Chemical Reaction Engineering –II (CLL 222/ CHL221)

Major Exam 2015 Date: 19 /11/2015

M.M : 40 Time : 1-3 PM

Venue: LH 121

1. The reaction $A \rightarrow 2B$ is carried out on a metallic monolith surface. At high temperature the reaction is mass transfer limited. The reaction is currently takes place on a monolith catalyst where 45 percent conversion is achieved. It is proposed to increase the number of plates (n) from 100 to 200 for the same width (w) and to halve the length (L) of the reactor and double the distance between the plates (b). What conversion can be expected for monoliths at high Reynold numbers? State all the assumptions made. Mass transfer correlation at high Reynold number for a monolith catalyst may be taken as

$Sh = 0.0006\,(Re/(L/2b))^{1.36}$, where $Sh = 8\,k_c b/D_{AB}$, and Reynold number, $Re = 8\,b\rho\,u/\mu$. (8)

2. n-Hexadecane ($C_{16}H_{34}$) feed stream contains the impurity dibenzo thiophene (DBT) present in trace amounts, which can deactivate the Pt/ HZSM 5 catalyst over which feed is being cracked to form i-Octane (C_8H_{18}) and 1- Octene (C_8H_{16}). The following data were taken at 50 atm. and 220 ^{0}C in a differential reactor.

i-Octane in exit stream (mol%)	4	3.34	2.62	2.12	1.70	1.12	0.74	0.48
t (s)	0	20	50	75	100	150	200	250

(a) Determine the order of decay and decay constant. (5)

(b) Assume the main reaction to be first order in n-hexadecane with a rate constant (k) 2.8 mol/g catalyst .s. atm. The molar flow rate of n-hexadecane and impurity is 100 mol/min and the entering concentration of n-hexadecane is 0.06 kmol/m^3. If the catalyst weight is 100 kg and the velocity of the solids is 0.1 kg/s, estimate the conversion of n-hexadecane in a moving bed reactor. (5)

Q. 3. Develop an expression for the effectiveness factor for a straight cylindrical pore of length 2L. Both ends of the pore are open to reactant gas of concentration. A first order irreversible reaction A---> B, occurs on the pore walls. Express the result as

$\eta = f(\phi_p)$, where ϕ_p is the Thiele modulus for a single pore. The pore radius is r and diffusivity of A in the pore is D. (8)

4. Pure hydrogen gas at 100 atm and 150°C is bubbled through a stirred slurry tank reactor in which glucose is hydrogenated to produce sorbital. The catalyst used is porous Raney nickel, and under these conditions the reaction proceeds as follows:

$$\underset{(A)}{H_{2(g \rightarrow l)}} + \underset{(B)}{C_6H_{12}O_6\ (l)(\text{glucose})} \dashrightarrow \underset{(C)}{C_6H_{14}O_6\ (l)\ (\text{Sorbitol})}$$

The rate expression for the above reaction is

$$-r'_A = -r'_B = k' C_A^{0.6} C_B, \quad k' = 5.96 \times 10^{-6} \frac{\text{mol}}{\text{kg} \cdot \text{s}} \left(\frac{\text{m}^3}{\text{mol}}\right)^{1.6}$$

Evaluate the conversion of glucose in the reactor. Following data are available for gas and liquid stream:

Flow rate of gas stream = 0.2 m^3/s, Henery law constant H_A = 280600 Pa. m^3/mol

Flow rate of liquid stream = 0.01 m^3/s, Liquid concentration C_{B0} = 2000 mol/m^3

Volume of reactor is 2 m^3 and fraction of solid catalyst in the reactor, f_s = 0.056

The average catalyst size d_p = 10 μm, and density of the catalyst ρ_s is 8900 kg/m^3, The effective diffusion coefficient in the catalyst pore D_e is 2×10^{-9} m^2/s.

The combined mass transfer coefficient in gas and liquid film can be taken as $(k_{Ag}, a_i)_{g+l}$ = 0.05 s^{-1}, and the mass transfer coefficient for liquid to solid catalyst surface $k_{Ac} = 2 \times 10^{-4}$ m/s. (8)

5. For the absorption of gas (A) in liquid (B), derive an expression for enhancement factor (E_i) assuming an instantaneous reaction,

$$A_{(g \rightarrow l)} + B_{(l)} \dashrightarrow R_{(l)},$$

$$E_i = 1 + k_{Bl} C_B / k_{Al} C_{Ai}$$

Where k_{Al}, k_{Bl} are the mass transfer coefficients in liquid phase and based on whole film thickness (x_0). C_{Ai} is concentration of gas at the gas liquid interphase and C_B is concentration of Liquid in bulk liquid. State clearly assumptions made if any. (6)