Circular Economy in Hot-Dip Galvanizing with Zinc and Iron Recovery from Spent Pickling Acids

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SUPPLEMENTARY INFORMATION

Calculation of the mass transfer coefficient

This supplementary information provides further information on data used to calculate the mass transfer coefficient (k_m), of zinc species through the porous membranes embedded with the organic phase,

$$k_m = \frac{D_{i,B} \cdot \varepsilon}{\delta \cdot \tau}$$

where $D_{i,B}$ is the diffusivity of the zinc chloride organic complex $ZnCl_2 \cdot 2\bar{H}Cl \cdot 4TBP$ in the organic extractant phase (m²/h), ε is the porosity of the membrane (-), δ is the thickness of the membrane (m), and τ is the tortuosity (-).

Diffusion coefficient ($D_{i,B}$)

The diffusivity was calculated using the Wilke-Chang equation,

$$D_{i,B} = \frac{7{,}4 \cdot 10^{-8} (\phi_B \cdot M_B)^{1/2} \cdot T}{\mu_B \cdot V_i^{0.6}}$$

where ϕ_B is the coefficient of association of the organic phase (-), M_B is the average molecular weight of the organic phase (g/mol), T is the temperature (K), μ_B is the viscosity of the organic phase (cP), and V_i is the molar volume of the complex $ZnCl_2 \cdot 2\bar{H}Cl \cdot 4TBP$ (cm³/mol).

Membrane tortuosity (τ).

The tortuosity of the porous membrane was calculated using the following equation,

$$\tau = \frac{(2 - \varepsilon)^2}{\varepsilon}$$

Next table shows the data used for the $D_{i,B}$ calculation.

Table SI.1. Data used for mass transfer coefficient ($D_{i,B}$) calculation.

Property	Value	Definition
ϕ_B	1	Coefficient of association of the organic phase
M_B	224.96 g/mol	Average molecular weight of the organic phase.
T	293 K	Temperature
μ_B	3.2 cP	Viscosity of the organic phase
V_i	1206.0 cm³/mol	Molar volume of $ZnCl_2 \cdot 2\bar{H}Cl \cdot 4TBP$

The diffusivity of the zinc complex was $D_{i,B}$ = $1.57 \cdot 10^{-10}$ m²/s, and the tortuosity of the porous membrane was τ=6.4. Thus, the mass transfer coefficient used in this mathematical model was k_m= 2.45·10^{-7} m/s