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Enhancement of Mass Transport and Separations of Species in a Electroosmotic Flow by Distinct Oscillatory Signals

Authors : Carlos Teodoro, Oscar Bautista

Abstract : In this work, we analyze theoretically the mass transport in a time-periodic electroosmotic flow through a parallel flat plate microchannel under different periodic functions of the applied external electric field. The microchannel connects two reservoirs having different constant concentrations of an electro-neutral solute, and the zeta potential of the microchannel walls are assumed to be uniform. The governing equations that allow determining the mass transport in the microchannel are given by the Poisson-Boltzmann equation, the modified Navier-Stokes equations, where the Debye-Hückel approximation is considered (the zeta potential is less than 25 mV), and the species conservation. These equations are nondimensionalized and four dimensionless parameters appear which control the mass transport phenomenon. In this sense, these parameters are an angular Reynolds, the Schmidt and the Péclet numbers, and an electrokinetic parameter representing the ratio of the half-height of the microchannel to the Debye length. To solve the mathematical model, first, the electric potential is determined from the Poisson-Boltzmann equation, which allows determining the electric force for various periodic functions of the external electric field expressed as Fourier series. In particular, three different excitation wave forms of the external electric field are assumed, a) sawteeth, b) step, and c) a periodic irregular functions. The periodic electric forces are substituted in the modified Navier-Stokes equations, and the hydrodynamic field is derived for each case of the electric force. From the obtained velocity fields, the species conservation equation is solved and the concentration fields are found. Numerical calculations were done by considering several binary systems where two dilute species are transported in the presence of a carrier. It is observed that there are different angular frequencies of the imposed external electric signal where the total mass transport of each species is the same, independently of the molecular diffusion coefficient. These frequencies are called crossover frequencies and are obtained graphically at the intersection when the total mass transport is plotted against the imposed frequency. The crossover frequencies are different depending on the Schmidt number, the electrokinetic parameter, the angular Reynolds number, and on the type of signal of the external electric field. It is demonstrated that the mass transport through the microchannel is strongly dependent on the modulation frequency of the applied particular alternating electric field. Possible extensions of the analysis to more complicated pulsation profiles are also outlined.

Keywords : electroosmotic flow, mass transport, oscillatory flow, species separation
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