Perchlorate Salts and Water on Mars: An Overview of Recent Work

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In 2008, the Mars Phoenix lander touched down on the northern plains of Mars, bearing a number of instruments, including the Wet Chemistry Laboratory (WCL), a set of four beakers equipped with ion-selective electrodes to measure ion concentrations in soil. Soil samples delivered to WCL contained concentrations of perchlorate anions at 0.4-0.6 wt% (Hecht et al. 2009). This discovery has wide-reaching implications for the modern geochemical environment on Mars, including atmospheric processes, thin-film water interactions, soil behavior, and astrobiology. Most importantly, perchlorate salts are extremely soluble in water and can result in brines that are stable under current Martian conditions (Chevrier et al. 2009). The state of perchlorate on Mars is still unknown. Geochemical modeling with Phoenix WCL data by Marion et al. (2010) suggest Mg-perchlorate may dominate, in which case, Mg-perchlorate hexahydrate would appear to be the most stable phase under current Mars surface conditions (Ming et al. 2010).

The global distribution of perchlorate on Mars is also unknown; however, several lines of evidence point to wide-spread occurrence. Chlorine is a well-documented component of Mars soils: the Viking landers measured abundances of 0.1-0.9 wt% at Chryse and Utopia Planitiae (Clark et al. 1976), Pathfinder measured 0.55 wt% at Ares Vallis (Wanke et al. 2001), Spirit measured 0.06-0.68 wt% at Gusev Crater (Gellert et al. 2004), Opportunity measured 0.2-2.6 wt% at Meridiani Planum (Rieder et al. 2004), and Odyssey's Gamma Ray Spectrometer estimated 0.2 to 0.8 wt% across Mars (Keller et al. 2006). Phoenix WCL analyses indicated that almost all of Phoenix soil chlorine was in perchlorate, with only 0.01-0.04 wt% present as chloride, suggesting that much of Mars' abundant chlorine may be in the form of perchlorate salts. Supporting this line of reasoning, re-evaluation of Viking GCMS soil analyses show perchlorate present in every soil sample. However, despite evidence for widespread chlorine, perchlorate itself is difficult to map over large areas. Remote sensing analysis using visible- to near-infrared spectroscopy is capable of detecting perchlorate; however, detection limits vary with perchlorate hydration state and cation presence (e.g., Cull et al. 2012).

It is hypothesized that perchlorate forms atmospherically (Catling et al. 2010), and, once formed, it can undergo redistribution by thin films of liquid water, some evidence for which is seen in clods of concentrated subsurface perchlorate at the Phoenix landing site (Cull et al. 2010) . Additionally, surface perchlorate is expected to decompose in the presence of the Mars surface ionizing radiation environment. Lab experiments by Quinn et al. (2011) have shown that perchlorate decomposes to oxyhalide, oxygen, and various chlorine species including chlorate, chlorite, and hypochlorite.

The perchlorate discovery also led to a re-evaluation of Viking lander results. Viking biology experiments returned no evidence of organic compounds in the soils, but found releases of chloromethane and dichloromethane, which were attributed to Earth-originating cleaning products. However, in reanalyzing these finding, Navarro-Gonzales et al. (2010) found that <0.1% perchlorate, mixed with soils bearing 0.7-6.5 ppm organic carbon, produces the observed chloromethane/dichloromethane signatures. These results suggest organic carbon was present in soils at the Viking landing sites, but their signatures were masked by reactions with perchlorate salts.