Multicomponent gas diffusion in conical tubes

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In many technical processes gas multicomponent diffusion takes place in confinements that are rarely uniform in direction of their long axis (e.g., catalysts pores, microelectromechanical systems). Here, we show that in conical tubes multicomponent diffusion is significantly hindered. This effect increases with ratio of inlet to outlet cone radius Λ, indifferent of the orientation of the tube. Based on the Maxwell–Stefan equations, predictive analytical solution for ideal multicomponent diffusion in slightly tapered tubes is developed. In two-bulb diffusion experiments on a uniform tube, the results of Duncan and Toor [1] were reproduced. Comparison of model and experiment shows that the solution provides a reliable quantitative prediction of the temporal change of H_2, N_2, and CO_2-concentration for both tube geometries, uniform and slightly conical (Figure 1).

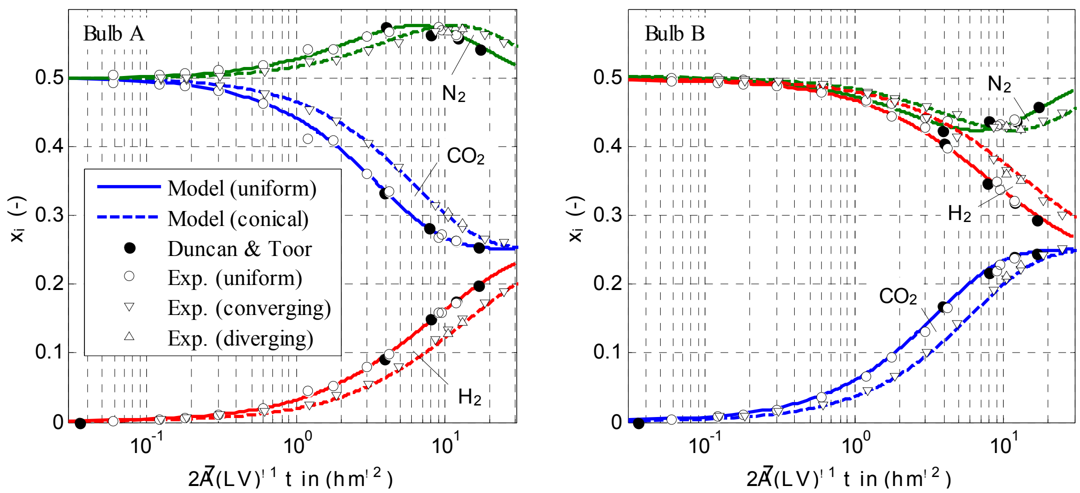

Figure 1: Analytical and experimental results of the two-bulb diffusion experiment for a uniform tube (solid lines, circles) and a conical tube (dashed lines, triangles) at 308.15 K and 0.1 MPa(a).

In the demonstrated case (Λ = 3.16), mass diffusion is 68 % delayed [2]. Thus, for gaseous diffusion in "real," typically tapered pores and systems the transport limitation is supposed to be more serious than considered so far.

Further investigation on process intensification, for example, gas separation and heterogeneous catalysis requires more accurate models and the taperedness of pores should be taken into account. We emphasize that the strong diffusion hindrance for gas mixtures by non-uniform tubes is even present under standard pressure in macroscopic tubes and hence under negligible gas rarefaction. This is in contrast to the "diode effect" in pressure-driven flows that only occurs under rarefied conditions [3]. It is experimentally confirmed that the "geometrical hindrance effect" for multicomponent gas diffusion presented here is independent of direction (converging/diverging cone), whereas the "diode effect" is direction depended.

References

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