Abstract

The thesis presents a numerical investigation on the motion of charged dielectric colloids under an external electric field through an electrolyte or hydrogel medium. The mathematical model is based on conservation principles, which are the coupled Stokes-Poisson-Nernst-Planck equations. The Stokes-Brinkman model is used to formulate the flow through the gel medium. Chapter 1 of the thesis is introductory.

In Chapter 2 and 3, we consider a charged colloidal sphere undergoing steady migration under an imposed electric field through an uncharged/charged hydrogel, respectively. We have estimated the electrophoretic mobility based on the balance of forces experienced by the particle for a wide range of electrokinetic parameters. The role of electroosmosis on the hydrodynamics of the particle is analyzed by comparing the drag with the corresponding uncharged case. The strong background electroosmotic flow (EOF) for a high fixed charge density of the polyelectrolyte hydrogel with a pore size comparable to the particle radius, drags the particle along the direction of the EOF.

The electrophoresis of a dielectric charged colloid in an electrolyte/charged hydrogel medium is studied in Chapter 4 and 5, respectively. The electric polarization of a dielectric particle due to an external electric field creates a non-uniform surface charge density, which in turn creates a non-uniform Debye layer. The solid polarization of the particle, the polarization of the double layer and the electroosmosis of mobile ions creates a nonlinear effect on the electrophoresis. Our computed result shows that the electrophoretic velocity decreases with the rise of the particle permittivity and attains a saturation limit at large values of the particle-to-electrolyte permittivity ratio. A significant impact of the solid polarization is found in gel electrophoresis compared to the free-solution electrophoresis.

Subsequently, the electrophoresis of a soft particle with a polarizable uncharged/charged rigid core coated with a polyelectrolyte layer is studied in Chapter 6 and 7. The occurrence of the induced non-uniform surface charge density on the outer surface of the inner core leads to a situation different from the existing analysis of a soft particle electrophoresis. The impact of this induced surface charge density together with the double layer polarization and relaxation due to ion convection and electromigration is analyzed. The dielectric permittivity and the charge density of the core have a significant impact on the particle electrophoresis when the Debye length is in the order of the particle size.

Keywords : Electrophoresis; Electroosmosis; Nernst-Planck equations; Solid polarization; Double layer polarization; Counterion condensation; Electrophoretic mobility; Numerical solution.