BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(MID SEMESTER EXAMINATION)

CLASS: BE **SEMESTER: VI**
BRANCH: CHEMICAL ENGG. **SESSION : SP/2019**

SUBJECT : CL6009 ADVANCES IN REACTION ENGINEERING

TIME: 1.5 HOURS **FULL MARKS: 25**

INSTRUCTIONS:
1. The total marks of the questions are 30.
2. Candidates may attempt for all 30 marks.
3. In those cases where the marks obtained exceed 25 marks, the excess will be ignored.
4. Before attempting the question paper, be sure that you have got the correct question paper.
5. The missing data, if any, may be assumed suitably.

Q1 Discuss the non-isothermal multiple chemical reactions in PFR and CSTR reactors. [5]

Q2 Parallel reaction in a PFR with heat effects: [5]
The following gas-phase reactions occur in a PFR:

Reaction 1: $A \xrightarrow{k_1} B \qquad -r_{1A} = k_{1A}C_A$

Reaction 2: $2A \xrightarrow{k_2} C \qquad -r_{2A} = k_{2A}C_A^2$

Pure A is fed at a rate of 100 mol/s, a temperature of 150^0C and a concentration of 0.1 mol/dm^3. Determine the temperature and flow rate profiles down the reactor.

Additional information:

$\Delta H_{Rx1A} = -20{,}000$ J/(mol of A reacted in reaction 1)

$\Delta H_{Rx2A} = -60{,}000$ J/(mol of A reacted in reaction 2)

$C_{P_A} = 90$ J/mol·°C $\qquad k_{1A} = 10 \exp\left[\frac{E_1}{R}\left(\frac{1}{300} - \frac{1}{T}\right)\right]$ s^{-1}

$C_{P_B} = 90$ J/mol·°C $\qquad E_1/R = 4000$ K

$C_{P_C} = 180$ J/mol·°C $\qquad k_{2A} = 0.09 \exp\left[\frac{E_2}{R}\left(\frac{1}{300} - \frac{1}{T}\right)\right] \frac{\text{dm}^3}{\text{mol}\cdot\text{s}}$

$Ua = 4000$ J/m^3·s·°C $\qquad E_2/R = 9000$ K

$T_a = 100$°C

Q3 Discuses and derive the expression for Langmuir adsorption isotherm. [5]

Q4 A solid catalyst is prepared by using the alumina particles (100 to 150 mesh size). This catalyst is then made into large cylindrical pellets for rate studies. The Al_2O_3 particles contain micropores, and the pelletting process introduces macropores surrounding the particles. From the experimental methods, the macropore volume of one pellet is 0.645 cm^3 and the micropore volume is 0.40 cm^3/g of particles. The gross measurements for one pellet are [5]
Mass = 3.15 g; Diameter = 1.00 in.; Thickness = 1/4 in.; Volume = 3.22 cm^3
From this information calculate:
(a) The micropore void fraction in the pellet
(b) The solid fraction
(c) The-density of the particles
(d) The density of the solid phase
(e) The void fraction of the particles

PTO

Q5 Describe the Shrinking-Core model for spherical particles of unchanging size with the help of a clear sketch. [5]

Q6 Hydrogen sulfide is absorbed by a solution of methanolamine (MEA) in a packed column. At the top of the column, gas is at 20 atm and it contains 0.1% of H_2S, while the absorbent contains 250 mol/m^3 of free MEA. The diffusivity of MEA in solution is 0.64 times that of H_2S. The reaction is normally regarded as irreversible and instantaneous. [5]

$$\underset{(A)}{H_2S} + \underset{(B)}{RNH_2} \rightarrow HS^- + RNH_3^+$$

For the flow rates and packing used

$$k_{Al}a = 0.03\ \text{s}^{-1}$$

$$k_{Ag}a = 60\ \text{mol/m}^3 \cdot \text{s} \cdot \text{atm}$$

$$H_A = 1 \times 10^{-4}\ \text{m}^3 \cdot \text{atm/mol, Henry's law constant for } H_2S \text{ in water.}$$

(a) Find the rate of absorption of H_2S in MEA solution.
(b) To find out whether it is worthwhile using MEA absorbent, determine how much faster is absorption with MEA compared to absorption in pure water.