Phoretic motion of ion exchangers

EHUD YARIV, Technion - Israel Institute of Technology

One-dimensional ionic conduction normal to an ion-exchange surface is a two-scale problem, with a charged Debye layer adjacent to the surface and an electro-neutral bulk outside it. Due to ion selectivity, the bulk salt concentration must vary linearly with distance. When the ion-exchange surface is curved, the electric field tangential to the surface results in an accompanying flow. Specifically, a freely suspended ion- exchange particle would move under the action of an external field. This problem is described in a systematic microscale model, wherein the boundary conditions on the highly-conducting particle surface represent ion-exchange kinetics. For thin Debye layers, an equivalent macroscale model is extracted, wherein boundary conditions reflect asymptotic matching with the Debye layer. Thus, the equi-potential condition on the literal particle surface is transformed to a nonuniform Dirichlet condition, accounting for Debye layer voltage (zeta potential). The latter is not a surface property, but rather depends upon surface kinetics. As in the one-dimensional problem, microscale ion selectivity on the particle surface results in a macroscale salt concentration polarization (on the particle scale), whereby the electric potential is rendered non-harmonic. Accordingly, the macroscale model is significantly more complicated than the comparable one for inert particles. Even in the weak-field limit, the effects of salt polarization and electric field on particle motion are comparable: Smoluchowski's formula does not apply. Open problems in the context of strong fields and self-propulsion will also be described.