CHE482-Chemical Engineering Laboratory III

2B- FRACTIONAL DISTILLATION

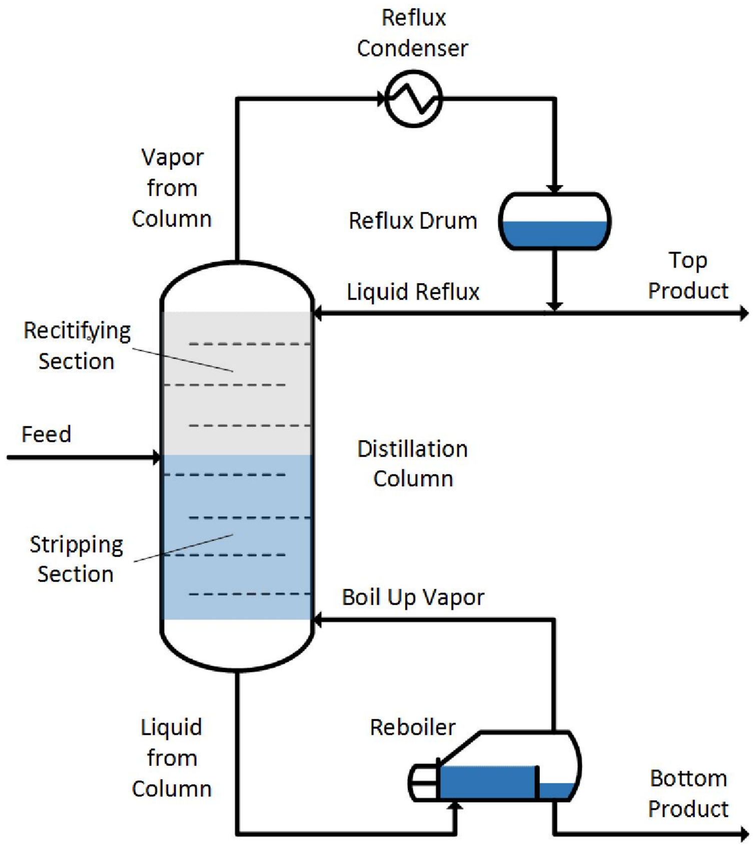
THEORY

- Distillation is a method for separating the various components of a liquid solution which depends upon the distribution of these components between a vapor phase and liquid phase.

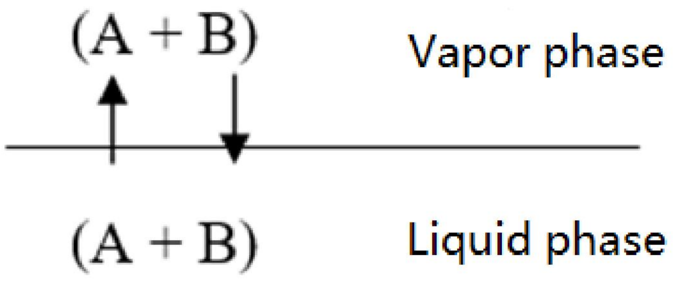
- Raoult's law, can be defined for vapor-liquid phases in equilibrium

$$p_A = P_A * x_A$$

p_A=Partial pressure of component A in the vapor
P_A=Vapor pressure of pure A
x_A=mol fraction of A in the liquid



Geankoplis, C. J. (2003). *Transport processes and separation process principles:(includes unit operations)*. Prentice Hall Professional Technical Reference.



- (A + B): Binary mixture
- A: More volatile component
- B: Less volatile component

- The more volatile component is enriched as the vapor stream rises upward.
- The liquid phase is rich in less volatile components.

Distillation terms

- **Volatiliy:** Volatility is a material quality which describes how readily a substance vaporizes. At a given temperature and pressure, a substance with high volatility is more likely to exist as a vapor.

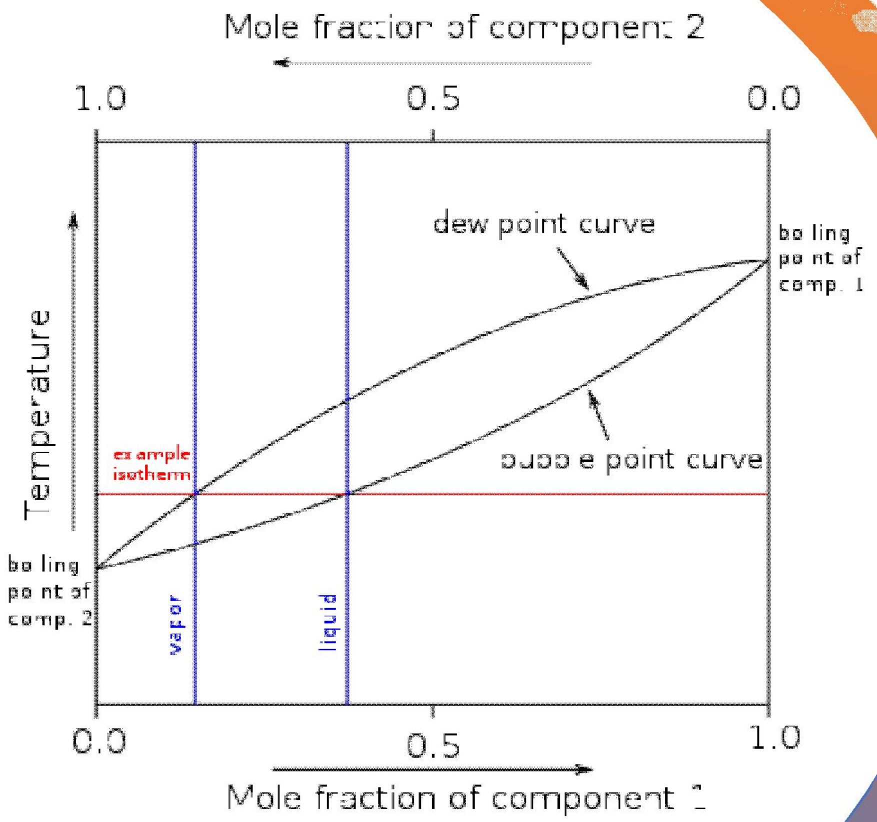
- **Relative Volatility:** Ratio of the concentration of A in the vapor to the concentration of A in the liquid divided by the ratio of the concentration of Bin the vapor to theconcnentration of B in the liquid.

$$a_{AB} = \frac{(\frac{yA}{xA})}{(\frac{yB}{xB})} = \frac{(\frac{yA}{xA})}{(1-yA)/(1-xA)} = \frac{PA}{PB}$$

$a_{AB} = 1$ **?**

$a_{AB} > 1$ **?**

Felder, Richard (2015). *Elementary Principles of Chemical Processes.* John Wiley & Sons. pp. 279–281.



The **bubble point** is the temperature where the first bubble of vapor is formed when heating a liquid consisting of two or more components.

Dew point is the temperature to which air must becooled to become saturated with water vapor.

Phase Rule

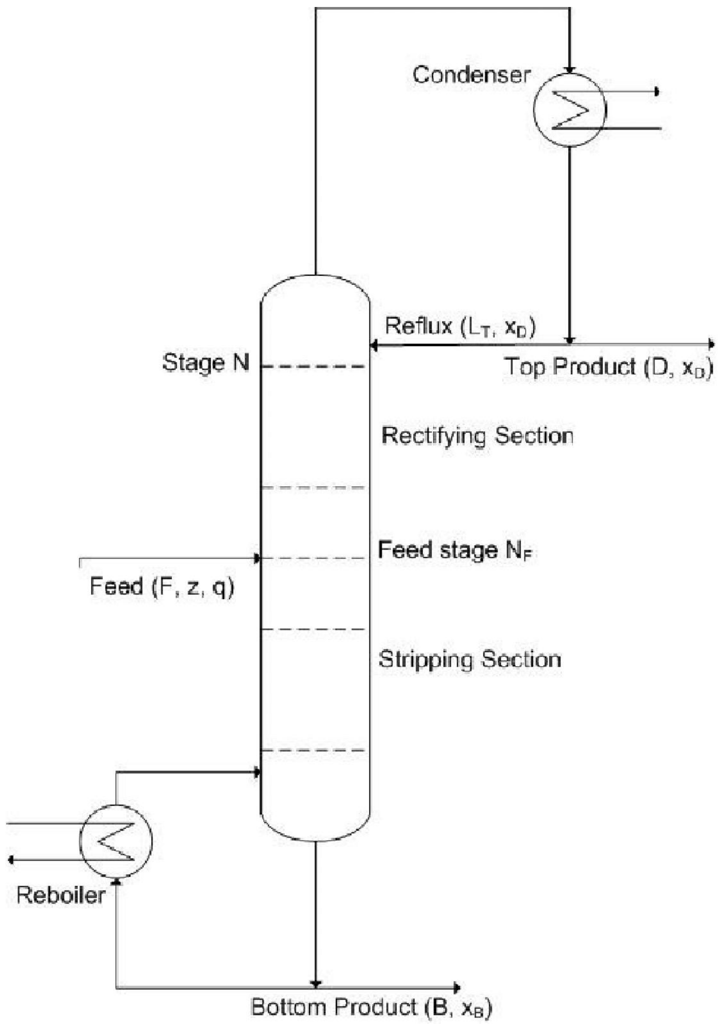
$$F = C + 2 - P$$

The equilibrium between two phase in a given situation is restricted by the phase rule;

F ; the number of variants ofdegrees of freedom of the system
C ; the number of total components
P ; the number of phases at equilibrium

Phase rule applies to the ethanol-water system ?

Components of the Distillation System

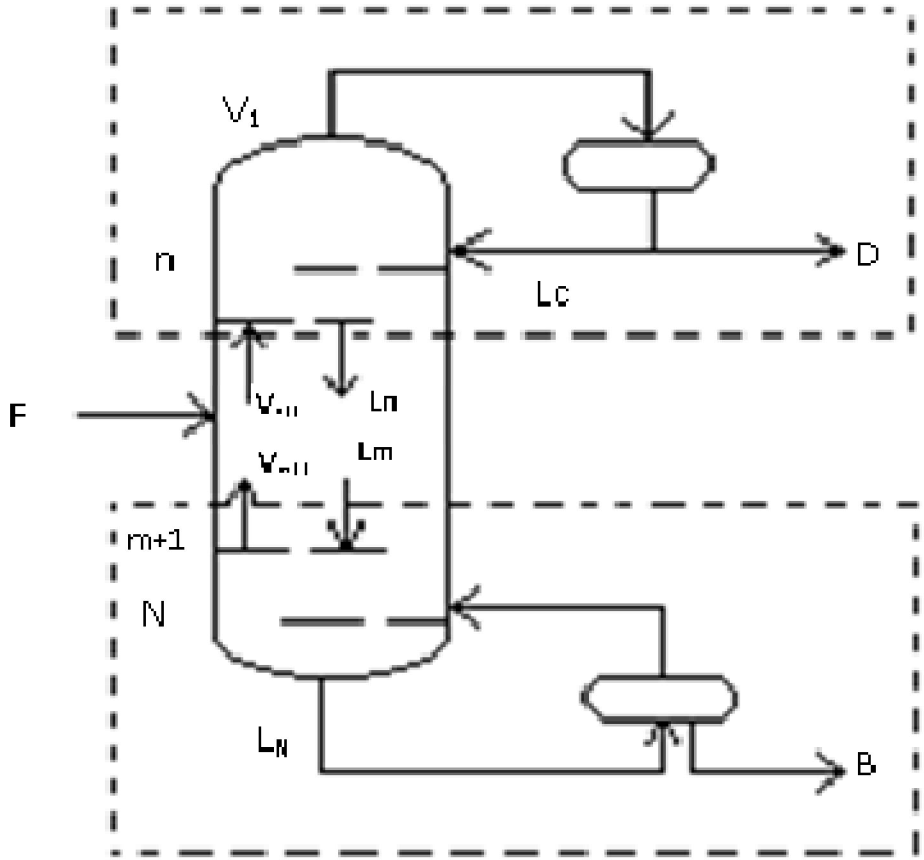


Which section is used in the experiment ?
Enriching Section
Stripping Section

Where are the hottest and coldest partsof the system?

Why tray distillation is used ?

Distillation Column Overall Material Balance



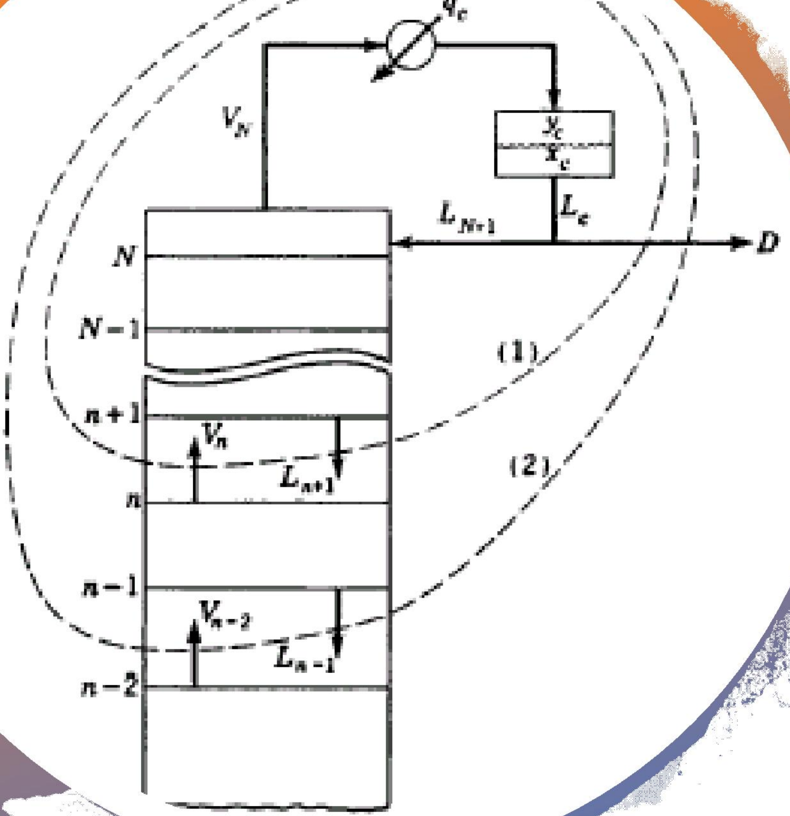
The entering feed of F in mol/h must equal the distillate D in mol/h plus the bottoms W in mol/h.

Overall Material Balance;

$$F = D + B$$

Total Material Balance on Component A;

$$F * X_F = D * X_D + B * X_B$$



Equation for Enriching Section

- $V_N = L_{N+1} + D$
- $D = V_N - L_{N+1}$

- $V_N * Y_N = L_{N+1} * X_{N+1} + D * X_D$
- $D * X_D = L_{N+1} * X_{N+1} - V_N * Y_N$

Operating Line

$$Y_N = \frac{L_{N+1}}{V_N} X_{N+1} + \frac{DX_D}{V_N}$$

$$Y_N = \frac{L_{N+1}}{(L_{N+1} + D)} X_{N+1} + \frac{DX_D}{(L_{N+1} + D)}$$

Reflux Ratio

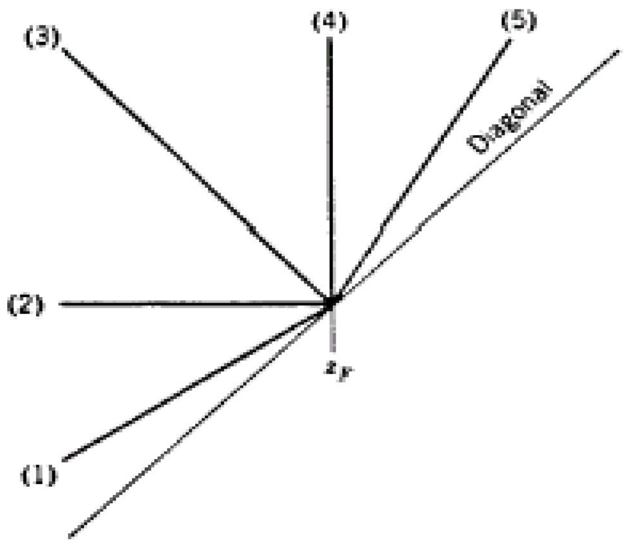
If R_D increases**?**

$R_D = L_0 / D$

It is the ratio between the amount of reflux that goes back down the distillation column and the amount of reflux that is collected in the receiver (distillate).

q Line

- Slope=- $\frac{(1-f)}{f}$ = -$\frac{q}{(1-q)}$



1= Superheated steam f>1 q<0

2= Saturated steam f=1 q=0

3= Vapor-liquid mixture 0<f<1 0<q<1

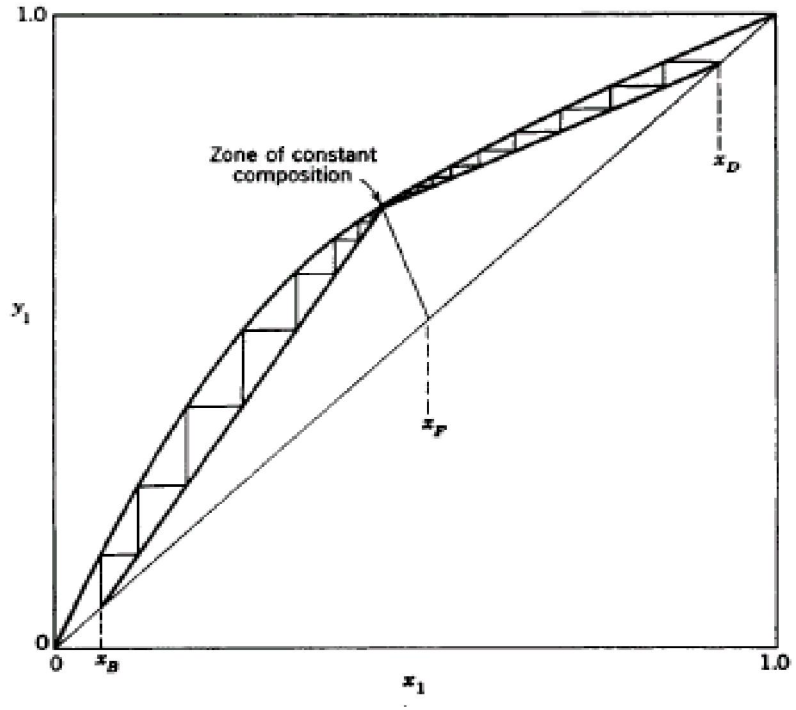
4=Saturated liquid f=0 q=1

5= Cold liquid f <0 q >1

Calculation forr Numberof Theoretical Stages- Mc-Cabe Thiele Method

- A mathematical-graphical method for determining the number of theoretical trays or stages neede for a given separation of binary mixture of A and B.

1. It intersects the y=x line (45oC diagonal line) at x=xD
2. The intercept of the operating line at x=0 is y=xD/(R+1)
3. Operating lines are plotted and two lines intersect on the q line.
4. A convenient way to locate the stripping operatinh line is to first plot the enriching operating line and the q line. Then draw the stripping line between the intersection of the q line andenriching operating line and the point y=x=xw



OBJECTIVE

- Determination of ideal tray number in distillation column
- Calculation of column efficiency
- Calculation of thermal loads

EXPERIMENTAL SYSTEM

Condenser

Sample container

Enriching section
20 Trays
Distillation Column

Control Board

Boiler

Ethanol Boiling Point ?

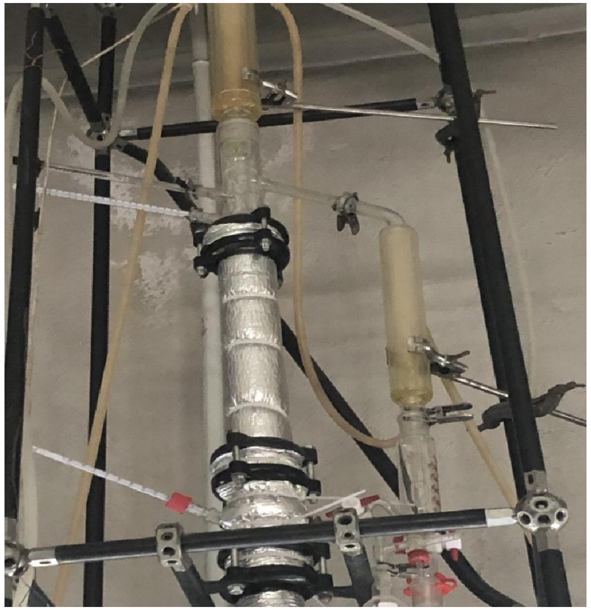
EXPERIMENTAL PROCEDURE

- Start feding the condenser water.
- Start heating the mixture in the boiler until it reaches the boiling point.
- Be sure the ethanol-water mixture with known composition exists in the reboiler.(vol%34)

- Check the positions of the hose pipes and valves.
- Check thermometer values to be steady state.

- Set the reflux ratios (R). Allow the column to reach steady-state conditions by waiting 10 minutes after the first liquid drop from the product condenser arrives.

- Determine the distillate flow rate using sample container. (20 mL)



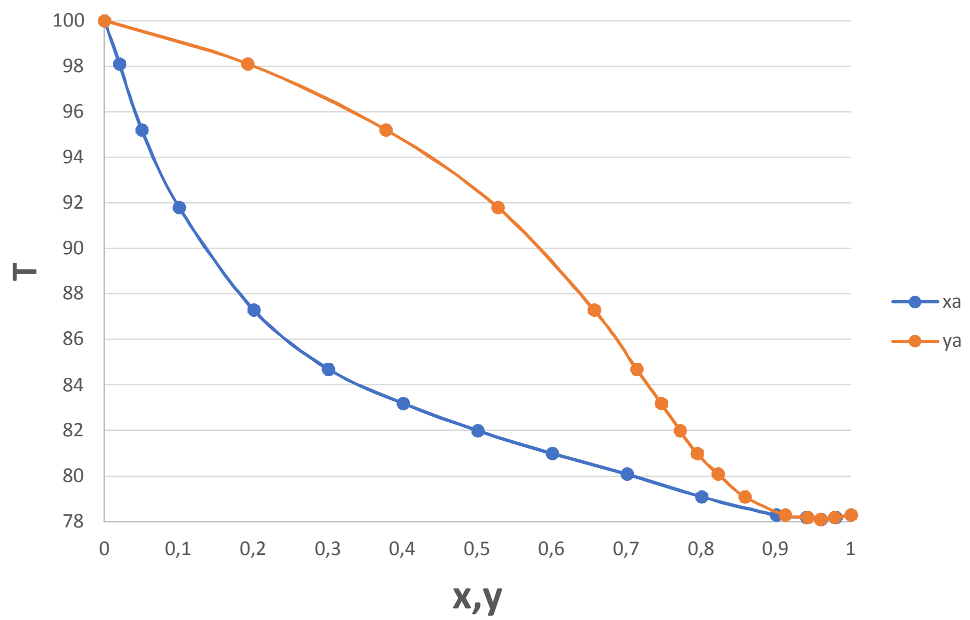
How the flow rate changes for different reflux values?

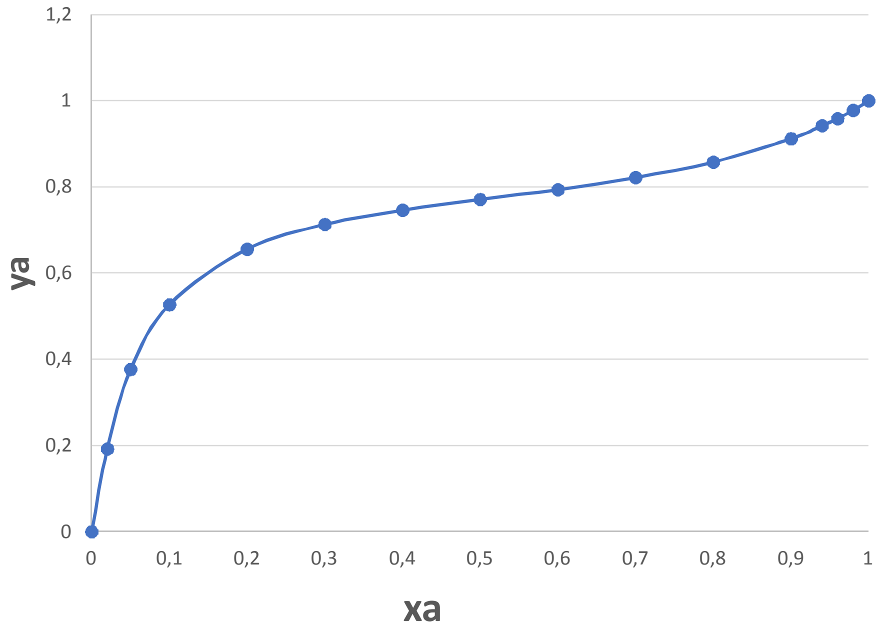
- Record all temperature and pressure data.
- Repeat the above procedure for different R values.
- Stop heating the boiler.
- Continue to pass the cooling water from the condenser for at least half an hour.

Calculations

- Antoine Equation $\ln P_i^o = A(i) - \frac{B(i)}{C(i)+T}$
- Raoult's Law

Ethanol-Water Equilibrium Data





Uysal, B. Z. (2003). *Kütle transferi: esasları ve uygulamaları*. Gazi Üniversitesi.
Geankoplis, C. J. (2011). Taşınma Süreçleri ve Ayırma Süreci İlkeleri.

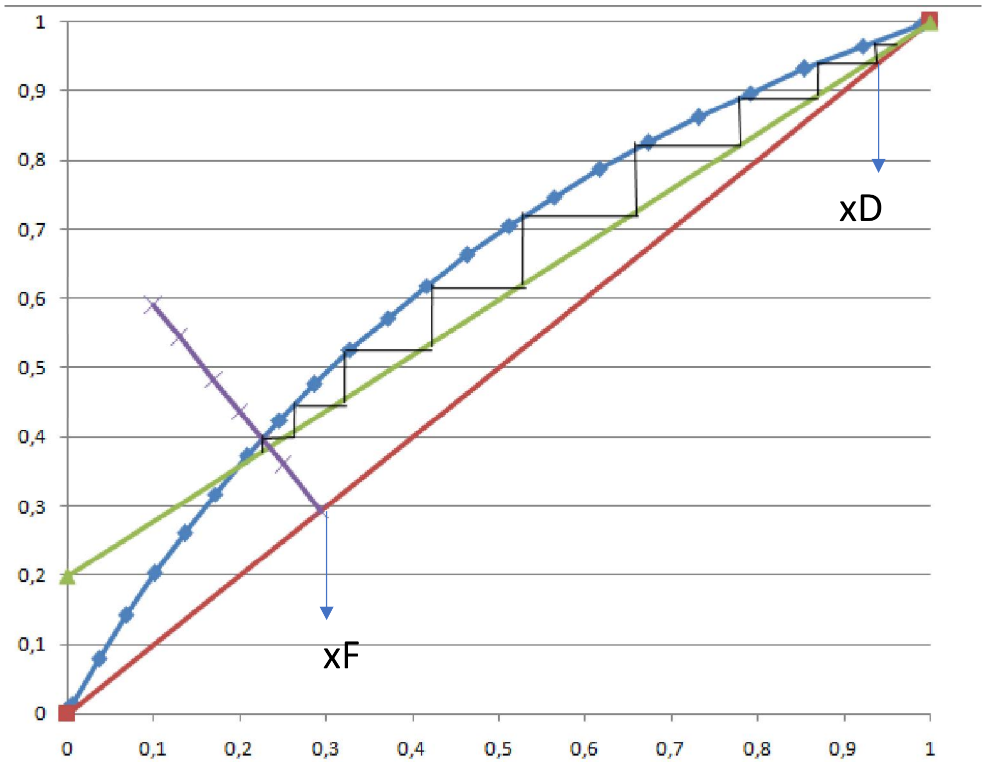
- L_0 and V_{N+1} values are calculated for different R_D values.
- xD is determined from the equilibrium data for constant temperature.
- xF is determined using the value of %vol composition.
- Material balance for enriching section is written.

- Enriching operation line is plotted.

$$y_{N+1} = \frac{R_D * (xN)}{R_D + 1} + \frac{x_D}{R_D + 1}$$

- Q line is plotted.

- Calculate ideal tray number.



- Tray efficiencies=$\frac{N\ ideal}{N\ actual}$

- Condenser thermal load= Q= $V_{N+1}*\lambda$

- Calculate the ideal tray number for each of the reflux ratio conditions studied by using McCabe-Thiele method.