CE407 SEPARATIONS

Lecture 17b

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Multi-Stage Countercurrent Extraction Treybal pp. 452 Fig 1040

Minimum Entering Solvent Flow

- A feed stream (flow rate = 1000 kg/hr) with composition 30 mass % acetic acid (solute, C) and 70 mass % isopropyl ether (diluent, A) is to be contacted with water (solvent, B) in a countercurrent liquid extraction battery. Entering water is pure. The exiting raffinate should contain 8 mass % acetic acid (C) and 92 mass % ether (A) on a water(B)-free basis.
  - What is the minimum flow rate $(V_{N+1})_{min}$ of entering water required to achieve the desired composition of the exiting raffinate (corresponding to an infinite number of stages)?
  - Suppose 1.5 times the minimum flow rate of entering water is used $V_{N+1} = 1.5 * (V_{N+1})_{min}$:
  - Determine

    The composition of the exiting extract

    The flow rate of the exiting raffinate

    The required number of ideal stages

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Equilibrium data for the ternary system isopropyl ether (A) – water (B) – acetic acid (C) are as follows:

Ether Rich			Water Rich	
x_B	x_C		y_B	y_C
0.01	0.02		0.92	0.06
0.02	0.05		0.84	0.13
0.04	0.11		0.71	0.26
0.07	0.215		0.59	0.37
0.08	0.26		0.53	0.41
0.10	0.30		0.47	0.44
0.13	0.34		0.40	0.455
0.17	0.38		0.34	0.46
0.21	0.42		0.27	0.45
0.24	0.44		0.24	0.44

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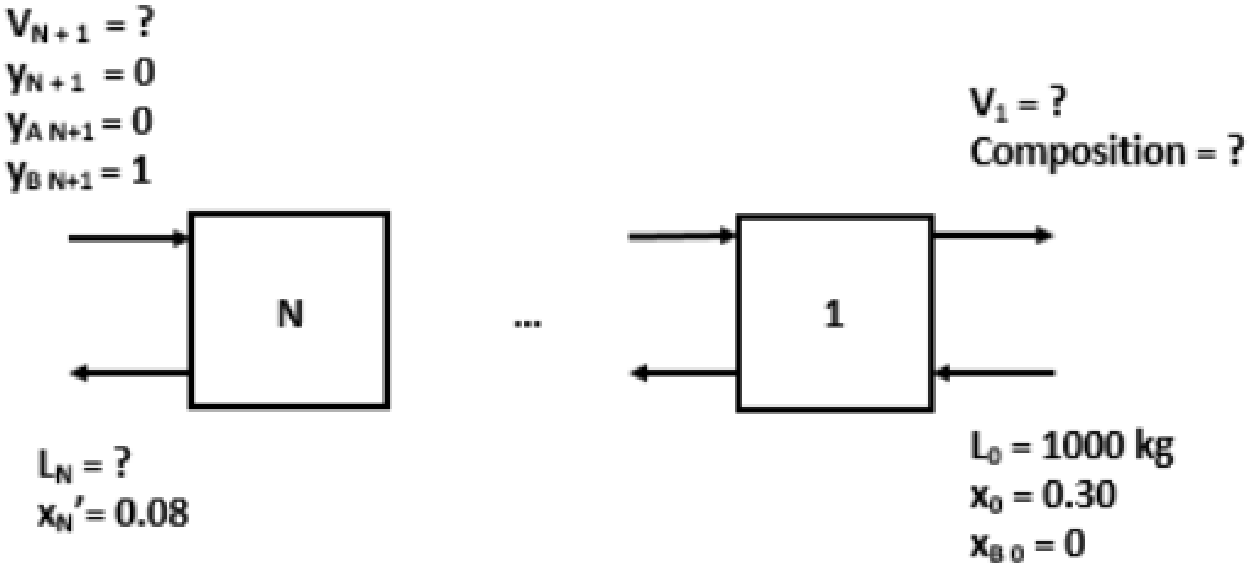
1 hour basis

A = Diluent, isopropyl ether
B = Solvent, Water
C = Solute, acetic acid



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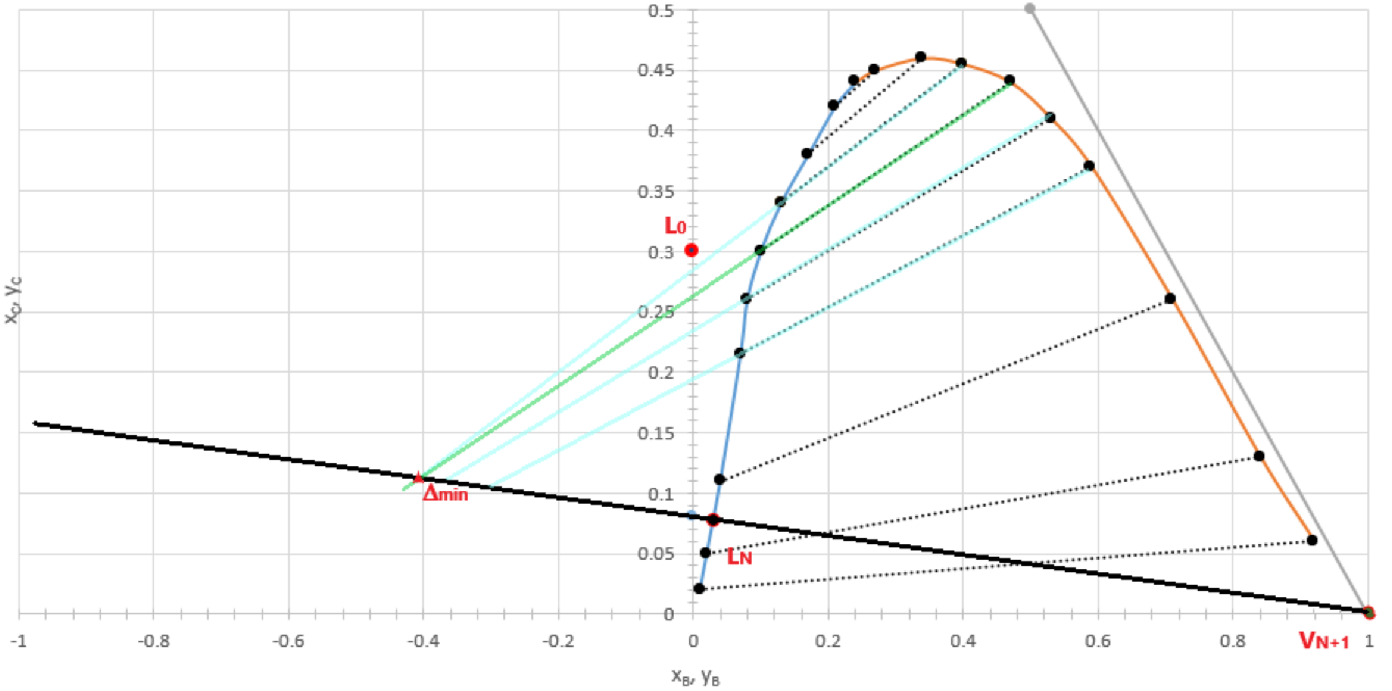
- The actual raffinate composition is found by drawing a line from L'_N to the Pure Solvent Point. The point where the line crosses the two-phase boundary give the composition of L_N as $(x_B, x_C) = (0.03, 0.078)$.
- Draw a line from V_{N+1} to L_N and extend it well past to the left. Extend each tie line that passes between L_0 and L_N. In this case the relative slopes of the tie lines is such that the uppermost tie line is NOT the one that intersects the line $\overline{L_N\,V_{N+1}}$ furthest to the left. The next lower tie line (shown in green) denotes the location of Δ_{min}.



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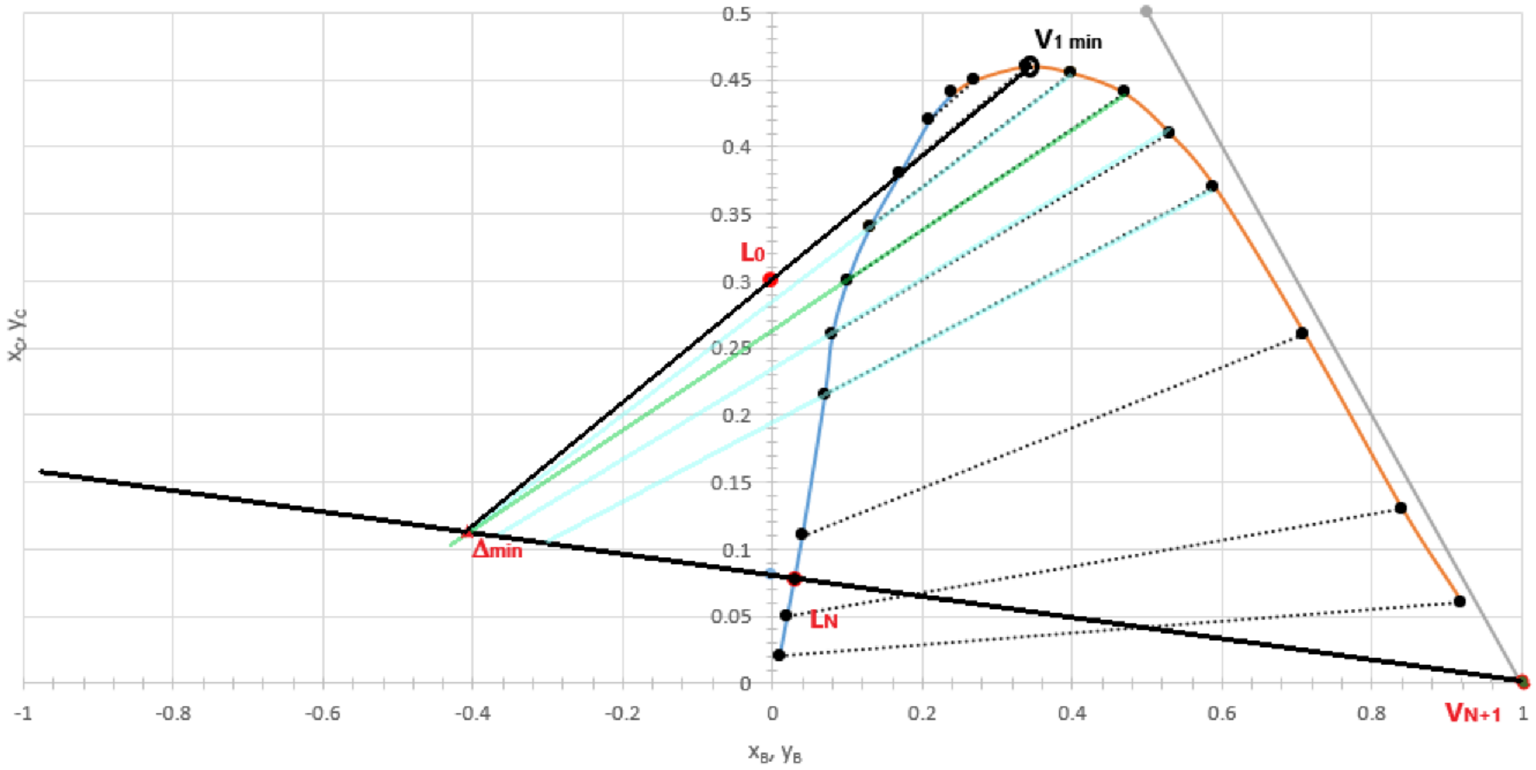
Minimum Entering Solvent Flow

- Now extend a line from Δ_{min} to L_0 and on to the extract side of the two phase boundary. This determines the location of $(V_1)_{min} = (y_B, y_C) = (0.34, 0.46)$. Oftentimes this line is a tie line, but in this case it is not exactly.



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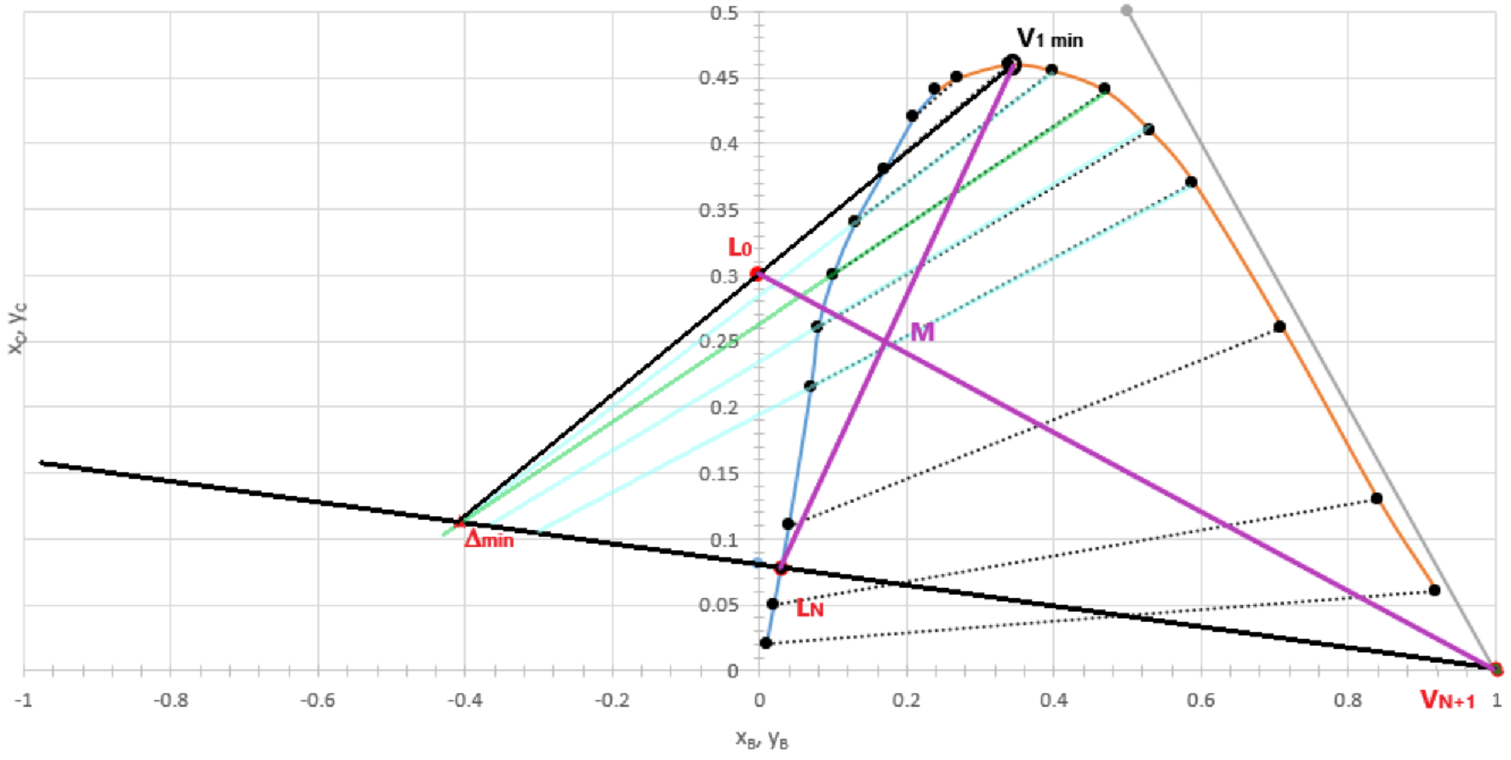
Minimum Entering Solvent Flow

- The lines $\overline{L_N\,V_1}$ and $\overline{L_0\,V_{N+1}}$ intersect at the point $M = (y_B, y_C) = (0.17, 0.25)$.



$x_M = 0.25$ $\qquad x_R = x_0 = 0.30$ $\qquad y_E = y_{N+1} = 0$

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Minimum Entering Solvent Flow

Solute Balance

- $L_0\, x_0 + V_{N+1}\, y_{N+1} = (L_0 + V_{N+1})\, x_M$
- $V_{N+1} = L_0 \dfrac{x_0 - x_M}{x_M - y_{N+1}}$
- $V_{N+1} = 1000 * \dfrac{0.30 - 0.25}{0.25 - 0} = 200\, kg/hr$

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Minimum Entering Solvent Flow

Solvent Balance

- $L_0 \, x_{B\,0} + V_{N+1} \, y_{B\,N+1} = (L_0 + V_{N+1}) \, x_{B\,M}$

- $V_{N+1} = L_0 \, \dfrac{x_{B\,0} - x_{B\,M}}{x_{BM} - y_{B\,N+1}}$

- $V_{N+1} = 1000 * \dfrac{0 - 0.17}{0.17 - 1} = 204.8 \, kg/hr$