10.1 For the 4 schemes: G, N, N, Good ◄

10.3 Here we have: N, N, N, G ◄

10.5 a) We should operate at the maximum allowable temperature when

$$E_1 > E_2 \text{ and } E_1 > E_3 \quad \text{◄ a)}$$

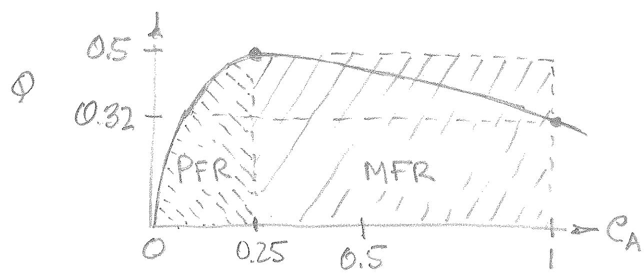
b) We should have a falling temperature when

$$E_1 > E_3 \text{ and } E_1 < E_2 \quad \text{◄ b)}$$

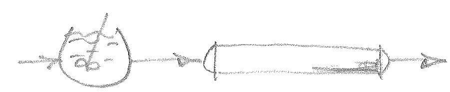
10.7 From Example 1

$$\varphi(S/A) = \frac{0.2C_A}{0.025 + 0.2C_A + 0.4C_A^2}, \text{ and } \begin{cases} C_A = 0.25 \\ C_S = 0.375 \\ \varphi_{max} = \dfrac{0.375}{1-0.25} = 0.5 \end{cases}$$

The φ vs C_A curve is



so use MFR followed by PFR



For MFR: $C_{Sm} = \varphi(C_{A0} - C_A) = 0.5(1-0.25) = 0.375$

For PFR: $C_{Sp} = \int \varphi \, dC_A = \int \frac{8C_A \, dC_A}{1 + 8C_A + 16C_A^2} = 8\int_0^{0.25} \frac{C_A}{(1+4C_A)^2} dC_A$

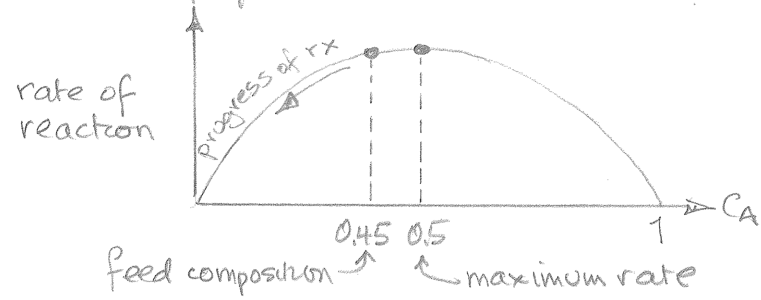
But from a table of integrals: $\int_1^2 \frac{x}{(a+bx)^2} dx = \frac{a}{b^2(a+bx)} + \frac{1}{b^2} \ln(a+bx) \Big|_1^2$

So

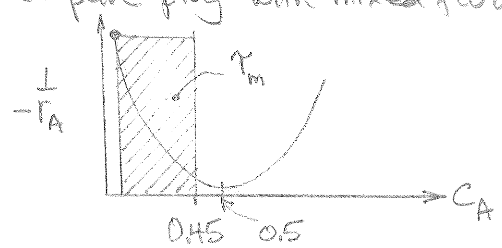
$$C_{Sp} = \left[\frac{1}{16} \cdot \frac{1}{1+4x} + \frac{1}{16} \ln(1+4x)\right]_0^{0.25} = \frac{1}{2}\left[\frac{1}{2} + \ln 2 - 1\right] = 0.0966$$

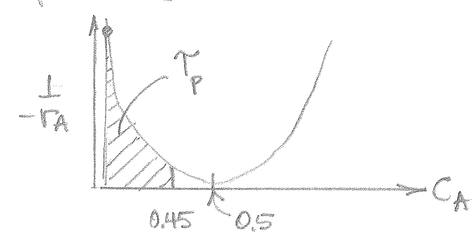
$$\therefore C_{S\,total} = C_{Sm} + C_{Sp} = 0.375 + 0.0966 = 0.4716 \quad ◄$$

10.9 Since $C_A + C_B = 1$ for all C_A the maximum rate is at $C_A = C_B = 0.5$ Check this if you don't believe it. Thus



Compare plug with mixed flow performance





Plug flow is best. Do not use recycle as recommended in Fig P9

10.11

$$A \xrightarrow{n=2} R \longrightarrow S \qquad A \xrightarrow{n=1} T \qquad R \longrightarrow U$$

$C_{A0} = 6$
$C_{R0} = 0.6$
$C_{T0} = 0$

The feed has $C_R/C_T = \infty$.

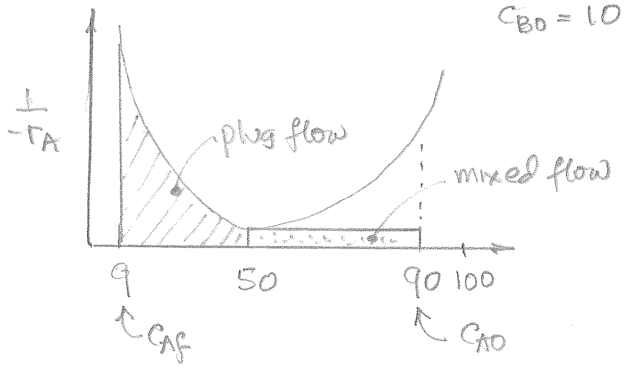
(a) So to maximize C_R/C_T do not react at all. The design of Fig P11 is no good. — a)

(b) To minimize C_R/C_T run to completion. All the R will disappear. — b)

Next reaction 1 is second order, reaction 2 is first order $\}$ keep C_A low

So use a large MFR, you will end up with most C_T — b)

10.13 $A+B \longrightarrow B+B \qquad -r_A = kC_AC_B \qquad C_{A0}=90 \quad C_{B0}=10 \qquad C_{Af}=9 \quad C_{Bf}=91$



Use a MFR followed by a PFR ⟵

10.15 Since $E_1 > E_2$ use a high temperature, or $T = 90°C$

at $90°C = 363K \qquad k_1 = 30\, e^{-20000/8.314(363)} = 0.0397\ \text{min}^{-1}$

$$k_2 = 1.9\, e^{-15000/8.314(363)} = 0.0132\ \text{min}^{-1}$$

$\therefore\ k_2/k_1 = 0.3322$

From Fig 8.13 or Eqs 8.8 & 8.9 $\qquad \dfrac{C_{R\,max}}{C_{A0}} = 0.58$ ⟵

$$t_{opt} = \frac{\ln(k_2/k_1)}{k_2-k_1} = \frac{\ln 0.3322}{0.0132-0.0397} = 41.6\ \text{min}$$ ⟵

10.17 Let $A = C_3H_6$
$B = O_2$
$R = C_3H_4O$ (desired)

then $A + B \longrightarrow R \qquad k_2/k_1 = 0.1$
$A + 4.5B \rightarrow S$
$R + 3.5B \rightarrow S \qquad k_3/k_1 = 0.25$

Rewrite the rates

$$A \xrightarrow{k_1=10} R \xrightarrow{k_3=2.5} S, \qquad A \xrightarrow{k_2=1} S$$

From the Denbigh reaction set, eq 49 gives

$$\frac{C_{R\,max}}{C_{A0}} = \frac{k_1}{k_{12}}\left(\frac{k_{12}}{k_3}\right)^{k_3/(k_3-k_{12})} = \frac{10}{11}\left(\frac{11}{2.5}\right)^{2.5/(2.5-11)} = 0.588$$ ⟵

Use plug flow ⟵

10.19 Given $k_1 = k_2 = 2\times10^{13}\exp(-159000/RT)$, $k_3 = 8.15\times10^{17}\exp(-209000/RT)$, $k_4 = 2.1\times10^{5}\exp(-83600/RT)$

$$\begin{tikzcd} & S \arrow[dr, "3"] & & \\ A \arrow[ur, "2"] \arrow[rr, "1"] & & R \arrow[r, "4"] & T \end{tikzcd}$$

Since E_4 is much smaller than all the other E values use the highest allowable temperature, or 1200K.

At 1200K
$$k_1 = 2.4\times10^6\ \text{hr}^{-1}$$
$$k_2 = 2.4\times10^6\ \text{hr}^{-1}$$
$$k_3 = 650\times10^6\ \text{hr}^{-1}$$
$$k_4 = 48.2\ \text{hr}^{-1}$$

Next since k_3 is much bigger than k_2 we can approximate the reaction by

$$\begin{tikzcd} A \arrow[r, "2.4\times10^6"] \arrow[r, bend left=40, "2.4\times10^6"] & R \arrow[r, "48.2"] & T \end{tikzcd} \Rightarrow A \xrightarrow[5]{4.8\times10^6} R \xrightarrow[6]{48.2} T$$

Now find C_{Rmax} from Eq 8.8

$$\frac{C_{Rmax}}{C_{A0}} = \left(\frac{k_5}{k_6}\right)^{k_6/k_6-k_5} = \left(\frac{4.8\times10^6}{48.2}\right)^{48.2/48.2-4.8\times10^6} = 0.99988$$

and

$$\bar{t}_{plug} = \frac{\ln(k_2/k_1)}{k_2-k_1} = 2.4\times10^{-6}\ \text{hr} = 0.0086\ \text{s}$$

With such a small time and such a high conversion practically any kind of reactor would be OK but in all cases straight plug flow is best

Do not recycle or bypass.

Note: In the article mentioned in the problem statement the minimum residence time allowed was 1.8 s. For this, C_R is lower than C_{Rmax}. From Eq 8.7 we find, for this time

$$\frac{C_R}{C_{A0}} = \frac{k_5}{k_6-k_5}\left[e^{-k_1t} - e^{-k_2t}\right] = (-1)\left[0-0.9762\right] = 0.9762$$