BATCH DISTILLATION 9/26/17

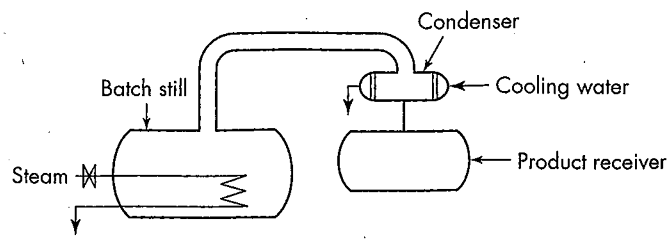
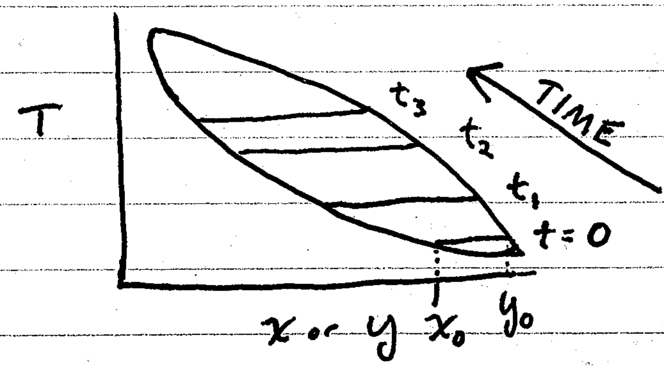


FIGURE 21.35
Simple distillation in a batch still.

Initially the mole fraction in the batch still is $x = x_0$

The mole fraction of the vapor being generated at any time, t, is in equilibrium with the mole fraction in the liquid at that same time: $y(t)$ is in EQ w/ $x(t)$



LIGHTER COMPONENT A COMES off PREFERENTIALLY
So x_A DECREASES WITH TIME

If n is # of moles left in still at time t
$x_A n$ is # of moles of Component A at time t
Understand that $x = x_A$

$$n_A = x\,n$$

moles A in still = (mole fraction A in still)(# total moles in still)

As a small amount of liquid, dn, is vaporized its composition is y (the value in equilibrium with the current value of x)

$$dn_A = y\,dn$$

NOTE THAT $dn_A = d(xn)$ as well

$$dn_A = d(xn) = n\,dx + x\,dn = y\,dn$$

$$n\,dx = (y-x)\,dn$$

$$\frac{dn}{n} = \frac{dx}{y-x}$$

NOTE y is a function of x (A complicated function, at that)

Integrate between x_0 and x_1, which correspond to n_0 and n_1

RAYLEIGH EQUATION

$$\int_{n_0}^{n_1} \frac{dn}{n} = \int_{x_0}^{x_1} \frac{dx}{y-x} = \ln \frac{n_1}{n_0}$$

↑ Integrate graphically or numerically

i) $$\frac{y_A}{y_B} = \alpha_{AB} \frac{x_A}{x_B}$$ FROM DEFINITION of α_{AB}

$\alpha_{AB} \approx$ CONSTANT OVER RANGE of Temperature

Mixture has n_A mol of A and n_B mol of B

$$\frac{n_A}{n_B} = \frac{x_A}{x_B} \; ; \quad dn_A = y_A\, dn \; ; \quad dn_B = y_B\, dn$$

$$y_A = \frac{dn_A}{dn} \; ; \quad y_B = \frac{dn_B}{dn}$$

SUBSTITUTING INTO i

$$\frac{dn_A/dn}{dn_B/dn} = \alpha_{AB} \frac{n_A}{n_B} = \frac{dn_A}{dn_B}$$

Integrate

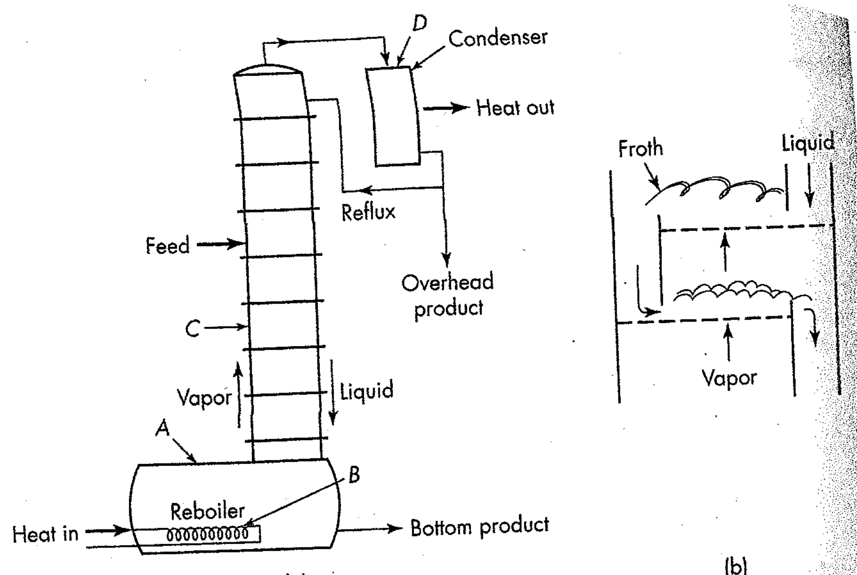
$$\ln \frac{n_A}{n_{o_A}} = \alpha_{AB} \ln \frac{n_B}{n_{o_B}}$$

$$\frac{n_B}{n_{o_B}} = \left(\frac{n_A}{n_{o_A}}\right)^{\frac{1}{\alpha}}$$

THINGS TO CONDSIDER:

- The purest distillate is initial distallate
- y_{A_o} is in EQUILIBRIUM w/ x_{o_A} YOU CAN'T DO BETTR THAN THIS
- THE MORE MATERIAL YOU EVAPORATE THE LESS PURE THE DISTILLATE

BATCH DISTILLATION w/ REFLUX



(a) (b)

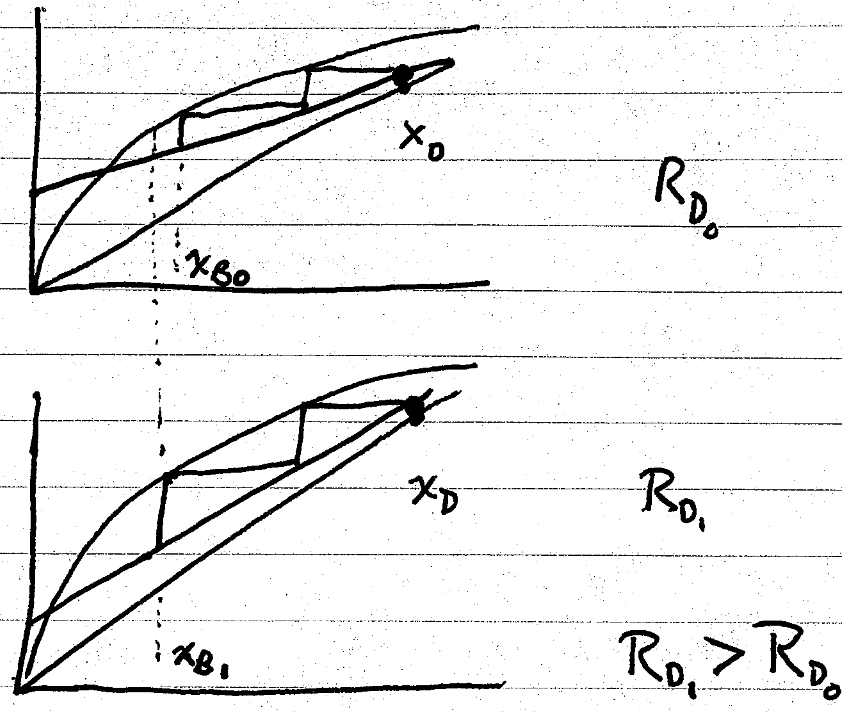
Rectifying COLUMN CAN BE ADDED TO GET BETTER SEPARATION

ANALYZED w/ McCABE-THIELE

$$y_{n+1} = \frac{R_D}{R_D+1} x_n + \frac{x_D}{R_D+1}$$

AS TIME PASSES x_{Bottom} DECREASES AND SO DOES x_D for a set Reflux RATIO.

- Stop BEFORE x_D drops below acceptable level
- IF R_D is adjusted as you go x_D can be held ~~const~~ CONSTANT. EVENTUALLY R_D BECOMES SO HIGH THAT YOU ARE NOT MAKING MUCH ADDITIONAL DISTILLATE



- FIXED NUMBER of PLATES IN COLUMN
- X_B IS DECREASING w/ TIME
- BY INCREASING R_D YOU ARRIVE AT SAME X_D

CAN YOU DISTILL THE ENTIRE BATCH?

- NO SEPARATION WOULD BE ACCOMPLISHED

QUESTIONS TO BE ANSWERED:

- HOW MUCH of BATCH CAN BE DISTILLED FOR NO RECTIFYING COLUMN CASE (or Constant R_D case)
- HOW LONG DOES OPERATION REQUIRE?