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Impact and Role of Temperature on Electrostatic Potentials and Velocity Profiles Prediction

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Electrostatic potential profiles are vital for understanding and controlling electroosmosis as well as particles mixing. The shape and magnitude of this profile, particularly a key parameter called the zeta potential (ζ), directly dictate the speed and direction of fluid flow when an electric field is applied. The role of temperature modifying this important parameter has not been analyzed from a mathematical approach. Therefore, this is a pertinent line of study as it may improve the design of microfluidic devices and technologies dealing with Capillary Electrophoresis for non-isothermal systems. In this study, two electro-phoretic cell geometries have been investigated under non-isothermal conditions. First, the heat transport model was solved for heat generation and Dirichlet boundary conditions, further coupled into the Poisson-Boltzmann equation to obtain zeta potential profiles for different temperature distributions. In addition, the Navier-Stokes equation for electroosmotic case was solved to obtain velocity profiles that yielded flow reversal examples under the impact of temperature development. The main outcome of this study is the analysis of temperature role in modifying zeta potential (ζ) and velocity profiles (Vx) in the axial direction

of a typical channel. Analysis of rectangular and cylindrical geometry cells are presented using a numerical solution approach to the fundamental Poisson-Boltzmann and Navier-Stokes equations. This study found that as a large temperature gradient is applied to the cell, the zeta potential experiences significant change, and flow reversal is exhibited in the velocity profile. An even more pronounced effect is observed when a joule heating parameter is at its highest possible value. Small temperature differences result in a linearly decreasing electrostatic potential and a typical laminar parabolic velocity profile. As the inverse Debye-Huckel length increases, the zeta potential decreases, and the velocity profile exhibits multiple flow reversals. These findings contribute greatly to the field of electroosmosis, as they predict and explain the hydrodynamic behavior of fluids for realistic, non-isothermal conditions. This contribution establishes a basis for the future study of the effects of temperature on the concentration distributions.