Chemical Reaction Engineering

Practical Session 6

17 December 2021

Gas/Liquid reactors

1. Overall rate of change through the 2-film theory

Air with gaseous species A bubbles through a vertical tower containing aqueous species B at uniform, constant temperature of 303 K. Reaction occurs as follows:

$$A_{(g\rightarrow l)} + 2B_{(l)} \rightarrow C_{(l)}$$

The reaction rate (per unit of liquid volume) is given by: $r = k_l C_A C_B^2$, with a kinetic constant $k_l = 10^8 \frac{m^6}{mol^2 h}$.

The diffusion coefficients of species A and B are $\Gamma_A = 10^{-6} \frac{m^2}{h}$ and $\Gamma_B = 10^{-6} \frac{m^2}{h}$. The liquid volume fraction is $f_L = 0.98$ and the gas/liquid interface area per unit of volume is $a = 20 \frac{m^2}{m^3}$. The Henry's constant at the given temperature is equal to $H_A = 10^5 \frac{Pa\, m^3}{mol}$ and the liquid and gas mass transfer coefficients equal to $K_L a = 2 \frac{1}{h}$ and $K_G a = 0.01 \frac{mol}{h\, m^3 Pa}$.

a) Determine and plot the operating line for a range of partial pressures of A from $100\ Pa$ to $5000\ Pa$ and a fixed concentration of species B equal to $1\ mol/m^3$.
b) Estimate and plot the enhancement factor and the overall rate of change in the same conditions reported above.

2. Simulation of a co-current bubble tower

The reaction described in Exercise 1 is carried out in a co-current bubble tower with internal circular section having diameter of $40\ cm$ and height of $5\ m$. The air stream (containing species A, with partial pressure of $5000\ Pa$) is fed at total pressure of $1\ atm$ and volumetric flow rate of $0.4\ l/s$. The liquid stream, containing only species B and water with concentrations equal to $1\ mol/m^3$ and $300\ mol/m^3$, respectively, is fed with volumetric flow rate of $10\ l/s$.

Calculate the profiles of partial pressure of A and concentrations of B and C along the reactor and estimate the conversion of A at the outlet section.

3. Simulation of a counter-current bubble tower

Repeat the previous exercise in case of counter-current configuration.