Smarter Electrolysis in Rock Reactors

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1. CO_2 mineralization enables capture and permanent carbon storage

We need to achieve gigaton-scale carbon dioxide (CO_2) removal to address climate change. CO_2 mineralization is a promising approach to capture and permanently store carbon. In this process, CO_2 reacts with silicates rich in metal ions (e.g., Ca^{2+} and Mg^{2+}) to generate stable carbonate solids. In nature, the pH swing required to initiate CO_2 mineralization is too small to convert CO_2 at meaningful rates. As a result, merely 0.13 gigatons of CO_2 is stored through mineralization each year. The Berlinguette Group designed a "Rock Reactor" capable of accelerating CO_2 mineralization by several orders of magnitude.

2. Rock Reactors accelerate CO_2 mineralization

The Rock Reactor is an electrolyzer that dissolves silicate minerals and captures CO_2 to store in the form of stable carbonate solids.[1] Silicate minerals are dissolved and release metal cations by consuming the acid generated at the anode carrying out the oxygen evolution reaction (OER). At the cathode, base is generated as a product of the hydrogen evolution reaction (HER) which captures and converts CO_2 into aqueous carbonate ions. A cation exchange membrane (CEM) separates the anode and cathode which facilitates crossover of the released metal cations and subsequent precipitation of carbonate solids in the catholyte.

3. Bayesian optimization to minimize energy intensity of the Rock Reactor

Many Rock Reactor electrolysis parameters, such as current density, electrolyte flow rate, and reservoir stirring speed, have yet to be fully optimized to achieve the lowest possible energy intensity. A grid-search-based experimental exploration of all combinations is prohibitively time-consuming due to the large number of interacting variables. We propose to use Bayesian optimization to efficiently navigate this multidimensional parameter space and identify conditions that maximize CO_2 mineralization per unit energy input.

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