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Impact of counter-ion properties on ion-exchange membrane behavior

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Electromembrane separation processes, such as electrodialysis (ED) and electrodeionization (EDI), form a group of industrially essential separation techniques envisioned to play a significant role in achieving a fully circular economy. Their utilization is frequently associated with green, recyclable, environmentally friendly, zero-liquid discharge, and sustainable technologies. Electrodialysis, primarily designed for the separation of small ions from treated solutions, finds versatile applications ranging from water desalination and wastewater treatment to the processing of biologically relevant samples.

The typical ED stack consists of aligned ion-exchange membranes (IEMs) that enable selective ion transport under an applied electric field. The standard membrane arrangement involves a regular alternation of cation-exchange (CEM) and anion-exchange membranes (AEM), resulting in the formation of two output streams: a diluate and a concentrate.

A deeper understanding of the transport phenomena governing these processes is essential for their further optimization. In particular, electroconvection in the vicinity of ion-exchange membranes plays a crucial role, as it significantly influences mass transfer and overall system performance.

To investigate these effects, a custom-designed experimental setup was developed, allowing the implementation of a small membrane sample into an observation cell. The system is equipped with a microscope and a high-resolution camera, enabling direct visualization of the region near the membrane surface. Convective flow is monitored using tracer particles, and the velocity field is evaluated by means of Particle Image Velocimetry (PIV).

Although electrodialysis is commonly applied for seawater desalination, real saline systems contain, in addition to NaCl, a variety of other ionic species. Therefore, this study focuses on the influence of selected ions, namely F^-, Cl^-, Br^-, I^-, and SO_4^{2-}, on the intensity of electroconvection near the membrane, with particular emphasis on the effect of their concentration.