Electrochemical Extraction and Conversion of CO_2 from Seawater

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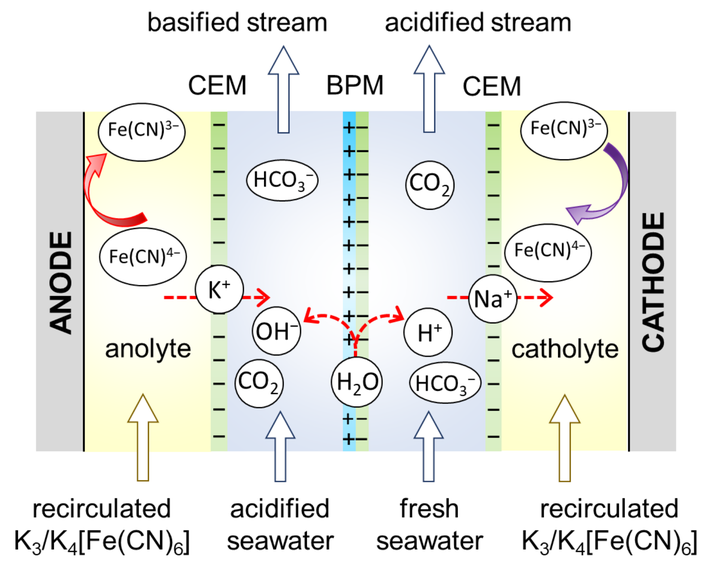
CO_2 from seawater

- CO_2 in the atmosphere is in constant equilibrium with the ocean.
- World's ocean represents a natural carbon sink that absorbs 25% of CO_2 entering the atmosphere.
- More than 98% of CO_2 of the carbon atmosphere-ocean system is stored in the oceans as dissolved inorganic carbon (DIC).
- The effective concentration of CO_2 in seawater is a factor of 128 times larger than in the air.

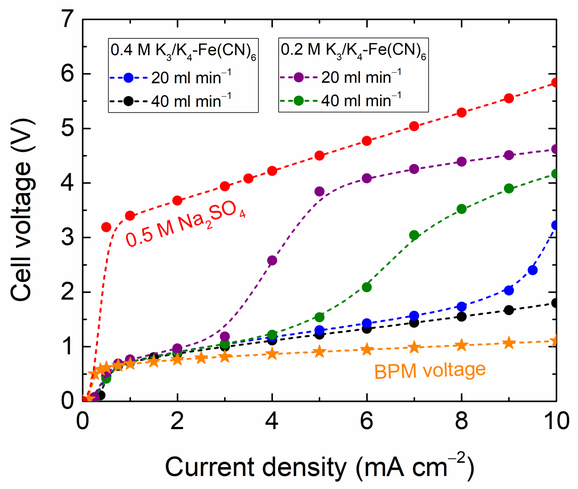
Bipolar Membrane Electrodialysis



Key performances

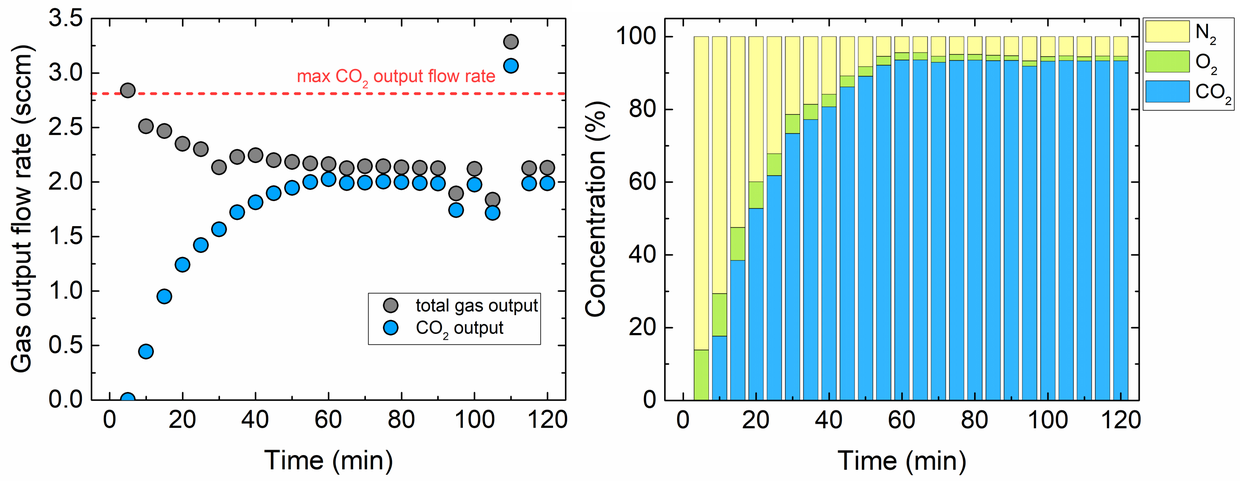
- Direct coupling of electrochemical CO_2 extraction and conversion by using a bipolar membrane (BPM) electrodialysis cell and a vapor-fed CO_2 reduction cell.
- Record low electrochemical energy consumption of 0.98 kWh kg^{-1} CO_2 or 155.4 kJ mol^{-1} CO_2 from seawater.
- Record high CO_2 extraction efficiency of 71% of total DIC in seawater.
- Highly selective conversion of CO_2 with more than 70% into fuels and chemicals in the vapor-fed device.

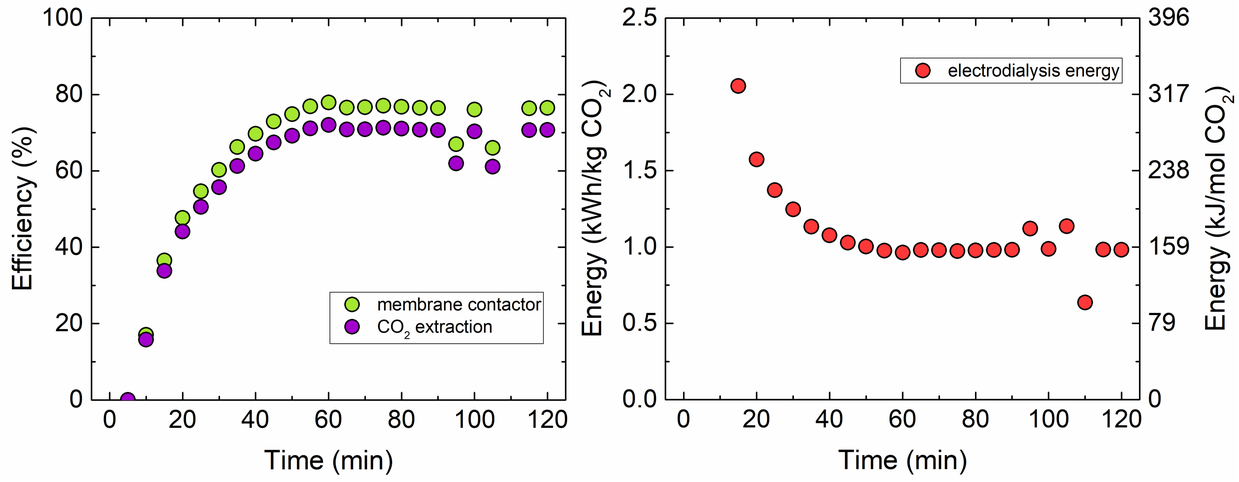
Electrodialysis performance



- Replacing the water splitting process at the electrodes with one-electron redox couple reactions, significantly reduced the cell voltage.
- At an optimum solution concentration and flow rate, the total cell voltage was close to the BPM voltage.
- The electrode reactions were limited by mass transport of the redox couple at low electrolyte concentrations and flow rates.

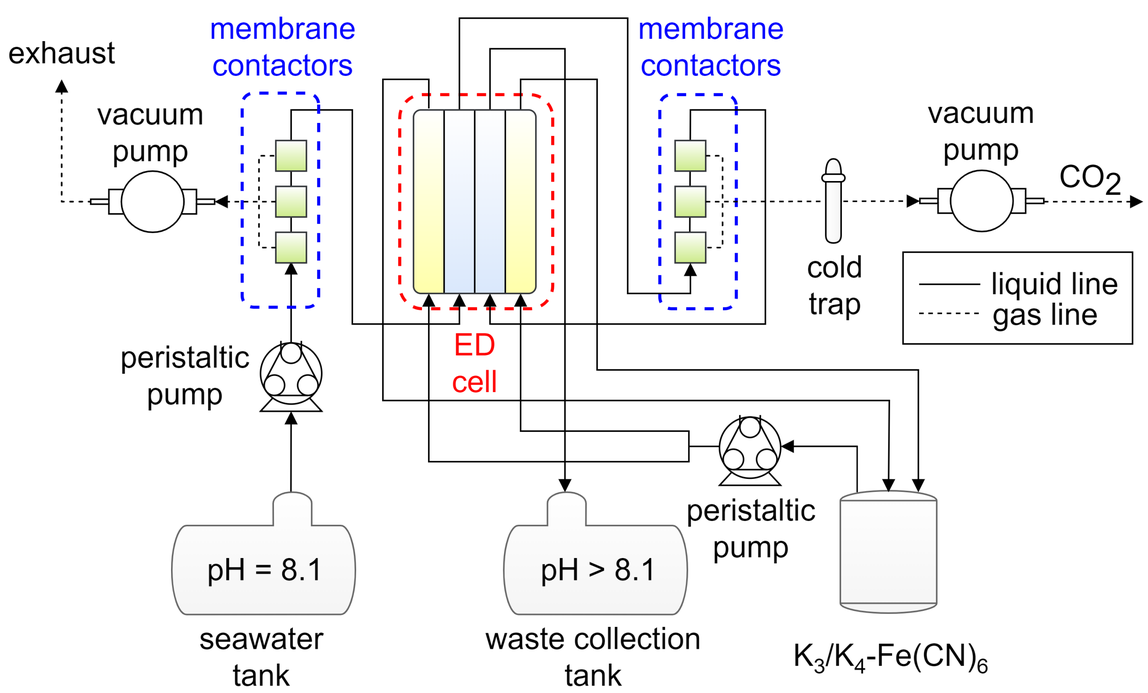
CO_2 extraction performance





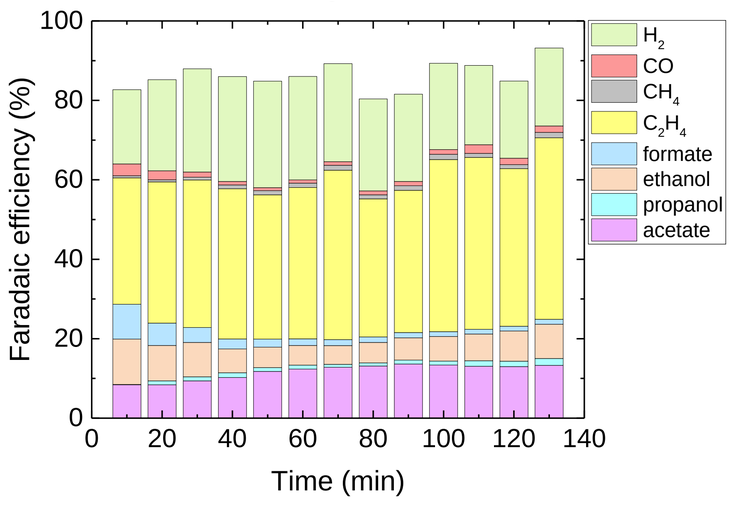
- CO_2 with output flow rate of 2 sccm was extracted from seawater with an input seawater flow rate of 37 ml min^{-1}.
- The extracted gas was a mixture of CO_2 (93%), O_2 (1.5%) and N_2 (5.5%).
- The extraction efficiency (measured CO_2 output/DIC input) was 71% and the membrane contactor efficiency (measured CO_2 output/theoretical CO_2 output flow at the given pH and seawater flow rate) was 76%.
- Record electrodialysis energy of 0.98 kWh kg^{-1} CO_2 or 155.4 kJ mol^{-1} CO_2.

CO_2 capture process

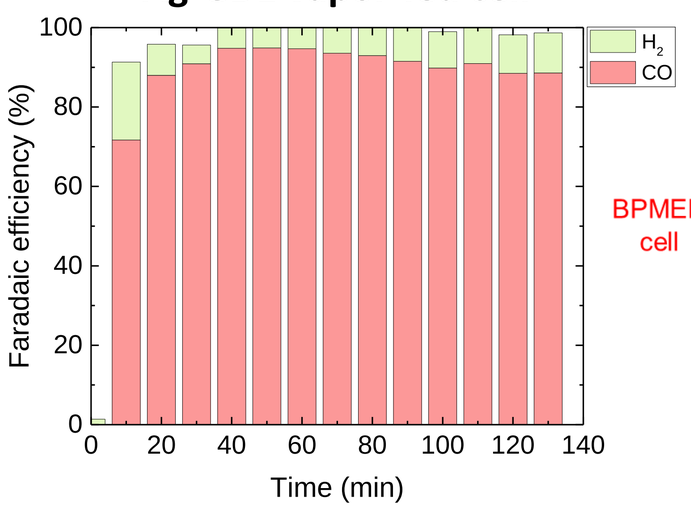


Electrochemical CO_2 conversion

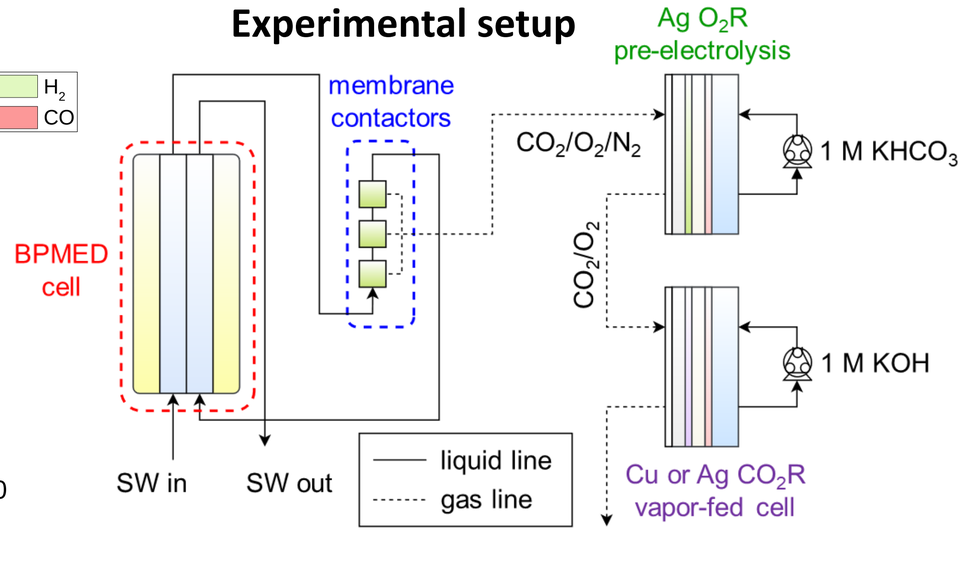
Cu-GDE vapor-fed cell



Ag-GDE vapor-fed cell



Experimental setup



- Extracted CO_2 from seawater was electrochemically converted in tandem oxygen reduction (O_2R) and CO_2 reduction (CO_2R) vapor fed cells.
- The CO_2R reaction achieved selectivity as high as 73% of CO_2 converted to fuels and liquid products for a vapor fed cell containing a Cu-GDE, and 98% of CO_2 conversion to CO for a vapor fed cell containing a Ag-GDE.
- The O_2R cell used Ag catalyst on a gas diffusion electrode (GDE) to mitigate oxygen flow into the CO_2R cell.
- The proof-of concept system provides a unique technological pathway for CO_2 capture and conversion using electrochemical processes only.

Caltech

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