Chapter 2 Problem A1

For the 2nd order aqueous reaction, \( V = \text{const} \), \( -R_A = kC_A^2 \). For the batch reactor,

\[
t = \int_{C_A}^{C_{A0}} \frac{dC_A}{(-R_A)} = \frac{1}{k} \int_{C_A}^{C_{A0}} \frac{dC_A}{kC_A^2} = \frac{1}{k} \left( \frac{1}{C_A} - \frac{1}{C_{A0}} \right)
\]

\( t = 1 \text{min} \), \( C_{A0} = 2.03M \), \( C_A = 1.97M \), then \( k \) is

\[
k = \frac{1}{t} \left( \frac{1}{C_A} - \frac{1}{C_{A0}} \right) = \frac{1}{1.97 - \frac{1}{2.03}} = 0.015M^{-1} \text{ min}^{-1}
\]

Thus the rate equation is

\[
-R_A = kC_A^2 \quad \Rightarrow \quad k = 0.015M^{-1} \text{ min}^{-1}
\]

Chapter 2 Problem E13

Let \( A \) represent for Kr-89, which has the 1st order reaction:

\[
-R_A = kC_A
\]

For a constant volume batch reactor (the ampoule),

\[
t = \int_{C_A}^{C_{A0}} \frac{dC_A}{(-R_A)} = \frac{1}{k} \int_{C_A}^{C_{A0}} \frac{dC_A}{kC_A} = \frac{1}{k} \ln \frac{C_{A0}}{C_A}
\]

Then the half life is

\[
t_{1/2} = \frac{1}{k} \ln 2 = 76 \text{ min}
\]

, by which we can calculate the rate constant:

\[
k = \frac{\ln 2}{t_{1/2}} = 0.009 \text{ min}^{-1}
\]

After 1 day (\( t = 24hr = 1440 \text{ min} \)),

\[
\frac{C_A}{C_{A0}} = \exp(-kt) = 0.0002%
\]

We can see that only 0.0002% of Kr-89 can be left after 1 day.
Chapter 2 Problem E15

\[
-R_A = \frac{200C_A C_E}{2 + C_A} = \frac{200C_A \times 0.001}{2 + C_A} = 0.2C_A
\]

For a constant volume batch reactor,

\[
t = -\int_{C_{A0}}^{C_A} \frac{dC_A}{-R_A} = -\int_{C_{A0}}^{C_A} \frac{2 + C_A}{0.2C_A} dC_A
\]

\[= 10 \ln \frac{C_{A0}}{C_A} + 5(C_{A0} - C_A) = 109.8 \text{ min}
\]

, where \(C_{A0} = 10M\) and \(C_A = 0.025M\).

Chapter 3 Problem D11

Assume constant density for this aqueous reaction in PFR. Then

\[
\tau = C_{A0} \int_0^{X_{Af}} \frac{dX_A}{(-R_A)} = C_{A0} \int_0^{X_{Af}} \frac{dX_A}{200C_A C_B}
\]

\[
= \frac{1}{200C_{A0}} \int_0^{X_{Af}} \frac{dX_A}{(1 - X_A)(M - X_A)}
\]

\[
= \frac{1}{200C_{A0}} \cdot \frac{1}{M - 1} \int_0^{X_{Af}} \left( \frac{1}{1 - X_A} - \frac{1}{M - X_A} \right) dX_A
\]

\[
= \frac{1}{200C_{A0}} \cdot \frac{1}{M - 1} \left( \ln \frac{1}{1 - X_{Af}} - \ln \frac{1}{M - X_{Af}} + \ln \frac{1}{M} \right)
\]

\[
= \frac{1}{200C_{A0}} \cdot \frac{1}{M - 1} \ln \frac{M - X_{Af}}{M(1 - X_{Af})}
\]

, where

\(C_{A0} = 100 \text{ mmol / lit} = 0.1 \text{ mol / lit}\)

\[M = \frac{C_{B0}}{C_{A0}} = \frac{200}{100} = 2\]

\[X_{Af} = 99.9\% = 0.999\]

Then

\[2\]
\[ \tau = \frac{1}{200C_{A0}} \frac{1}{M - 1} \ln \frac{M - X_{Af}}{M (1 - X_{Af})} \]

\[ = \frac{1}{200 \times 0.1} \times \frac{1}{2 - 1} \times \ln \frac{2 - 0.999}{2 \times (1 - 0.999)} = 0.31 \text{min} \]

Then the volume of the reactor is

\[ V = v_0 \tau = 400 \times 0.31 = 124 \text{lit} \]

Chapter 3 Problem H29
\[ \sqrt{3}, \text{H}_2 \text{A} \]

\[ 2 \text{A} \xrightleftharpoons{\text{K}_1} \text{R} \]

\[ \text{K}_1 = 2 \text{ mole} / \text{L} \cdot \text{hr} \cdot \text{atm}^{-1} \]

\[ @ 946^\circ \text{C} = 1219 \text{ K} \]

\[ \text{K}_p = 1 \text{ atm} \] @ equilibrium

\[ \text{find equilibrium} \quad \text{X}_A = ? \]

\[ \text{After} \quad \text{X}_A = 50\% \]

\[ \text{F}_{\text{in}} = 10 \text{ kmol/hr} \] @ 10 atm

\[ \text{V} = ? \]

\[ \text{K}_p = \frac{\text{K}_1}{\text{K}_2} \]

\[ \text{K}_2 = \frac{\text{K}_1}{\text{K}_p} = \frac{2 \text{ mole} / \text{L} \cdot \text{hr} \cdot \text{atm}^{-1}}{1 \text{ atm}} = 2 \text{ mole} / \text{L} \cdot \text{hr} \cdot \text{atm} \]

\[ K = \frac{K_1 P_A - K_2 P_R}{2} \]

\[ \text{in PPR} \]

\[ P \cdot V = F \cdot T + \frac{R \cdot T}{V} \]

\[ \dot{V} = \dot{V}_0 (1 + \text{X}_A \text{X}_0) \]

\[ \text{CA} = \frac{F}{\dot{V}} = \frac{C_{\text{A}_0}}{1 + \text{X}_0 \text{X}_0} \]

\[ \text{P} = \text{C}_{\text{A} \cdot \text{RT}} = \frac{C_{\text{A}_0}}{1 + \text{X}_0 \text{X}_0} \cdot RT \]

\[ \text{P}_R = \text{C}_{\text{R} \cdot \text{RT}} = \frac{\frac{C_{\text{A}_0} \text{X}_0}{1 + \text{X}_0 \text{X}_0}}{1 + \text{X}_0 \text{X}_0} \cdot RT \]

\[ \frac{\text{RA}}{\text{X}_0} = \frac{K_1 \text{C}_A^2 - K_2 \text{C}_R}{1 + \text{X}_0 \text{X}_0} = \frac{K_1 \text{C}_A^2}{1 + \text{X}_0 \text{X}_0} \]

\[ \text{K}_1 \text{C}_A^2 = \text{K}_1 \text{C}_A^2 \]

\[ \text{K}_1 \text{C}_A^2 \text{X}_0 = \text{K}_1 \text{C}_A^2 \text{X}_0 \]

\[ \text{K}_0 = \text{K}_1 \text{C}_A^2 \text{X}_0 \]

\[ \text{K}_0 = \frac{2 \text{ mole} / \text{L} \cdot \text{hr} \cdot \text{atm}^{-1}}{0.1 \text{ atm}} = 20000 \text{ L/mol/hr} \]

\[ \text{C}_{\text{A}_0} = \frac{\text{P}_0 \cdot \text{RT}}{\text{F} \cdot \text{atm}} = \frac{0.1 \text{ atm} \cdot \text{L} / \text{mol} \cdot \text{K}}{1219 \text{ K}} = 0.1 \text{ mol/L} \]

\[ \text{K}_{\text{C}} = \frac{\text{K}_1 \text{C}_A^2}{\text{K}_0} = \frac{20000 \text{ L/mol/hr}}{1 \text{ atm}^{-1}} = 20000 \text{ L/hr} \]

\[ \frac{\text{V}}{\text{F}_{\text{in}}} = \int_0^\infty \frac{\text{X}_A \text{dX}_A}{1 - \text{X}_A} = \int_0^\infty \frac{\text{X}_A \text{dX}_A}{2 (K_1 \text{P}^2 - K_2 \text{P}_R)} \]

\[ \text{V} = \text{F}_{\text{in}} \left[ \frac{\text{X}_A \text{dX}_A}{2 (K_1 \text{P}^2 - K_2 \text{P}_R)} \right] = \text{F}_{\text{in}} \left( \frac{\text{K}_1 \text{C}_A^2}{1 + \text{X}_0 \text{X}_0} \right) \]

\[ \text{V} = \frac{\text{F}_{\text{in}}}{2} \left[ \frac{\text{X}_A \text{dX}_A}{2 (K_1 \text{P}^2 - K_2 \text{P}_R)} \right] = \frac{\text{F}_{\text{in}}}{2} \left[ \frac{\text{K}_1 \text{C}_A^2}{1 + \text{X}_0 \text{X}_0} \right] \]

\[ \int_0^{0.5} \frac{\text{dX}_A}{2 \text{ atm}^{-1} (1 \text{ atm} \cdot \text{L} / \text{mol} \cdot \text{hr})} = \int_0^{0.5} \frac{\text{dX}_A}{\text{L} / \text{hr} \cdot 1 - \text{X}_A} = \int_0^{0.5} \frac{\text{dX}_A}{\text{L} / \text{hr} \cdot 1 - \text{X}_A} = \int_0^{0.5} \frac{\text{dX}_A}{0.0055} = 32.7 \text{L} \]

\text{Equilibrium rate} \quad \text{K}_1 \text{C}_A^2 = \text{K}_0 \text{C}_R 

\[ \text{K}_0 \left( \frac{\text{X}_A (1 - \text{X}_A)}{1 - \hat{\text{X}}_A} \right)^2 = \text{K}_2 \text{C}_R \text{X}_0 \left( \frac{1 - \hat{\text{X}}_A}{1 - \text{X}_A} \right)^2 \]

\[ \int_0^{20000} \left( \frac{\text{X}_A (1 - \text{X}_A)}{1 - \hat{\text{X}}_A} \right)^2 = 200 \left( \frac{\pm \text{X}_0 (1 - \text{X}_A)}{1 - \hat{\text{X}}_A} \right) \]
Chapter 4 Problem C11

For the aqueous reaction, assume constant density in CSTR:

$$\tau = \frac{V}{v_0} = \frac{C_{A0}X_A}{-R_A} = \frac{C_{A0}X_A}{kC_A^{1.5}}$$

$$= \frac{C_{A0}X_A}{kC_{A0}^{1.5}(1-X_A)^{1.5}}$$

$$= \frac{1}{kC_{A0}^{0.5}} \cdot \frac{X_A}{(1-X_A)^{1.5}}$$

Since $C_{A0}$ and $v_0$ remains same,

$$\frac{X_A}{(1-X_A)^{1.5}} \propto V$$

After doubling the volume,

$$\frac{X_A}{(1-X_A)^{1.5}} = 2 \cdot \frac{70\%}{(1-70\%)^{1.5}} = 8.52$$

Solving this equation yields

$$X_A = 79.44\%$$

---

Chapter 4 Problem G25
4. G35

\[ b = \text{const.} \quad \text{decomposition} \quad \text{keep } C_A \text{exit constant} \quad \text{MPR} \]

<table>
<thead>
<tr>
<th>T/°C</th>
<th>19</th>
<th>27</th>
<th>31</th>
<th>37</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ b \text{ arbitrary} ]</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

\[ \frac{V}{V_0} = \frac{C_{A_0} - C_A}{C_{A_0} - C_A} = \frac{C_{A_0} - C_A}{k_A e^{-E/RT}} \]

\[ e^{-E/RT} = \frac{C_{A_0} - C_A}{k_A e^{E/RT}} \]

\[ \frac{e^{-E/RT}}{V_0} = \text{const.} \]

\[ e^{-E/RT} = k_A e^{E/RT} \]

\[ -E/RT = \ln C_i + \ln V_0 \]

\[ \ln V_0 = -\ln C_i - \frac{E}{R} \frac{1}{T} \]

Plot \( \ln V_0 \times \frac{1}{T} \) on Excel:

\[ y = -8132.9x + 27.878 \]

Gradient: \[ -\frac{E}{R} = -8132.9 \]

\[ E = 8132.9 \cdot 8.314 \cdot 5 \approx 67617 \text{ J/mol} \]

6. A7

\[ h_{1,2} = m_2, E_2, \quad \rho \leq E_3 \quad \text{low temperature is favored} \]

\[ k = k_3 e^{-E/RT} \]

\[ A \times S \]

| 1.15 | 2.35 | 0.25 |

\[ R_{r} = k_1 C_A \quad \rho = k_2 C_A \quad R_T = k_3 \]

\[ h_3 < h_1 < h_2 \quad \text{intermediate concentration} \]

\[ \text{use CSTR} \]

(?)
Chapter 5 Problem A11

For the constant density PFR with recycle ratio $R$, 

$$\frac{V}{F_A} = (R+1) \int_{\frac{R}{(R+1)}}^{X_f} \frac{dX_A}{kC_{A0}(1-X_A)}$$

$$= (R+1) \left[ \frac{1}{kC_{A0}} \ln \frac{1}{1-X_A} \right]_{\frac{R}{(R+1)}}^{X_f}$$

$$= \frac{1}{kC_{A0}} \left[ (R+1) \ln \frac{1}{1-X_A} \right]_{\frac{R}{(R+1)}}^{X_f}$$

Now $R=2$ and $X_{Af} = 90\%$.

$$\left( \frac{V}{F_A} \right)_{R=2} = \frac{1}{kC_{A0}} \left( 3 \ln \frac{1}{1-X_A} \right)_{0.5}^{0.9} = \frac{1}{kC_{A0}} \cdot 3 \ln 4 = \frac{1}{kC_{A0}} \cdot \ln 64$$

After shutting off the recycle stream, $R = 0$ and $X_{Af} = 90\%$.

$$\left( \frac{V}{F_A} \right)_{R=0} = \frac{1}{kC_{A0}} \left( \ln \frac{1}{1-X_A} \right)_0^{0.9} = \frac{1}{kC_{A0}} \cdot \ln 10$$

If $V$ remains the same, then

$$\frac{\ln 64}{\ln 10} = 1.553\]$$

Thus shutting off the recycle stream will increase the processing rate of feed by $80.6\%$.

Chapter 6 Problem A11

Since the desired product is the last product of the series, it’s always better to choose mixed flow reactor. Also, since $n_1 < n_2$ and $n_3 < n_4$, mixed flow reactor works even more effectively. Since $E_1 > E_2$ and $E_3 > E_4$, high temperature favors the formation of $R$ and $S_{desired}$. 
Chapter 6 Problem B33

It is equivalent to

For the series reactions, it is always better to choose plug flow reactor, and high $C_A$ with front entry of $A$. For the parallel reactions, since $n_2 = n_4$, it doesn't make difference for high $C_B$ or low $C_B$. Although $B$ can be added in any way, side entry of $B$ keeps $C_A$ as high as possible which is desirable.

Chapter 7 Problem B27

$$A + 2B \rightarrow R$$
$$A + B \rightarrow S$$

$$-R_A = k_1 C_A C_B^2 + k_2 C_A C_B$$
$$-R_B = 2k_3 C_A C_B^2 + k_2 C_A C_B$$

$$\varphi(R/B) = \frac{R_A}{-R_B} = \frac{k_1 C_A C_B^2}{2k_1 C_A C_B^2 + k_2 C_A C_B} = \frac{C_B}{2C_B + k_2 / k_1}$$

$$C_{Bf} = \varphi_f \left( C_{Bf} - C_{B0} \right) = \frac{C_{Bf}}{2C_{Bf} + k_2 / k_1} \left( C_{B0} - C_{Bf} \right)$$

$$C_{A0} = C_{B0} = 1, C_{Bf} = C_{Bf} = 0.2$$

$$0.2 = \frac{0.2}{2 \times 0.2 + k_2 / k_1} \times (1 - 0.2)$$

$$k_2 / k_1 = 0.4$$
\[ \varphi(R/A) = \frac{R_g}{-R_A} = \frac{k_1 C_A C_B^2}{k_1 C_A C_B^2 + k_2 C_A C_B} = \frac{C_B}{C_B + k_2 / k_1} \]

\[ C_{af} = \varphi_f(C_{a0} - C_{af}) = \frac{C_{bf}}{C_{bf} + k_2 / k_1} (C_{a0} - C_{af}) \]

\[ 0.2 = \frac{0.2}{0.2 + 0.4} (1 - C_{af}) \]

\[ C_{af} = 0.4 \]

\[ X_{af} = \frac{C_{a0} - C_{af}}{C_{a0}} = \frac{1 - 0.4}{1} = 0.6 \]

\[ \tau = \frac{V}{v_0} = \frac{C_{a0} X_{af}}{-R_A} = \frac{C_{a0} X_{af}}{k_1 C_A C_B^2 + k_2 C_A C_B} \]

\[ \frac{1}{12} = \frac{1 \times 0.6}{k_1 \times 0.4 \times 0.2^2 + k_2 \times 0.4 \times 0.2} \]

\[ 0.2k_1 + k_2 = 90 \]

\[ \frac{k_2}{k_1} = 0.4 \]

\[ k_1 = 150 \text{lit}^2 \text{mol}^{-2} \text{hr}^{-1} \]
\[ k_2 = 60 \text{lit} \text{mol}^{-1} \text{hr}^{-1} \]

To sum up, the kinetics of the above reaction is:

\[ R_g = k_1 C_A C_B^2, \quad k_1 = 150 \text{lit}^2 \text{mol}^{-2} \text{hr}^{-1} \]
\[ R_s = k_2 C_A C_B, \quad k_2 = 60 \text{lit} \text{mol}^{-1} \text{hr}^{-1} \]

**Chapter 7 Problem D33**

Income by selling R:

\[ \varphi(R/A) = \frac{R_g}{-R_A} = \frac{k_1 C_A}{k_1 C_A + k_2 C_A} = \frac{k_1}{k_1 + k_2} = \frac{2}{3} \]

\[ C_{bf} = \varphi_f(C_{a0} - C_{af}) = \frac{2}{3} C_{a0} X_{af} \]
\[ F_{rf} = \frac{2}{3} F_{A0} X_{Af} = \frac{2}{3} \times 600 X_{Af} = 400 X_{Af} \text{ (mol/hr)} \]

Income$_r$ = 1$\times$ F$_{rf}$ = 400$X_{Af}$ ($\$$/hr)

Cost by buying A:

Cost$_A$ = 0.2$\times$ F$_{A0}$ = 120 ($\$$/hr)

Cost of reactor and R-separator:

\[ \tau = \frac{V}{v_0} = \frac{C_{A0} X_{Af}}{-R_A} = \frac{C_{A0} X_{Af}}{(k_1 + k_2) C_A} = \frac{1}{k_1 + k_2} \cdot \frac{X_{Af}}{1 - X_{Af}} \]

\[ V = \frac{v_0}{k_1 + k_2} \cdot \frac{X_{Af}}{1 - X_{Af}} \]

\[ v_0 = F_{A0} / C_{A0} = 600 \text{lit/hr} \]

\[ V = \frac{600 \cdot X_{Af}}{2 + 1} \cdot \frac{1}{1 - X_{Af}} = 200 \left( \frac{1}{1 - X_{Af}} - 1 \right) \]

Cost$_{reactor}$ = 0.1$\times$ V = \left( \frac{20}{1 - X_{Af}} - 20 \right) ($\$$/hr)

Cost of operation:

\[ \text{Cost$_{operation}$} = 1 \times \frac{v_0}{7.5} = 80 ($\$$/hr) \]

To sum up, the net profit is

\[ \text{profit} = \text{Income}_r - \text{Cost}_A - \text{Cost}_{reactor} - \text{Cost}_{operation} \]

\[ = 400 X_{Af} - 120 - \left( \frac{20}{1 - X_{Af}} - 20 \right) - 80 \]

\[ = \left( 400 X_{Af} - \frac{20}{1 - X_{Af}} - 180 \right) ($\$$/hr) \]

To get the maximum profit, just equate the derivative with 0:

\[ \frac{d}{dX_{Af}} \text{profit} = 400 - 20 \frac{1}{(1 - X_{Af})^2} = 0 \]

\[ (X_{Af})_{\text{opt}} = 1 - \sqrt{0.05} = 0.7764 = 77.64\% \]

\[ (\text{profit})_{\text{max}} = 400 X_{Af} - \frac{20}{1 - X_{Af}} - 180 = 41.1 ($\$$/hr) \]

\[ V = 6 \text{lit} < ? \]
Chapter 8 Problem A3

A---ergosterol
R---active form of vitamin D
S---inactive form of vitamin D

In the given process, the conversion of A is high, but the selectivity of the desired product R is low. The main reason is that for a series reaction, back-mixing causes the intermediate product to overreact. So the way to improve the process is to eliminate the back-mixing of the irradiated stream.

In the given process, it’s good to use just a small stream for reaction. This is close to plug flow, which favors the formation of the intermediate product R. However, it’s not good to let the irradiated stream go back to the vat, because this will cause serious mixing. Instead, I recommend that the reacted stream flows to the separator for separation of R+S from A, then the fluid rich of A flows back to the vat. In this way, mixing effect is reduced, and thus the selectivity of R will increase.

Chapter 8 Problem B5

A+B→R+H
R+B→S+H

A---C₆H₅NH₂
B---C₂H₅OH
R---C₆H₅NH₂C₂H₅
S---C₆H₅N(C₂H₅)₂
H---H₂O

(a) In the batch reactor,

\[
\begin{align*}
C_{A0} &= C_{B0} \\
C_B &= 0 \\
\frac{-\Delta C_R}{C_{A0}} &= \frac{C_{B0} - C_R}{C_{A0}} = 1.0 \\
\frac{k_2}{k_1} &= \frac{1}{1.25} = 0.8
\end{align*}
\]

According to the chart in Chapter 8.10 in Omnibook, we can find

\[
\frac{C_R}{C_{A0}} = 0.4
\]

Stop at \( t = 13 \text{ hr} \)
Thus

\[ C_A = 0.3C_{A0} \]
\[ C_R = 0.4C_{A0} \]

According to the material balance,

\[ (-\Delta C_A) = \Delta C_R + \Delta C_S = C_R + C_S \]
\[ 0.7C_{A0} = 0.4C_{A0} + C_S \]
\[ C_S = 0.3C_{A0} \]

To sum up,

\[
\begin{align*}
C_A &= 0.3C_{A0} \\
C_B &= 0 \\
C_R &= 0.4C_{A0} \\
C_S &= 0.3C_{A0}
\end{align*}
\]

(b) In the mixed flow reactor,

\[
\frac{k_2}{k_1} = 0.8 \\
C_{B0} = 2C_{A0} \\
X_B = 70\%
\]

\[
C_B = (1 - X_B)C_{A0} = 0.3C_{B0} = 0.6C_{A0}
\]

\[
\frac{-\Delta C_B}{C_{A0}} = \frac{2C_{A0} - 0.6C_{A0}}{C_{A0}} = 1.4
\]

According to the chart in Chapter 8.12 in Omnibook, we can find

\[
X_A = 1 - \frac{C_A}{C_{A0}} = 0.8 \\
\frac{C_R}{C_{A0}} \approx 0.2
\]

Thus

\[ C_A = 0.2C_{A0} \]
\[ C_R = 0.2C_{A0} \]

According to the material balance,

\[ (-\Delta C_A) = \Delta C_R + \Delta C_S = C_R + C_S \]
\[ 0.8C_{A0} = 0.2C_{A0} + C_S \]
\[ C_S = 0.6C_{A0} \]

To sum up,

\[
\begin{align*}
C_A &= 0.2C_{A0} \\
C_B &= 0.6C_{A0} \\
C_R &= 0.2C_{A0} \\
C_S &= 0.6C_{A0}
\end{align*}
\]

Then the ratio of mono- to diethylaniline is
(c) In the plug flow reactor,

\[ C_{A0} = C_{B0} \]
\[ K_2 = k_2 / k_1 = 0.8 \]
\[ \left| \frac{C_R}{C_{A0}} \right|_{\text{max}} = K_2^{1 - K_2} = 0.4096 \]
\[ \left| \frac{C_S}{C_{A0}} \right|_{\text{max}} = 1 - K_2^{1 - K_2} - K_2^{1 - K_2} = 0.2627 \]

So

\[ C_R = 0.4096 C_{A0} \]
\[ C_S = 0.2627 C_{A0} \]

According to the material balance,

\[ (-\Delta C_A) = \Delta C_R + \Delta C_S = C_R + C_S = 0.6723 C_{A0} \]
\[ (-\Delta C_B) = 2\Delta C_S = C_R + 2C_S = 0.935 C_{A0} \]

Thus

\[ X_A = 67.23\% \]
\[ X_B = 93.5\% \]