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Simulating Biomarker Degradation in Martian Oxychlorine-Rich Regolith: Experimental Constraints for Mars Sample Return and In-Situ Detection

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Organic compounds on Mars have been reported by Curiosity and Perseverance: detections include benzene, naphthalene, thiophenes, chlorinated aromatics, and chloro-hydrocarbons.[1, 2] Recent results suggest the possible presence of decane ($C_{10}H_{22}$), undecane ($C_{11}H_{24}$), and dodecane ($C_{12}H_{26}$), potentially derived from long-chain carboxylic acids.[3] The identification of chlorinated compounds has drawn particular interest, with one hypothesis proposing that indigenous organic compounds were chlorinated prior to analysis through in-situ reactions with oxychlorines or their radical intermediates.

We present a systematic investigation of biomarker degradation under martian conditions within oxychlorine-rich substrates. Oxychlorine salts, pervasive in martian regolith, generate radicals under UV irradiation that oxidize and fragment organic matter. Understanding this process is critical for interpreting mission data, designing sample return protocols, and biosignature detection. Using our Mars Simulation Chamber, we exposed cholesterol—a ubiquitous eukaryotic biomarker—to Mars gas mixture, surface pressure, and simulated solar UV flux. Experiments were conducted in martian soil simulants with and without sodium chloride/perchlorate. Reaction products were analyzed via GC-MS and LC-MS.

Preliminary results reveal three key findings. First, degradation is rapid: pseudo-first-order kinetics show >95% cholesterol depletion within 36 hours of UV exposure, even in minimally oxidizing matrices. Second, we identified seven cholesterol oxidation products and a highly oxidized derivative consistent with a complex polycyclic product. Third, the initial degradation pathway is not fragmentation but addition of oxygen-containing groups yielding higher molecular weight intermediates prior to bond cleavage. This functionalization phase is enhanced in oxychlorine-bearing matrices.

These experiments demonstrate that UV-driven oxychlorine reactions transform biomarkers into complex oxidized products in Mars analog environments. Our findings (1) provide a mechanistic link between putative biomarkers and SAM observations consistent with in-situ chlorination, (2) establish a framework for interpreting fragmentation patterns in future missions, and (3) constrain the depth required for sample collection to encounter intact organics. These results underscore the necessity of subsampling UV-shielded materials and inform curation strategies for preserving molecular evidence of past life.

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2. Eigenbrode, J.L., et al., Science, 2018. 360(6393): p. 1096-1101.
3. Freissinet, C., et al., Proc. Nat. Acad. Sci, 2025. 122(13): p. e2420580122.