A First Course on Kinetics and Reaction Engineering
Unit 39. Gas-Liquid Reactions

Definitions

Hatta number - a dimensionless measure of the rate of reaction in a liquid relative to the rate of diffusion in that liquid

Two film model - representation of a gas liquid system wherein a stagnant layer exists between the interface and the bulk gas and a second stagnant layer exists between the interface and the bulk liquid

Surface renewal model - a representation of gas-liquid reactions wherein elements of liquid reside at the gas-liquid interface for a finite period of time after which they are replaced by a different fluid element

Liquid utilization factor - ratio of the actual rate of reaction to the rate that would result in the absence of liquid phase concentration gradients

Enhancement factor - ratio of the actual rate of absorption (i. e. when reaction does occur) divided by the rate of absorption that would have been observed in the absence of reaction

Gas utilization factor - ratio of the actual rate of reaction to the rate that would result in the absence of liquid phase and gas phase concentration gradients

Nomenclature

γ	Hatta number
η_L	liquid utilization factor
ζ	enhancement factor
A_V	Interfacial area per liquid volume
C_A	liquid phase concentration of A; an additional subscript i denotes the concentration at the gas-liquid interface; an additional subscript b denotes the concentration in the bulk liquid
D_A	liquid phase diffusion coefficient for A
N_A	flux of reagent A
P_A	partial pressure of A; an additional subscript i denotes the partial pressure at the gas-liquid interface
Sh	Sherwood number
h_A	Henry's law constant for reagent A
k	rate coefficient
k_L	liquid phase, concentration mass transfer coefficient
x	distance into the liquid phase perpendicular to the liquid surface and measured from the gas-liquid interface; a subscript L denotes the thickness of the liquid phase boundary layer
r_A	net rate of generation of A by chemical reaction per unit volume

Equations

$$P_{Ai} = h_A C_{Ai} \tag{39.1}$$

$$D_A \frac{\partial^2 C_A}{\partial x^2} = r_A \tag{39.2}$$

$$D_B \frac{\partial^2 C_B}{\partial x^2} = r_B \tag{39.3}$$

$$C_A\left(x=0\right) = C_{Ai} \tag{39.4}$$

$$C_A\left(x=x_L\right) = C_{Ab} \tag{39.5}$$

$$C_B\left(x=x_L\right) = C_{Bb} \tag{39.6}$$

$$N_B\Big|_{x=0} = 0 \quad \Rightarrow \quad -D_B \frac{dC_{Bf}}{dx}\bigg|_{x=0} = 0 \quad \Rightarrow \quad \frac{dC_{Bf}}{dx}\bigg|_{x=0} = 0 \tag{39.7}$$

$$D_A \frac{\partial^2 C_A}{\partial x^2} = kC_A \tag{39.8}$$

$$C_A = \frac{C_{Ai}\sinh\left[\gamma\left(1-\frac{x}{x_L}\right)\right] + C_{Ab}\sinh\left(\frac{x}{x_L}\right)}{\sinh\left(\gamma\right)} \tag{39.9}$$

$$\gamma = x_L\sqrt{\frac{k}{D_A}} \tag{39.10}$$

$$k_L = \frac{D_A}{x_L} \tag{39.11}$$

$$\gamma = \frac{\sqrt{kD_A}}{k_L} \tag{39.12}$$

$$N_A = -D_A \frac{\partial C_A}{\partial x} \tag{39.13}$$

$$N_A\Big|_{x=0} = \frac{\gamma D_A}{x_L}\frac{C_{Ai}\cosh\gamma - C_{Ab}}{\sinh\gamma} = \frac{\gamma}{\tanh\gamma}\left[1-\frac{C_{Ab}}{C_{Ai}}\left(\frac{1}{\cosh\gamma}\right)\right]k_L C_{Ai} \tag{39.14}$$

$$\eta_L = \frac{A_v N_A\big|_{x=0}}{kC_{Ai}} \tag{39.15}$$

$$\eta_L = \frac{1}{\gamma Sh \tanh\gamma}\left(1 - \frac{C_{Ab}}{C_{Ai}}\frac{1}{\cosh\gamma}\right); \quad Sh = \frac{k_L}{A_v D_A} \tag{39.16}$$

$$\zeta = \frac{N_A}{k_L\left(C_{Ai} - C_{Ab}\right)} \tag{39.17}$$

$$\zeta = \frac{\gamma}{\tanh\gamma}\left[1 - \frac{C_{Ab}}{C_{Ai}}\left(\frac{1}{\cosh\gamma}\right)\right] \tag{39.18}$$