Correlated Electrolytes Solutions and Ion-induced Interactions between Nanoparticles

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Electrolytes play a crucial role in soft and biological matter in various dynamic as well as static processes such as electro-osmotic flow, reaction rates, interfacial tension, and suspension stability. More than 80 years ago, Debye and Hückel formulated a thermodynamic theory that has since become the most important and widely used model for electrolyte solutions, albeit often implemented in form of linearized approximations.

In this work, we show with simple generalized equation that the original theory can now be applied analytically exactly without approximation, thanks to modern computational power. Our results show quantitative agreement with both molecular dynamics and Monte Carlo simulations and yield quantitative information about the degree of ion-pairing. This is in contrast to the linearized results, which are limited in scope of applicability. Our nonlinear model may provide a promising basis to study effects due to strong ion correlation that are still little understood. We also report on strong ion-induced attractions between nanoparticles that may be important for catalysis and directed self-assembly.