Balances on Multiple Units

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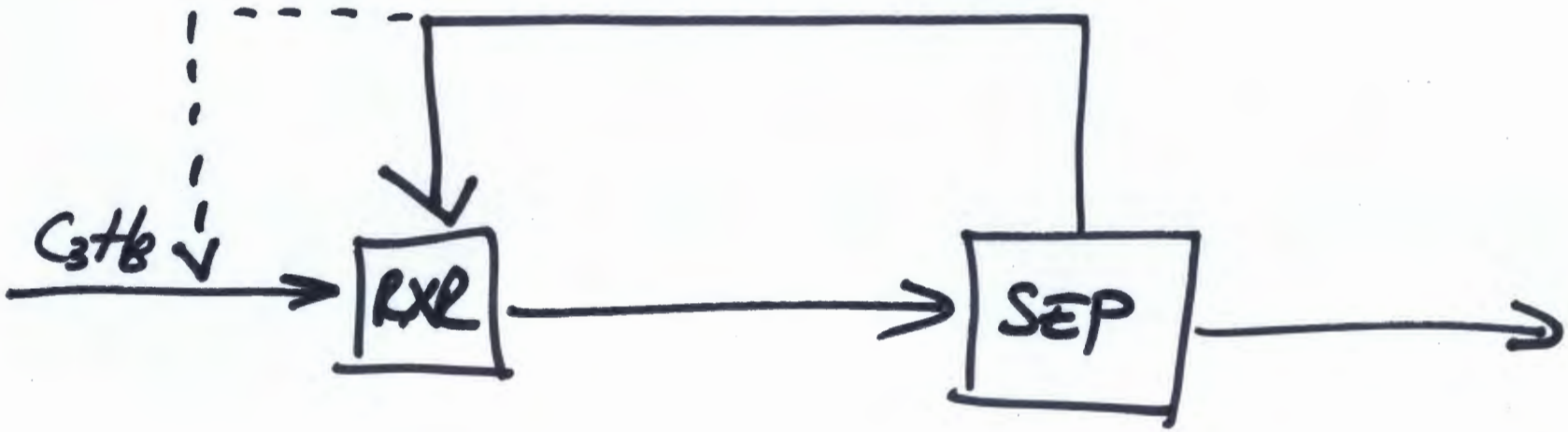
Problem: Propane is dehydrogenated to form propylene in a catalytic reactor:

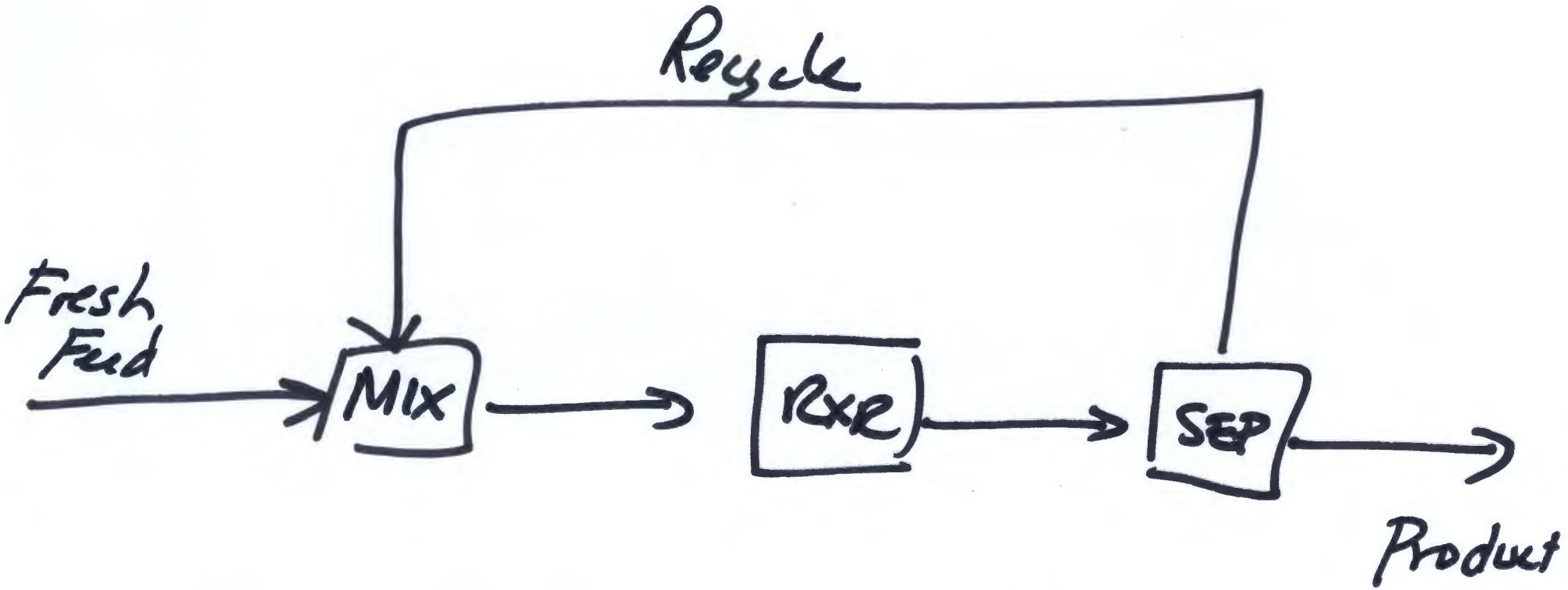
$$C_3H_8 \rightarrow C_3H_6 + H_2$$

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.

Reference: Felder and Rouseau, 2nd edition, page 135.



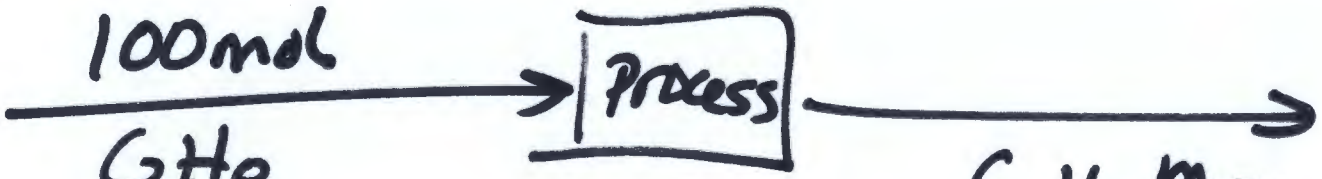
Our first attempt at the flow sheet left out the mixing point. We start over.



This is the correct configuration.
We now choose a basis + use the overall conversion.
Next: balances on SEP

95% conversion

$$C_3H_8 \longrightarrow C_3H_6 + H_2$$



C_3H_8 ξ = 5 moles

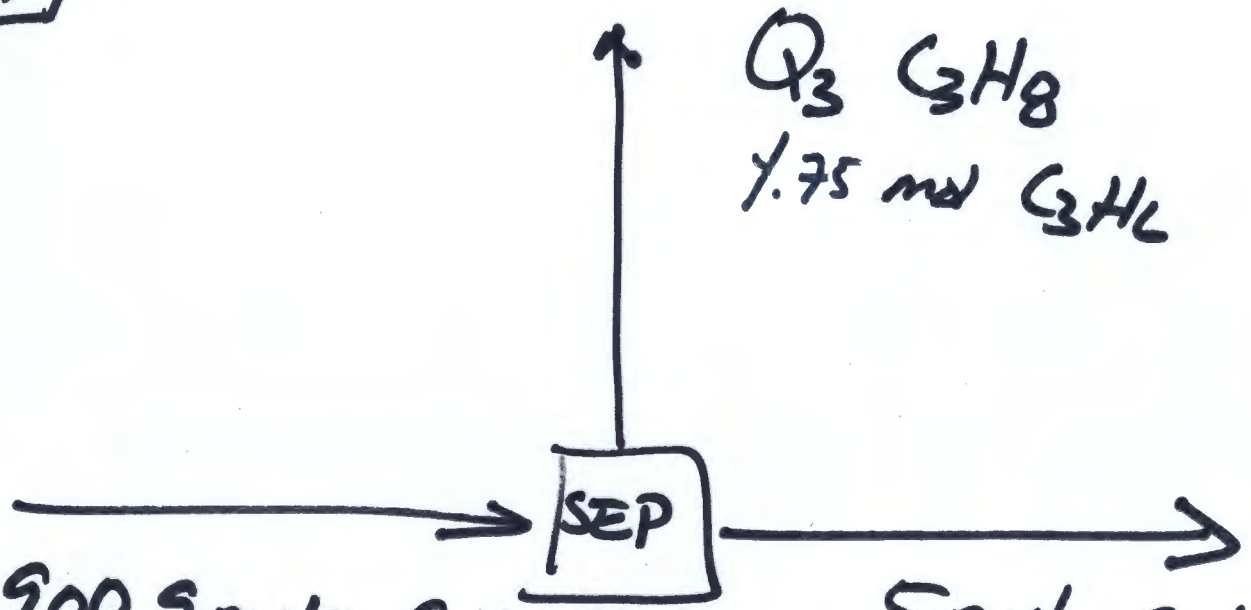
C_3H_6 ξ = 95 moles

H_2 ξ = 95 moles

$$0.95 = \frac{\text{moles reacted}}{\text{moles fed}} = \frac{\xi}{100}$$

ξ = 95 moles overall

BALANCES ON SEP



(1) H_2 mol BAL

(2) C_3H_6 Mol BAL

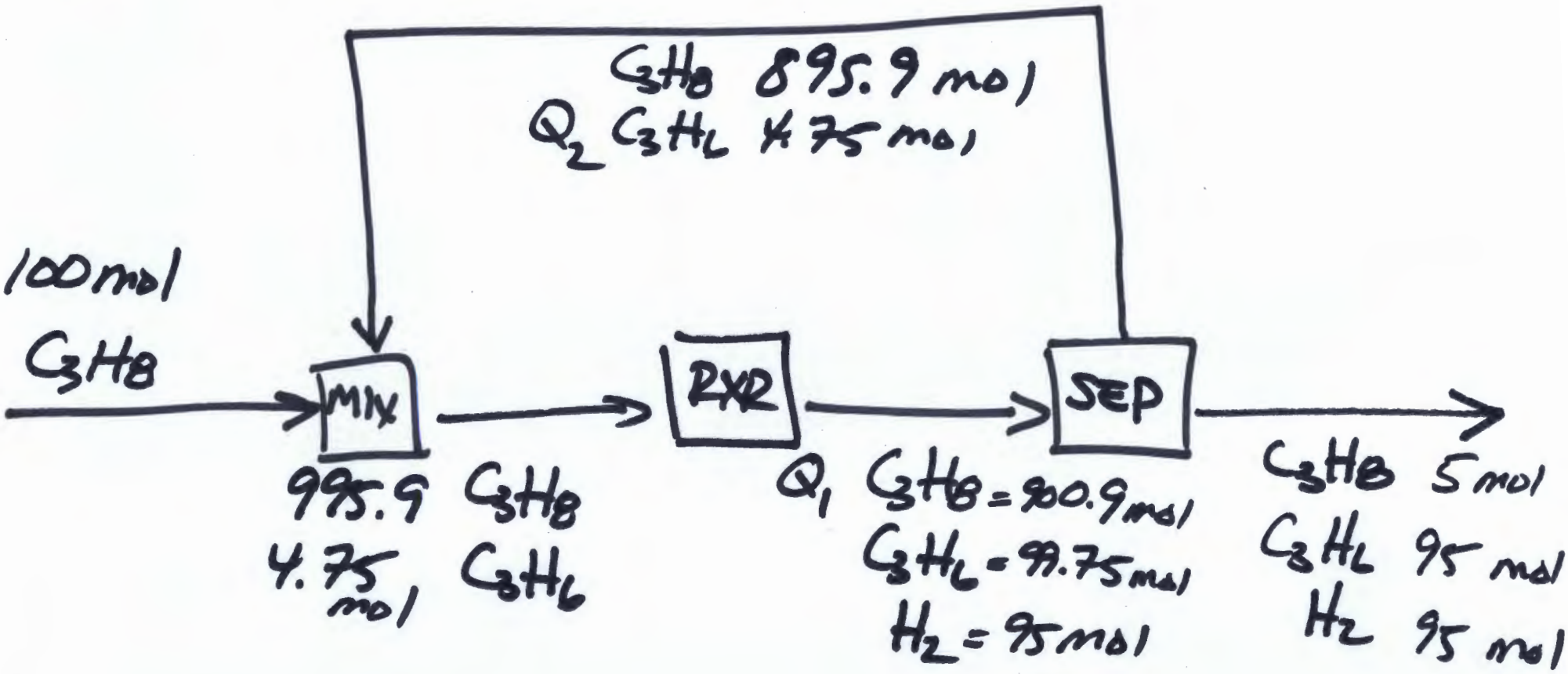
$Q_4 = 4.75 + 95 - 99.75$ mol

(3) C_3H_8 bal

$900.9 = Q_3 + 5$

$Q_3 = 895.8$ mol

USE OTHER 2 FACTS:



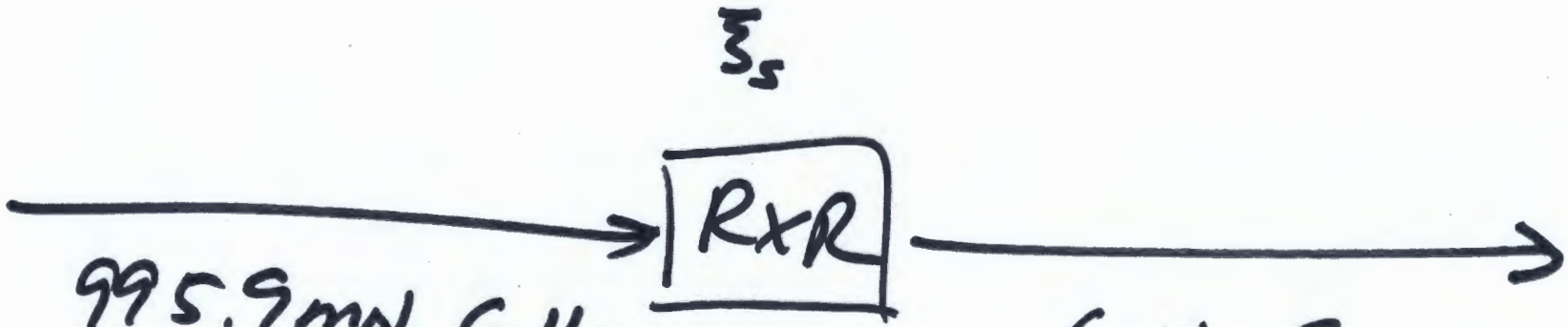
$$0.00555 = \frac{5\,\text{mol}}{Q_1}$$

$$\boxed{Q_1 = 900.90\ \text{moles}}$$

$$Q_2 = 0.05(95)$$

$$\boxed{Q_2 = 4.75\ \text{moles}}$$

Finally, calculate single pass extent of rxn + fractional conversion:



$$f_s = \frac{\text{moles reacted}}{\text{moles fed}} = \frac{95}{995.9} = 0.0954$$