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Theoretical framework for energy analysis of hypersaline pressure retarded osmosis

Henrik T. Madsen [a,n], Steen Søndergaard Nissen [b], Erik G. Søgaard [c]

[a] *Department of Chemistry and Bioscience, Aalborg University, A.C Meyers Vænge, 2450 Copenhagen, Denmark*

[b] *Applied Biomimetic, Sønderborg, Denmark*

[c] *Department of Chemistry and Bioscience, Aalborg University, Esbjerg, Denmark*

Abstract

Pressure retarded osmosis (PRO) has traditionally been focused on the mixing of seawater and river water, but in pilot scale tests, this mixing scheme has been found to be economically unattractive due to power densities that are too low. One way of obtaining higher power densities may be through use of hypersaline draw solutions. In this work, the theoretical framework for calculation of the free energy of mixing, the maximum extractable work in batch and co-current PRO systems, and the potential power densities of hypersaline solutions is presented. Calculations show that very high values in all categories are realizable. By diluting 26 wt% (saturated NaCl) to seawater concentration, 15.7 kW h/m3 draw is released and a maximum power density of 143 W/m2 membrane can be obtained with a commercially available FO membrane. In cases where the hypersaline solution is the limiting solution, large losses of energy can be expected if the process is carried out as a constant pressure single stage operation. To minimize losses, a serial setup can be applied. Although the practical challenges for hypersaline PRO may be greater than for seawater based PRO, the high potential gains may make hypersaline PRO a more promising way of making the PRO concept realizable.