (±1.5) mM, [K+] = 0.36(±0.3) mM, and an E_h of 253 (±6) mV. The most unexpected finding was perchlorate (ClO_4^-), with an average concentration 2.5 (±1) mM [3-6].

Here we describe a heritage-based next generation Mars wet chemistry laboratory for an upcoming mission that, in addition to analyses performed by the Phoenix lander WCL [2-6], extends the capability to several dozen or more soil samples without increasing the demand on spacecraft resources, and extends the quantitative chemical aspects of the analyses to provide for better understanding of the aqueous geochemistry and toxicity of the martian soil.

2. The Next Generation WCL

Built on the heritage and successful performance of the Phoenix WCL the Mars Chemical Analysis Laboratory (MCAL) has been designed and assembled for use on a future MER or larger class mission, along with sample caching, that would provide the ability to perform wet chemical analyses at multiple locations over the rover's trajectory and lifetime. The MCAL consists of individual mini-WCL units, as shown in Figure 2, but with improved

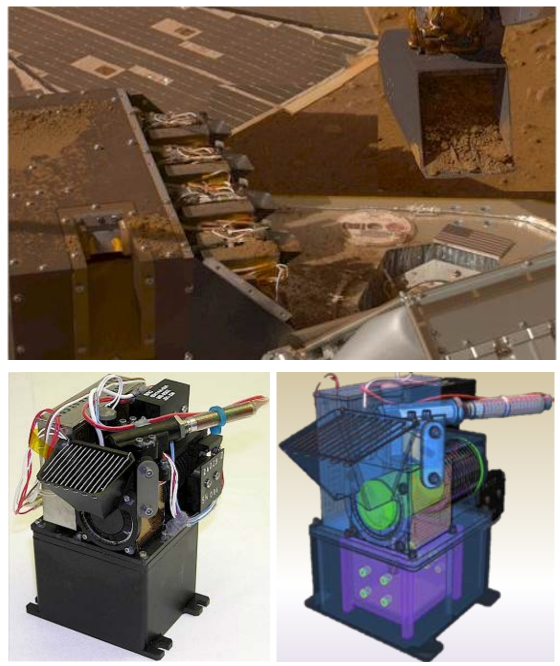

Figure 1. The four WCL units were part of the Phoenix MECA instrument package (top). Each WCL consisted of a lower beaker containing sensors and an upper actuator for adding soil, water, reagents, and stirring (bottom).

calibration, reagent addition, and additional sensors, including redundancy, better reproducibility and a wider selection of chemical species and conditions. Similar to the Phoenix WCL, each unit consists of a "beaker" where the sensors are housed, and holds 1 cc of soil and 7 mL of a leaching solution. It also includes an upper "actuator assembly" which incorporates the leaching solution tank, sample and liquid calibration delivery mechanisms. Instead of using calibration pellets composed of pressed salts as the Phoenix WCL leaching solution tank, sample and liquid calibration delivery mechanisms. Instead of using calibration pellets composed of pressed salts as the Phoenix WCL did, it allows for addition of liquid reagents to ensure rapid dissolution and equilibration of any added reagent. Thus, it enables both instantaneous and long term chemical equilibrium monitoring of the soil/water mixture and will provide chemical data that can be compared to that previously returned by the Phoenix WCL [3-6].

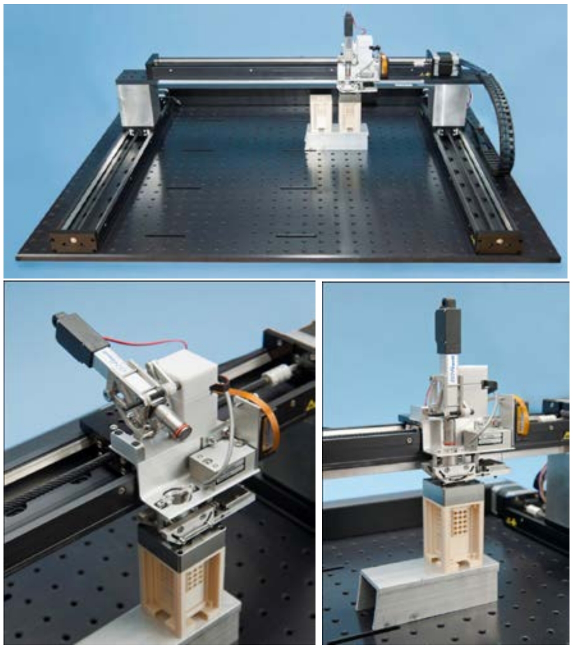

Figure 2: Shuttle with soil piston in position to receive sample (left) and to push sample into beaker (right).

2. Mechanical System

The mini-WCL based system hardware is built on a "modular" concept so that it can be adjusted to facilitate the specifications set by any future mission payload limits. For this reason, it is configured on a grid system that can accommodate any number of individual mini-WCL units, from a 1×4 grid as in the Phoenix MECA package, or for example a 5×20 grid with 100 units as shown in Figure 3. An even larger number of units could conceivably be accommodated if payload limits allow. Above the grid of beakers is a movable gantry system to ferry a shuttle to the selected unit for sample acquisition, delivery, and analysis. In contrast to the Phoenix WCL, and because of the lessons learned during surface operations, soil delivery for MCAL is accomplished using positive displacement to insure delivery. Once the soil sample is loaded into the shuttle weighing container, a linear actuator on the shuttle pushes the sample into the beaker through a central loading shaft. This actuator is shown rotated to accept a soil sample (left) and subsequently loading of the sample into the beaker (right).

3. Sensor Array

Each beaker contains three sensor array walls in a 4×4 grid. The remaining beaker wall is reserved for sensors to be determined at a later date. The ISE sensors are the prime analytical device for determining the dissolved ionic species in the soil/water mixture and monitoring their concentrations over time. These sensors are similar to those use in the Phoenix WCL [2] with the exception that the hydrogel was replaced with nanoporous carbon (NPC). This results in sensors that provide increased lifetime, stability, and able to better withstand the drastic changes in temperatures and thaw/freeze cycling. Sensor tests using several ion species show excellent responses for all species concentrations between ~ 10^{-5} to 10^{-1} M. [9]

4. Conclusion

MCAL builds on the heritage and demonstrated success of the Phoenix WCL, taking advantage of lessons learned and recent improvements in sensor technology. As part of a rover, it will provide the ability to perform wet chemical analyses while ranging over a wide variety of geological surfaces, materials, soil chemistries, and over the lifetime of a long term mission. The sensor array can be tailored to include parameters and substances of high priority to both sample return and human exploration health concerns. It is being developed with the view towards allowing for a scalable payload that will match a variety of in-situ analytical requirements and possess the flexibility for use on any type of future mission.

Acknowledgements

Funding support from NASA PIDD program.

References

[1] Smith, P. H. et al. (2009) *Science*, *325*, 58-61. [2] Kounaves, S. P. et al. (2009) *JGR*, *114*, E00A19. [3] Hecht, M. H. et al. (2009) *Science*, *325*, 64-67. [4] Kounaves, S. P. et al. (2010) *JGR*, *115*, E00E10. [5] Kounaves, S. P. et al. (2010) *GRL*, *37*, L09201. [6] Quinn, R. C. et al. (2011) *GRL*, *38*, L14202. [7] Planetary Science Decadal Survey (2012) Vision and Voyages, NRC Press. [8] MEPAG (2010) Mars scientific goals, objectives, investigations, and priorities: 2010. [9] McElhoney, K., et al., (2012) *Electroanalysis*, 24, 2071-2078.