University of Technology

Chemical Engineering Department

Mid-Year Examination – Third Class

2014/2015

Subject: Reactor Design

Branch: Chem.Proc.&Oil Ref. Branches

Examiner: Dr. Mohammad Fadhil

Time: 1 1/2 hours

Date : 26/01//2015

Q1)- Component *A* undergoes an irreversible isomerization liquid-phase reaction *A* ⟶ *B*, carried out in a CSTR operated adiabatically to produce 10^6 kg/year of *B* at 97% conversion of A. If the feed stream is to consist of pure *A* entering at 20 °C, determine:

a) Reactor volume.

b) Rate of heat generation.

Additional Data

Rate constant at 20 °C = 0.8 hr^{-1} ; Activation energy = 2900 cal/ mole
Heat of reaction = — 83 cal/g ; Molecular weight of B = Mwt of A = 250 g/gmol
The heat capacities of species *A* and *B* may be assumed to be identical and equal to 0.5 cal/g-°C. Their densities may be assumed to be equal to 0.9 g/cm^3.

(8 Marks)

Q2) Answer one of the following questions (7 Marks)

A- A gas-phase irreversible first order reaction A ⟶ R+S is carried out isothermally in a constant pressure batch reactor with initial conditions of T_o=300K, total pressure = 5 atm. The half-life of the reaction is 2 min measured at 400 K, and the heat capacity of A, R and S are 30, 25, and 20 kcal /kmol. K, respectively. Compute the time required to achieve a conversion 80% of A. The activation energy= 2 kcal/mol. -A

B- A solution of A is to be hydrolyzed with B solution. Two stirred tanks of equal size will be used in series setup. A and B solutions flow separately into the first tank at equal volumetric flow rates each one equal 0.004 m^3/s and with concentrations of 0.02 kmol A/m^3 and 1.0 kmol B/m^3. The reaction is:

A + B ⟶ C, the rate constant (k) = 0.033m^3/kmol.s of the temperature at which both tanks operate. If the required conversion of A is 95%, determine

a) The volume of the tanks needed.

b) The space velocity of the whole system.

Rg = 0.082 atm.lit/gmol.K = 1.987 cal/gmol.K

Answers of Mid-Year Exam. – 3rd Year
2014 – 2015

A1/

1- Use the energy balance eqn. of an adiabatic CSTR to obtain T_1 at a given $X = 0.97$.

$$T_1 = \frac{C_{PA} T_0 + X(-\Delta H_R)}{C_{PA}}$$

2- Apply Arrhenius eqn. to obtain K_1 at T_1

$$\ln \frac{K_1}{K_{293}} = \frac{E}{R}\left[\frac{1}{293} - \frac{1}{T_1}\right]$$

3- Obtain $F_{A0} = \frac{F_B}{X}$; and $m_A = F_{A0} * Mwt_A$

and $V_0 = \frac{m_A}{\rho}$

4- $$V = \frac{V_0 X}{K_1 (1 - X)}$$

5- Rate of heat generation = Rate of heat released by reaction

$$= -(-r_A) V (-\Delta H_R)$$

$$= -F_{A0} X (-\Delta H_R)$$

A2/ (A)

1- Obtain K (at 400 K) by using the formula of the half-life of 1st order reaction

$$t_{1/2} = \frac{\ln 2}{K}$$

2- Obtain K (at 300 K) by applying Arrhenius eqn.

$$\ln \frac{K_{400}}{K_{300}} = \frac{E}{R}\left[\frac{1}{300} - \frac{1}{400}\right]$$

3- Determine the reaction time in a constant volume batch reactor at 300 K

$$t = \frac{1}{K}\int_0^{0.8} \frac{dX}{(1-X)(1+X)} \quad ; \quad \varepsilon = y_{A0}\,\delta = 1\,(2-1) = 1$$

A2/(B)

(1) Set the reaction rate law:

$$(-r_A) = K C_A C_B = K C_{A0}(1-x)\, C_{A0}\left(\frac{C_{B0}}{C_{A0}} - x\right) \quad \text{--- (1)}$$

(2) The initial concentrations of A & B at reaction conditions,

$$C_{A0} = 0.02 * \frac{0.004}{0.008} = 0.01 \quad \text{Kmol } A/m^3$$

$$C_{B0} = 1 \times \frac{0.004}{0.008} = 0.5 \quad \text{Kmol } B/m^3$$

(3) Set material balance eqns. for CSTR1 and CSTR2 to obtain,

$$V_1 = \frac{v_0 C_{A0} X_1}{K C_{A0}^2 \left[(1-X_1)\left(\frac{C_{B0}}{C_{A0}} - X_1\right)\right]} \quad \text{---- (2)}$$

$$V_2 = \frac{v_0 C_{A0} (X_2 - X_1)}{K C_{A0}^2 \left[(1-X_2)\left(\frac{C_{B0}}{C_{A0}} - X_2\right)\right]} \quad \text{--- (3)}$$

(4) Equating eqn (1) and (2)

$$V_1 = V_2$$

$$\frac{X_1}{(1-X_1)(50-X_1)} = \frac{(0.95 - X_1)}{(1-0.95)(50-0.95)}$$

(5) A third order eqn in X_1 is obtained which is solved to obtain X_1

(6) X_1 is substituted in eqn (2) or (3) to obtain V_1 or V_2

(7) Space velocity of the whole system $= \dfrac{v_0}{V_1 + V_2}$