Bachelor of Engineering in Chemical Engineering Supplementary Examination, 2018 (OLD)

CHEMICAL REACTION ENGG

Time: 3 hours **Total marks: 100**

Answer any five questions

Assume any missing data

1. Prove that $t_{opt} = \frac{(\ln k_1 - \ln k_2)}{(k_1 - k_2)}$ for irreversible series reaction. 8

   Acetaldehyde vapour is decomposed in an idea tubular reactor according to the reaction $CH_3CHO \rightarrow CH_4 + CO$. The reactor is 3 cm ID with 80 cm long and is maintained at 516 C. The acetaldehyde vapour is measured at room temperature and slightly above atm pressure for consistency the measured flow rate is corrected to standard condition (0^0C & 1 atm pressure) before the space velocity is reported. In one run at a reported space velocity of 8 hr^{-1}, 40% of acetaldehyde is decomposed in the reactor. The 2^{nd} order reaction, rate constant is 0.30 m/(sec gmmole) at 516^0C and the reaction is irreversible. Calculate the actual; residence time and compare it with the space time at 516^0C. Use the following expression:

   $$t = C_{A0}\int \frac{dx_A}{-r_A(1+\varepsilon_A x_A)}\ ; \qquad -r_A = kC_{A_0}^2 \frac{(1-x_A)^2}{(1+\varepsilon_A x_A)^2}$$ 12

2. Derive the final expression for series reaction.

   Liquid A decomposes by 2^{nd} order reaction kinetics and in a batch reactor. 50% of A is converted in 5 in run. How much longer will it take to reach 75% conversion. 10 + 10

3. Under appropriate condition, A decomposes as follows: 20

   $A \xrightarrow{K_1} R \xrightarrow{K_2} S$ R is to be produced from 1000 lt/hr of feed in which C_{A0} = 1 mol/lt, C_{R0} = C_{S0} = 0, K_1=K_2 = 0.1/min.

   a) What size of plug flow reactor will maximize the yield of R and what is the concentration of R in effluent stream from this reactor.

   b) What size mixed reactor will maximize the yield of R & what is the $C_{R\,max}$ in the effluent stream from this reactor.

   $$\tau_{Optimum,mixed} = \frac{1}{\sqrt{k_1 k_2}}$$

4. A mixture of coal particles is burnt in air on a moving grate. The grate is moving with a velocity of 1 m/min. The composition of complete conversion time for particle mixture is given in table.

Calculate the mixture length of grate to achieve average conversion of a)70%, b) 90% (Process combustion is chemical reaction controlled). 12

Mixture composition (%)	Particle Size (μ)	Complete conversion time (min)
25	50	10
50	75	15
25	100	20

Prove that $\frac{t}{t_c} = x_s$ for gas film controlled diffusion where t is time, t_c is complete reaction time, x_s is the fractional conversion of solid for non catalytic heterogeneous reaction.. 8

5. Dilute aqueous solution of acetic anhydride is to be hydrolyzed continuously at 25^{0}C. at this temperature, the equation is $-r_A = 0.158C$ gm mole/cm^3 min. C= concentration of acetic anhydride, gmmole/cc. The feed rate is 500 cm^3/min of solution and initial concentration of acetic anhydride is 1.5 x 10^{-4} gmmole/cc. Calculate the final conversion for the following:
   a) single CSTR (Volume 5 lt)
   b) Two single CSTR in parallel (each 2.5 lt).
   c) Two CSTR (each 2.5 lt volume) in series.
   d) CSTR followed by plug flow (each 2.5 lt).
   e) Tubular followed by CSTR (each 2.5 lt). 20
   f) What will be the expression for J_D for heterogeneous packed bed catalytic reactor.

6. Derive the expression of general mass and energy balance equation of fractional conversion for CSTR adiabatic reactor (1st order reaction). 10

Spherical particles of Zinc blende, ZnS (ρ_s = 4.13 g/cm^3, 42500 mole/cm^3) are roasted in an 8% oxygen stream at 1 atm and 900^{0}C (C_A = 0.83 mole/m^3) at which condition the stoichiometry and rates given by: $2\,ZnS + 3O_2 \rightarrow 2\,ZnO + 2SO_2$; k_s = 0.02 m/s; D_{eff} 8 x 10^{-6} m^2/s. Assuming that the reaction proceeds by the shrinking core model, calculate the time needed for complete conversion of solids and find the % contribution of ash diffusion and of reaction to the overall resistance, if the particle size of 2 cm. Use the following expression:

$$\tau_{ash} = \frac{\rho_s R_p^2}{6 s D_{eff} C_{Ag}};\ \tau_{reaction} = \frac{\rho_s R_p}{s k_s C_{Ag}};$$ 10

where R_p is particle diameter, s is stoichiometric coefficient of solid particle.