



**UNIVERSITI TUN HUSSEIN ONN MALAYSIA**

**FINAL EXAMINATION  
SEMESTER II  
SESSION 2015/2016**

COURSE NAME : CHEMICAL REACTION  
ENGINEERING

COURSE CODE : BNQ 20304

PROGRAMME CODE : BNN

EXAMINATION DATE : JUNE / JULY 2016

DURATION : 3 HOURS

INSTRUCTION : ANSWER **FOUR (4)** QUESTIONS  
ONLY

THIS QUESTION PAPER CONSISTS OF SEVEN (7) PAGES

**Q1** The elementary gas phase reaction with first order reaction is carried out in a plug flow reactor (PFR) with no pressure drop in which the volumetric flow rate is,  $v$ , is constant.



- (a) List the assumption made in the derivation of the design equation for PFR. (2 marks)
- (b) Describe the changes of concentrations of the reactants and products with respect to time for the reaction carried out in a plug flow reactor. (4 marks)
- (c) Derive an equation relating the reactor volume to the entering and exiting concentration of A, the rate constant  $k$ , and the volumetric flow rate,  $v$ . (8 marks)
- (d) Determine the reactor volume to reduce the exiting concentration to 10% of the entering concentration when the volumetric flow rate is  $10 \text{ dm}^3/\text{min}$  and rate constant,  $k$ , is  $0.23 \text{ /min}$ . (3 marks)
- (e) Calculate the reactor volumes if the reaction consume 99% of A at the entering molar flow rate is  $5 \text{ mol/h}$ . The reaction is a second order reaction and the reaction rate,  $k$ , is  $3 \text{ dm}^3/\text{mol}\cdot\text{min}$ . (8 marks)

**Q2** In the hippopotamus, digestion occurs as an autocatalytic reaction in the stomach followed by a catalytic reaction in the intestines. This system can be modeled as a series of CSTR-PFR. The volumetric flow rate of food intake into the system can be assumed to be  $100 \text{ L/d}$ , at a concentration of  $7.5 \text{ mol/L}$ . The volume of the stomach (modeled as CSTR) is  $450 \text{ L}$ . Reciprocal rates (in  $\text{mol/L}\cdot\text{d}$ ) for the two types of reactions are provided in Table Q2 (i) and Table Q2 (ii):

Table Q2 (i): Autocatalytic reaction in the stomach

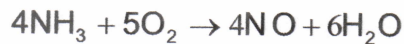
X	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
$1/-r_A$ (mol/L.d)	8.0	5.0	1.5	2.0	2.5	3.5	5.0	7.0	9.0

Table Q2 (ii): Catalytic reaction in the intestines

X	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
$1/-r_A$ (mol/L.d)	8.0	5.0	1.5	2.0	2.5	3.5	5.0	7.0	9.0

- (a) Calculate the volume of the intestines if the total conversion of 50% is observed. (15 marks)
- (b) (i) Plot a graph which can indicate the volume of the intestines.  
(ii) Shaded the area represent the volume in the graph. (10 marks)

- Q3** The isothermal reaction of nitric oxide produced by the gas phase oxidation of ammonia in a flow reactor is shown by the following reaction.



The feed consists of 15 mol % ammonia in air at 8.2 atm and 227°C.

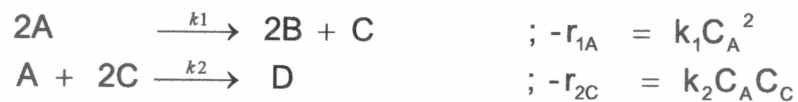
- (a) Calculate the total entering concentration. (3 marks)
- (b) Determine the entering concentration of ammonia. (2 marks)
- (c) Develop a stoichiometric table for the reaction with ammonia as your basis of calculation. (10 marks)
- (d) Evaluate the concentration for each species involve in the reaction in terms of conversion. (10 marks)
- Q4** Consider the following reaction to produce 300 million pounds of ethylene a year from a feed stream of pure ethane in plug flow reactor.



The reaction is irreversible and follows an elementary rate law. We want to achieve 80% conversion of ethane, operating the reactor isothermally at 1100K at a pressure of 6atm. Assume that the reaction is first order with  $k = 0.072\text{s}^{-1}$  at 1000K.

- (a) Express the concentration of each species in terms of conversion. (6 marks)
- (b) Calculate the entering concentration of species A. (3 marks)
- (c) Determine the volume at 80% conversion. (7 marks)
- (d) Examine the possible conversion that would achieved if the reaction occur in two  $600\text{dm}^3$  CSTR arranged in parallel reactor with entering volumetric fed to main stream is  $10\text{ dm}^3$  with  $k = 0.044\text{ min}^{-1}$ . (9 marks)

**Q5** The following complex liquid phase reaction is carried out in a 50 L CSTR :



The concentration of A fed into the reactor is 100 mol/L. The flow rate into the reactor is constant and at 20 L/min. The value of specific constants  $k_1$  and  $k_2$  are 0.35 (L/mol.min) and 0.25 (L/mol.min) respectively.

- (a) Carry out the net rate of reaction for A, B, C and D. (14 marks)
- (b) Using the appropriate design equation, calculate:
- (i) the yield of C ( $Y_C$ )
  - (ii) the selectivity of C over D ( $S_{CD}$ ) that can be achieved after 90% A is consumed. (5 marks)
- (c) Propose on how would you design the system to get maximum product of C. (6 marks)

- END OF QUESTIONS -

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$$V = \frac{F_{A0} - F_A}{-r_A}$$

$$C_{A0} = \frac{P_{A0}}{RT_0} = \frac{y_{A0}P_0}{RT_0}$$

$$V = \frac{F_{j0} - F_j}{-r_j} \text{ or } \frac{v_j C_{j0} - v C_j}{-r_j}$$

$$F_{A0} = C_{A0} v_0$$

$$F_A = F_{A0}(1 - X)$$

$$\frac{dN_A}{dt} = r_A V$$

$$[N_A] = N_{A0}(1 - X)$$

$$t_1 = \int_{N_{A1}}^{N_{A0}} \frac{dN_A}{-r_A V}$$

$$\frac{(N_A/V_0)}{dt} = \frac{dC_A}{dt}$$

$$N_{A0} \frac{dX}{dt} = -r_A V$$

$$\frac{dF_A}{dV} = r_A \quad v = F_{A0} \int_0^X \frac{dX}{-r_A}$$

$$\frac{F_{A0} dX}{dV} = -r_A$$

$$V = \int_{F_{j0}}^{F_j} \frac{dF_j}{r_j} = \int_{F_j}^{F_{j0}} \frac{dF_j}{-r_j}$$

$$\int_{x_0}^{x_2} f(x) dx = \frac{h}{3} [f(x_0) + 4f(x_1) + f(x_2)]$$

$$V = \frac{F_{A0} \cdot X}{-r_A}$$

$$\int_0^x \frac{(1 + \epsilon x)}{(1 - x)} dx = ((1 + \epsilon)n) \frac{1}{1 - x} - \epsilon x$$

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$$\tau = \int_{C_A}^{C_{A0}} \frac{dC_A}{-r_A}$$

$$[k] = \frac{(\text{Concentration})^{1-n}}{\text{time}}$$

$$r_{A,\text{net}} = r_{A,\text{forward}} + r_{B,\text{reverse}}$$

$$r_{A \text{ reverse}} = k_{-A} C_d^c C_D^d$$

$$r_{A \text{ forward}} = -k_A C_A^a C_B^b$$

$$K_{\text{equilibrium}} = K_c = \frac{C_{Ce}^e C_{De}^d}{C_{Ae}^a C_{Be}^b}$$

$$\frac{-r_A}{a} = \frac{-r_B}{b} = \frac{r_C}{c} = \frac{r_D}{d}$$

$$C_B = \frac{N_B}{V} = \frac{N_{B0} - (b/a)N_{A0}X}{V}$$

$$= \frac{N_{A0}(\Theta - (b/a)X)}{V}$$

$$F_{B0} = F_{A0} \Theta_B$$

$$-\frac{b}{a}(F_{A0}X)$$

$$F_B = F_{A0} \left( \Theta_B - \frac{b}{a}X \right)$$

$$F_T = F_{T0} + F_{A0} \cdot \delta \cdot X$$

$$v = v_0 (1 + y_{A0} \delta X) \frac{P_0}{P} \frac{T}{T_0}$$

$$= v_0 (1 + \epsilon X) \frac{P_0}{P} \frac{T}{T_0}$$

$$PV = ZRT$$

$$C_T = \frac{F_T}{v} = \frac{P}{ZRT}$$

$$\epsilon = y_{A0} \delta$$

$$\left( \frac{d}{a} + \frac{c}{a} - \frac{b}{a} - 1 \right) = \delta$$

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$$\Theta_i = \frac{N_{i0}}{N_{A0}} = \frac{C_{i0}}{C_{A0}} = \frac{y_{i0}}{y_{A0}}$$

$$\text{Selectivity}(S_{D/U}) = \frac{r_D}{r_U} = \frac{\text{rate of formation of D}}{\text{rate of formation U}}$$

$$Y_D = \frac{r_D}{-r_A}$$

$$r_{AD} = k_A \left( P_A C_v - \frac{C_{A \cdot S}}{K_A} \right)$$

$$\tilde{Y}_D = \frac{F_D}{F_{A0} - F_A}$$

$$\frac{P_A}{C_{A \cdot S}} = \frac{1}{K_A C_t} + \frac{P_A}{C_t}$$

$$r_A = r_D + r_U$$

$$C_{A \cdot S} = K_A P_A C_v$$

$$r_A = k_D C_A^{\alpha_1} + k_U C_A^{\alpha_2}$$

$$C_{C \cdot S} = \frac{(K_A P_A)^{1/2} C_t}{1 + 2(K_A P_A)^{1/2}}$$

$$S_{D/U} = \frac{r_D}{r_U} = \frac{k_D}{k_U} C_A^{\alpha_1 - \alpha_2}$$

$$S_{D/U} = \frac{r_D}{r_U} = \frac{k_D}{k_U} C_A^{\alpha_1 - \alpha_2} C_B^{\beta_1 - \beta_2}$$

$$C_j = C_{T0} \left( \frac{F_j}{F_T} \right)$$

$$R = 8.314 \text{ kPa} \cdot \text{dm}^3 / \text{mol} \cdot \text{K}$$

$$K = C + 273.16$$

$$R = 1.987 \text{ cal} / \text{mol} \cdot \text{K}$$

$$R = 1.8 \times KR =$$

$$0.73 \text{ ft}^3 \cdot \text{atm} / \text{lbmol} \cdot \text{°R}$$

$$E = 82,000 \text{ cal/gmol}$$