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Autocatalytic reaction-diffusion-advection fronts in radial geometry

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Reaction diffusion (RD) fronts are ubiquitously found in a wide variety of sytems in chemistry, biology, physics and ecology, and understanding their properties is especially important for hydrogeological problems involving chemical reactions. The dynamics of RD fronts in geological media is generally complex, due to the interplay of several physical and chemical processes. Autocatalytic fronts represent an important subset of RD fronts, for which that the coupling of diffusion and chemical processes gives rise to self-organization phenomena and pattern forming instabilities [1]. It has been shown that, when the reactant and the catalyst are put into contact and the interface is a straight line, the front behaves as a solitary wave. This means that, as the front travels at a constant speed towards the nonreacted species, its shape remains unchanged [2]. When uniform advection occurs, the properties of the system do not change, provided that a proper comoving reference frame is used for its description.
In this work we show that the geometrical properties of the injection source have a significant impact on the reaction front dynamics. Indeed, when the catalyst is injected radially into the reactant at a constant flow rate, the pre-asymptotic dynamics of the front is strongly affected by the presence of a nonuniform velocity field. Moreover, although at long times the front still behaves as a solitary wave, the efficiency of the reaction is strongly increased in virtue of the increasing volume occupied by the radial front. Changing the position of the species also impacts the front dynamics significantly. We show that injecting a finite amount of reactant into the catalyst gives rise to collapsing fronts, which we characterize in terms of their position, and width, as well as the production rate. In contrast, when the reactant is injected into the catalyst at a constant flow rate, a stationary regime is reached where, unlike the case of solitary waves, the autocatalytic front does not move.

References
[1] I. R. Epstein and J. A. Pojman, An Introduction to Nonlinear Dynamics: Oscillations, Waves, Patterns, and Chaos (Oxford University Press, Oxford, 1998)
[2] P. Gray, K. Showalter, and S. K. Scott, J. Chim. Phys. 84, 1329 (1987)

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Participation

In person

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