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Equilibrium electro-osmotic instability in concentration polarization at a perfectly charge-selective membrane

Isaak Rubinstein and **Boris Zaltzman**
Ben-Gurion University, Israel

It has been recently shown that, for a non-perfectly charge selective interface, equilibrium electroconvective instability in concentration polarization may occur due to lateral variations of the interface electro-chemical potential of counter-ions. For a perfect interface, this has been reckoned impossible, leaving the non-equilibrium instability as the only possibility. This reckoning has been based on assuming in the existing models that perfect charge selectivity is tantamount to assuming a fixed counter-ion concentration at the interface (equal to the high concentration of fixed charges) along with its infinite conductivity. Taken together, both imply a vanishing lateral variation of the electro-chemical potential of counter-ions in the interface. In practice, the charge-selective solids, e.g., ion-exchange electro-dialysis membranes indeed are highly, essentially perfectly, charge (perm)-selective. At the same time their conductivity is by no means infinite. We propose a simple novel model of concentration polarization at a perfectly perm-selective membrane with finite conductivity. The linear stability analysis in this model shows that the equilibrium electro-osmotic instability is possible yielding the division of the parameters' space into the domains in which the equilibrium and non-equilibrium instability mechanisms dominate. Identification of the instability mechanism for a given system requires a detailed experimental study of the vicinity of the instability threshold, both in terms of the VC dependence and flow visualization.

robinst@bgu.ac.il