NTK/KW/15/7838

Faculty of Engineering & Technology

Seventh Semester B.Tech. (Chemical Engg.)
(C.B.S.) Examination

CHEMICAL REACTOR DESIGN

Paper—III (BT CHE 703 T)

Time : Three Hours] [Maximum Marks : 80

INSTRUCTIONS TO CANDIDATES

(1) All questions carry marks as indicated.

(2) Answer any **FIVE** questions.

(3) Due credit will be given to neatness and adequate dimensions.

(4) Assume suitable data wherever necessary.

(5) Diagrams and Chemical equations should be given wherever necessary.

(6) Illustrate your answers wherever necessary with the help of neat sketches.

(7) Use of slide rule, Logarithmic tables, Steam tables, Mollier's chart, Drawing instruments, Thermodynamic tables for moist air, Psychrometric charts and Refrigeration charts is permitted.

1. For mixed flow of particles of single unchanging size, uniform Gas composition and chemical reaction step is controlling, derive an expression for the determination of mean conversion X_B in terms of (τ/t). 16

2. (a) The H_2S content of a gas is to be reduced from 1% down to 1 ppm by contact in a packed column with an aqueous solution containing 0.25 mol/liter of methanolamine (MEA). Determine a reasonable L/G to be used and the height of tower needed. Data : H_2S and MEA react as follows :

$$H_2S + RNH_3 \rightarrow HS^- + RNH_3^+$$

and since this is an acid-base neutralisation we can regard it as irreversible and instantaneous. As a reasonable gas flow rate take $G = 3 \times 10^{-3}$ mol/cm². sec

$K_{Al}a = 0.03$ sec, $K_{Ag}a = 6 \times 10^{-5}$ mol/cm³.sec.atm.

$D_{Al} = 1.5 \times 10^{-5}$ cm²/sec, $D_{Bl} = 10^{-5}$ cm²/sec.

$H_A = 0.115$ liter. atm/mol—for H_2S in water. 12

(b) Spherical particles of zinc blend of size R = 1 mm are roasted in an 8% oxygen stream at 900°C and 1 atm. The stoichiometry of the reaction is

$$2\ ZnS + 3O_2 \rightarrow 2\ ZnO + 2\ SO_2$$

8. Write short notes on (any **FOUR**) :—

(i) Long chain approximation used in polymerization kinetics.

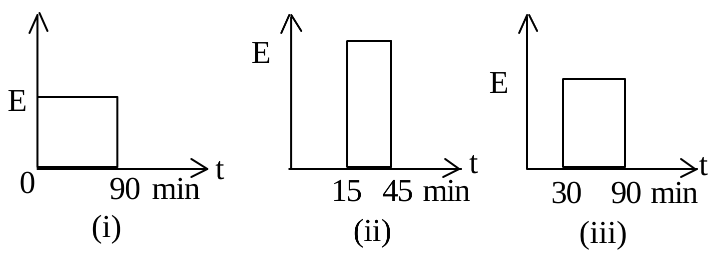
(ii) Effectiveness factor in solid catalysed reactions.

(iii) Polydispersity index.

(iv) Adiabatic temperature and equilibrium conversion.

(v) Determination of rate controlling step in fluid-particle reactions. 16

(b) Hydrogen sulfide is removed from coal gas by passing the gas through a moving bed of iron oxide particles. In the coal gas environment (consider uniform). The solids are converted from Fe_2O_3 to FeS by SCM/reaction control, $\tau = 1$ hr. Find the fractional conversion of oxide to iron sulfide if the RTD of solids in the reactor is approximated by E curves of : 10



4. (a) Draw the Schematic diagram of tower and tank contactors used in gas-liquid reactions such as spray tower, packed tower, plate tower, bubble tank and agitated tank. 6

(b) For the catalytic reaction $A \rightarrow 4R$ the following rate concentration data is available :

C_A **mol/liter**	$-r_A^{1}$ **mol A/hr. kg cat**
.039	3.4
0.0575	5.4

C_A **mol/liter**	$-r_A^{1}$ **mol A/hr. kg cat**
0.075	7.6
0.092	9.1

Directly from this data and without using a rate expression find the size of packed bed needed to treat 2000 mol/hr of pure A at 117°C (or C_{Ao} = 0.1 mol/liter ; $\in_A = 3$) to 35% conversion, all at 3.2 atm. 10

5. (a) Discuss in brief the process and criteria for the selection of good contactor for gas-liquid reactions on solid catalyst. 6

(b) A gas containing A (2 mol/m^3) is fed (1 m^3/hr) to a plug flow reactor with recycle loop (0.02 m^3 loop volume, 3 kg catalyst) and the output composition from the reactor system is measured (0.5 mol A/m^3). Find the rate equation for the decomposition of A for the following :

Very large recycle $A \rightarrow 3R$,

n = 1 50% A — 50% inerts in feed. 10

6. (a) Write the performance equations for reactors used for gas-liquid reactions on solid catalyst for the following cases :

(i) For reactant liquid B used in excess for plug flow of gas A and any flow of liquid B and

(ii) For reactant gas A used in excess for plug flow of liquid B and any flow of gas A. 4

(b) The elementary irreversible gas-phase reaction

$$A \rightarrow B + C$$

is carried out adiabatically in a PFR packed with a catalyst. Pure A enters the reactor at a volumetric flow rate of 20 dm^3/s at a pressure of 10 atm and a temperature of 450 K.

(i) Plot the conversion and temperature down the plug flow reactor untill an 80% conversion (if possible) is reached. The maximum catalyst weight that can be packed into the PFR is 50 kg). Assume that $\Delta P = 0.0$

(ii) What catalyst weight is necessary to achieve 80% conversion in a CSTR ? 12

7. (a) Discuss the mechanism of free radical polymerization in brief and hence derive the expression for $-r_M$. 10

(b) Illustrate (with the help of relevant plots) the procedure to find multiple steady states and hence, how to draw ignition-extinction curves in non-isothermal reactor design. 6

Assuming the reaction proceeds by the shrinking core model :

(i) Calculate the time needed for complete conversion of particle and the relative resistance of ash layer diffusion during this operation.

(ii) Repeat for particles of size R = 0.05 mm.

Data : Density of solid $\rho_B = 4.13$ gm/cm^3

Reaction rate constant, $K_s = 2$ cm/sec

For gases is ZnO layer $D_e = 0.08$ cm^2/sec

Note that film resistance can safely be neglected as long as a growing ash layer is present. 4

3. (a) CO_2 is to be removed from air by countercurrent contact with water at 25°C.

(i) What are the relative resistances of gas and liquid film for this operation ?

(ii) What simplest form of rate equation would you use for tower design ?

(iii) For this removal operation would you expect reaction with absorption to be helpful ? Why ?

From the literature we have for CO_2 between air and water $K_g a = 80$ mol/hr. liter. atm. $K_l a = 25$/hr, H = 30 atm. liter/mol. 6