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Aqueous oxidation of sulfide by chlorate: Implications for native sulfur formation on Mars

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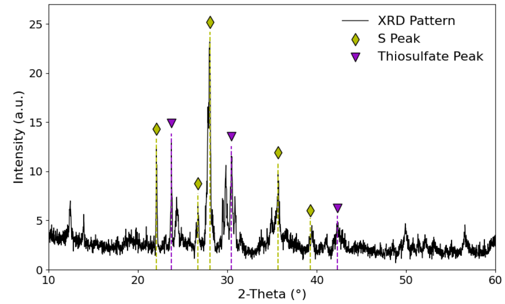
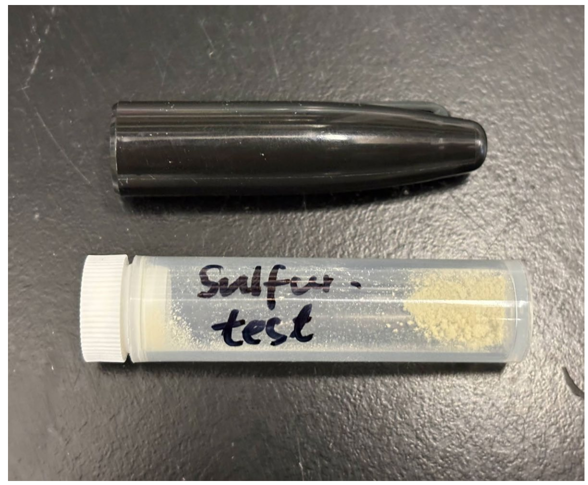
The recent discovery of elemental sulfur by NASA's *Curiosity* rover in Gale Crater has sparked significant interest in its formation pathways and implications for the Martian sulfur cycle [1, 2]. Since Gale Crater lacks evidence of volcanism, previous studies proposed that native sulfur could result from the oxidation of clathrate-derived H_2S by SO_2 near surface[2]. However, the large SO_2 flux required to produce such extensive native sulfur deposits (~10^7–10^8 kg, [1]) seems unlikely due to its rapid photo-oxidation in the atmosphere. At the same time, experimental studies have demonstrated that chlorate (ClO_3^-), which is abundant and relatively stable on Mars [3], can oxidize sulfide minerals to produce both elemental sulfur and sulfate [4]. This suggests that aqueous oxidation of H_2S by chlorate may have contributed to native sulfur formation in Gale Crater, offering new insights into the coupled S-Cl cycle on Mars. Despite its potential significance, the kinetics of this process under Mars-relevant conditions remain poorly constrained, with prior studies providing only qualitative insights.

To address this knowledge gap, we conducted a series of anaerobic batch experiments by reacting chlorate- and sulfide-containing fluids under variable conditions (pH = 1–5, 4–90°C), with oxidizing potential controlled by initial ClO_3^- concentration. Some experiments included Fe(II) to assess its catalytic effects. To replicate the observed coexistence of Ca-sulfate and elemental sulfur on Mars [2], some experiments are conducted with addition of Ca^{2+}. Preliminary results showed rapid formation of elemental sulfur via chlorate-driven sulfide oxidation under acidic condition. The solution became milky immediately after acidification. The particles generated went through coarsening and precipitation within 1 day. XRD pattern of the light-yellow particles demonstrated the formation of elemental sulfur and thiosulfate through oxidation. Analysis of the reaction fluid with ion chromatography indicated significant SO_4^{2-} production. These findings suggest that chlorate-driven oxidation is a potetnially important pathway of native sulfur and sulfate formation on Mars.





Reference

[1] Berger et al. (2025), 56th LPSC

[2] King et al. (2025), 56th LPSC

[3] Glavin et al. (2013), J. Geophys. Res. Planets, 118, 1955–1973

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