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Study of Donnan Dialysis for the Recovery of Valuable Substances from Wastewater

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Nowadays membrane separation technologies are widely applied in various industrial fields, including drinking and wastewater treatment, as well as food and pharmaceutical production. A promising area of membrane technology application is the recovery of valuable substances from wastewater streams, where membrane processes such as electrodialysis and Donnan dialysis can be utilized. One important example is the recovery of lithium from waste streams generated during lithium-ion battery recycling, where membrane processes may provide an effective alternative for the recovery of valuable compounds. Donnan dialysis is a membrane separation process based on the selective transport of ions through an ion-exchange membrane driven by an electrochemical potential gradient. While cation-exchange membranes are commonly used for direct transport of metal ions, anion-exchange membranes can also be applied in recovery processes involving metal salts, where the transport of counter-ions plays an important role in the conversion of the target metal into a recoverable form. A proper understanding of ion transport and ion-exchange equilibria is essential for the design and optimization of such membrane systems. For this purpose, the Nernst–Planck equation is usually used to describe ion transport through ion-exchange membranes. However, this approach represents a relatively complex transport model requiring equilibrium data, such as membrane ion-exchange capacity and selectivity, together with transport properties, such as diffusion coefficients. In practice, simplified approaches based on Fick's law are often used, where the transport process is described by an overall mass transfer coefficient. This work focuses on the experimental study of ion-exchange equilibria and transport properties of investigated anion-exchange membrane in selected binary anion systems involving sulfate, chloride, nitrate, hydroxide, and carbonate ions. Transport parameters, including diffusion coefficients and overall mass transfer coefficients, were determined from experimental data obtained in a CSTR membrane module equipped with an anion-exchange hollow-fiber membrane. The obtained transport parameters were subsequently used in the developed mathematical model for the prediction of ion transport in an independent batch membrane system for selected anion pairs. The comparison of predicted and experimental concentration profiles enabled the evaluation of model accuracy and the applicability of both the Nernst–Planck and Fick approaches for the description of ion transport in Donnan dialysis systems.

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