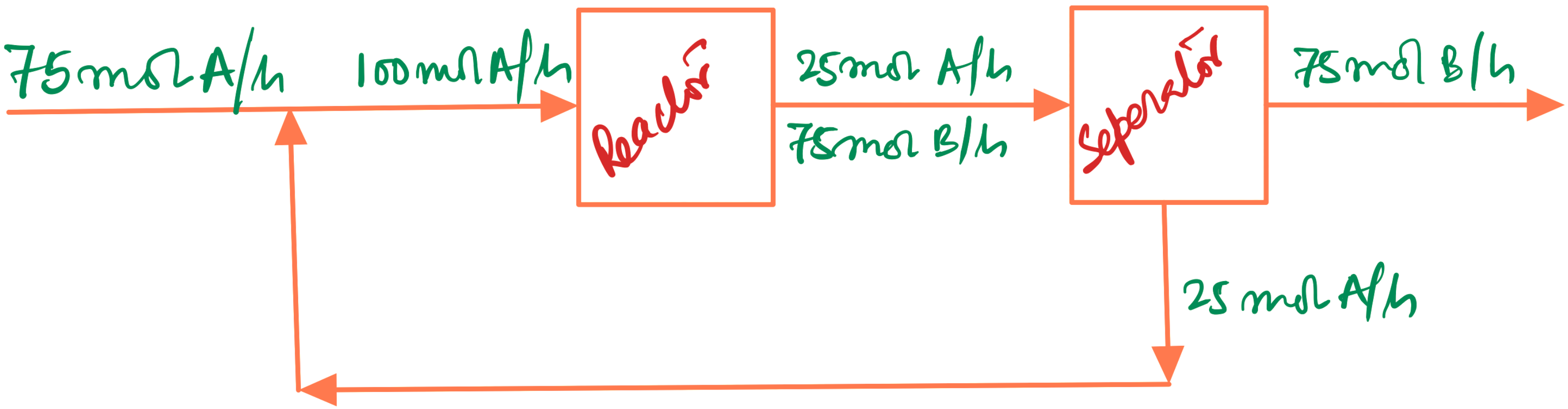
CHEMICAL PROCESS CALCULATIONS

(Reactive process balance)

Lecture # 15: October 20, 2022

Recycle and conversion



$$\text{Overall conversion} = \frac{\text{reactant input} - \text{reactant output}}{\text{reactant input}} \quad \Big\| \ \text{Process}$$

$$\text{Single pass conversion} = \frac{\text{reactant input} - \text{reactant output}}{\text{reactant input}} \quad \Big\| \ \text{Reactor}$$

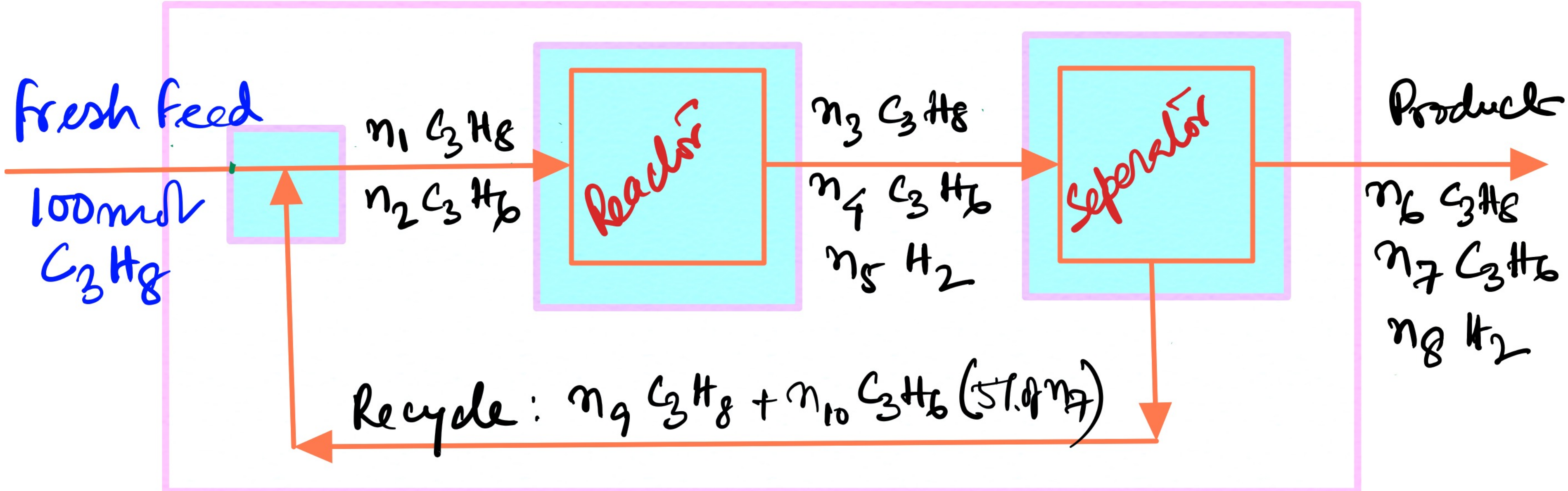
$$C_3H_8 \rightarrow C_3H_6 + H_2$$

Overall conversion of propane : 95%

Seperation after reaction

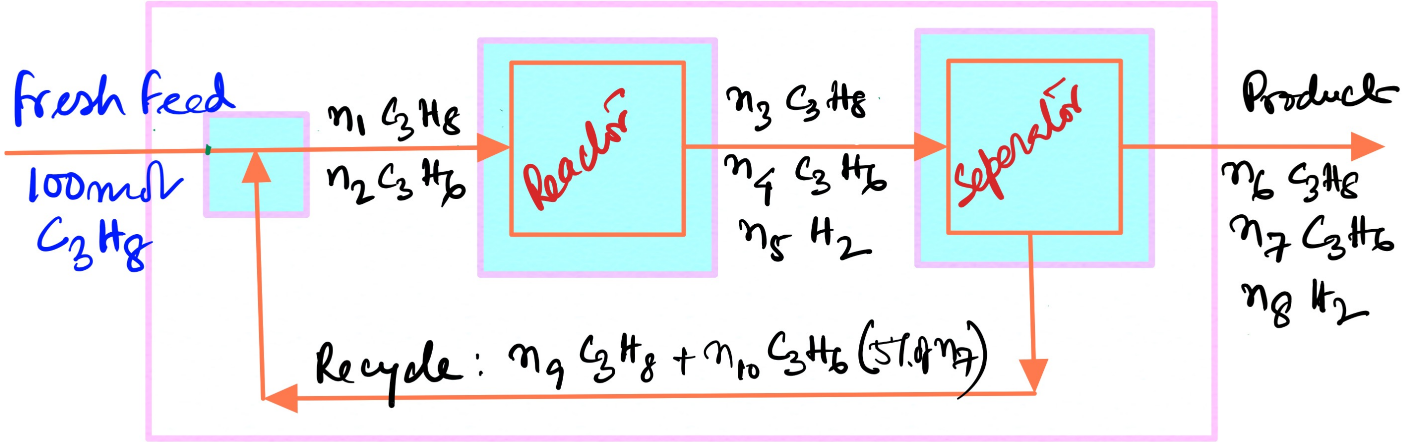
→ H_2, C_3H_6 & 0.555% of C_3H_8 leaving the reactor [Product]

→ unreacted C_3H_8 & 5% of C_3H_6 in the product stream [Recycle]



Overall System

$$DOF = 3(n_6, n_7, n_8) - 2(C, H) - 1(\text{conversion})$$
$$= 0$$



Mixing Point

$$DOF = 4(n_9, n_{10}, n_1, n_2) - 2(C_3H_8, C_3H_6) = 2$$

Reactor

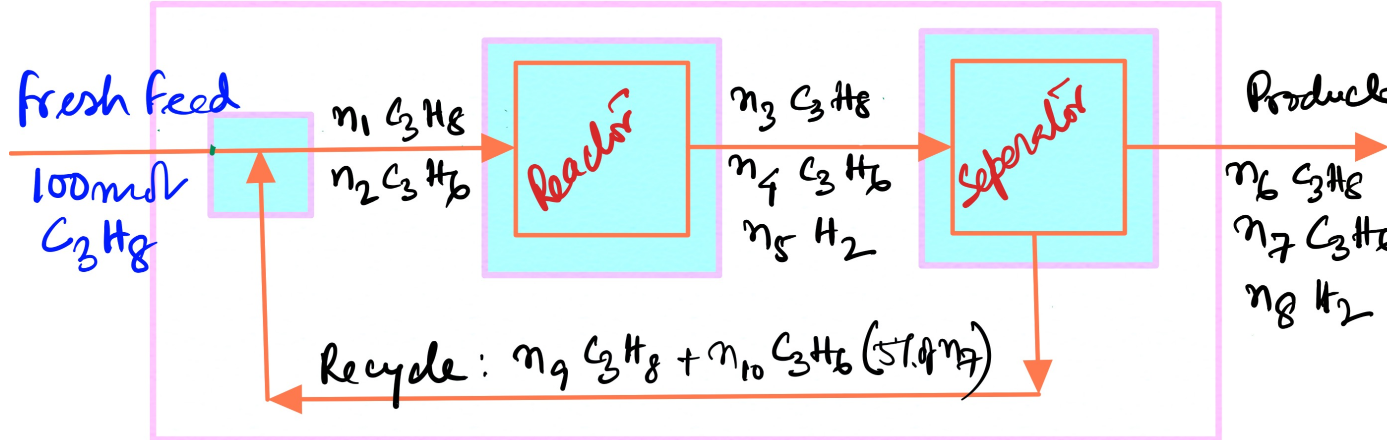
$$DOF = 5(n_1, n_2, n_3, n_4, n_5) - 2(C, H) = 3$$

Separator

$$DOF = 5(n_3, n_4, n_5, n_9, n_{10}) - 3(C_3H_8, C_3H_6, H_2)$$

$$- 2(n_6 = 0.00555 n_3 \ \& \ n_{10} = 0.05 n_7)$$

$$= 0$$



95% Overall conversion of Propane

$\Rightarrow$ 5% unconverted

$\Rightarrow$ $n_6 = 0.05 \times 100 = \underline{\underline{5 \text{ mol}}}\ C_3H_8$

Overall C balance

$100 \times 3 = n_6 \times 3 + n_7 \times 3 \Rightarrow n_7 = \underline{\underline{95}} \text{ mol } C_3H_6$

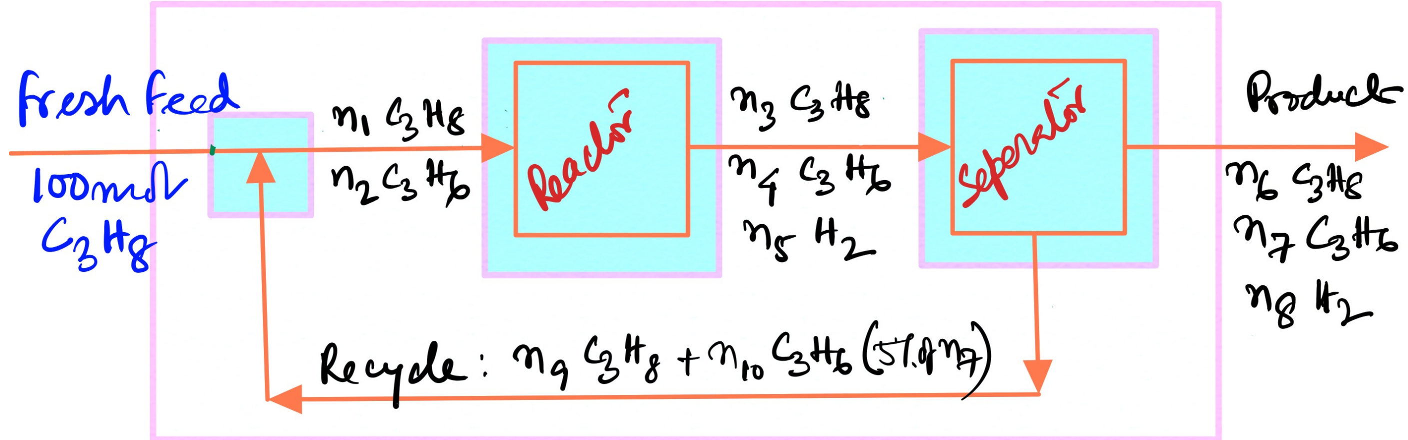
Overall H balance

$100 \times 8 = n_6 \times 8 + n_7 \times 6 + n_8 \times 2$

$\Rightarrow n_8 = \underline{\underline{95}} \text{ mol } H_2$

Product composition

$$\left.\begin{array}{l} 5 \text{ mol } C_3H_8 \\ 95 \text{ mol } C_3H_6 \\ 95 \text{ mol } H_2 \end{array}\right\} \begin{array}{l} 2.6\%\ C_3H_8 \\ 48.7\%\ C_3H_6 \\ 48.7\%\ H_2 \end{array}$$



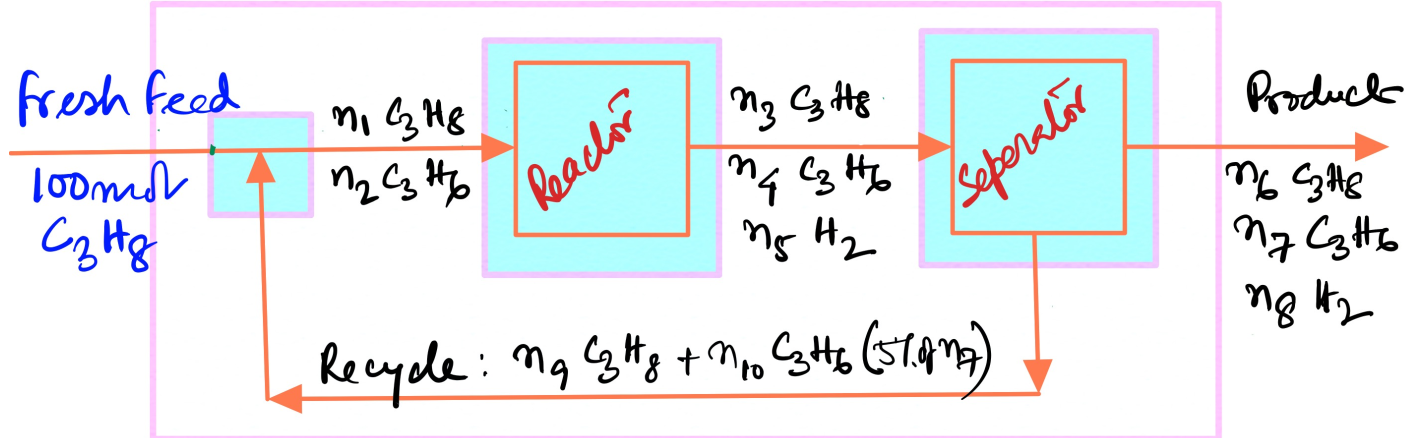
$$n_6 = 0.00555\, n_3 \Rightarrow n_3 = 900.9 \text{ mol } C_3H_8$$

$$n_{10} = 0.05\, n_7 \Rightarrow n_{10} = 4.75 \text{ mol } C_3H_6$$

Propane balance on Separator

$$n_3 = n_6 + n_9 \Rightarrow n_9 = 895 \text{ mol } C_3H_8$$

Similarly n_4 & n_5



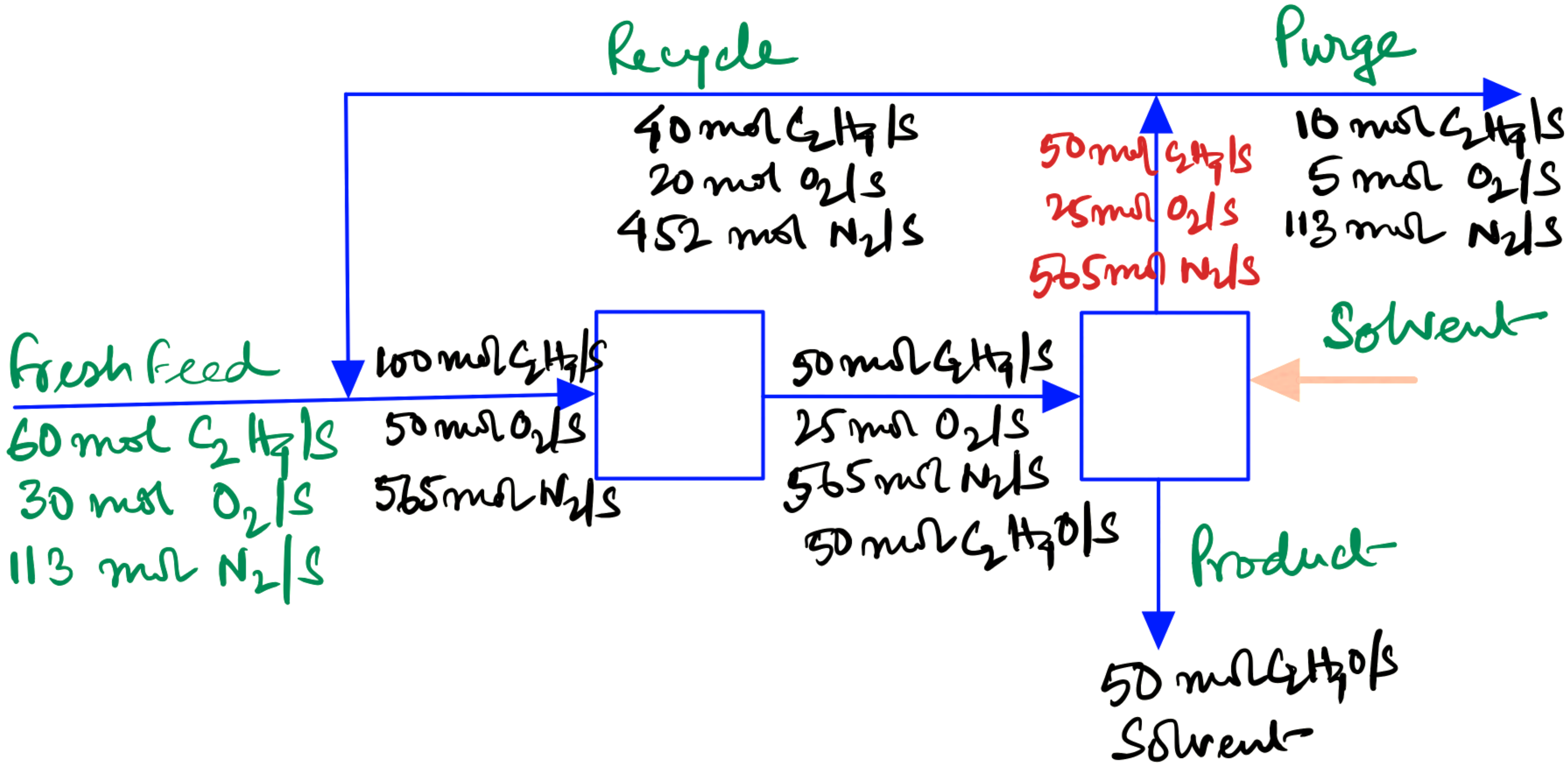
Propane balance on mixing point

$$100 + n_9 = n_1 \Rightarrow n_1 = 995 \text{ mol } C_3H_8$$

$$\text{Recycle ratio} = \frac{n_9 + n_{10}}{100} = 9.00 \frac{\text{mol recycle}}{\text{mol fresh feed}}$$

$$\text{Single pass conversion} = \frac{n_1 - n_3}{n_1} \times 100\% = 9.6\%$$

Purging system



Methanol is synthesized from carbon monoxide and hydrogen in a catalytic reactor. The fresh feed to the process contains 32.0 mole% CO, 64.0% H_2, and 4.0% N_2. This stream is mixed with a recycle stream in a ratio 5 mol recycle/1 mol fresh feed to produce the feed to the reactor, which contains 13.0 mole% N_2. A low single-pass conversion is attained in the reactor. The reactor effluent goes to a condenser from which two streams emerge: a liquid product stream containing essentially all the methanol formed in the reactor, and a gas stream containing all the CO, H_2 , and N_2 leaving the reactor. The gas stream is split into two fractions: one is removed from the process as a purge stream, and the other is the recycle stream that combines with the fresh feed to the reactor.

For a basis of 100 mol fresh feed/h, calculate the production rate of methanol (mol/h), the molar flow rate and composition of the purge gas, and the overall and single-pass conversions.