CE407 SEPARATIONS

Lecture 16b

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Multi-Stage Cross Current LLE

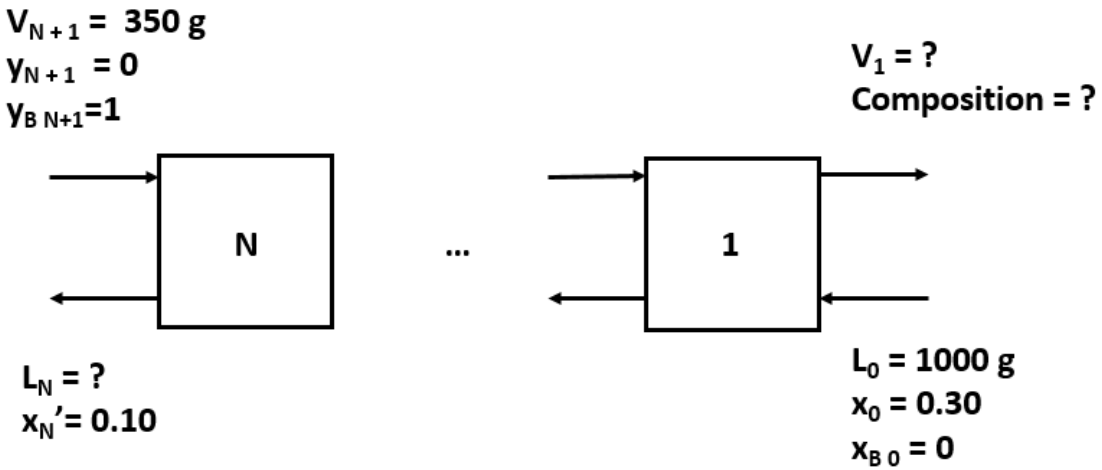
- 1000 g/sec of a feed solution with a composition of 30 mass% acetic acid (solute, C) and 70 mass % isopropyl ether (diluent, A) is to be contacted with water (solvent, B) in a countercurrent extraction battery. The acid concentration in the ether-rich (raffinate) phase is to be reduced to 10 mass % on a water-free basis (i.e. the exiting raffinate should contain acid and ether in the proportion acid/ether = 10/90). The water enters pure at the rate of 350 g/s.
  a) What will be the compositions and flow rates of the exiting raffinate and extract.
  b) How many ideal stages are required to perform the desired separation
- 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	0.01		0.96	0.03
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	0.22		0.59	0.37
0.11	0.31		0.45	0.44
0.15	0.36		0.37	0.46

Multi-Stage Cross Current LLE

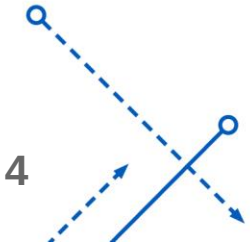
1 second basis

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



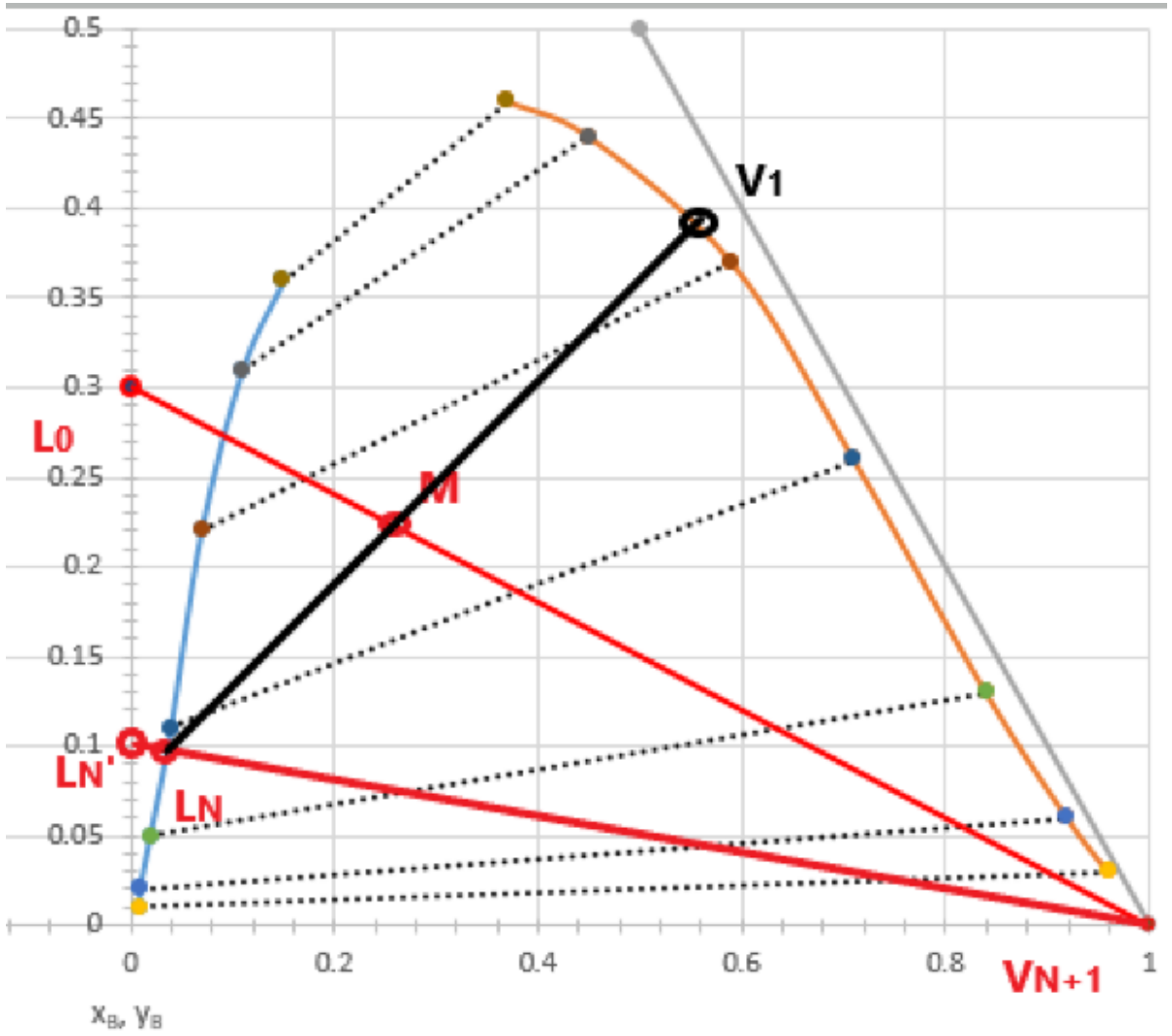
Multi-Stage Countercurrent LLE

- Start by calculating the fictitious mixture point
- M = the rate at which liquid enters the system = $L_0 + V_{N+1} = 1350\ g$
- $x_M = (x_c)_M = \frac{x_0 L_0 + y_{N+1} V_{N+1}}{L_0 + V_{N+1}}$
- $x_M = (x_c)_M = \frac{0.30*1000 + 0*350}{1000+350} = 0.22$



Multi-Stage Countercurrent LLE

- Locate points $\boldsymbol{L_0 = (0, 0.30)}$ and $\boldsymbol{V_{N+1} = (1, 0)}$
- Locate $\boldsymbol{M}$ as a point on the line $\overline{\boldsymbol{L_0\, V_{N+1}}}$ where $\boldsymbol{x_M = (x_c)_M = 0.22}$
- $\boldsymbol{L_N}$ is located by positioning $\boldsymbol{L'_N = (0, 0.1)}$ and pure solvent, $\boldsymbol{(1, 0)}$:
  - Where this line crosses the raffinate side of the two-phase boundary is $\boldsymbol{L_N}$ is $\boldsymbol{x_C = 0.095}$
- We can extend the line $\overline{\boldsymbol{L_N\, V_M}}$ to reach the two-phase boundary in order to locate $\boldsymbol{V_1}$
- $\boldsymbol{(y_c)_1 = 0.39}$
- Raffinate Composition: $\boldsymbol{L_N = (x_B, x_C) = [0.04, 0.095]}$
- Extract Composition: $\boldsymbol{V_1 = (y_B, y_C) = [0.56, 0.39]}$

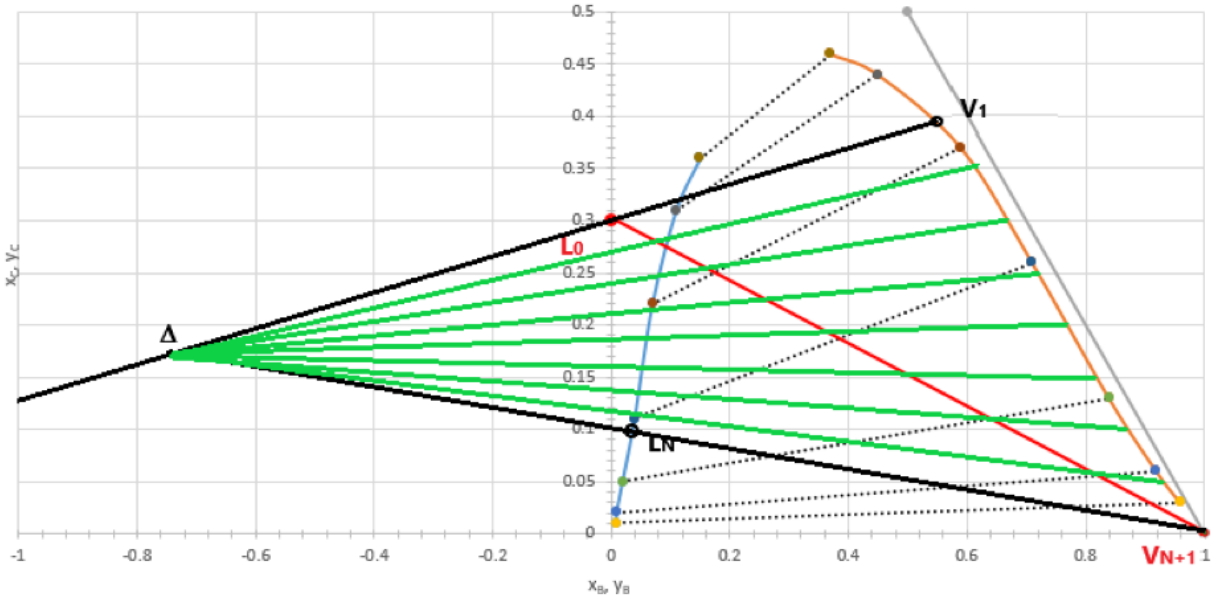


Multi-Stage Countercurrent LLE

- Working with Solute Mass Fractions:
- $\frac{E}{R} = \frac{x_M - x_R}{y_E - x_M}$
- $\frac{E}{R} = \frac{0.22 - 0.095}{0.39 - 0.22} = 0.74$
- $R = \frac{M}{1 + {}^{E}/_{R}} = \frac{1000 + 350}{1 + 0.74} = 775.9\ g/s$
- $E = M - R = 1350 - 775.9 = 574.1\ g/s$

Multi-Stage Countercurrent LLE

- Extend a line from V_1 through L_0 and a line from V_{N+1} through L_N. Their intersection is the point Δ
- The point Δ is then extended multiple times. The values of $(x_C,\ y_C)$, or the mass fraction of solute are located where a given line crosses the two-phase boundary on the raffinate and on the extract sides.
- **Equilibrium curve** is generated from taking x_C from the ether rich phase as x and y_c from the water rich side as y



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x	y
0.115	0.05
0.135	0.10
0.160	0.15
0.185	0.20
0.215	0.25
0.245	0.30
0.280	0.35
0.320	0.39

Multi-Stage Countercurrent LLE

- There are 2.5 ideal stages
- Round up to 3 ideal stages