Reaction-induced motion: chemical swimming, sailing and surfing

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The design of nanoengines that can convert stored chemical energy into motion is a key challenge of nanotechnology, especially for engines that can operate autonomously. Recent experiments have demonstrated that it is possible to power the motion of nanoscale and microscale objects by using surface catalytic reactions – so-called catalytic nanomotors [1]. The precise mechanism(s) responsible for this motion is(are) still debated, although a number of ideas have been put forth [2]. Here, a very simple mechanism is discussed: A surface chemical reaction creates local concentration gradients of the reactant (the fuel) and product species. As these species diffuse in an attempt to re-establish equilibrium, they entrain the motor causing it to move. This process can be viewed either as osmotic propulsion or as self-diffusiophoresis – or more figuratively as 'chemical swimming.' The concentration distributions are governed by the ratio of the surface reaction velocity to the diffusion velocity of the reactants and/or products. For slow reactions the reaction velocity determines the self-propulsion. When surface reaction dominates over diffusion the motor velocity cannot exceed the diffusive speed of the reactants. The implications of these features for different reactant concentrations and motor sizes are discussed and the theoretical predictions are compared with Brownian Dynamics simulations. We also show that it is possible to obtain directed reaction-induced motion by controlling the *shape* of the motor – 'chemical sailing' – which may lead to easier fabrication of nanomotors. Finally, when motors are confined to an interface they can 'surf' the reaction-induced concentration gradient. Through these mechanisms the motor is able to harness the ever present random thermal motion via a chemical reaction to achieve directed autonomous motion.

References

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