Balances on Multiple Units

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Problem: Propane is dehydrogenated to form propylene in a catalytic reactor:

\[ C_3H_8 \rightarrow C_3H_6 + H_2 \]

The process is to be designed for a 95% overall conversion of propane. The reaction products are separated into two streams: the first, which contains hydrogen gas, propylene \((C_3H_6)\), and 0.555% of the propane that leaves the reactor, is taken off as product; the second stream, which contains the balance of the unreacted propane, 5% of the propylene in the product stream, and no \(H_2\), is recycled to the reactor. Calculate the flow rates and compositions of all streams and the single-pass conversion of propane in the reactor.

Our first attempt at the flow shut left out the mixing point. We start over.
This is the correct configuration.

We now choose a basis + use the overall conversion.

Next: balances on [SEP]
95% conversion

\[ \text{C}_{3}\text{H}_8 \rightarrow \text{C}_3\text{H}_6 + \text{H}_2 \]

\[
\begin{align*}
100 \text{ mol} & \rightarrow \text{Process} \\
\text{C}_3\text{H}_8 & \rightarrow 5 \text{ mol} \\
\text{C}_3\text{H}_6 & \rightarrow 95 \text{ mol} \\
\text{H}_2 & \rightarrow 95 \text{ mol}
\end{align*}
\]

0.95 = \frac{\text{mol} \text{ of reactants}}{\text{mol} \text{ of fed}} = \frac{5}{100}

\[ \exists = 95 \text{ mol} \text{ overall} \]
BALANES ON SEP

Q₃ C₂H₈
1.75 mol C₂H₆

900.9 mol C₂H₈
99.75 mol Q₂ C₂H₆
95 mol H₂

5 mol C₂H₈
95 mol C₂H₆
95 mol H₂

① H₂ mol BAL
② C₂H₈ mol BAL

Q₂ = 4.75 + 95 - 99.75 mol

Q₂ = 895.8 mol
USE OTHER 2 FACTS:

\[ \text{C}_3\text{H}_8 \quad 0.959 \text{ mol} \]
\[ \text{Q}_2 \quad \text{C}_3\text{H}_6 \quad 4.75 \text{ mol} \]

100 mol
\[\text{C}_3\text{H}_8 \rightarrow \text{MIX} \rightarrow \text{RXR} \rightarrow \text{SEP} \rightarrow \text{C}_3\text{H}_8 \quad 5 \text{ mol} \]
\[ \text{Q}_1 \quad \text{C}_3\text{H}_8 \quad 900.9 \text{ mol} \]
\[ \text{C}_3\text{H}_6 \quad 99.75 \text{ mol} \]
\[ \text{H}_2 \quad 95 \text{ mol} \]

\[ 0.00555 = \frac{5 \text{ mol}}{\text{Q}_1} \]
\[ \text{Q}_1 = 900.9 \text{ mol} \]

\[ \text{Q}_2 = 0.05 (95) \]
\[ \text{Q}_2 = 4.75 \text{ mol} \]
Finally, calculate single pass extent of rxn + fractional conversion:

\[ \frac{f_s}{f} = \frac{\text{mol reacted}}{\text{mol fed}} = \frac{95}{995.9} = 0.0954 \]