Brine valorization using bipolar membrane electrodialysis

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Motivation

Membrane-based technologies, such as reverse osmosis, are widely used in industry. While effective at purifying water, they always produce brine that must be managed. One of the limitations preventing further water recovery is the scaling of minerals on the membrane surface. Furthermore, current brine treatment strategies are costly and pose environmental risks [1], which have driven the interest in resource recovery methods [2]. Bipolar membrane electrodialysis (BMED) is a promising technology for brine valorization [3], as it enables the production of valuable acids and bases [4] (Fig. 1). However, BMED requires pretreatment to remove scaling-inducing components (e.g., Ca^{2+}, Mg^{2+}). Conventional methods, such as chemical precipitation or ion exchange, rely on chemical additives. This research proposes a chemical-free brine softening process, coupling crystallization with BMED (Fig. 2) to enhance water recovery, mitigate scaling, and promote resource recovery through acid and base production.

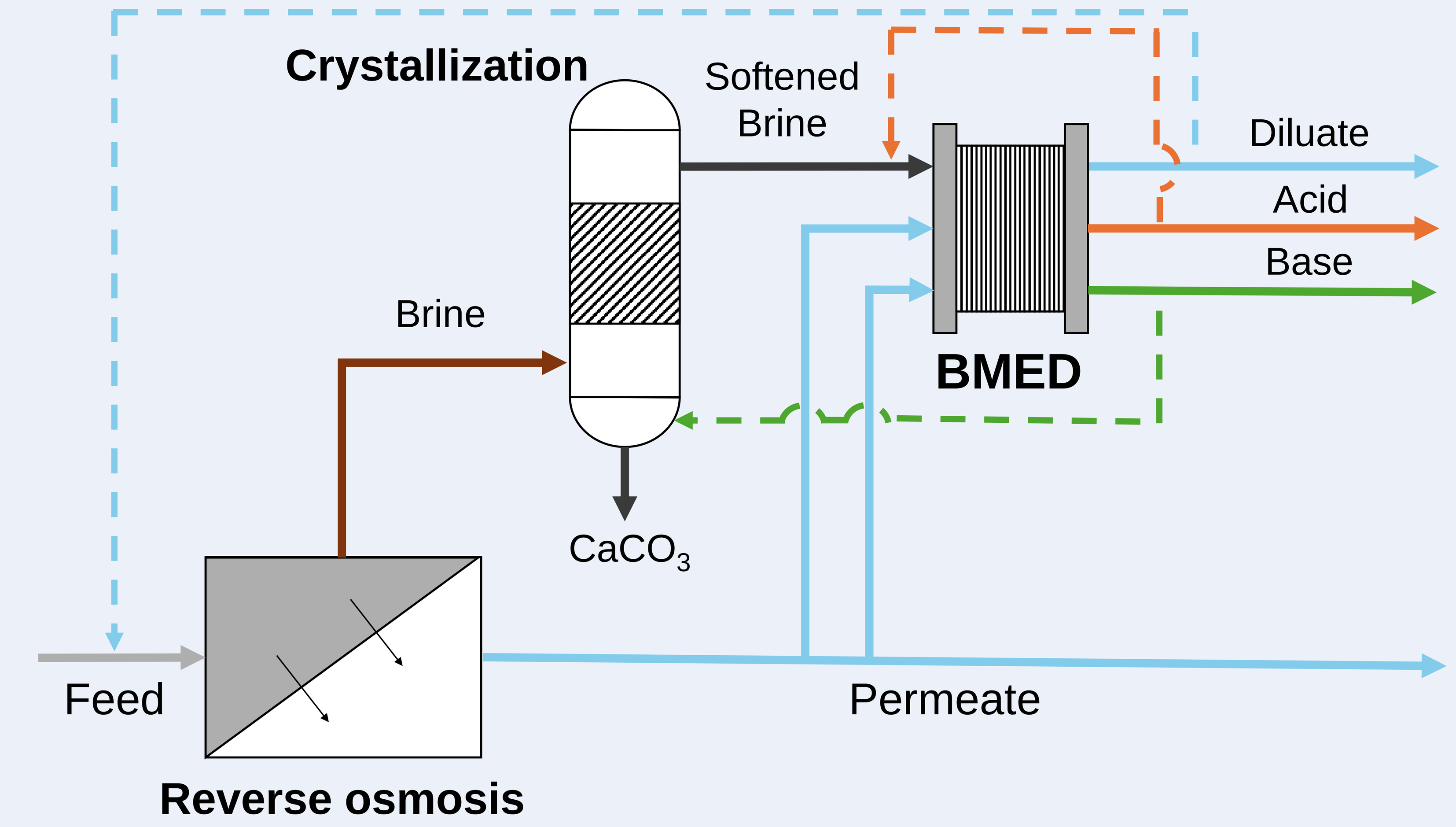

Fig. 2. Process flow diagram illustrating the integration of crystallization with BMED. The RO brine is first treated through crystallization to remove multivalent ions. The softened brine is then processed by BMED to produce acid and base, which are utilized within the system to support the overall process.

Technological challenge

The main technological challenges include:

- Brine contains a variety of ions and compounds beyond NaCl.
- High hardness and alkalinity increase scaling risk in BMED, while low NaCl concentrations limit acid and base production.
- Real brine often contains antiscalants, humic acids, and other compounds that may affect the process.
- The integrated system must operate without external chemical additives, relying solely on the ions present in the feed water.
- Balancing the crystallization kinetics and BMED process to have a stable operation.

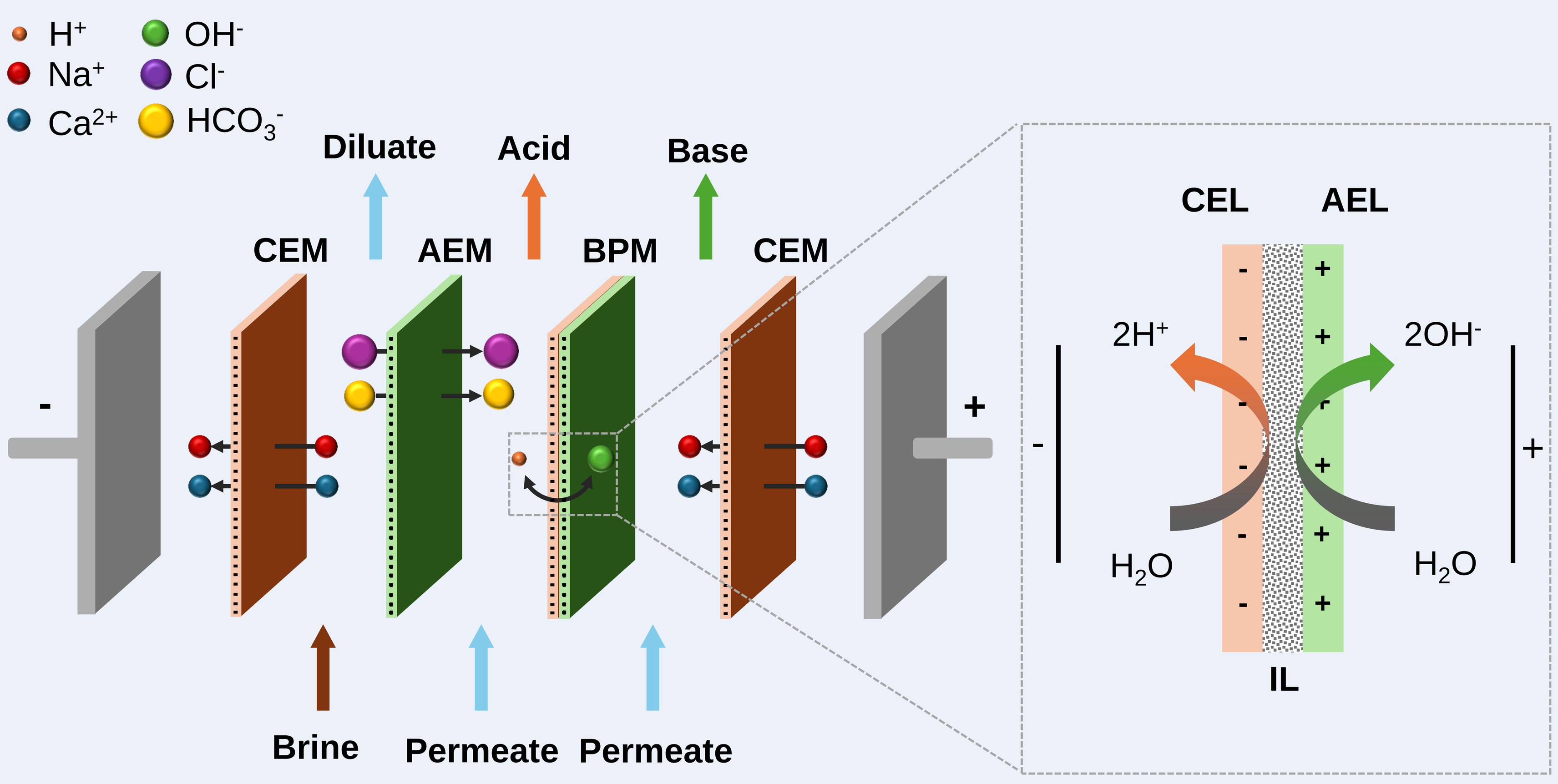

Fig. 1. Conceptual diagram of acid and base production from brine using BMED. CEM: cation exchange membrane. AEM: anion exchange membrane. BPM: bipolar membrane. CEL: cation exchange layer. AEL: anion exchange layer. IL: interfacial layer. Water dissociates in the interfacial layer (IL) into H^+ and OH^- ions, thus producing acid and base.

Research goals

- Determine and optimize the operational parameters of BMED to maximize acid and base production, while mitigating scaling risk.
- Investigate the ideal conditions for crystallization to effectively remove scaling-inducing components.
- Assess how variations in brine composition influence the performance of crystallization and BMED processes.
- Develop and validate an integrated crystallization-BMED process for brine valorization.
- Evaluate the techno-economic feasibility, scalability, and environmental impact of the integrated crystallization-BMED process.

[1] Mavukkandy, M. O., *et al. Desalination,* **472** (2019), 114187.
[2] Ogunbiyi, O., *et al. Desalination,* **513** (2021), 115055.
[3] Fernandez-Gonzalez, C., *et al. Separation & Purification Reviews,* **45**(4) (2016), 275 – 287.
[4] Pärnamäe, R., *et al. Journal of Membrane Science,* **617** (2021), 118538.

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