

OSMOTIC SELF-PROPULSION

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Osmotic self-propulsion of micron-size particles is a vibrant research area which has attracted significant attention in the physics, chemistry, and engineering communities. The underlying mechanism is a catalytic reaction at the particle boundary, converting chemical energy into mechanical motion in a viscous liquid solution. When the chemical reaction is nonuniform, this may result in particle motion. Practically, the desired non-uniformity is accomplished by employing inhomogeneous surfaces; thus, typical experiments make use of nano-rods composed of platinum-gold segments. Golestanian *et al.* [1] presented an idealized continuum description, where the chemical catalysis is modeled by a prescribed distribution of solute flux and the interaction of solute molecules with that boundary is represented by diffusio-osmotic slip. Neglecting solute advection, Golestanian *et al.* [1] obtained a linear model which they employed to calculate the swimming velocity of a spherical particle and a slender rod.

I will discuss two problems. The first [2] is motivated by the desire to properly model the nano-rod swimmers prevailing in experiments. We consider self-diffusiophoresis of an axisymmetric particle whose boundary is specified by an arbitrary axial distribution of cross-sectional radius. Focusing upon slender particle shapes and making use of matched asymptotic expansions we obtain a remarkably simple approximation for the particle velocity. This approximation can accommodate discontinuous flux distributions, which are commonly used for describing bimetallic particles; it agrees strikingly well with the numerical calculations of Popescu *et al.* [3], performed for spheroidal particles. Our approximation differs from that derived by Golestanian *et al.* [1]; their erroneous formula appears to be the consequence of an attempt to apply an intuitive approach in a delicate situation where the diffusio-osmotic slip and self-propulsion speed are not of the same asymptotic order.

The continuum model of Golestanian *et al.* [1] was recently extended by Michelin & Lauga [4], who incorporated solute advection and modeled the chemical reaction using both the prescribed-flux condition and a more realistic kinetic description, where the kinetic-rate coefficient itself is prescribed. The second problem I will discuss [5] is motivated by numerical solutions [4] of the resulting nonlinear model, performed for various values of the Péclet (Pe) and Damköhler (Da) numbers; in particular, simulations performed at large values of Pe indicate that the swimming velocity scales inversely with the 1/3 power of that number. We have analyzed this problem using a boundary-layer approximation. The scaling pertinent to that limit allows to decouple the problem governing the solute concentration from the flow field. The resulting nonlinear boundary-layer problem is handled using a transformation to stream-function coordinates and a subsequent application of Fourier transforms, and is thereby reduced to a nonlinear integral equation governing the interfacial concentration. Its solution provides the requisite approximation for the particle velocity, which indeed scales as the $Pe^{-1/3}$. In the fixed-rate model, large Péclet numbers may be realized in different limit processes. We consider the case of large swimmers or strong reaction, where Da is large as well, scaling as Pe. In that double limit, where no boundary layer is formed, we obtain a closed-form approximation for the particle velocity, expressed as a nonlinear functional of the rate-constant distribution; this velocity scales as Pe^{-2} . Both the fixed-flux and fixed-rate asymptotic predictions agree with the numerical values provided by computational solutions of the nonlinear transport problem.

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