Practical 11

Gas – Liquid Reactors

Exercise 1

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:

$$A(g\rightarrow l) + 2B(l) \rightarrow C(l) \quad (1)$$

The reaction rate (per unit of liquid volume) is given by: $r=k_l C_A C_B^2$, with a kinetic constant $k_l=10^6$ m^6 mol^{-2} h^{-1}. The diffusion coefficients of species A and B are $D_{A(l)}=10^{-6}$ m^2 h^{-1} and $D_{B(l)}=10^{-6}$ m^2 h^{-1}. The liquid volume fraction is $f_L=0.98$ and the gas/liquid interface area per unit of volume is $a=20$ m^{2}m^{-3}. The Henry's constant at the given temperature is equal to $H_A=10^5$ Pa m^{3}mol^{-1} and the liquid and gas mass transfer coefficients equal to $k_L a=20$ h^{-1} and $k_G a=0.01$ mol h^{-1} m^{-3} Pa^{-1}.

For a point in the absorber-reactor where, $p_A = 5\times10^3$ Pa and $C_B = 100$ mol m^{-3},

A) Estimate the enhancement factor and locate the reaction zone and calculate the overall rate of reaction (mol m^{-3} hr^{-1})
B) Locate the resistance to reaction (what % is in the gas film, in the liquid film, in the main body of liquid)

Exercise 2

Gaseous A absorbs and reacts with liquid B in a packed bed as follows:

$$A(g\rightarrow l)+B(l)\rightarrow C(l) \quad (1)$$

The reaction rate (per unit of liquid volume) is given by: $r=kC_A C_B$, with a kinetic constant k in m^3 (liquid) mol^{-1} h^{-1}. The diffusion coefficients of species A and B are $D_{A(l)}=10^{-6}$ m^2 h^{-1} and $D_{B(l)}=10^{-6}$ m^2 h^{-1}. The liquid volume fraction is $f_L=0.1$ and the gas/liquid interface area per unit of volume is $a=100$ m^{2}m^{-3}. The Henry's constant at the given temperature is expressed in Pa m^{3}mol^{-1} and the liquid and gas mass transfer coefficients equal to $k_L a=100$ h^{-1} and $k_G a=0.1$ mol h^{-1} m^{-3} Pa^{-1}.

At a point inside the reactor where, p_A = 100 Pa and C_B = 100 mol m^{-3} liquid, for the following cases

k [m^3 (liquid) mol^{-1} hr^{-1}]	H_A [Pa m^3 (liquid) mol^{-1}]
10	10^5
10	10^3
10^{-2}	1
10^8	1

A) Calculate the overall rate of reaction (mol m^{-3} hr^{-1}) and locate the major resistance to reaction
B) Comment on the nature of the observed changes in the transport processes taking place in the system

Exercise 3

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:

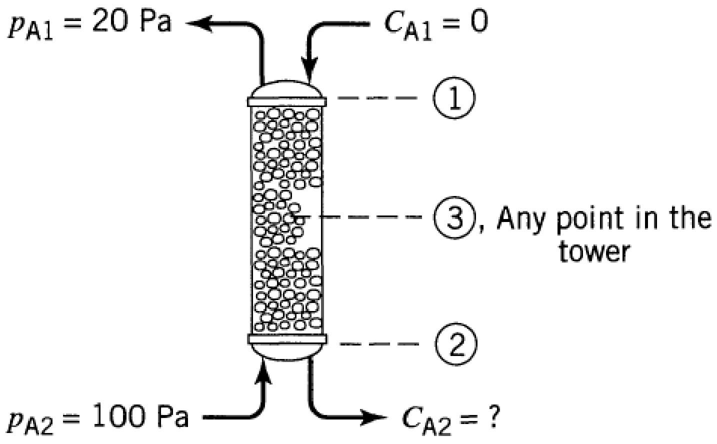
$$A(g \rightarrow l) + 2B(l) \rightarrow C(l) \quad (1)$$

The reaction rate (per liquid volume) is given by: $r = k_l C_A C_B^2$, $k_l = 10^8$ m^6 mol^{-2} h^{-1}. The reaction 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, partial pressure 5000 Pa) is fed at total pressure of 1 atm and volumetric flow rate of 0.8 L s^{-1}. 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 20 L s^{-1}. 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.

Exercise 4

The concentration of undesirable impurity in an industrial flue gas (at 1 bar = l0^5 Pa) is to be reduced from 0.1% (or 100 Pa) to 0.02% (or 20 Pa) by *straight* absorption in pure water.

A) Find the height of tower required for countercurrent operations.



Data

For the packing to $k_L\, a$=0.1 h^{-1} and $k_G\, a$=0.32 mol h^{-1} m^{-3} Pa^{-1}. The diffusion coefficients of species A and B are $D_{A(l)}$=10^{-6} m^2 h^{-1} and $D_{B(l)}$=10^{-6} m^2 h^{-1}. The liquid volume fraction is f_L=0.9. The solubility of A in water is given by Henry's law constant HA = 12.5 Pa. m^3mol^{-1}. The flow rates per meter squared cross section of tower are F_g/A_{CS} = 1 x 10^5 mol hr^{-1} m^2 and F_l/A_{CS} = 7X10^5 mol hr^{-1} m^2. The molar density of liquid under all conditions is C_T = 56,000 mol m^{-3}.

To the water of previous example, a high concentration of reactant B is added, C_B = 800 mol m^{-3} or approximately 0.8 N. Material B reacts with A extremely rapidly

$$A(g \rightarrow l) + B(l) \rightarrow C(l) \qquad (1)$$

B) Assuming that the diffusivities of A and B in water are the same, determine the tower height for a reduction of 80% of impurity in the flue gas.
C) What happens when a low concentration feed with C_B = 32 mol m^{-3}, is used instead?