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Electrokinetic transport in porous media

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Electrokinetic transport phenomena, predominantly realized in charged polymeric and porous media, offer possibilities for applications in nanofluidic systems, energy harvesting and biosensing. In this work, we present a theoretical and numerical study of nonlinear coupling between wall deformation and the flows of water and ions in a charged, deformable nanochannel. The classical treatment of mass and momentum conservation in the solid-liquid coupled system is based on the Stokes-Poisson–Nernst–Planck equations. For elastic but non-viscous walls in the limit of small deformation, analytically solvable differential equations were obtained in one dimension. The response of the walls'relaxation dynamics and the channel's electrokinetic transport was investigated at different charging regimes. Within the framework of nonequilibrium thermodynamics, compact formulae in terms of Onsager's phenomenological coefficients were derived for the electrokinetic transport parameters and energy conversion efficiency. Furthermore, an extension of the model is presented for electroactuator modelling which operates through a coupling of electrical and mechanical interactions for closed nanochannels. In this scenario, we explore numerically the transient dynamics and steady-state solutions for closed, finite nanopores. A full theoretical account, along with numerical results, of the effect of membrane charging and mechanical response on the differential capacitance is presented.

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