Transport Phenomena in Ion Exchange Membranes

Sandra E. Kentish[a], Sin Sieng Sim[a], Qiuyue Wang[a], George Chen[a*]

[a] Department of Chemical Engineering, The University of Melbourne, Parkville, Victoria 3010, Australia

Corresponding author: gechen@unimelb.edu.au; +61 3 8334 4365

Abstract:

Electrically driven membrane processes have gained an important place in both food processing and fermentation bioprocessing. The same membranes are often used in batteries, electrolysers and in electrochemical CO_2 conversion reactors. However, our understanding of the transport of both charged and uncharged species through these systems remains under-developed in comparison to the polyamide membranes used in water treatment, or the cellulose acetate membranes used in gas separation.

This presentation will give an overview of our recent experimental work to better understand these fundamental transport mechanisms, through individual measurements of ion solubility and diffusivity. We first consider inorganic salts in this context. Donnan theory is sufficient to explain the solubility of counterions in cation exchange membranes. Conversely, counterion transport of binary mixtures through anion exchange membranes is more complex. We observe reductions in sulphate uptake relative to chloride, that may result from ion pairing or the stronger hydration of these species. Conversely, we see increased uptake of nitrate relative to chloride, which may reflect the lower hydration of these species.

We next consider organic anions such as acetate, lactate, tartrate and citrate that can exist in multiple valency states, depending upon the pH. We show that the speciation of these ions within the membrane can differ from that in the external solution, due to the altered thermodynamic environment. For lactate and acetate, the more hydrophobic environment within the membrane results in greater concentrations of the uncharged neutral species. We also speculate that acetate dimers can form within the membrane for a similar reason, based on a declining diffusion coefficient observed for this species. For tartrate, we similarly see evidence of monovalent or neutral species, where divalent ions alone would be anticipated. More work is required to better model these systems to account for such effects.

Keywords: electrodialysis; bioprocessing; solubility; diffusivity.