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Rigorous derivation of Michaelis–Menten kinetics in the presence of diffusion

Bao Ngoc Tran

Institute of Mathematics and Scientific Computing, University of Graz, Austria
bao-ngoc.tran@uni-graz.at

Reactions with enzymes are critical in biochemistry, where the enzymes act as catalysis in the process. One of the most used mechanisms for modeling enzyme-catalyzed reactions is the Michaelis–Menten (MM) kinetic. In the ODE level, i.e. concentrations are only on time-dependent, this kinetic can be rigorously derived from mass action law using quasi-steady-state approximation. This issue in the PDE setting, for instance when molecular diffusion is taken into account, is considerably more challenging and only formal derivations have been established. In this paper, we prove this derivation rigorously and obtain MM kinetic in the presence of spatial diffusion. In particular, we show that, in general, the reduced problem is a cross-diffusion-reaction system. Our proof is based on improved duality method, heat regularisation and a suitable modified energy function. To the best of our knowledge, this work provides the first rigorous derivation of MM kinetic from mass action kinetic in the PDE setting.