Material Balances:

It is more convenient to express balance equations in terms of mole ratios and on solute free basis:

↳ chapter ⑧

- Quantities of solvent are unchanged
- Straight line operating lines

Nomenclature:

Gas Phase:

G:= Total gas flow rate — mole / time/ unit cross sectional area

G_s:= Flow of insoluble gas (carrier) — mole / time/ unit cross sectional area

y := solute mole fraction

Y := solute mole ratio = solute / carrier gas

$\bar{p}$:= Partial pressure of solute

$$Y = \frac{y\,G}{(1-y)G} = \frac{y}{(1-y)} = \frac{\bar{p}}{(p_t-\bar{p})} = \frac{\text{partial pressure of solute}}{\text{partial pressure of carrier}}$$

$$y = \frac{Y}{(1+Y)}$$

$$G_s = (1-y)\,G = \frac{y}{Y}\,G = \frac{Y}{1+Y}\,\frac{1}{Y}\,G$$

$$G_s = \frac{G}{(1+Y)}$$

Liquid Phase:

L:= Total liquid flow rate — mole / time/ unit cross sectional area

L_s:= Flow of liquid (carrier) — mole / time/ unit cross sectional area

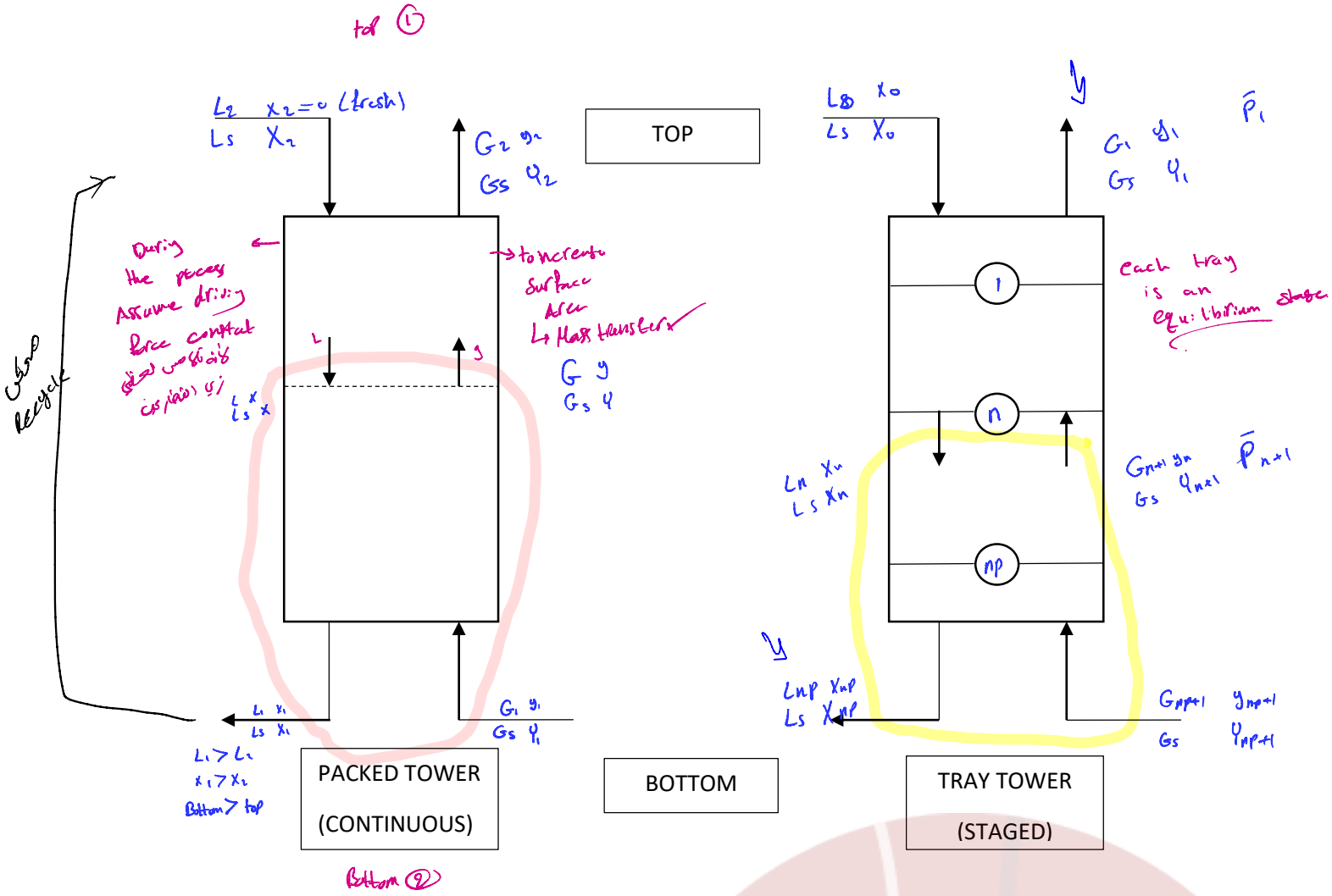
x := solute mole fraction

X := solute mole ratio = solute / solvent

$$X = \frac{x}{(1-x)} \qquad x = \frac{X}{(1+X)}$$

$$L_s = (1-x)\,L \qquad L_s = \frac{L}{(1+X)}\,\frac{1}{X}\,G$$

Counter Current Flow (Absorption or Stripping)



Operating Lines (Solute Material Balances)

At any section

$$G_s\,(Y_1 - Y) = L_s\,(X_1 - X)$$

$$Y = \frac{L_s}{G_s}X + \left[Y_1 - \frac{L_s}{G_s}X_1\right]$$

At any Tray

$$G_s\left(Y_{N_p+1} - Y_{n+1}\right) = L_s\left(X_{N_p} - X_n\right)$$

$$Y_{n+1} = \frac{L_s}{G_s}X_n + \left[Y_{N_p+1} - \frac{L_s}{G_s}X_{N_p}\right]$$

Notes:

- These are straight lines with slope = $\frac{L_S}{G_S}$ giving the relation between passing streams at any section or at any tray.
- For absorption (gas → liquid) carrier gas loses solute

$$Y_{bot} > Y_{top} \quad ; \quad X_{bot} > X_{top}$$

- For stripping (liquid → gas) carrier gas gains solute

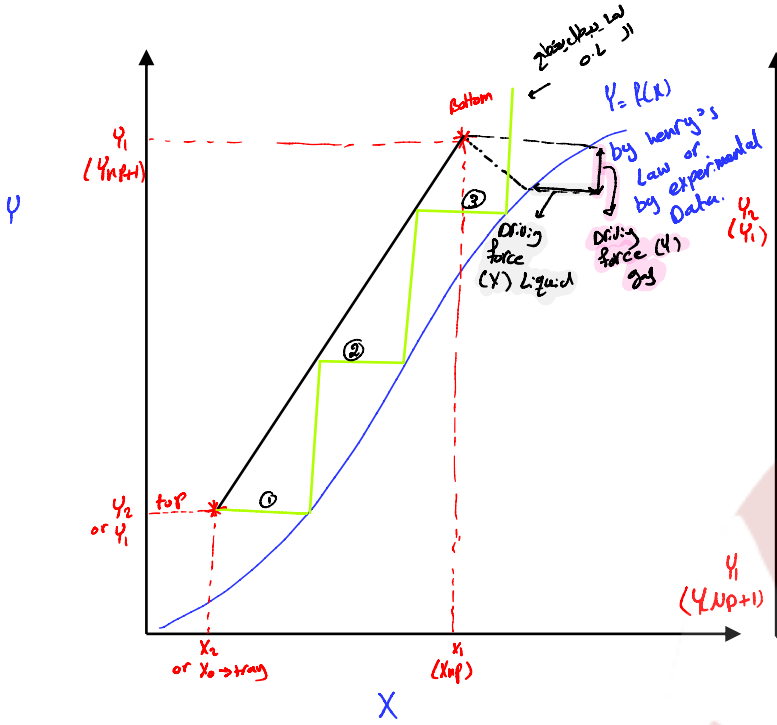
$$Y_{bot} < Y_{top} \quad ; \quad X_{bot} < X_{top}$$

- For most purposes the pressure and temperature can be considered constant inside the column

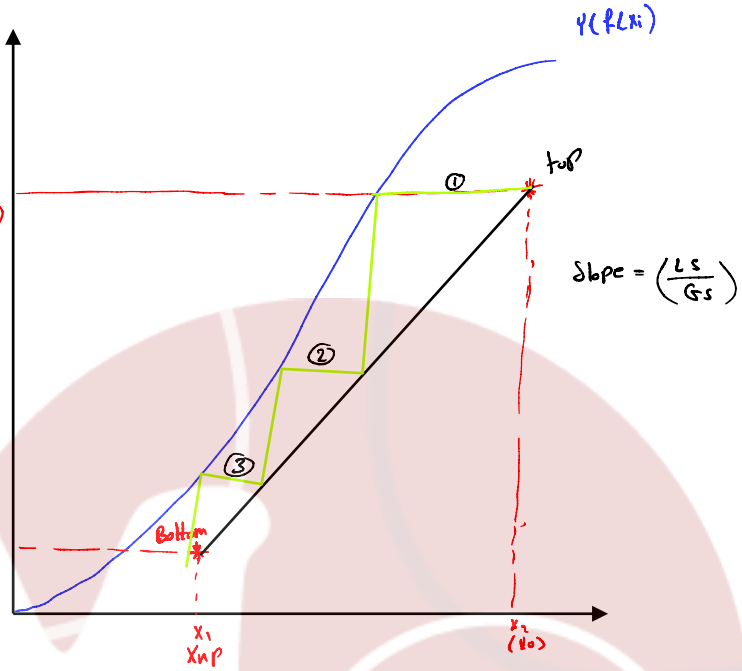
The operating lines can be plotted together with equilibrium data on XY diagram.

⊙ ⇒ for trays only

Absorption



Stripping



Concentration gradient in direction of mass transfer

absorption ⇐ gas → liquid
$y_1 \rightarrow y_2$