From downside to upside: leveraging permeance inhibition to enhance hydrogen production in membrane steam reformers

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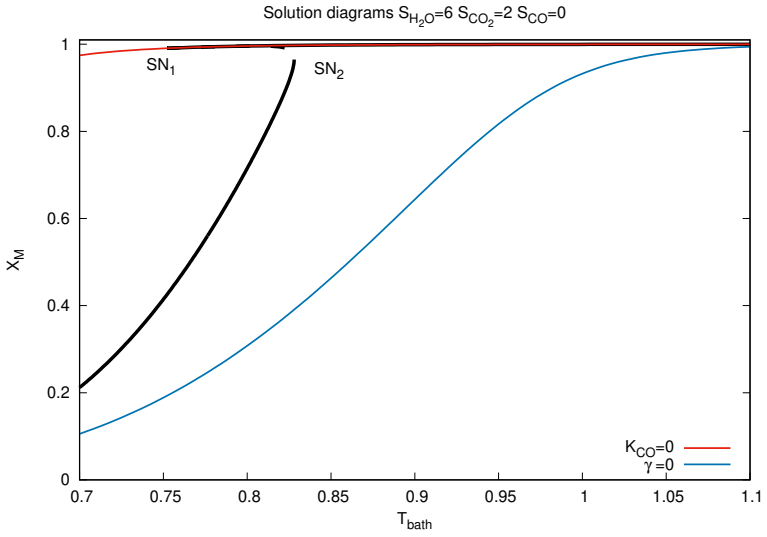
Membrane steam reformers are interesting devices for the decentralized production of hydrogen as they allow the integrated production and separation of hydrogen, as well as the possibility of lowering the operating temperature compared to conventional reforming processes and produce a reformat that is easier to treat. Hydrogen removal efficiency may decline considerably due to permeance inhibition of the hydrogen-selective membrane by the competitive adsorption of CO, one of the products of the reactions. Here, we show that that such inhibition may also lead to steady-state multiplicity. This can be attributed to the fact that, in the presence of inhibition, the mechanism limiting the performance of the reactor may shift from the kinetics of the chemical reactions to hydrogen permeation, depending on the initial gas composition. The region of multistability is affected by a number of parameters, including the Damkohler number, membrane permeance, and feed composition. We show that the presence of multistability is more pronounced when feeding biogas than it is when feeding methane to the system. Although multistability represents an issue in terms of control strategies to be employed, this work shows that it may also be used to obtain almost full methane conversion at temperatures considerably lower than those traditionally employed in steam reformers and with steam-to-methane ratio in the feed close to the stoichiometric one. This entails high rates of hydrogen production as well as a retentate consisting almost exclusively of CO_2 and therefore easily transferrable to carbon capture or utilization systems. The figure shows the solution diagram, representing methane conversion as a function of reactor temperature, under fixed operating conditions for a traditional reactor with no membrane (blue curve), for a membrane reactor without inhibition (red curve), and a for a membrane reactor with inhibition (black curve).



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