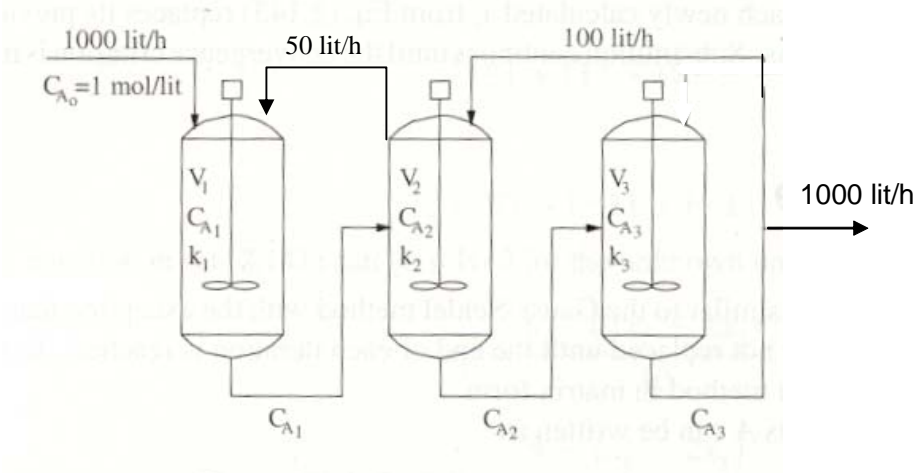


# ChE 400 Applied Chemical Engineering Calculations

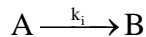
## LAE and Non LAE: Proposed Problems

### 1. Series of continuous stirred tank reactors:

A chemical reaction takes place in a series of three continuous stirred tank reactors arranged as shown in the figure.



The chemical reaction is a first-order irreversible reaction of the type:

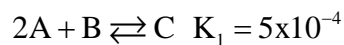


The conditions of temperature in each reactor are such that the value of the rate constant  $k_i$  is different in each reactor. Also, the volume of each reactor  $V_i$  is different. The values of  $k_i$  and  $V_i$  are given below. Calculate the concentration of A in each of the reactors. Use the method of your choice to solve the equations.

Reactor	$V_i$ (L)	$k_i$ ( $h^{-1}$ )	Reactor	$V_i$ (L)	$k_i$ ( $h^{-1}$ )
1	1000	0.1	3	100	0.4
2	1500	0.2			

2. Solve Problem 1 but considering that the reaction is second order.

3. **Chemical Equilibrium.** Determine the equilibrium conversion of the following reactions



the initial concentrations are:  $C_{A,0} = 40$   $C_{B,0} = 15$   $C_{C,0} = 0$   $C_{D,0} = 10$

All concentrations are in  $kmol/m^3$ .

4. The elementary reaction (elementary reaction means that the stoichiometry of the reaction dictates the order of the reaction rate)  $A \rightarrow B + C$  is carried out in a continuous stirred tank reactor. Pure A enters the reactor at a flow rate of 12 mol/s and a temperature of 25 °C. The reaction is exothermic and cooling water at 50 °C is used to absorb the heat generated. The energy balance for this system, assuming constant heat capacity and equal heat capacity of both sides of the reaction can be written as:

$$-F_{A0}X\Delta H_R = F_{A0}C_{pA}(T - T_0) + UA(T - T_a)$$

where

$F_{A0}$  = molar flow rate, mol/s

X = conversion

$\Delta H_R$  = heat of reaction, J/mol A

$C_{pA}$  = heat capacity of A, J/mol K

T = reactor temperature, °C

$T_0$  = reference temperature, 25°C

$T_a$  = cooling water temperature, 20°C

U = overall heat transfer coefficient, W/m<sup>2</sup>K

A = heat transfer area, m<sup>2</sup>

For a first order reaction the conversion can be calculated from

$$X = \frac{\tau k}{1 + \tau k}$$

where  $\tau$  is the residence time of the reactor in seconds and k is the specific reaction rate in s<sup>-1</sup> defined by the Arrhenius formula:

$$k = 650 \exp\left[-3800/(T + 273)\right]$$

Solve the energy balance equation for temperature and find the steady state operating temperature of the reactor and the conversions corresponding to these temperatures. Additional data are:

$$\Delta H_R = -1500 \text{ kJ/mol}, \tau = 10 \text{ s}, C_{pA} = 4500 \text{ J/molK},$$

$$UA/F_{A0} = 700 \text{ W s/mol K}$$

5. **Separation Train.** Paraxylene, styrene, toluene, and benzene are to be separated with the array of distillation columns shown in the figure. Calculate the molar flow rates: D, B, D<sub>1</sub>, B<sub>1</sub>, D<sub>2</sub>, and B<sub>2</sub>.

