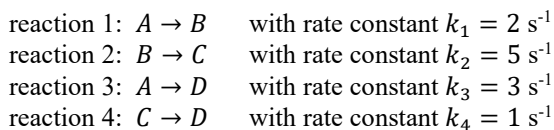


Exam III
Administered: Monday, November 2, 2020
22 points

For each problem part: 0 points if not attempted or no work shown,
 1 point for partial credit, if work is shown,
 2 points for correct numerical value of solution

Problem 1. (12 points)

Consider an isothermal flow reactor with a volume, $V = 10$ liters, in which the following set of elementary reactions take place



The inlet flow rates are given by

$$F_{A,in} = F_{B,in} = 2 \frac{\text{mole}}{\ell \cdot \text{s}} \quad \text{and} \quad F_{C,in} = F_{D,in} = 0 \frac{\text{mole}}{\ell \cdot \text{s}}$$

The outlet flow rates are given by

$$F_{A,out} = \hat{F}_{out} C_A, F_{B,out} = \hat{F}_{out} C_B, F_{C,out} = \hat{F}_{out} C_C \text{ and } F_{D,out} = \hat{F}_{out} C_D \frac{\text{mole}}{\ell \cdot \text{s}}$$

where $\hat{F}_{out} = 4 \text{ s}^{-1}$ and concentrations are measured in moles/liter.

The steady state mass balances are

accumulation = in – out + generation – consumption

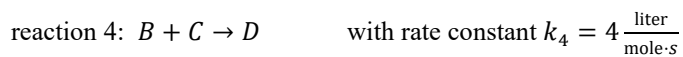
$$\begin{aligned} 0 &= F_{A,in} - \hat{F}_{out} C_A - k_1 C_A - k_3 C_A \\ 0 &= F_{B,in} - \hat{F}_{out} C_B + k_1 C_A - k_2 C_B \\ 0 &= F_{C,in} - \hat{F}_{out} C_C + k_2 C_B - k_4 C_C \\ 0 &= F_{D,in} - \hat{F}_{out} C_D + k_3 C_A + k_4 C_C \end{aligned}$$

- (a) Write this set of equations in matrix notation, $\underline{Ax} = \underline{b}$. Identify all three quantities, $\underline{A}$, $\underline{x}$ and $\underline{b}$.
- (b) Calculate the determinant of $\underline{A}$.
- (c) Calculate the rank of $\underline{A}$.
- (d) Calculate the rank of $\underline{A}|\underline{b}$.
- (e) How many solutions are there to this problem?
- (f) Calculate the steady state concentrations of A, B, C and D in this reactor under these conditions.

(over)

Problem 2. (10 points)

If we rework problem 1 with the single change that we replace reaction 4 with



Then the steady state mass balances become

accumulation = in – out + generation -consumption

$$0 = F_{A,in} - \hat{F}_{out} C_A - k_1 C_A - k_3 C_A$$

$$0 = F_{B,in} - \hat{F}_{out} C_B + k_1 C_A - k_2 C_B - k_4 C_C C_B$$

$$0 = F_{C,in} - \hat{F}_{out} C_C + k_2 C_B - k_4 C_C C_B$$

$$0 = F_{D,in} - \hat{F}_{out} C_D + k_3 C_A + k_4 C_C C_B$$

- Is this system of equation linear or nonlinear?
- What numerical technique is appropriate for solving this problem?
- Solve for the steady state concentrations. (6 points)