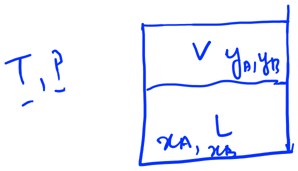
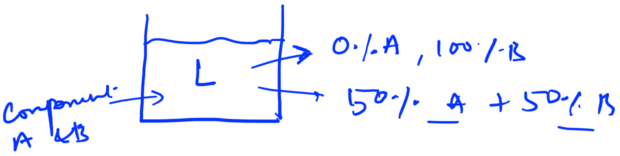
Lecture 23: Vapor - Liquid Equilibrium (VLE)



- We will limit our discussion to binary mixtures
- Two components A & B.
- Component A is more volatile (At any temperature, vapor pressure of A is higher)
- Liquid components dissolve in all proportions



- Gibbs phase rule: $F = C - P + 2$; F = Degree of freedom
  C = Number of components
  P = Number of phases

For two phases, vapor & liquid, having two components A & B, $F = 2 - 2 + 2 = 2$

There are four variables for this case: T, P, x_A, y_A

Fixing any two of the four variables given above will fix the state of the system:

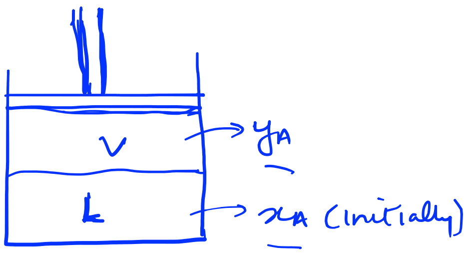
Ex: 1) Fix T & P $\Rightarrow$ x_A & y_A are fixed automatically

2) Fix T & x_A $\Rightarrow$ P, y_A are fixed automatically

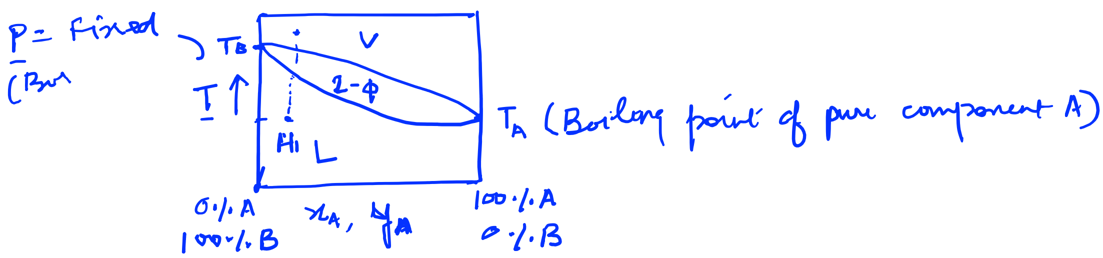
Experimental determination of VLE:

1) Constant pressure, increase temperature

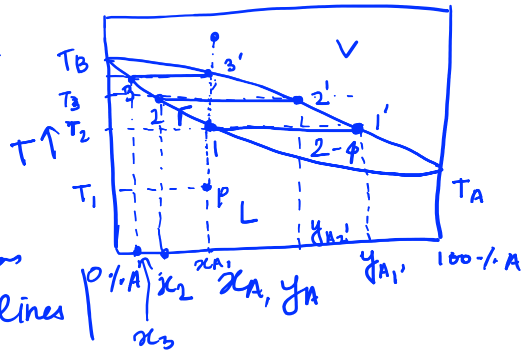
2) Fix temperature, increase ~~temperature~~ pressure



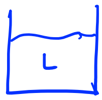
Constant Pressure VLE: T-X-Y Diagram



P= fixed



1-1', 2-2' are known as the tie-lines



Temp: T_1

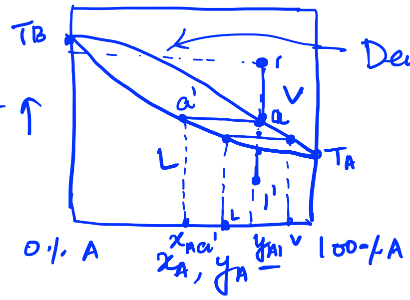
Composition: x_{A1}, x_{B1}

$x_{A1} + x_{B1} = 1$

$y_{A1'} + y_{B1'} = 1$

Curve 1-2-3 is the bubble point curve

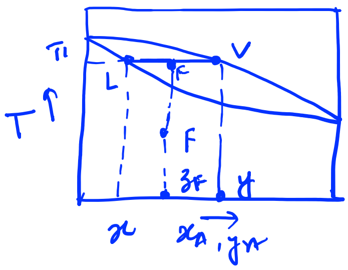
p= fixed



Dew point curve

What is the amount of liquid & vapor if we heat a feed F (liquid) having z_F mole fraction of A.

P= fixed



Mass balance:

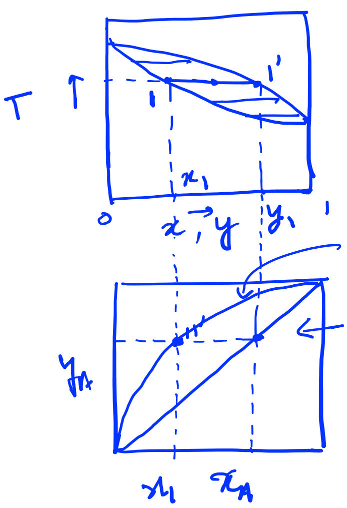
$$F = L + V \quad -(i)$$

Species balance:

$$F z_F = L x + V y \quad -(ii)$$

$$\Rightarrow \frac{L}{V} = \frac{y - z_F}{z_F - x} = \frac{\text{length of FV}}{\text{length of LF}}$$

This is also known as the Lever-arm rule

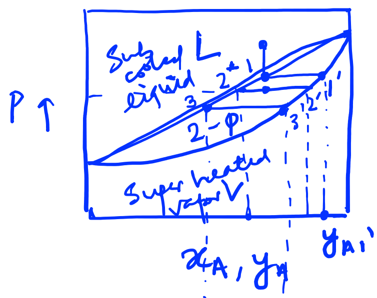


Equilibrium relationship

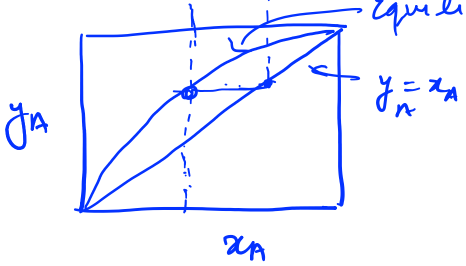
$y_A = x_A$

Constant Temperature : P–X–Y diagram

Temp is fixed



Region ~~1, 2, 3~~ above 1, 2 . . curve is called the subcooled liquid



; $y_A > x_A$