Universiti Malaysia PAHANG
Engineering • Technology • Creativity

Process Chem and Pharmaceutical Engineering 1

Vapor-liquid Separation Part 2

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Chapter Description

- Aims
  - Solve problems related to extraction process by applying the formula relevant to specific operations

- Expected Outcomes
  - Describe the vapor-liquid separation in single condensable component and multicomponent systems
  - Apply Raoult's law and Henry's Law in problem solving
  - Comprehend the distillation process

- References
  - Principles of Mass Transfer and Separation Processes, Binay K. Dutta, PHI Learning Private Limited, 2009

Henry's Law

<u>Assumptions</u>

- For pressure low – it is low that it can be assumed as ideal gas
- For species present as a very dilute solution in liquid phase

Henry's Law

$$y_i P = x_i H_i \quad (i = 1,2, \ldots N)$$

Where:

x_i = L-phase mole fraction

y_i = V-phase mole fraction

H_i = Henry's constant

P = total pressure

Henry's constant for gases dissolved in water at 25 °C

Gas	H/bar
Acetylene	1350
Air	72950
Carbon dioxide	1670
Carbon monoxide	54600
Ethane	30600
Ethylene	11550
Helium	126600
Hydrogen	71600
Hydrogen sulphide	550

Azeotrope

- When $x_1=y_1$, the dew point and bubble point curves are tangent to the same horizontal line.

- A boiling L of this composition produce a vapour exactly the same composition; L does not change in composition as it evaporates.

- Relative volatility:

$$\alpha_{12} \equiv \frac{y_1/x_1}{y_2/x_2}$$

$$(\alpha_{12})_{x1=0} = \frac{P_1^{sat} \exp A}{P_2^{sat}}$$

$$(\alpha_{12})_{x1=1} = \frac{P_1^{sat}}{P_2^{sat} \exp A}$$

If one limit is >1 and the other limit is <1; azeotrope exists

When given a mixture of composition at certain T or P

Bubble point

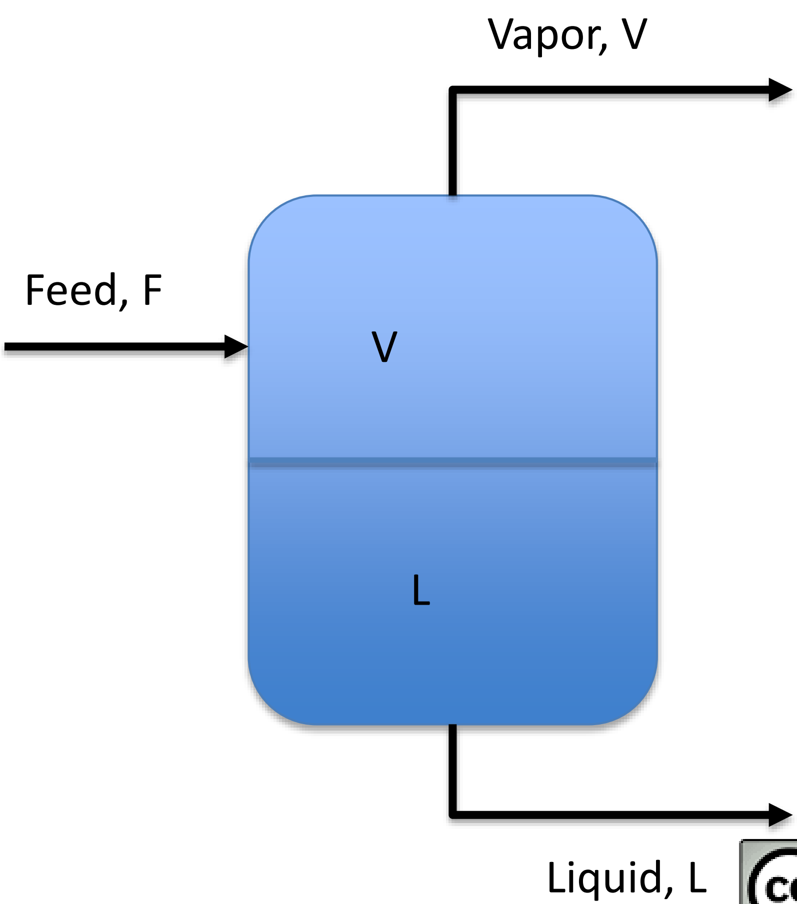
- Insignificant L
- The given mole fraction is y_i
- Composition of dew is $x_i = y_i/K_i$

Dew point

- System is almost condensed
- The given mole fraction is x_i
- Composition of bubble is $y_i=K_ix_i$

Flash Calculation

- The most important application of VLE.
- Originates from a fact that a liquid at pressure equal to or greater that its bubble point pressure “flashes” or evaporates when the pressure is reduced, producing a two-phase system of vapour and liquid in equilibrium.



Liquid at $P > P_{bubble}$ partially evaporates when P is reduced, producing 2-phase system of V and L in equilibrium.

Find T,P and z.

Flash Vaporization of a Binary Mixture

A binary mixture consists of component A and B. In the flowrate, the composition and enthalpy of the feed, the condensed top product (or distillate) and the bottom liquid product are denoted as (F, Z_f, H_f), (D, x_D, H_D) and (W, x_W, H_W) respectively and Q is the rate of supply of heat to the heat exchanger. The material and energy balances as the following:

- $F = D + W$
- $F_{zF} = D_{xD} + W_{xW}$
- $(D+W)_{zf} = D_{xD} + W_{xW}$
- $FH_f + Q = DH_D + WH_W$

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

Binary Flash Distillation

A mixture of 40% mol% benzene and 60 mol% toluene is being flash-distilled at a rate of 10 kmol/h at 1 atm total pressure. The liquid product should not contain more than 30 mol% benzene. Calculate the amounts and the compositions of the top and the bottom products. The relative volatility of benzene in the mixture is 2.5.

F + D = W

Given: F = 10, z_F = 0.4

Benzene balance: $F_{zF} = D_{xD} + W_{xW}$

Given x_W = 0.3

$(10)(0.4) = D_{xD} + W(0.3)$

$$\frac{x_D/(1-x_D)}{x_W/(1-x_W)}$$

D = 4.61, W = 5.39 mol/h, x_D = 0.517

Conclusion of The Chapter

This chapter discussed about bubble and dew point, Raoult's law and Henry's law, azeotrope and flash calculation

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Reference

Principles of Mass Transfer and Separation Processes, Binay K. Dutta, PHI Learning Private Limited, 2009