

Flow Control of Reaction Fronts by Radial Injection

A. De Wit, G. Schuszter, F. Brau

Université libre de Bruxelles (ULB), Nonlinear Physical Chemistry Unit, CP231
1050 Brussels, Belgium. E-mail: adewit@ulb.ac.be

Key words: reaction fronts, dispersion of reactants, mixing

Characterizing the transport of chemical reactants into soils is of interest in a wide variety of applications ranging from bioremediation, mineralization of CO₂ in sequestration techniques and control of flow properties in oil recovery. It is of particular need to be able to predict the spatio-temporal distribution of reactants and products of reactions in the presence of an advective transport of the chemical species.

In this context, the properties $A + B \rightarrow C$ reaction fronts in presence of passive advection when A is injected into B has been the subject of many studies. The temporal evolution of the front position, x_f , defined as the location of maximum C production, of the front width w and of the local production rate, $R(x_f)$, have long been derived theoretically [1] and confirmed experimentally [2] in the case of a rectilinear displacement when a solution of A displaces at a fixed velocity U the solution of B along a contact line of constant length. The related scalings $x_f \sim t^{1/2}$, $w \sim t^{1/6}$ and $R(x_f) \sim t^{-2/3}$, form the basis of $A + B \rightarrow C$ reaction-diffusion front theory confirmed in many applications.

However, in most environmental applications, the injection of the reactant A occurs radially within the soil saturated in reactant B . The question is then whether the radial injection has a different impact of the properties of the reaction front than the rectilinear one.

To answer this question, we investigate both experimentally and theoretically the properties of $A + B \rightarrow C$ reaction fronts in presence of a radial injection of A into B at a constant flow rate Q . We compute the long-time evolution of the radial front position, r_f , of its width, w , and of the local production rate R of the product C at r_f . We show that, while the radial advection does not change the well-known scaling exponents in time of the evolution of corresponding reaction-diffusion fronts, their dynamics is however significantly influenced by the radial geometry of the injection. In particular, the total amount of product varies as $Q^{-1/2}$ for a given volume of injected reactant and the front position as $Q^{1/2}$ for a given time, paving the way to a flow control of the amount and spatial distribution of the reaction front product. This control strategy compares well with calcium carbonate precipitation experiments for which the amount of solid product generated in flow conditions at fixed concentrations of reactants and the front position can be tuned by varying the flow rate.

References

- [1] L. Gálfi and Z. Rácz, Phys. Rev. A **38**, 3151 (1988).
- [2] Y.E. Koo, L. Li and R. Kopelman, Mol. Cryst. Liq. Cryst. **183**, 187 (1990).
- [3] F. Brau, G. Schuszter and A. De Wit, Physical Review Letters, **118**, 134101, (2017).