Boundary Layer Solutions of Charge-Conserving Poisson-Boltzmann Equations

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ABSTRACT

The Poisson–Boltzmann (PB) equation is a fundamental model for describing ionic distributions. When a charged surface (e.g., an electrode, membrane, or colloid) is in contact with an electrolyte, a structured layer of charge known as the electric double layer (EDL) forms. To understand the structure of the EDL, we study the boundary layer solutions to the singularly perturbed problems for Charge-Conserving PB (CCPB) equations with a small parameter ϵ in smooth bounded multiply connected domains under the Robin boundary conditions. The CCPB equations present particular analytical challenges due to their nonlocal nonlinearity introduced through integral terms enforcing charge conservation. Using the principal coordinate system, exponential-type estimates and the method of moving planes, we rigorously prove asymptotic expansions of boundary layer solutions throughout the whole domain and reveal the influence of the boundary mean curvature.