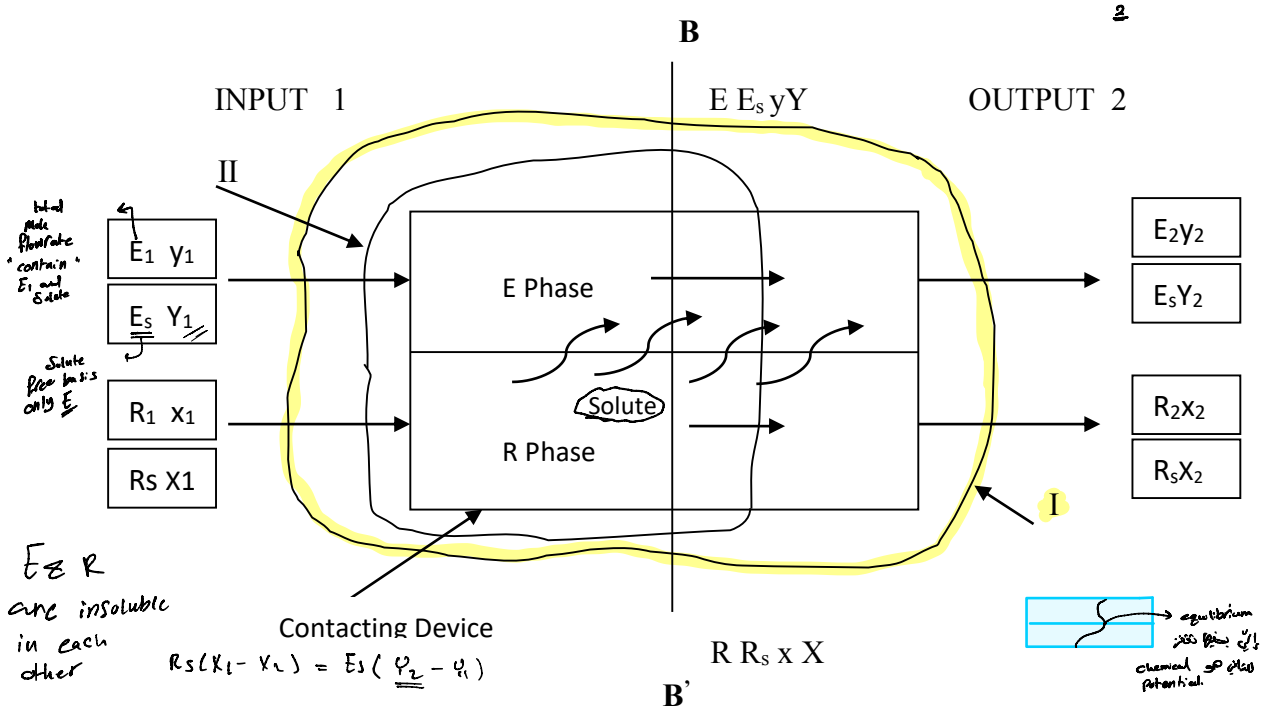
Material Balances:

System: two insoluble phases E and R and single solute transferring from phase R to Phase E

Steady State Contacting Processes

Co Current Process:



R_i, E_i : moles total material/time ; R_s, E_s : moles non diffusing material/time (constant)

x_i, y_i : mole fractions of solute in stream **i** ; X_i, Y_i : mole ratios of solute in stream i

i : stream number

Solute Material Balance

Envelope I (overall)

$$\underbrace{R_1 x_1 + E_1 y_1}_{\text{IN}} = \underbrace{R_2 x_2 + E_2 y_2}_{\text{OUT}}$$

OR

$$R_1 x_1 - R_2 x_2 = E_2 y_2 - E_1 y_1$$

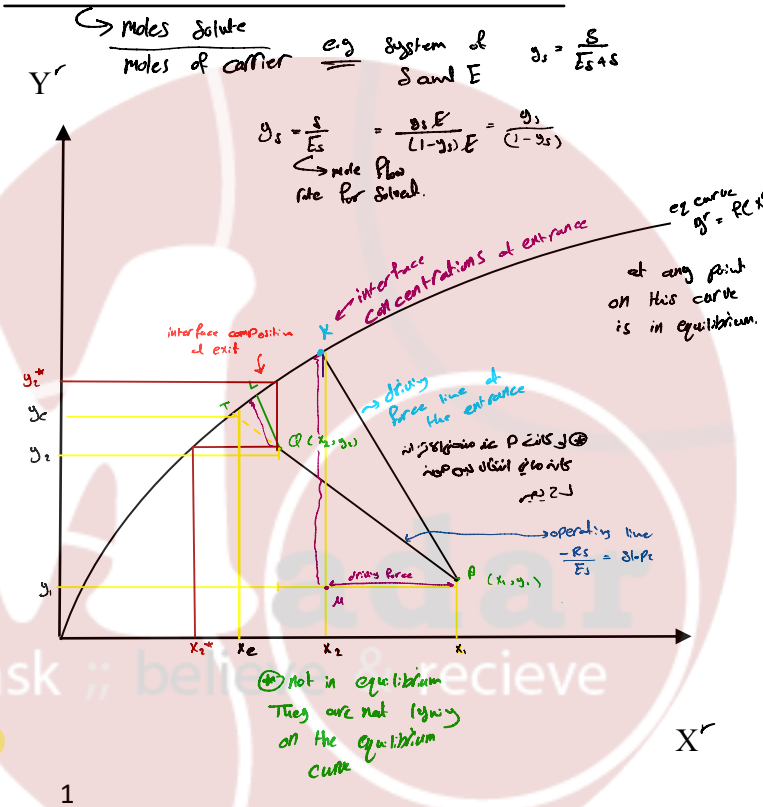
general case.

$$R_i x_i = R_s \frac{x_i}{1 - x_i} = R_s X_i$$

$$E_i y_i = E_s \frac{y_i}{1 - y_i} = E_s Y_i$$

$$R_s (X_1 - X_2) = E_s (Y_2 - Y_1)$$

Straight line with slope $= -\frac{R_s}{E_s}$ (line PQ)



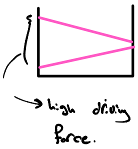
change of the concentration from the start point until any point.

Envelope II (General Balance)

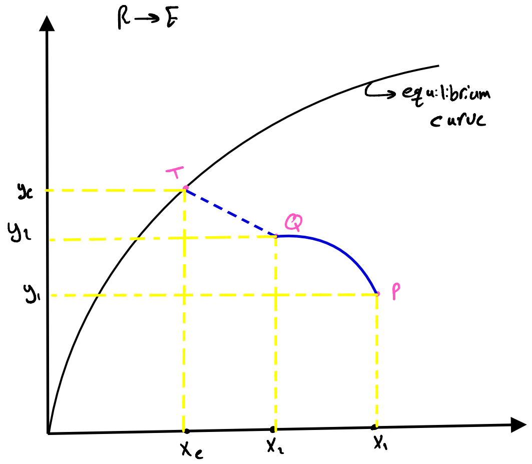
On solute free basis

$$Rs\,(X_1 - X) = Es\,(Y - Y_1)$$

Straight line: slope $= -\dfrac{R_S}{E_S}$ (Same as line PQ)



- ✓ General expression relating compositions of phases in equipment at any distance from entrance Points P and Q represent inlet and exit concentrations
- ✓ This straight line is called operating line
- ✓ KP driving force line at entrance
  K: interface composition at interface
  KM, MP driving forces in E-phase (KM) and R-phase (MP) at entrance conditions
- ✓ LQ : driving force line at exit
  L : interface composition
- ✓ Point T represents equilibrium compositions (Xe, Ye) if the equipment were longue enough. At this point the driving force is zero.



Representation using other units

$$R_1\,x_1 - R\,x = E\,y - E_1\,y_1 \quad \text{Operating curve}$$

$$E\,y = R_1\,x_1 + E_1\,y_1 - R\,x$$

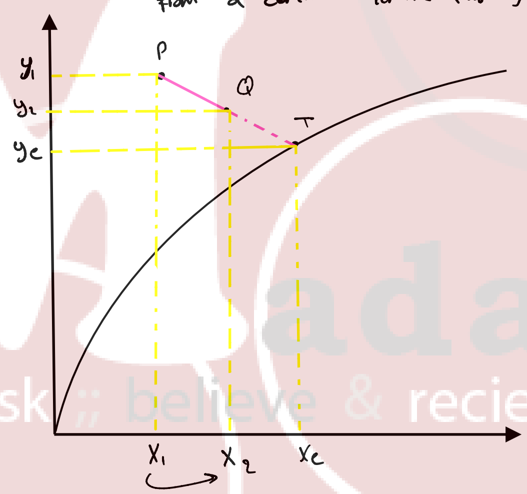
$$y_2 = \frac{R_1 x_1 + E_1 y_1}{E} - \frac{R}{E}\,x_2 \quad \text{Operating Curve}$$

Note: If $E_1 = E_2 = E$ and $R_1 = R_2 = R$ ⟹ Straight line operating line in terms of mole fractions

when the solute is very low (dilluted system) ⟹ because the transfer is very low.

how much the concentration of the solute will change from a certain reference (usually the entrance)

Solute transferring from E → R



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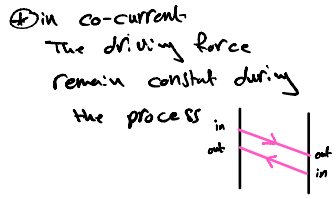
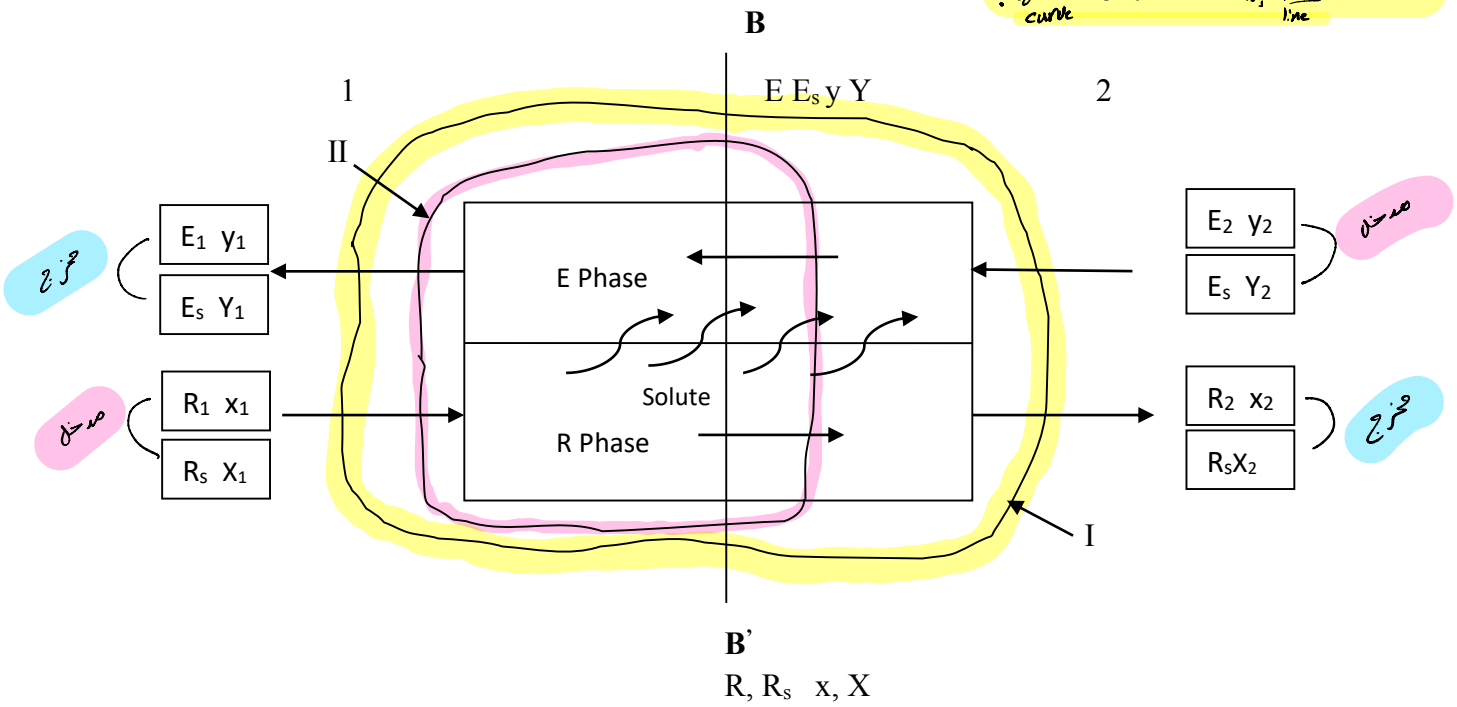


Material Balances:

Steady State Contacting Processes

System: two insoluble phases E and R and single solute transferring from phase R to Phase E

Counter Current Process:



Ri, Ei : moles total material/time ; **Rs, Es** : moles non diffusing material/time (constant)
xi, yi : mole fractions of solute in stream **i** ; **Xi, Yi** : mole ratios of solute in stream i
i : stream number

Solute diffusing from R → E

Solute Material balance

Envelop I (overall)

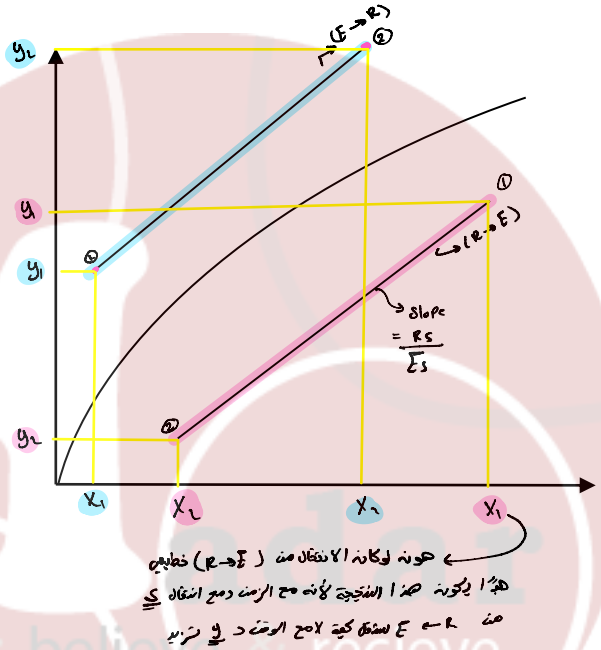
Input Output

$$R_1 x_1 + E_2 y_2 = R_2 x_2 + E_1 y_1 \quad \text{mole fractions}$$

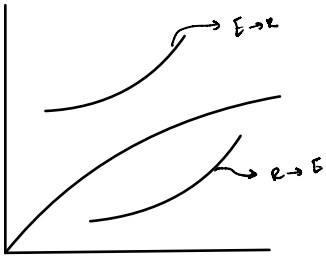
$$R_i x_i = R_S X_i \qquad E_i y_i = E_S Y_i$$

$$R_S(X_1 - X_2) = E_S(Y_1 - Y_2) \quad \text{mole ratios}$$

This is a straight line equation with slope $+\frac{R_S}{E_S}$



Envelop II (General) operating lines



In terms of mole fractions:

Input Output

$$R_1 x_1 + E\ y = R\ x + E_1 y_1$$ mole fractions

$$E\ y = R\ x + E_1 y_1 - R_1 x_1$$

$$y = \frac{R}{E} x + \frac{(E_1 y_1 - R_1 x_1)}{E}$$ operating curve

In terms of mole ratios (solute free basis)

$$R_S (X_1 - X) = E_S (Y_1 - Y)$$

$$E_S Y = R_S X - R_S X_1 + E_S Y_1$$

$$Y = \frac{R_S}{E_S} X - \frac{(R_S X_1 - E_S Y_1)}{E_S}$$ straight line operating line slope $= +\frac{R_S}{E_S}$

In the case where the solute is passing from E → R, the operating line will be above the equilibrium curve.

- The operating line represents the material balance passing from point at one end to the point at the other end.
- A point on the operating line represents bulk concentrations of passing streams
- Lines such as PM indicate driving force