Fundamentals of Chemical Engineering

Material Balance

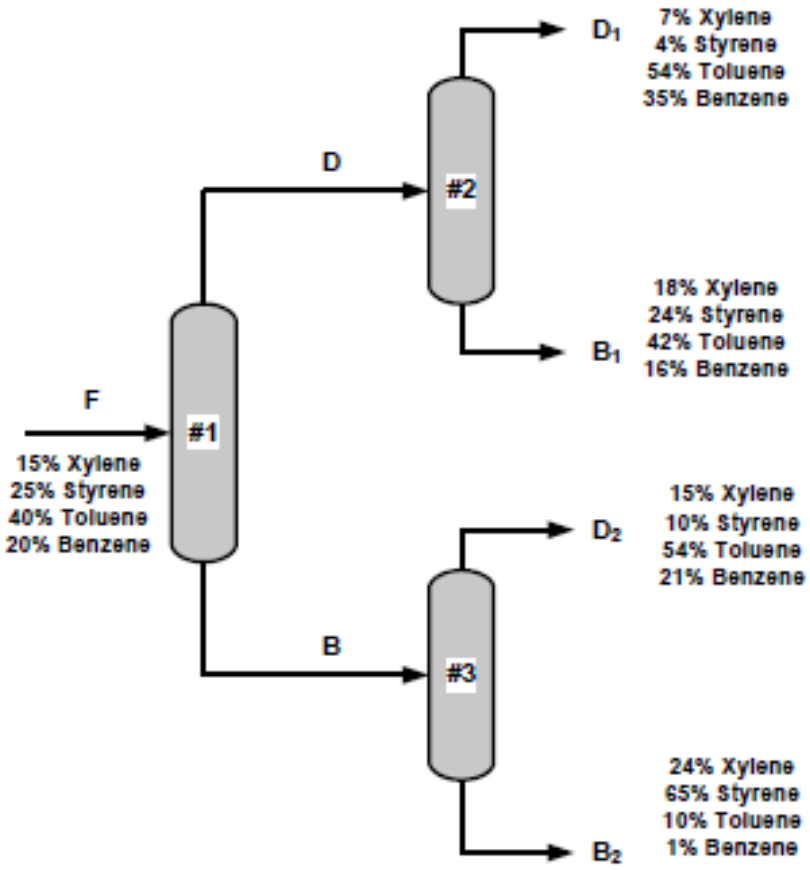
1. **Non-Reactive system**

Example: Separation Train

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. F is the feed flow rate of 70 mol/min,

a. calculate the flow rates of the top and bottom products of the second and third distillation columns,

b. calculate the molar flow rates of the four components in both streams B and D.



Part a:

Solution of such a system can be performed by solving a set of algebraic equations simultaneously, these equations are material balance equations for each component.

Material balance equations on the overall of the three columns will yield:

$0.15\times70=0.07\times D1+0.18\times B1+0.15\times D2+0.24\times B2$

$0.25\times70=0.04\times D1+0.24\times B1+0.10\times D2+0.65\times B2$

$0.40\times70=0.54\times D1+0.42\times B1+0.54\times D2+0.10\times B2$

$0.20\times70=0.35\times D1+0.16\times B1+0.21\times D2+0.01\times B2$

This can be shown in the form of a matrix:

AX=B

$$\begin{bmatrix} 0.07 & 0.18 & 0.15 & 0.24 \\ 0.04 & 0.24 & 0.10 & 0.65 \\ 0.54 & 0.42 & 0.54 & 0.10 \\ 0.35 & 0.16 & 0.21 & 0.01 \end{bmatrix} \begin{bmatrix} D_1 \\ B_1 \\ D_2 \\ B_2 \end{bmatrix} = \begin{bmatrix} 0.15 \times 70 \\ 0.25 \times 70 \\ 0.40 \times 70 \\ 0.20 \times 70 \end{bmatrix}$$

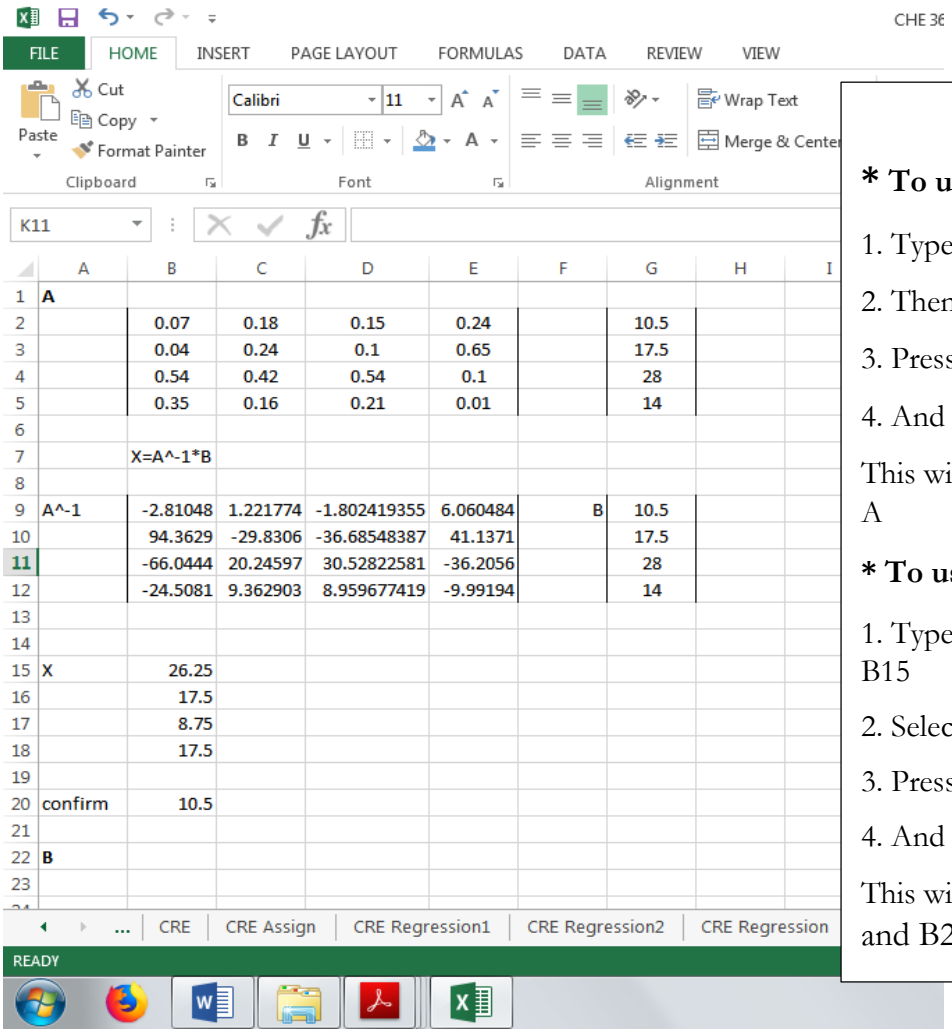
Its solution is as follows

$X=A^{-1}B$

This can be solved in Microsoft excel by using the built-in function "MINVERSE" and "MMULT".

"MINVERSE" will find the inverse of matrix A while "MMULT" will multiply the inverse of matrix A and matrix B

The calculated matrix is then the solution to the above system of equations and required flow rates are calculated. i.e D1, B1, D2 and B2



	A	B	C	D	E	F	G
1	A						
2		0.07	0.18	0.15	0.24		10.5
3		0.04	0.24	0.1	0.65		17.5
4		0.54	0.42	0.54	0.1		28
5		0.35	0.16	0.21	0.01		14
6							
7		X=A^-1*B					
8							
9	A^-1	-2.81048	1.221774	-1.802419355	6.060484	B	10.5
10		94.3629	-29.8306	-36.68548387	41.1371		17.5
11		-66.0444	20.24597	30.52822581	-36.2056		28
12		-24.5081	9.362903	8.959677419	-9.99194		14
13							
14							
15	X	26.25					
16		17.5					
17		8.75					
18		17.5					
19							
20	confirm	10.5					
21							
22	B						
23							

Note:

*** To use the "Minverse"**

1. Type ' = Minverse(A1:C4)' in B9
2. Then select cell B9:E12
3. Press F2
4. And finally press ctrl+shift+enter

This will give you the inverse of matrix A

*** To use the "MMULT"**

1. Type '= mmult(B9:E124,G9:G12)' in B15
2. Select cell B15:B18
3. Press F2
4. And finally press ctrl+shift+enter

This will give the values of D1, B1, D2 and B2

Part b :

The two streams B and D can be got from material balance equations around both towers number 2 and 3,

For tower 2: D=D1+B1

$DxDX = 0.07 \times D1 + 0.18 \times B1$
$DxDS = 0.04 \times D1 + 0.24 \times B1$
$DxDT = 0.54 \times D1 + 0.42 \times B1$
$DxDB = 0.35 \times D1 + 0.16 \times B1$

For tower 3: B=D2+B2

$BxBX = 0.15 \times D2 + 0.24 \times B2$
$BxBS = 0.10 \times D2 + 0.65 \times B2$
$BxBT = 0.54 \times D2 + 0.21 \times B2$
$BxBB = 0.21 \times D2 + 0.01 \times B2$