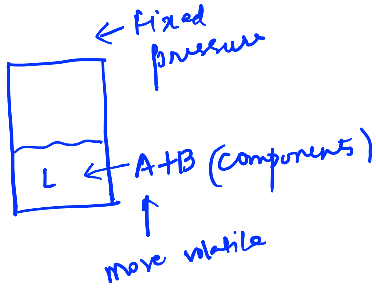
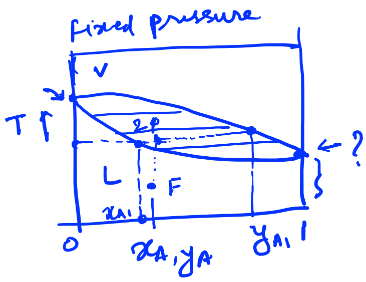
Lecture 27: Enthalpy - concentration Diagram

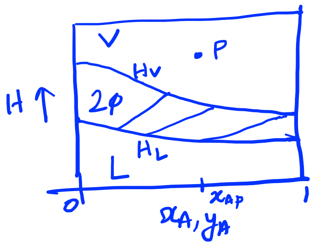
Topics:
(i) Enthalpy - conc. diagram
(ii) Flash vaporization

Recall: T - X - Y; P - X - Y, Similarly, one can also represent the vapor-liquid equilibrium using the enthalpy - conc. diagram.





Similarly, ⇒ one can represent VLE on HC diagram



Molar enthalpy of solution @ Temp T (kJ/mol) → $H_L = \Delta H_s + \underbrace{C_L M_{av}(T - T_0)}_{\text{Sensible heat}}$

ΔH_s: Heat of mixing (= 0 for ideal solution)

ΔH_s = Heat of mixing [< 0 for exothermic]

T_0 = Reference temperature

C_L = Specific heat of solution @ temp T [kJ/kmol.K]

M_{av} = Average molecular mass of the solution (g/mol)

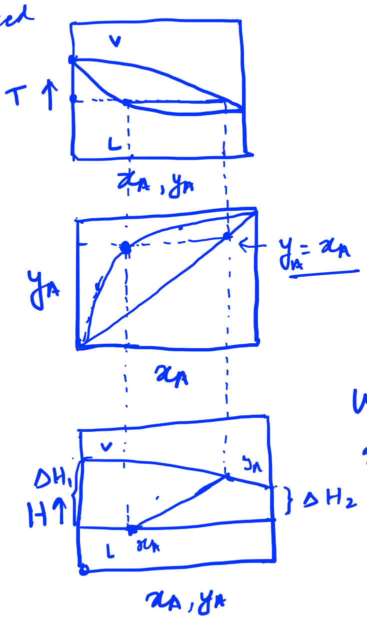
$$H_V = y_A M_A \left[C_{LA}(T - T_0) + \lambda_A\right] + (1 - y_A) M_B \left[C_{LB}(T - T_0) + \lambda_B\right]$$

C_{LB}, C_{LA} = Specific heat of pure liquids A & B ; kJ/kg.K

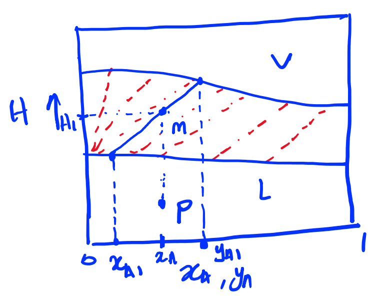
M_A, M_B = Molecular mass of pure components A & B

λ_A, λ_B = Heat of vaporization @ temp T for components A & B ; kJ/kg

Tie lines on H-X-Y diagram:



Effect of heating followed by the cooling of the vapor phase:

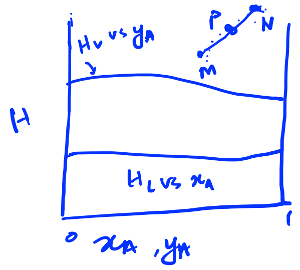


What is ΔH_1 & ΔH_2?

$x_A = 0$, $\Delta H_1 = \lambda_B$

$x_A = 1$; $\Delta H_2 = \lambda_A$

Characteristics of H-X-Y diagram



Say, M moles of a mixture of enthalpy H_m & concentration z_m is mixed adiabatically with N moles of a mixture of enthalpy H_N & Conc. z_n to produce P moles of a mixture of enthalpy H_P & conc. z_P.

$M\ (z_m, H_m)$

$N\ (z_N, H_N)$

$P\ (z_P, H_P)$

Mass balance: $P = M + N$ — ①

Species balance: $z_m M + z_N N = z_P P$ — ②

Enthalpy balance: $M H_m + N H_N = P H_P$ — ③

① - ③ $\Rightarrow$

$$\frac{M}{N} = \frac{z_n - z_P}{z_P - z_m} = \frac{H_N - H_P}{H_P - H_m}$$

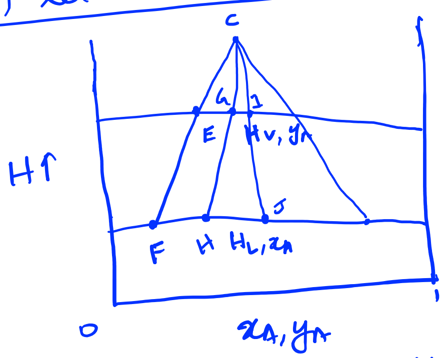
; M, N, P lie on a straight line

Also,

$$\frac{M}{N} = \frac{\text{line } NP}{\text{line } PM}$$

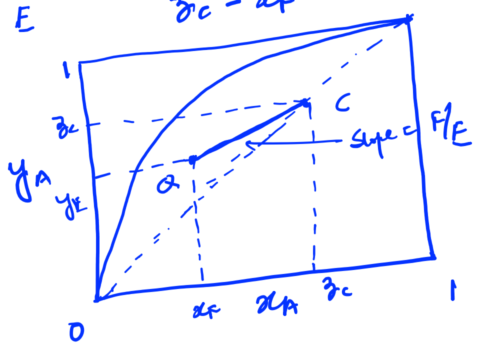
Similarly, If 'N' is adiabatically removed from the mixture 'P', then the mixture 'M' would result.

Similarly, let's consider the following:



- Mixing C & F can give mixture E.
- Mixture C can be obtained by adiabatically removing saturated liquid F from saturated vapor E.
- Similarly, C can be obtained by adiabatically removing saturated liquid H & J from ~~the~~ saturated vapor G & I, respectively.

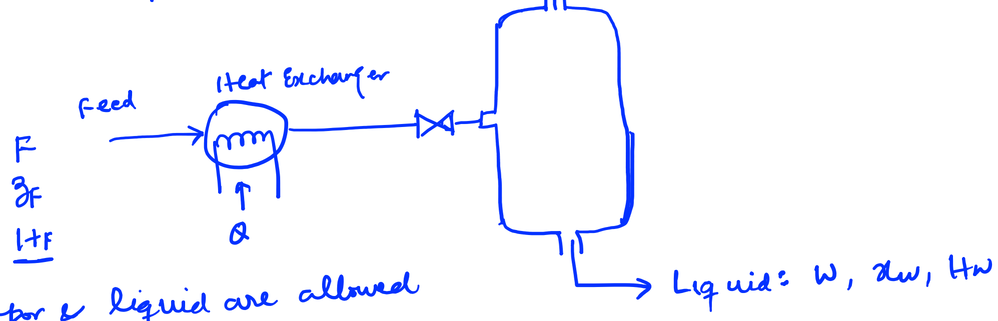
$$\frac{F}{E} = \frac{z_c - y_E}{z_c - x_F} = \frac{\text{line } CE}{\text{line } CF}$$



Important: EF may not be the tie line. If Q lies on the equilibrium curve, then EF can be the tie line.

Flash vaporization:

- Single stage operation wherein a liquid mixture is partially vaporized.



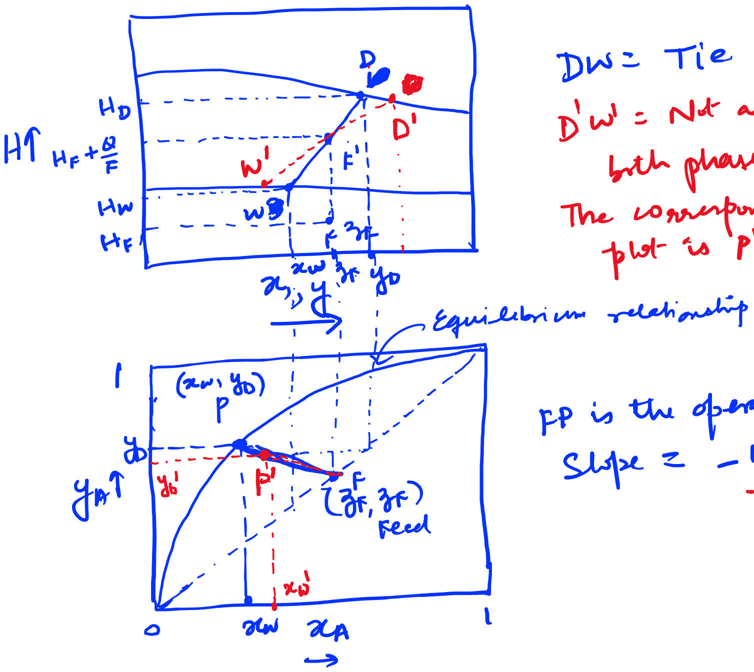
- The vapor & liquid are allowed to come to equilibrium & then separated.

Mass balance: $F = D + W$

Species balance: $z_F F = y_D D + x_W W$

Enthalpy balance: $F H_F + Q = D H_D + W H_W$

$$-\frac{W}{D} = \frac{y_D - z_F}{x_W - z_F} = \frac{H_D - (H_F + Q/F)}{H_W - (H_F + Q/F)}$$



DW = Tie line

D'W' = Not a tie line because both phases are not in equilibrium.

The corresponding point on the X–Y plot is P'.

FP is the operating line.

Slope = $-W/D$