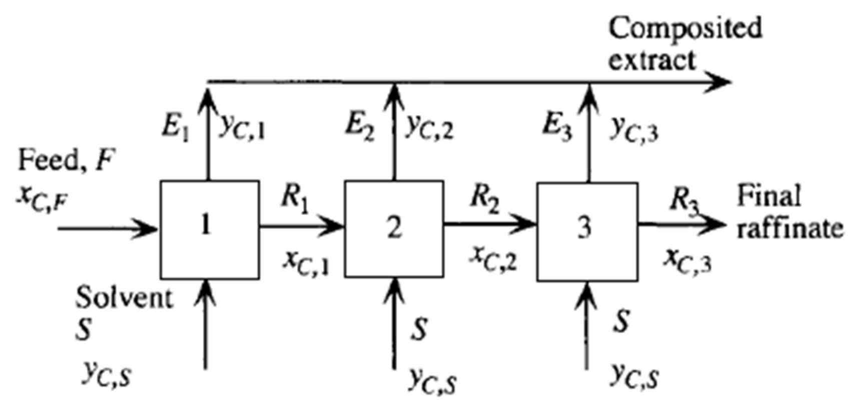
# Multistage extraction

# Multistage Cocurrent Extraction

- Multistage cocurrent extraction can be decided as extension of a single-stage extraction.
- In this kind of extraction the raffinate is successively contacted with fresh solvent, and may be done continuously or in batches.

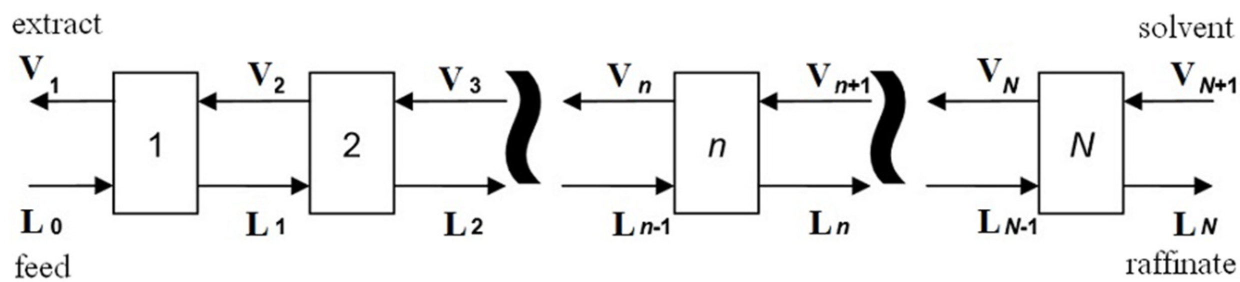



The schematic diagram for a three-stage crosscurrent extraction process

- A single final raffinate results, and the extracts can be combined to provide a composited extract, as shown.
- The stage number can be adjusted depending on the process.The calculations for single stage extraction can be performed for the first stage.
- Subsequent stages are dealt with in the same manner, except that the feed to any stage is the raffinate from the previous stage.
- Unequal amounts of solvent can be used in the various stages. For a given final raffinate concentration, the greater the number of stages the less total solvent will be used.

# Multistage Countercurrent Extraction

- Multistage countercurrent extraction is often employed to use less solvent and to obtain a more concentrated exit extract stream.




Schematic representation of a multistage countercurrent extraction process

- The feed stream containing the solute A to be extracted and the solvent stream enters at opposite ends. The extract and raffinate streams flow countercurrently from stage to stage, and the final products are the extract stream $V_1$ leaving stage 1 and the raffinate stream $L_N$ leaving stage N.

- The material balances on all N stages are;

$$L_0 + V_{N+1} = L_N + V_1 = M$$

$$L_0 x_{A0} + V_{N+1} y_{AN+1} = L_N x_{AN} + V_1 y_{A1} = M x_{AM}$$

$$L_0 x_{C0} + V_{N+1} y_{CN+1} = L_N x_{CN} + V_1 y_{C1} = M x_{CM}$$

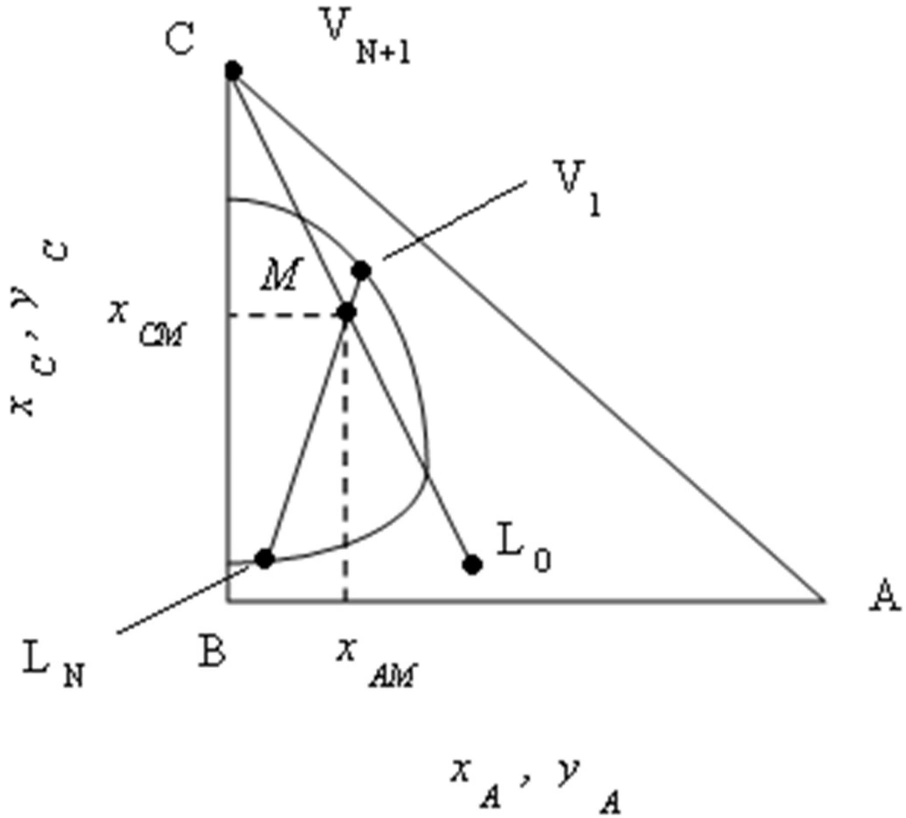
$$x_{AM} = \frac{L_0 x_{A0} + V_{N+1} y_{AN+1}}{L_0 + V_{N+1}} = \frac{L_N x_{AN} + V_1 y_{A1}}{L_N + V_1}$$

$$x_{CM} = \frac{L_0 x_{C0} + V_{N+1} y_{CN+1}}{L_0 + V_{N+1}} = \frac{L_N x_{CN} + V_1 y_{C1}}{L_N + V_1}$$

- The point M is the cross section point of two lines which are $V_{N+1}$–$L_0$ and $V_1$–$L_N$. In the processes, the flows and compositions of $L_0$ and $V_{N+1}$ are the known properties.
- The desired exit composition $x_{AN}$ is set. When the points $L_0$, $V_{N+1}$ and $M$ of which coordinates are known are plotted, these three points can be connected with a straight line.
- Bu using the following information the unknowns can be calculated:

–$L_N$, $M$ and $V_1$ must lie on the same line;

– $L_N$ and $V_1$ must lie on the phase envelope.



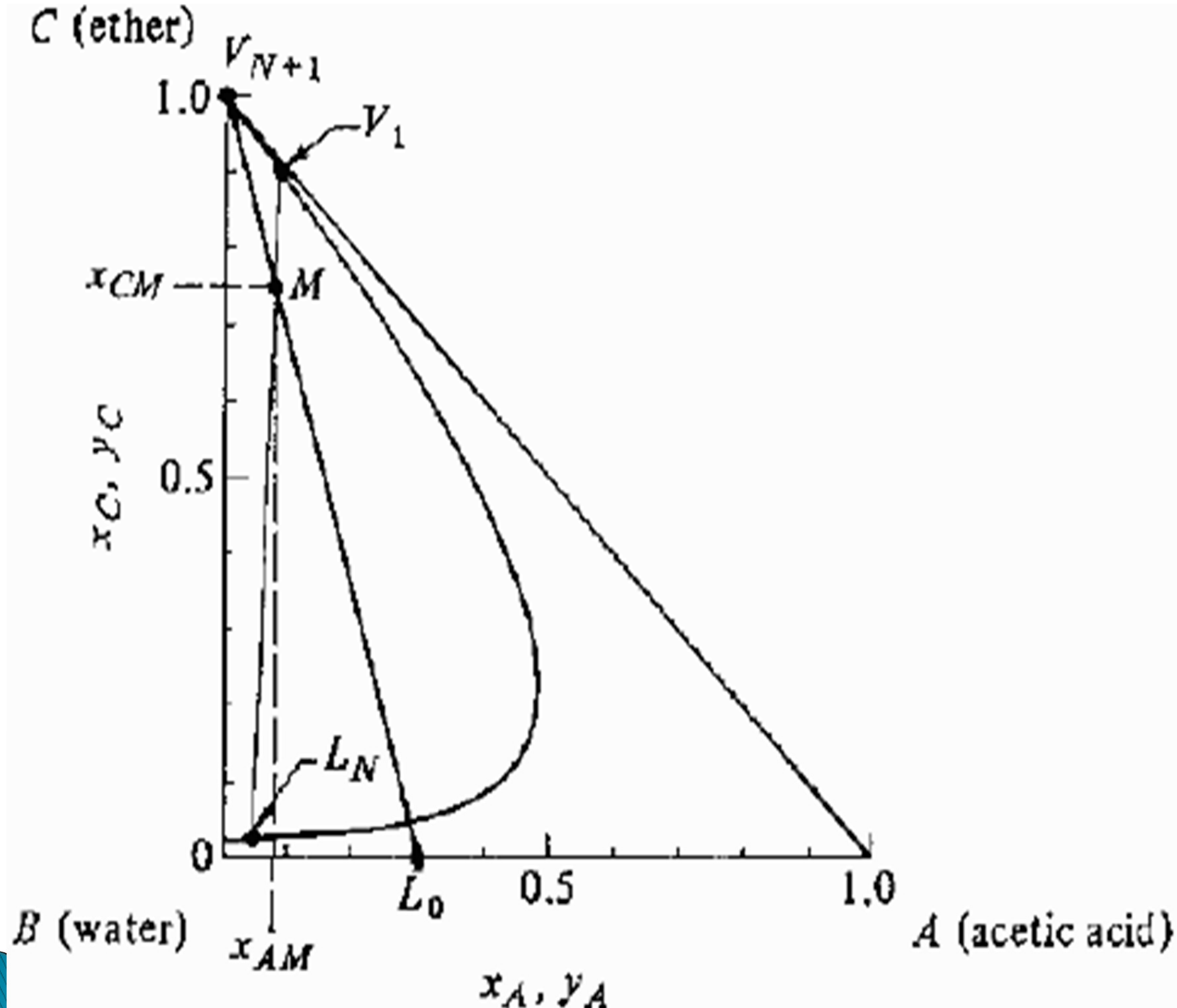
C
$V_{N+1}$
$V_1$
$M$
$x_{CM}$
$x_C, y_C$
$L_0$
A
$L_N$
B
$x_{AM}$
$x_A, y_A$

Example

Multistage countercurrent extraction is used to extract an aqueous solution of $L_0$ (400 kg/h) which contains 30 wt% acetic acid (A). The pure solvent used for the extraction is isopropyl ether at a rate of $V_{N+1}$ (1200 kg/h). The exit acetic acid concentration in the aqueous phase should be 5%. Calculate the compositions and amounts of the ether extract $V_1$ and the aqueous raffinate $L_N$ by using the equilibrium data given in following table.

**Table** The equilibrium data for Acetic acid (A)–Water (B)–Isopropyl ether solvent (C) at 20 °C

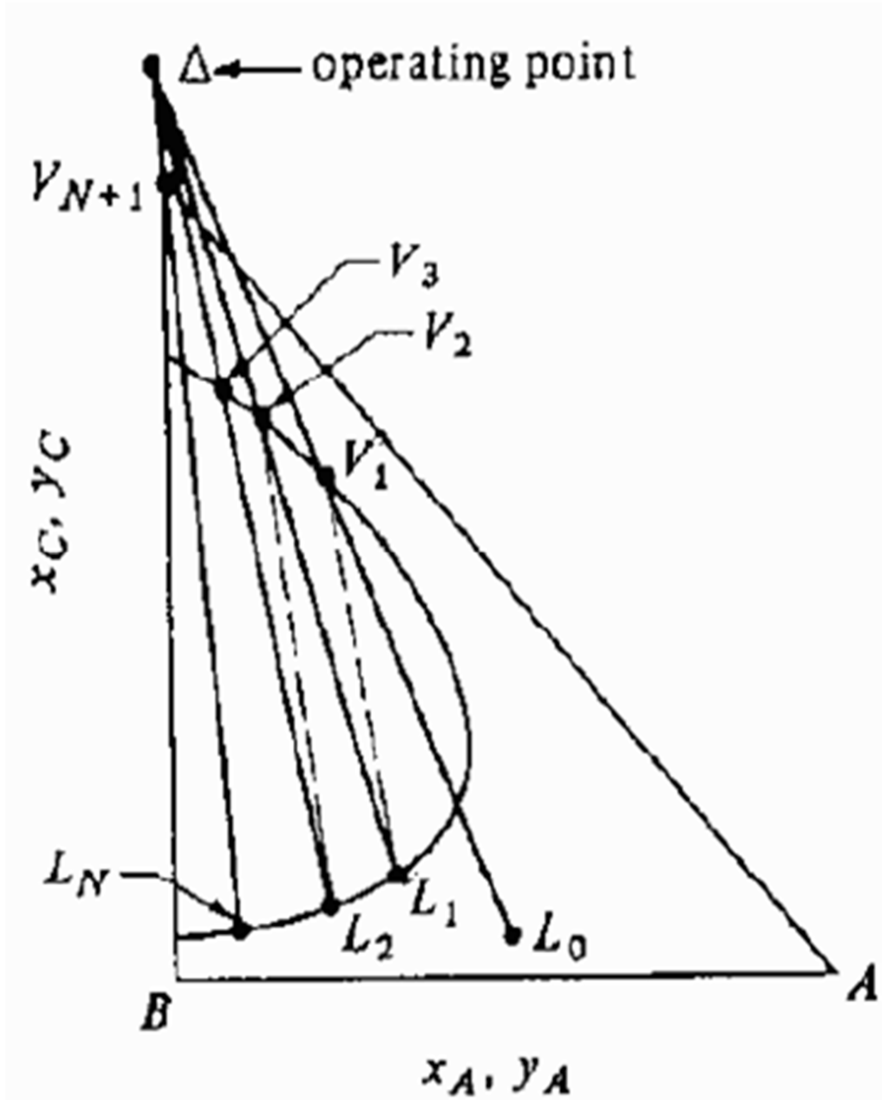
| Water layer (wt %) | | | Isopropyl Ether layer (wt %) | | |
|---|---|---|---|---|---|
| Acetic Acid | Water | Isopropyl Ether | Acetic Acid | Water | Isopropyl Ether |
| 0 | 98.8 | 1.2 | 0 | 0.6 | 99.4 |
| 0.69 | 98.1 | 1.2 | 0.18 | 0.5 | 99.3 |
| 1.41 | 97.1 | 1.5 | 0.37 | 0.7 | 98.9 |
| 2.89 | 95.5 | 1.6 | 0.79 | 0.8 | 98.4 |
| 6.42 | 91.7 | 1.9 | 1.93 | 1.0 | 97.1 |
| 13.30 | 84.4 | 2.3 | 4.82 | 1.9 | 93.3 |
| 25.50 | 71.1 | 3.4 | 11.40 | 3.9 | 84.7 |
| 36.70 | 58.9 | 4.4 | 21.60 | 6.9 | 71.5 |
| 44.30 | 45.1 | 10.6 | 31.10 | 10.8 | 58.1 |
| 46.40 | 37.1 | 16.5 | 36.20 | 15.1 | 48.7 |



C (ether)
$V_{N+1}$
1.0
$V_1$
$x_{CM}$
M
$x_C, y_C$
0.5
$L_N$
0
$L_0$
0.5
1.0
B (water)
$x_{AM}$
A (acetic acid)
$x_A, y_A$

# The method to calculate number of stages

- –Locate $L_0$ on the diagram.
- –Draw the line $L_0\Delta$ which locates $V_1$ on the phase boundary.
- –Locate $L_1$ by using the tie line through $V_1$.
- – Draw the line $L_1\Delta$ which locates $V_2$ on the phase boundary.
- –Locate $L_2$ by using the tie line through $V_2$.
- –Repeat this stepwise procedure until the desired raffinate composition $L_N$ is reached.



Δ
operating point
$V_{N+1}$
$V_3$
$V_2$
$V_1$
$x_C, y_C$
$L_N$
$L_2$
$L_1$
$L_0$
B
A
$x_A, y_A$

Example

An aqueous solution of acetic acid (A) and water (B) mixture with a flow rate of 150 kg/h is being extracted by pure isopropyl ether (C) of 450 kg/h in a countercurrent multistage extraction unit. The water concentration of the inlet aqueous solution is given as 70 wt% and the exit acid concentration in the aqueous phase is given as 10 wt %. Calculate the number of stages required.