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Micro-Reactor Mixing Unit Interspacing for Fast Liquid-Liquid Reactions Leading to a Generalized Scale-up Methodology

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Abstract

The effect of geometrical arrangements of a residence time channel (RTC) positioned in between LL-Rhombus static mixing elements on interphase mass transfer rates is investigated. Four variations of a micro-reactor plate are tested with four immiscible aqueous-organic systems: water coupled with n-butanol, n-hexanol, methyl tert-butyl ether and toluene. The alkaline hydrolysis of 4-nitrophenyl acetate is used to determine the overall volumetric mass transfer coefficient ($K_d a$). For all solvent pairs, the micro-reactor without a RTC has the greatest $K_d a$ at a given flow rate due to a greater energy dissipation rate (ε) and the fact that drops can re-coalesce leading to reduced advective transfer in the RTC pending the flow regime. An increase in flow rate results in a rise in conversion up to a maximum, after which viscous dissipation impedes further turbulent breakdown of the droplets as they near the Kolmogorov length scale. When the resulting flow is finely dispersed, interphase mass transfer rates no longer depend on reactor geometry but was correlated to the solvent system and rate of energy dissipated. The negative impact of operating at greater ε values than at maximum conversion is shown via the required pressure loss to achieve a certain conversion or residence time. Lastly, relevant to production rates in the fine chemical and pharmaceutical industry, an algorithm for scaling a generic mass transfer-limited liquid-liquid reaction at identified optimal operating conditions is presented.

Highlights

- Four different mixer spacing arrangements were used for a liquid-liquid reaction.
- Four organic solvents were used: nBuOH, nHeOH, MTBE and toluene.
- In drop flow, the reactors performed similarly for a given energy dissipation rate.
- Droplet diameters were as low as 4 to 16 times the Kolmogorov length.
- An algorithm for identifying and scaling at optimal operating conditions is presented.

Keywords

Micro-reactor; mixer spacing; liquid-liquid; energy dissipation; transport phenomena; scale-up.

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