Problem 1

An effluent stream from a process contains benzene (300 kmol/h), toluene (35 kmol/h) and ethyl benzene (16 kmol/h). The stream is to be separated in three fractions by distillation. The product specifications are:

- 99.8 % of the benzene is to be recovered with a purity of 99.95 mol%.
- 98 % of the toluene is to be recovered and must not contain more than 5 mol% benzene and ethyl-benzene all together.

As the stream is cold (10 °C), it must be heated to 1 °C below the boiling point. The stream pressure is 1.2 bara and the condenser pressure of the first column is 1 bar with a pressure drop of 0.2 bar.

a) Do the simulation in Hysys (or Unisim). Use a shortcut column to calculate the parameters of the distillation column

b) What is the required reflux ratio if the first column (benzene column) has 50 stages.

c) And for the same column, how many plates is required if we accept a reflux ratio of 2.0.

a) Setting the vapor fraction in stream 1 to 0, the boiling temperature is

$T_b = 89{,}35\ °C$

This means that the temperature into the column is $88{,}35\ °C$

In column 1

LK - Benzene

HK - Toluene, 0,0005

Vet at 99,8% benzene går i destillatet

$\Rightarrow 300\ \text{kmol/h} \cdot 0{,}02\,\% = 0{,}6\ \text{kmol/h}$

Strøm ut av toppen: $F_{benzene} = 99{,}8\,\% \cdot 300\ \text{kmol/h}$

$= 299{,}4\ \text{kmol/h}$

Benzene er 99,95% av F_{top}

$$\Rightarrow F_{top} = \frac{299{,}4\ \text{kmol/h}}{99{,}95\,\%} = 299{,}55\ \text{kmol/h}$$

$$F_{btm} = F_1 - F_{top} = 351 - 299{,}55 = 51{,}45\ \text{kmol/h}$$

$$X_{LK} = \frac{0{,}6}{51{,}45} = 0{,}01166$$

For $R_{min} = 0,8940$

Gjetter 15% høyere $\Rightarrow R = 0,966$

Min antall trays: 13,868 $\Rightarrow$ 14

Actual number of trays: 35,445 $\Rightarrow$ 36

Optimal feed stage: 21,811 $\Rightarrow$ 22

In column 2

HK - E-benzene

LK - Toluene

Toluene in top $= 0,98 \cdot (35 - 0,0005 \cdot 299,55)\,kmol/h = 34,15\ kmol/h = 0,95 \cdot F_{top}$

$F_{top} = \frac{34,15}{95\%} = 35,95\ kmol/h$

$F_{btm} = F_{in} - F_{top} = (51,45 - 35,95)\,kmol/h = 15,5\ kmol/h$

Toluene in btm $= 0,02 \cdot$ toluene inn

$= 0,02 \cdot (35 - 0,0005 \cdot 299,55) = 0,697$

$X_{LK} = \frac{0,697}{15,5} = 0,0450$

Antar at all benzen fordamper $\Rightarrow$ 5% av topp = benz + e-benz

$\Rightarrow$ e-benz $= 35,95 \cdot 0,05 - 0,6 = 1,1975\ kmol/h$

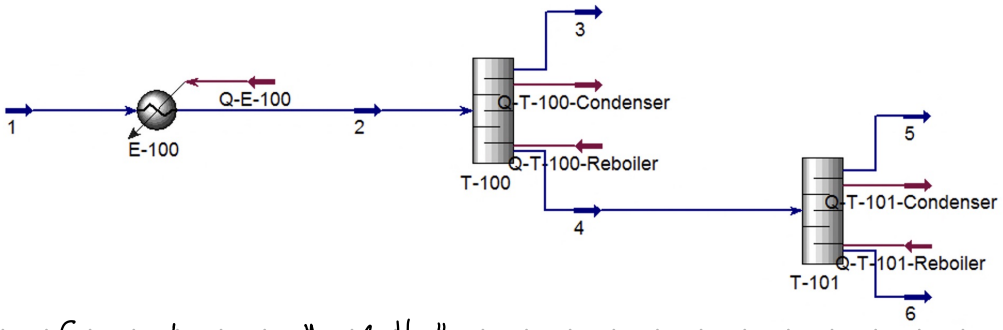
$X_{HK} = \frac{1,1975}{36,105} = 0,0333$

$\Rightarrow$ $R_{min} = 1,232$, $R = 1,15 \cdot R_{min} = 1,417$

Min # trays: 9,536 $\Rightarrow$ 10

Actual trays: 23,970 $\Rightarrow$ 24

Optimal feed stage: 10,727 $\Rightarrow$ 11

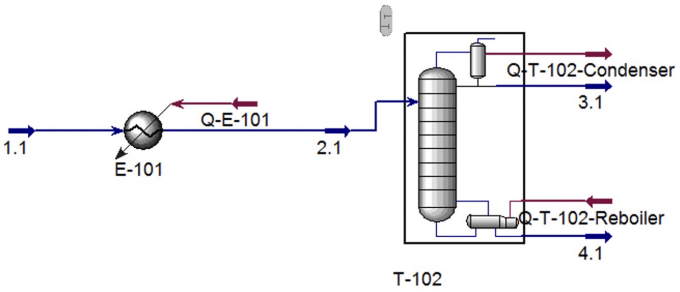


b) Bygger første kolonne "ordentlig"

Spesifiserer at den skal løses for $N = 50$, $X_{Benzene,top} = 0{,}99995$

$F_{benzene,btm} = 0{,}6$ kmol/h

$\Rightarrow$ $R = 0{,}9949$



c) Going back to the shortcut column, using $R = 2$

$\Rightarrow$ $N_{min} = 14$

$N = 21$