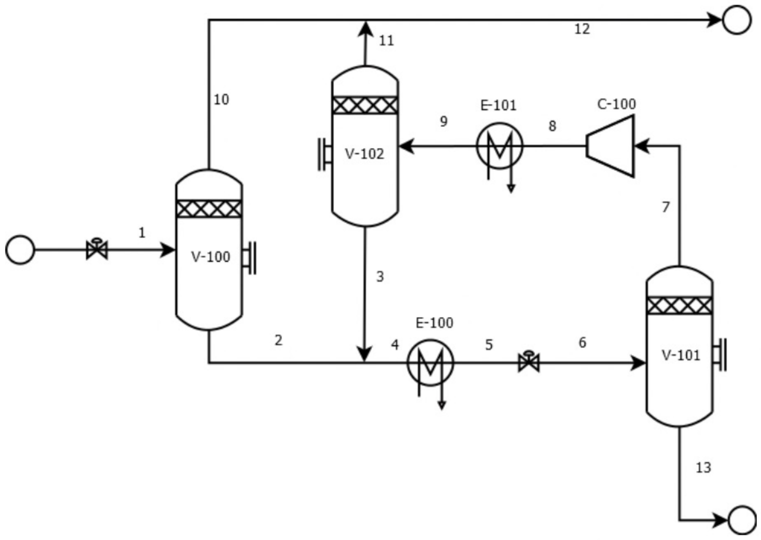
Problem 1

From a simulation of a process, as shown in the figure below, we can read the gas flow rate of stream 11 from separator V-102 to be 24890 kg/h and the gas density to be 94 kg/m^3. The liquid flow rate of stream 3 is 8002 kg/h and the density is 479 kg/m^3. Size the separator V-102.



Ser ut som en vertikal separator ($\frac{V}{L}$ er stor også)

$$u_t = 0{,}07\left(\frac{\rho_L - \rho_V}{\rho_V}\right)^{1/2} = 0{,}07\cdot\left(\frac{479-94}{94}\right)^{1/2} = 0{,}1417 \text{ m/s}$$

Det er ikke spesifisert om vi har en dråpefanger eller ikke

Antar at vi har en => $u_s = u_t$

$$\varphi_V = \frac{24890 \text{ kg/h}}{3600 \text{ s/h}\cdot 94 \text{ kg/m}^3} = 0{,}0736 \text{ m}^3/\text{s}$$

$$\frac{\pi}{4} D_V^2 u_s = \varphi_V$$

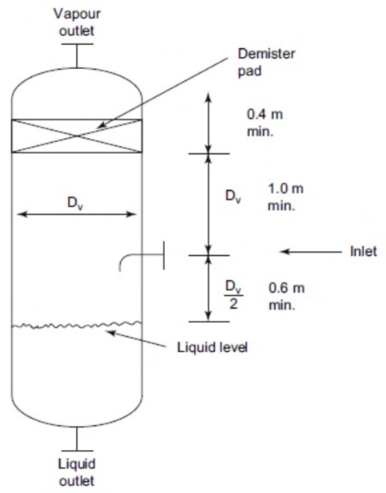
$$\Rightarrow D_V = \sqrt{\frac{4\varphi_V}{\pi u_s}} = \sqrt{\frac{4\cdot 0{,}0736}{\pi\cdot 0{,}1417}} = \underline{0{,}813 \text{ m}}$$

$$\varphi_L = \frac{8002 \text{ kg/h}}{3600 \text{ s/h}\cdot 479 \text{ kg/m}^3} = 4{,}64\cdot 10^{-3} \text{ m}^3/\text{s}$$

10 minutter med "hold-up"

$$\Rightarrow V_L = \varphi_L \cdot 10 \text{ min}\cdot 60 \tfrac{\text{s}}{\text{min}} = 2{,}78 \text{ m}^3$$

$$H_L = \frac{2{,}78 \text{ m}^3}{\pi\cdot\left(\frac{D_V}{2}\right)^2} = 5{,}36 \text{ m}$$



$D_v < 1$ m => Legger til 1,4m

$H_L > 0{,}3$ => Trenger ikke ekstra plass til LC

+ 0,4 m til dråpefanger

=> $H = 7{,}16$ m

=> $\underline{\underline{D_v = 0{,}813 \text{ m}, \ H = 7{,}16 \text{ m}}}$

Problem 2

Two reversible reactions take place on a solid catalyst. The fluid is a gas consisting of five chemical components. The reactants, A and B, react to the desired product C. The component D is also formed, which reacts further with A to form E.

$$A + B \overset{r_1}{\rightleftharpoons} C + D$$
$$A + D \overset{r_2}{\rightleftharpoons} E$$

A kinetic model is developed of the system, and the net forward reaction rates of the two reaction are given by the component partial pressures. The partial pressures are given in atm.

$$r_1 = k_1(p_A p_B - p_C p_D / K_1)$$
$$r_2 = k_2(p_A p_D - p_E / K_2)$$

There is mass transfer resistance in the catalyst pellet, but the effectiveness factors are lumped into the rate constants k_1 and k_2. The reaction rates are given in units kmol/(m^3 s). We will apply a fixed bed reactor, and we may assume that the flow can be well approximated by a plug flow reactor model (PFR). The heat of reactions are low and the temperature along the reactor is assumed to be constant and equal to the inlet temperature, 200 °C. The pressure drop over the catalyst bed can be describe by Ergun's equation. However, since the gas velocity is relatively small, we will neglect the pressure drop and set the pressure along the bet equal to the feed pressure, 50 atm. At 200 °C the reaction rate constants are $k_1 = 4 \cdot 10^{-5}$ and $k_2 = 2 \cdot 10^{-5}$, while the equilibrium constants are $K_1 = 12$ and $K_2 = 0.8$ atm^{-1}. The molecular weights are 50, 70, 100, 20 and 70 for the components A, B, C, D and E, respectively. The composition of the feed gas is equimolar 50 mol% A and B with a total feed of 100 ton/h.

a) Show that the following relations between the component reaction rates hold.

$$R_C = -R_B$$
$$R_D = R_A - 2R_B$$
$$R_E = -R_A + R_B$$

b) Construct equations describing how the composition is changing along the reactor.

c) Make a Python script that solves the equations and determine the necessary volume of the reactor if the concentration of C is 35 mol% at the outlet.

d) With a reactor volume of 20 m^3, determine feed composition that maximized the C concentration out of the reactor.

a) $R_i = \sum_j \nu_{i,j} \cdot r_j$

$R_A = -r_1 - r_2$

$R_B = -r_1$

$\boxed{R_C = r_1 = -R_B}$

$\boxed{R_D = r_1 - r_2 = (-r_1 - r_2) - 2 \cdot (-r_1) = R_A - 2R_B}$

$\boxed{R_E = r_2 = -(-r_1 - r_2) + (-r_1) = -R_A + R_B}$

b) For PFR vil molbalanse gi

$F_i|_V - F_i|_{V+\Delta V} + R_i dV = 0$

$\Rightarrow -dF_i + R_i dV = 0$

$\frac{dF_i}{dV} = R_i$, $F_i = y_i \cdot F \Rightarrow y_i \frac{dF}{dV} + F \cdot \frac{dy_i}{dV} = R_i$

Endring av total molstrøm er summen av "endring per komponent"

$\Rightarrow \frac{dF}{dV} = \sum_j R_j$

Dermed får vi: $\boxed{\frac{dy_i}{dV} = \frac{R_i - y_i \sum_j R_j}{F}}$

Omgjøringsformler $F = \frac{W}{\bar{M}}$

$\bar{M} = \sum y_i M_i$

c) Numerisk får vi at reaktoren må være på ca. 21,57 m^3

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----- Oppgave c)-----
Vi når 35 mol% C ut av PFRen når reaktorvolumet er ca. 21.57 m3.
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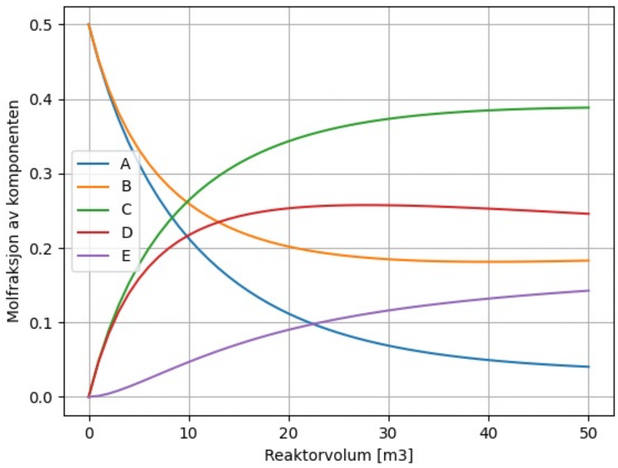

d) y_C^{out} er størst når $y_A^{in} \approx 0,54$

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----- Oppgave d)-----
For en PFR på med V = 20 m3, er den størst mulig molfraksjonen av C ut av PFRen: 0.3467.
Da er yA = 0.5420
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