2. STEADY STATE MATERIAL BALANCES ON A SEPARATION TRAIN

2.1 Numerical Methods

Solution of simultaneous linear equations.

2.2 Concepts Utilized

Material balances on a steady state process with no recycle.

2.3 Course Useage

Introduction to Chemical Engineering.

2.4 Problem Statement

Xylene, styrene, toluene and benzene are to be separated with the array of distillation columns that is shown below where F, D, B, D1, B1, D2 and B2 are the molar flow rates in mol/min.

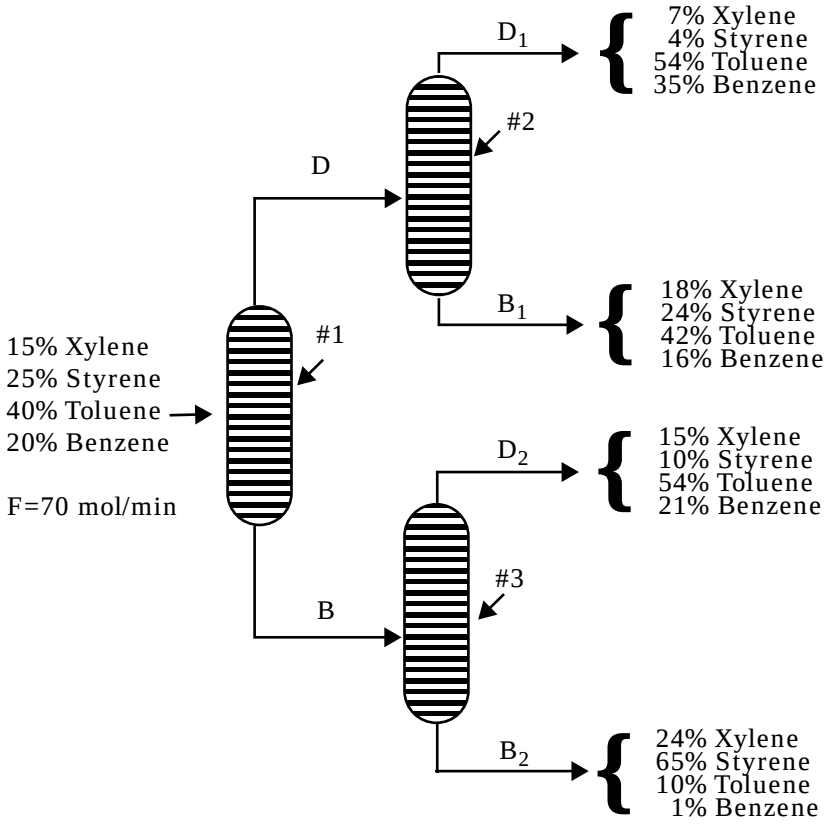

Figure 1 Separation Train

Material balances on individual components on the overall separation train yield the equation set

$$\begin{aligned}
\text{Xylene: } & 0.07D_1 + 0.18B_1 + 0.15D_2 + 0.24B_2 = 0.15 \times 70 \\
\text{Styrene: } & 0.04D_1 + 0.24B_1 + 0.10D_2 + 0.65B_2 = 0.25 \times 70 \\
\text{Toluene: } & 0.54D_1 + 0.42B_1 + 0.54D_2 + 0.10B_2 = 0.40 \times 70 \\
\text{Benzene: } & 0.35D_1 + 0.16B_1 + 0.21D_2 + 0.01B_2 = 0.20 \times 70
\end{aligned} \quad \textbf{(6)}$$

Overall balances and individual component balances on column #2 can be used to determine the molar flow rate and mole fractions from the equation of stream D from

$$\text{Molar Flow Rates: } D = D_1 + B_1$$

$$\begin{aligned}
\text{Xylene: } & X_{Dx}D = 0.07D_1 + 0.18B_1 \\
\text{Styrene: } & X_{Ds}D = 0.04D_1 + 0.24B_1 \\
\text{Toluene: } & X_{Dt}D = 0.54D_1 + 0.42B_1 \\
\text{Benzene: } & X_{Db}D = 0.35D_1 + 0.16B_1
\end{aligned} \quad \textbf{(7)}$$

where X_{Dx} = mole fraction of Xylene, X_{Ds} = mole fraction of Styrene, X_{Dt} = mole fraction of Toluene, and X_{Db} = mole fraction of Benzene.

Similarly, overall balances and individual component balances on column #3 can be used to determine the molar flow rate and mole fractions of stream B from the equation set

$$\text{Molar Flow Rates: } B = D_2 + B_2$$

$$\begin{aligned}
\text{Xylene: } & X_{Bx}B = 0.15D_2 + 0.24B_2 \\
\text{Styrene: } & X_{Bs}B = 0.10D_2 + 0.65B_2 \\
\text{Toluene: } & X_{Bt}B = 0.54D_2 + 0.10B_2 \\
\text{Benzene: } & X_{Bb}B = 0.21D_2 + 0.01B_2
\end{aligned} \quad \textbf{(8)}$$

(a) Calculate the molar flow rates of streams D_1, D_2, B_1 and B_2.
(b) Determine the molar flow rates and compositions of streams B and D.