

Evaluating Electrochemical Mineral Trapping for Carbon Dioxide Removal: Insights from Experiments and Predictive Modeling

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Abstract

In light of global warming and to replace fossil fuels, electrochemical carbon dioxide removal (CDR) is gaining attention [1]. It promises low energy consumption, decentralized operation, and low cost [2]. Utilizing electric current to attain spatially basic and acidic environments in aqueous electrolytes captivates through ease of operation and exploits the direct correlation of alkalinity and dissolved inorganic carbon (DIC) [3]. Natural water bodies (e.g. seawater, rivers, ...) are especially interesting since they are saturated in DIC and contain a volumetric carbon content 150 times higher than ambient air. Due to kinetic barriers, natural electrolytes are usually supersaturated with carbon containing minerals like calcite, huntite, and magnesite. A localized increase in alkalinity at the cathode can overcome activation barriers, facilitating the formation of stable minerals promoting long-term carbon sequestration [4].

This work investigates the gas-liquid-solid equilibrium of ex-situ mineral trapping technologies through both modeling and lab-scale experiments. Model implementations use extended Pitzer equations and describe the interplay between alkalinity, CO₂ partial pressure, electrolyte composition, and DIC. The analysis includes water compositions reflecting different natural electrolytes like rivers or seawater. Salinities are varied from 0.05 g·kg⁻¹ to 46 g·kg⁻¹ and temperatures range from 273.15 K to 313.15 K. Current densities are varied and shift the electrolyte speciation through hydrogen evolution (HER), oxygen evolution (OER), or chlorine evolution reaction (CIER). The computed values are compared with experimental results derived in a self-constructed experimental setup. Deviations are discussed. Since the flow cell used within the experiments influences the process, flow management and contributions of ohmic resistance are assessed. Ion chromatography enables mass balance analysis. Finally, the assessment compares energy demand of ex-situ mineral trapping with thermodynamic boundaries.

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