



UNIVERSITI TUN HUSSEIN ONN MALAYSIA

**FINAL EXAMINATION
SEMESTER II
SESSION 2014/2015**

COURSE NAME : CHEMICAL REACTION
ENGINEERING

COURSE CODE : BNQ 20304

PROGRAMME : 2 BNN

EXAMINATION DATE : JUNE 2015 / JULY 2015

DURATION : 3 HOURS

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

THIS QUESTION PAPER CONSISTS OF SEVEN (7) PAGES

- Q1** The following gas-phase decomposition reaction is carried out isothermally in a 24 dm³ constant-volume batch reactor. 30 mols of pure reactant is initially placed in the reactor. The reactor is well mixed. The rate of disappearance of CH₃CHO is 5 mol/dm³.s



- (a) List **THREE (3)** advantages and disadvantages of the batch reactor. (6 marks)
- (b) State the rate of formation of CH₃CHO and the rate of disappearance of CH₄ and CO. (6 marks)
- (c) Determine the time necessary to reduce the number of moles CH₃CHO in the reactor to 0.3 mol if the reaction is first order : (6 marks)
- $$-r_A = kC_A \quad \text{with } \{k\} = 0.844 \text{ min}^{-1}$$
- (d) If the reaction is second order, determine the time necessary to consume 28 mols of CH₃CHO. (7 marks)
- $$-r_A = kC_A^2 \quad \text{with } \{k\} = 3 \text{ dm}^3/\text{mol}\cdot\text{min}$$

- Q2** A gas mixture consists of 50% inert A and 50% inert B at 10 atm (1013 kPa) and enters the reactor with a volumetric flow rate of 6 dm³/s at 300°F (422.2 K).

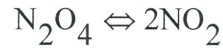
- (a) Calculate the entering concentration of A, C_{A0} and entering molar flow rate, F_{A0}. (4 marks)
- (b) Evaluate the individual reactor volume necessary to achieve 40% conversion in a CSTR and PFR using the data given in Table 1, with the molar flow rate increase up to 300 mol/min.

Table 1

X	0	0.2	0.4	0.5	0.6	0.8	0.9
$-r_A$ (mol/dm ³ .min)	10	16.67	50	50	50	12.5	9.09

- (6 marks)
- (c) Examine the individual reactor volume as well as the total volume when the intermediate conversion is 40% and final conversion is 90% for PFR-CSTR reactor series. (10 marks)
- (d) Predict the maximum conversion that can be achieved in a 10.5 dm³ CSTR. (5 marks)

- Q3** The reversible gas-phase decomposition of nitrogen tetroxide is shown by the reaction below was carried out at constant temperature and pressure. The feed consists of pure N_2O_4 at 340 K and 2 atm.



- (a) Tabulate a stoichiometric table for the reaction in a constant-volume batch reactor. (8 marks)
- (b) Determine the concentration for each species involve in the reaction and express the equilibrium conversion of N_2O_4 in term of concentration. (9 marks)
- (c) Assuming the reaction is elementary, define the rate law and express the reaction rate solely as a function of conversion. (8 marks)

- Q4** Identify the net rate of reaction for each species in each of the following multiple reactions.



- Q5** The overall process by which heterogeneous catalytic reactions proceed can be broken down into the sequence of individual steps.

- (a) Discuss in detail the steps involve in a catalytic reactions. (14 marks)
- (b) Sketch the steps to support your discussion. (11 marks)

- Q6** The elementary gas-phase reaction for the following reaction is carried out isothermally in a flow reactor with no pressure drop. The specific reaction rate at 50 °C is 10^{-4} min^{-1} and the activation energy is 85 kJ/mol. Pure di-*tert*-butyl peroxide enters the reactor at 10 atm and 127 °C and a molar flow rate of 2.5 mol/min.



- (a) Determine **FIVE (5)** assumptions made for the above reaction. (5 marks)
- (b) Calculate the reactor volume to achieve 90% conversion in CSTR reactor. (10 marks)
- (c) Calculate the reactor volume if the above reaction was carried out in PFR reactor at the same conditions. (8 marks)
- (d) Determine the remaining concentration of reactant involve in the above reaction. (2 marks)

- END OF QUESTION -

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

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

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

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

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

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

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

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

$$\frac{(N_A/N_0)}{dt} = \frac{dC_A}{dt}$$

$$\frac{dF_A}{dV} = r_A$$

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

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

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

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

$$V = F_{A0} \int_0^X \frac{dX}{-r_A}$$

$$\int_{X_0}^{X_2} f(X) dX = \frac{h}{3} [f(X_0) + 4f(X_1) + f(X_2)]$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$PV = ZR_T T$$

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

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

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

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

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

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

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

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

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

$$r_A = r_D + r_U$$

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

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

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

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

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

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