CHEMICAL PROCESS CALCULATIONS

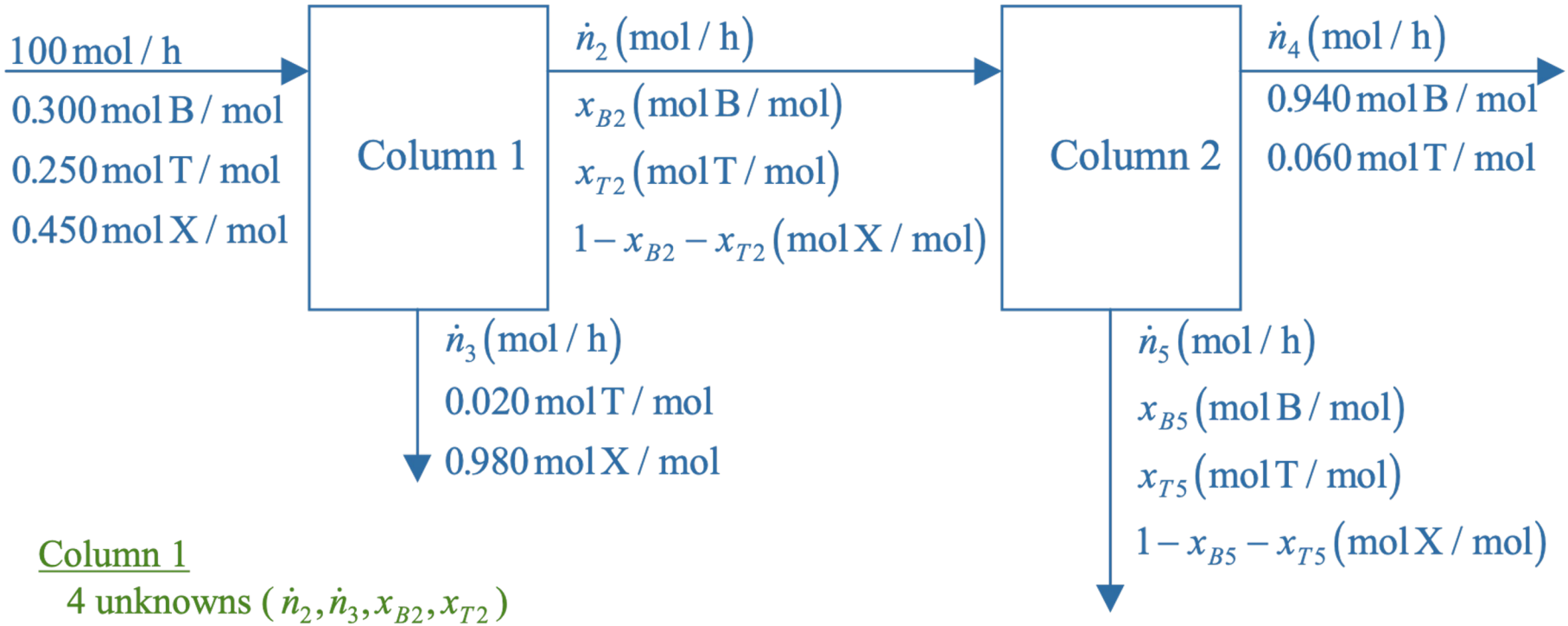
Lecture #7: August 24, 2023

A liquid mixture containing 30.0 mole% benzene (B), 25.0% toluene (T), and the balance xylene (X) is fed to a distillation column. The bottoms product contains 98.0 mole% X and no B, and 96.0% of the X in the feed is recovered in this stream. The overhead product is fed to a second column. The overhead product from the second column contains 97.0% of the B in the feed to this column. The composition of this stream is 94.0 mole% B and the balance T.

Draw and label a flowchart of this process and do the degree-of-freedom analysis to prove that for an assumed basis of calculation, molar flow rates and compositions of all process streams can be calculated from the given information. Write in order the equations you would solve to calculate unknown process variables. In each equation (or pair of simultaneous equations), highlight the variable(s) for which you would solve. Calculate:

(a) the percentage of the benzene in the process feed (i.e., the feed to the first column) that emerges in the overhead product from the second column and

(b) the percentage of toluene in the process feed that comes out in the bottom product from the second column.



Column 1

4 unknowns ($\dot{n}_2, \dot{n}_3, x_{B2}, x_{T2}$)

–3 balances

– 1 recovery of X in bot. (96%)

0 DF

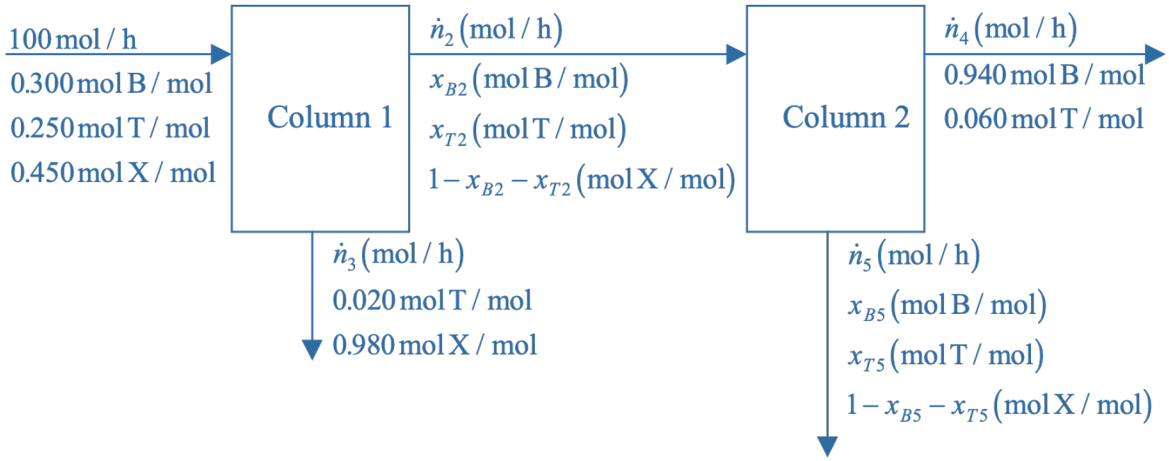
Column 2:

$\dot{n}_4$ $\dot{n}_5$ x_{B5} x_{T5}

– 3 balances

– 1 recovery of B in top (97%)

0 DF



Column 1

96% X recovery: $0.96(0.450)(100) = 0.98\dot{n}_3$

Total mole balance: $100 = \dot{n}_2 + \dot{n}_3$

B balance: $0.300(100) = x_{B2}\dot{n}_2$

T balance: $0.250(100) = x_{T2}\dot{n}_2 + 0.020\dot{n}_3$

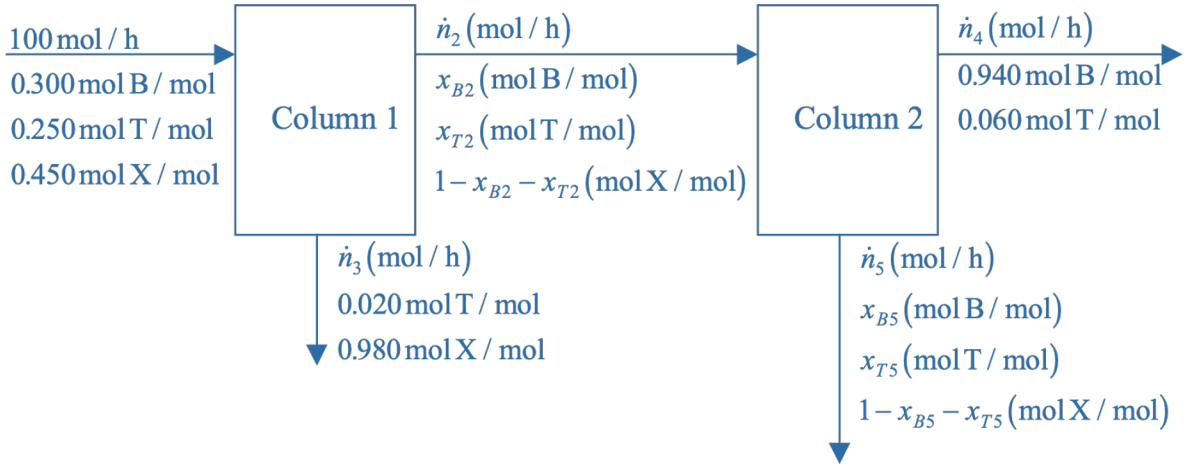
Column 2

97% B recovery: $0.97x_{B2}\dot{n}_2 = 0.940\dot{n}_4$

Total mole balance: $\dot{n}_2 = \dot{n}_4 + \dot{n}_5$

B balance: $x_{B2}\dot{n}_2 = 0.940\dot{n}_4 + x_{B5}\dot{n}_5$

T balance: $x_{T2}\dot{n}_2 = 0.060\dot{n}_4 + x_{T5}\dot{n}_5$



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$\dot{n}_3 = 44.1\,\text{mol / h}$ $\quad \dot{n}_2 = 55.9\,\text{mol / h}$

$x_{B2} = 0.536\,\text{mol B / mol}$ $\quad x_{T2} = 0.431\,\text{mol T / mol}$

$\dot{n}_4 = 30.95\,\text{mol / h}$ $\quad \dot{n}_5 = 24.96\,\text{mol / h}$

$x_{B5} = 0.036\,\text{mol B / mol}$ $\quad x_{T5} = 0.892\,\text{mol T / mol}$

Overall benzene recovery : $\dfrac{0.940(30.95)}{0.300(100)} \times 100\% = 97\%$

Overall toluene recovery : $\dfrac{0.892(24.96)}{0.250(100)} \times 100 = 89\%$

CHEMICAL PROCESS CALCULATIONS

Lecture #8: August 28, 2023

A sedimentation process is to be used to separate pulverized coal from slate. A suspension of finely divided particles of galena (lead sulfide, SG = 7.44) in water is prepared. The overall specific gravity of the suspension is 1.48.

Four hundred kilograms of galena and a quantity of water are loaded into a tank and stirred to obtain a uniform suspension with the required specific gravity. Draw and label the flowchart (label both the masses and volumes of the galena and water), do the degree-of-freedom analysis, and calculate how much water (m^3) must be fed to the tank.