CE407 SEPARATIONS

Lecture 15b

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Multi-Stage Cross Current LLE

- Consider a countercurrent liquid extraction process. The 8000 kg/hr feed ($\boldsymbol{L_0}$) stream comprises 8 mass % lactic acid (solute $\boldsymbol{C}$) and 92 mass % water (diluent $\boldsymbol{A}$). The 25,000 kg/hr entering solvent ($\boldsymbol{V_{N+1}}$) stream is pure nonanol (solvent $\boldsymbol{B}$). The exiting raffinate should have 0.5 mass % lactic acid on a nonanol-free basis.
- What will be the flow rate of the exiting extract?
- What will be the composition of the exiting extract on a water-free basis?

- Note: the location of the Mixing point will make doing mass balances on the C component will be difficult – do mass balances on the B component instead.

Multi-Stage Cross Current LLE

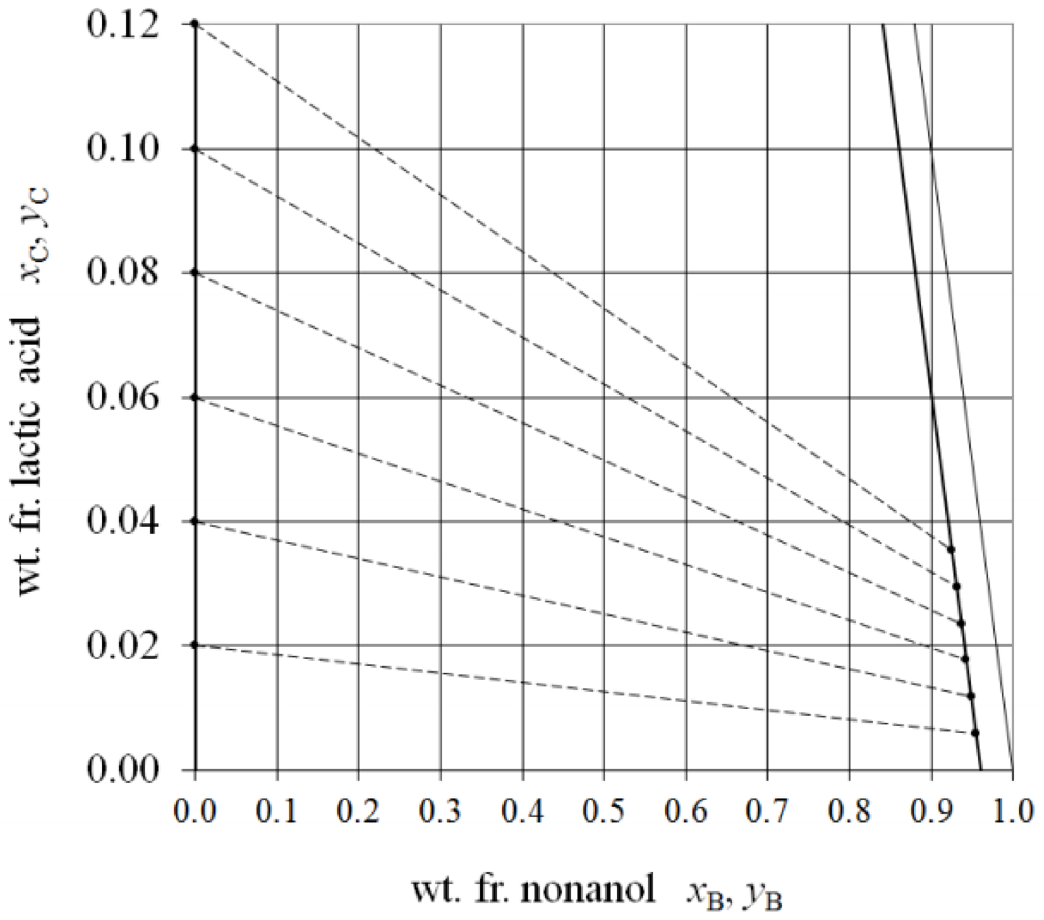
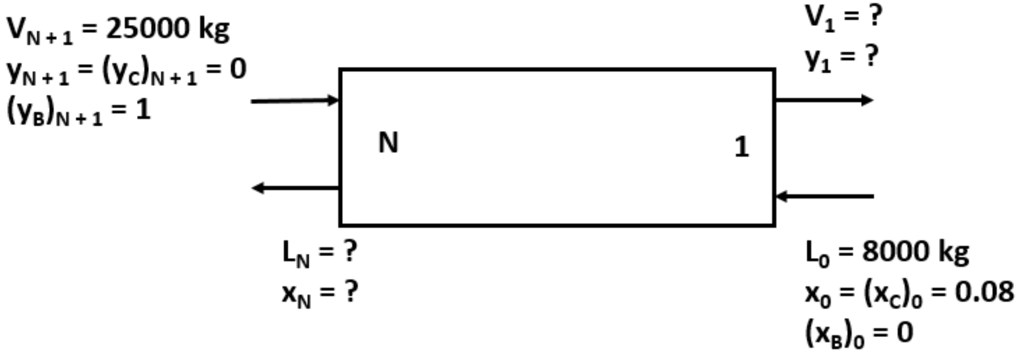


Figure 3: Phase diagram quantifying liquid–liquid equilibria of ternary mixtures of water (diluent, A), nonanol (solvent, B) and lactic acid (solute, C)

Multi-Stage Countercurrent LLE

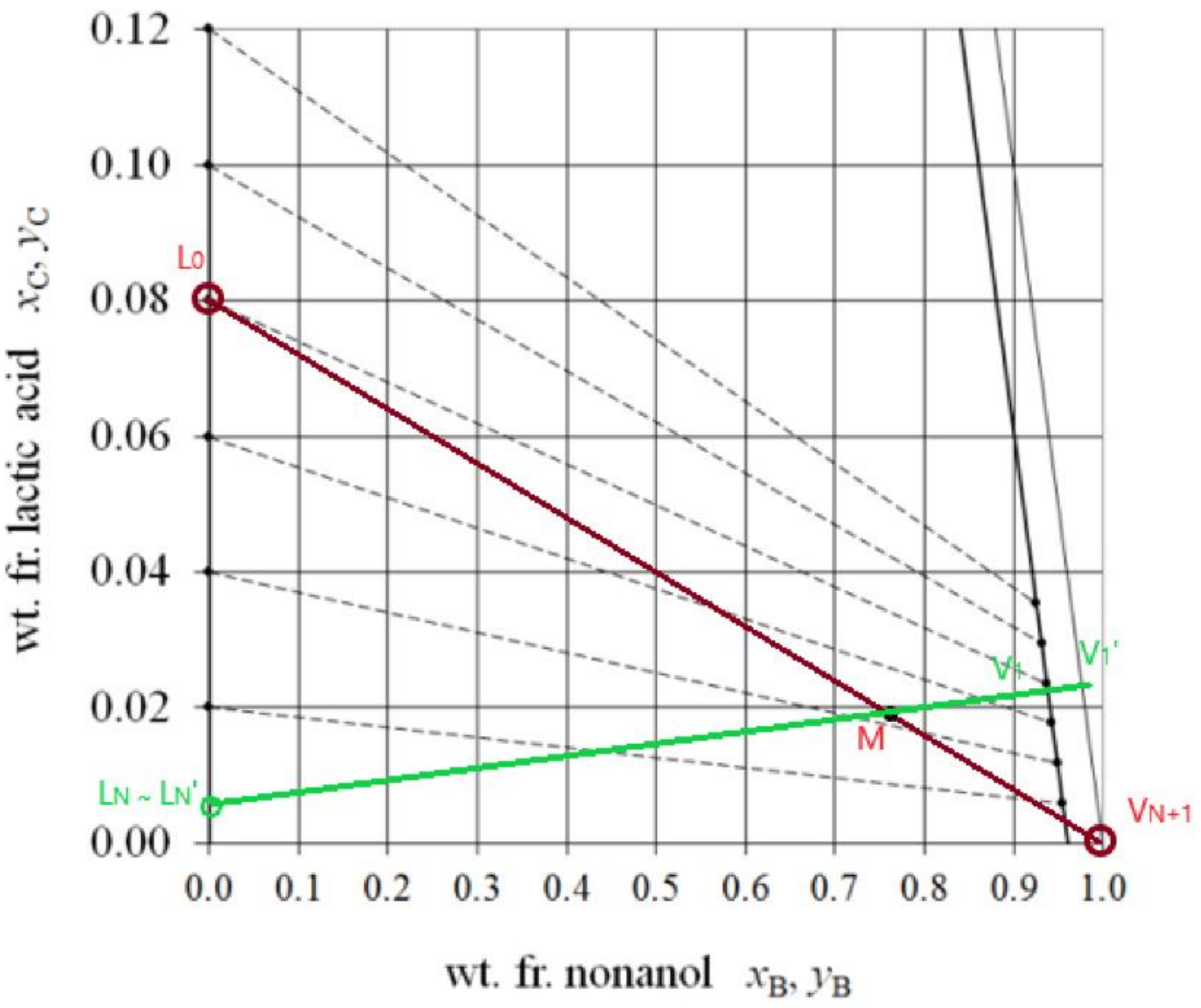
1 hour basis A (diluent) = water B (solvent) = nonanol
C (solute) = lactic acid



- Start by calculating the fictitious mixture point
- M = the rate at which liquid enters the system = $L_0 + V_{N+1} = 33,000\ kg$
- $x_M = (x_c)_M = \frac{x_0\, L_0 + y_{N+1}\, V_{N+1}}{L_0 + V_{N+1}}$
- $x_M = (x_c)_M = \frac{0.08 * 8000 + 0 * 25,000}{8000 + 25,000} = 0.0194$
- $(x_B)_M = \frac{(x_B)_0\, L_0 + (y_B)_{N+1}\, V_{N+1}}{L_0 + V_{N+1}} = \frac{0 * 8000 + 1 * 25,000}{8000 + 25,000} = 0.7576$

Multi-Stage Countercurrent LLE

- Locate $\boldsymbol{M}$ as a point on the line $\overline{L_0 V_{N+1}}$ where $x_M = (x_c)_M = 0.0194$ or $(x_B)_M = 0.7576$
- Because the left-hand side of the two-phase boundary is essential at $x_B = 0$, we can state that $L_N \approx L'_N = 0.005$
- $\boldsymbol{M}$ is also equal to the rate at which liquid exits the system and therefore lies on the line $\overline{L_N V_1}$
- We can extend the line $\overline{L_N V_M}$ to reach the two-phase boundary in order to locate V_1
- $(y_B)_1 = 0.94$ and $(y_c)_1 = 0.022$



Multi-Stage Countercurrent LLE

- Working with Solute Mass Fractions:
- $\frac{V_1}{L_N} = \frac{x_M - x_N}{y_1 - x_M} = \frac{0.0194 - 0.005}{0.022 - 0.0194} = 5.54$
- $L_N = \frac{M}{1 + {V_1}/{L_N}} = \frac{33{,}000}{1 + 5.54} = 5045\ kg$
- $V_1 = M - L_N = 33{,}000 - 5045 = 27{,}955\ kg$

- Working with Solvent Mass Fractions:
- $\frac{V_1}{L_N} = \frac{(x_B)_M - (x_B)_N}{(y_B)_1 - (x_B)_M} = \frac{0.7576 - 0}{0.94 - 0.7576} = 4.15$
- $L_N = \frac{M}{1 + {V_1}/{L_N}} = \frac{33{,}000}{1 + 4.15} = 6403\ kg$
- $V_1 = M - L_N = 33{,}000 - 6403 = 26{,}597\ kg$

Small errors in reading the graph will have much less effect on the B balance answer. The second set of values is more reliable.

Multi-Stage Countercurrent LLE

- $V_1 = 26,597\ kg$
- $(y_B)_1 = 0.94$ and $(y_c)_1 = 0.022$
- $(y_C)_1|_{water-free} = \frac{0.022}{0.94+0.022} = 0.023$
- $(y_B)_1|_{water-free} = \frac{0.94}{0.94+0.022} = 0.977$
- One could also read V_1' off of the graph