Q. Guide

Felder

- No notes making - Save time
- Note only mistakes
- The V3Q sub → Video → 3 Qs from the first 20 of Exercise
- Order of practice
  - V 3Q → solved Q
  - Tutorials
  - Prev yr papers
  - Other Qs from the book

- Small statement

$C = KP$ ← Henry's Law

General Process

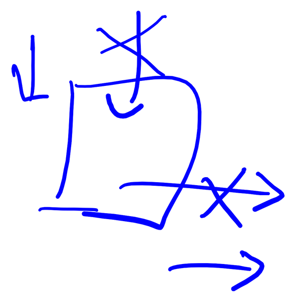
Raw materials → Fuels
Raw materials → Base chemicals → Intermediates → Fine chemicals
↑ Carbonyl (into Intermediates)

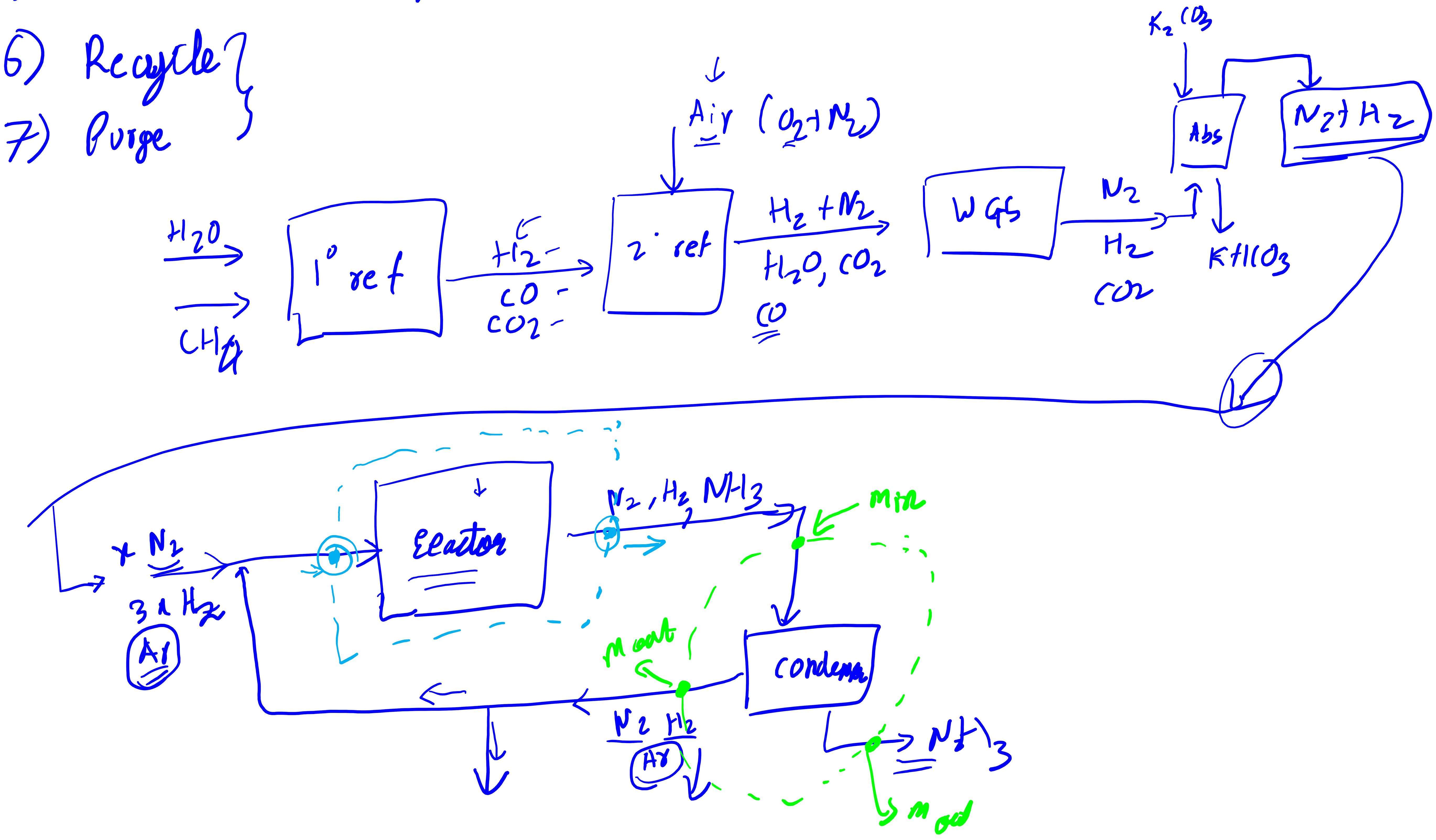
> 10,000 TPA – Bulk che.

< 10,000 TPA → Fine +/ Speciality che.

Terms

1) Steady State process → Condit^n's don't vary wrt time
2) Cont process → accumulat^n = 0
3) Batch
4) Semi batch → acc ≠ 0
5) Transient → appr of steady
6) Recycle
7) Purge





→ Mass Balance

$\text{Total } M_{in} - \text{Total } M_{out}$ for any boundary ← acc = 0 → steady state

→ One component

→ Comin in – Going out – reacted + generated = 0

Overall moles: moles in ~~–~~ moles out → $m_{in} - m_{out} - \text{reacted} + \text{gen} = 0$

$N_2 + 3H_2 \xrightarrow{100\%} 2NH_3$

$\frac{dm}{dt}$

$$\underset{\uparrow \text{ in}}{F_{T_{0,\vec{}}}} - \underset{\uparrow \text{ out}}{F_T} + \underset{\uparrow \text{ gen - exited}}{\text{Net generated}} = \frac{dN_{AL}}{dt}$$

(1) (2) (3) (4)

zero ?

cont , steady → (4)

Batch → (1), (2)

Cont , unsteady → None

Semi batch → None → (1) ≠ (2)

Selectivity

$\overset{100}{A} \longrightarrow \overset{50}{B}$ ← desired

$\underset{50}{B} \longrightarrow \underset{25}{C} + \underset{25}{D}$ ← undesired

A → 50
B → 25 ←
C → 25
D → 25

Selectivity $= \frac{25}{25+25} = \frac{\text{Desired}}{\text{Sidepdt}}$

$= \frac{1}{2}$

Conversion of A → $\frac{100-50}{100} = \frac{1}{2}$ → $\frac{\text{In} - \text{Remain}}{\text{In}}$

Yield of B → $\frac{25}{50} = \frac{1}{2}$ → $\frac{\text{actual}}{\text{hyp in abs of side rx's}}$

Law of mass actn

$$K_{eq} = \frac{[C]^2[D]}{[A][B]}$$ ← terms of extent

$A + B \longrightarrow 2C + D$

100 100

50 50 100 50

50%

$(100)(1-\varepsilon)$ ← B

$(100)(\varepsilon) \times 2$ ← C

Excess Air

$C_n H_e$

Assume that all the fuel is converted

$C \longrightarrow CO_2$ ✓
$H \longrightarrow H_2O$ ✓

~~Actual conversion~~

$C \rightarrow$ ~~CO partial~~

O_2 → theoretical air / O_2

Excess → Actual amount given →

1 mol C → 1 mol O_2

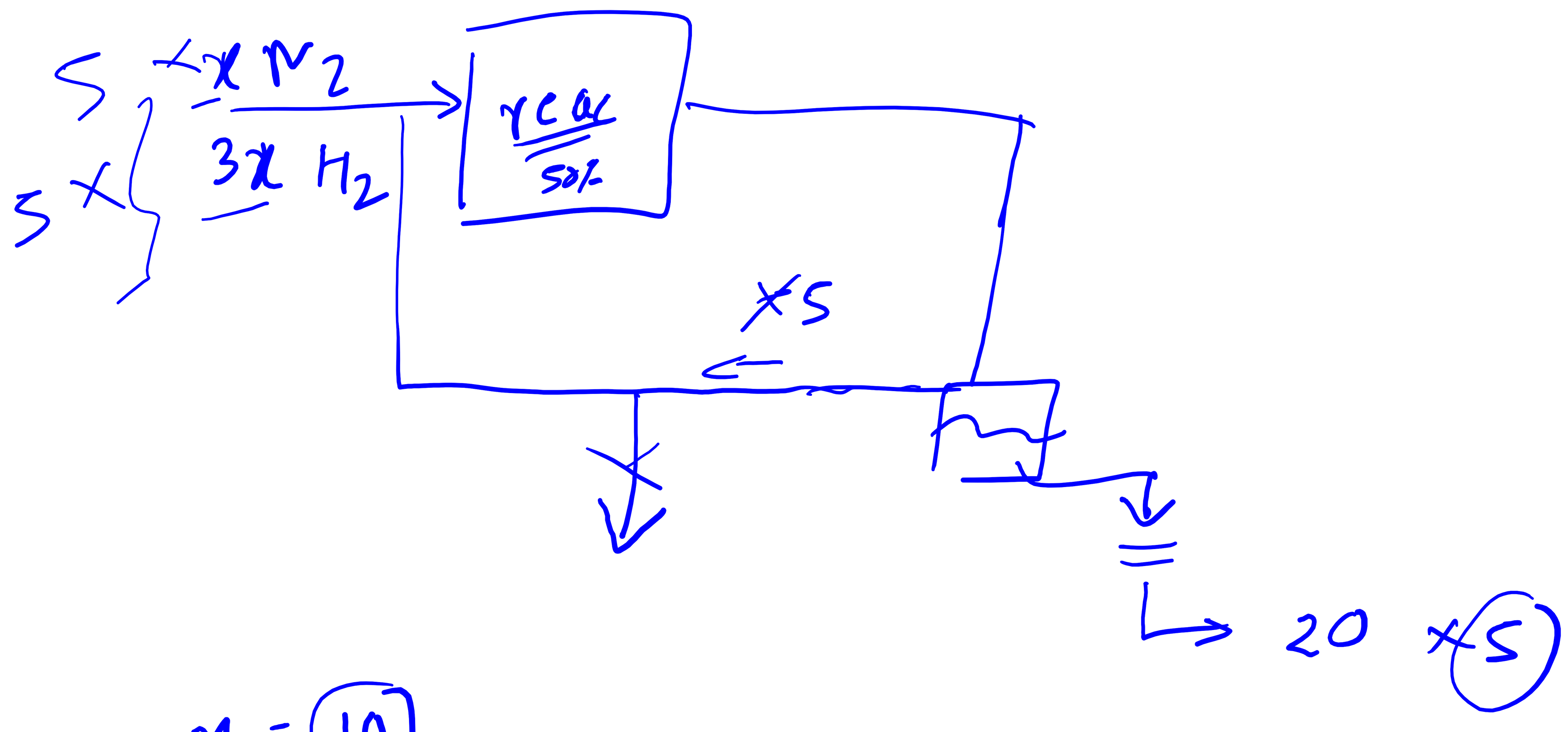
Ex = 1.2 × the → air provides = 1.2 mol

Balancing & DOF

Basis of calc

NH_3 productⁿ

-100 kmol/day

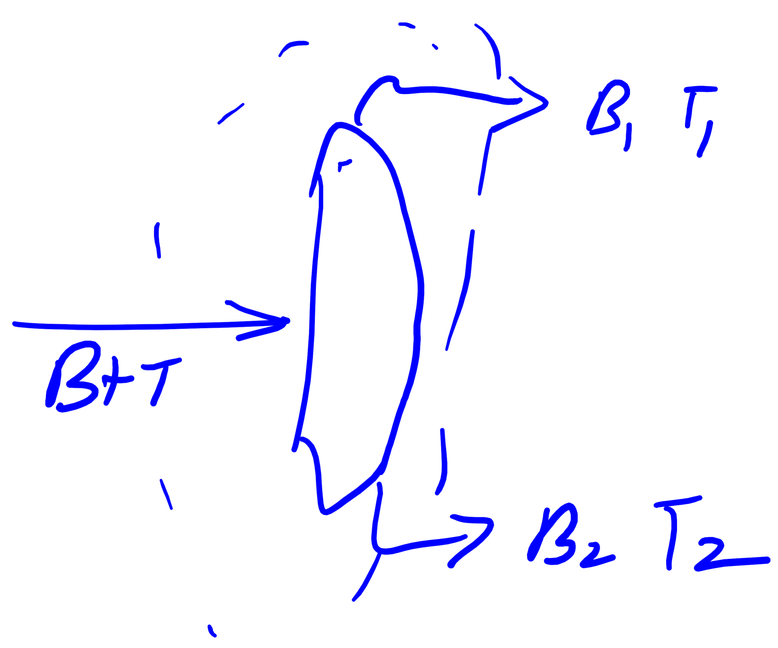


$x = 10$

Ways of Balancing

- Extent → ϵ / J
- Molecular → conc → Reacted ?
- Atomic → Balance atoms → Reacted ≠ 0

The max no. of indep. eqⁿs of mate balance = # of species



→ B

→ T

~~Total mass~~

DOF

→ # of unknown − # of constraints = DOF

DOF = 0 ← sys is solvable

< 0 ← Excess info

> 0 ← more info req.

→ Mat balance

→ Energy —"—

→ gas laws, values, Process specificatⁿ, Stoichiometry

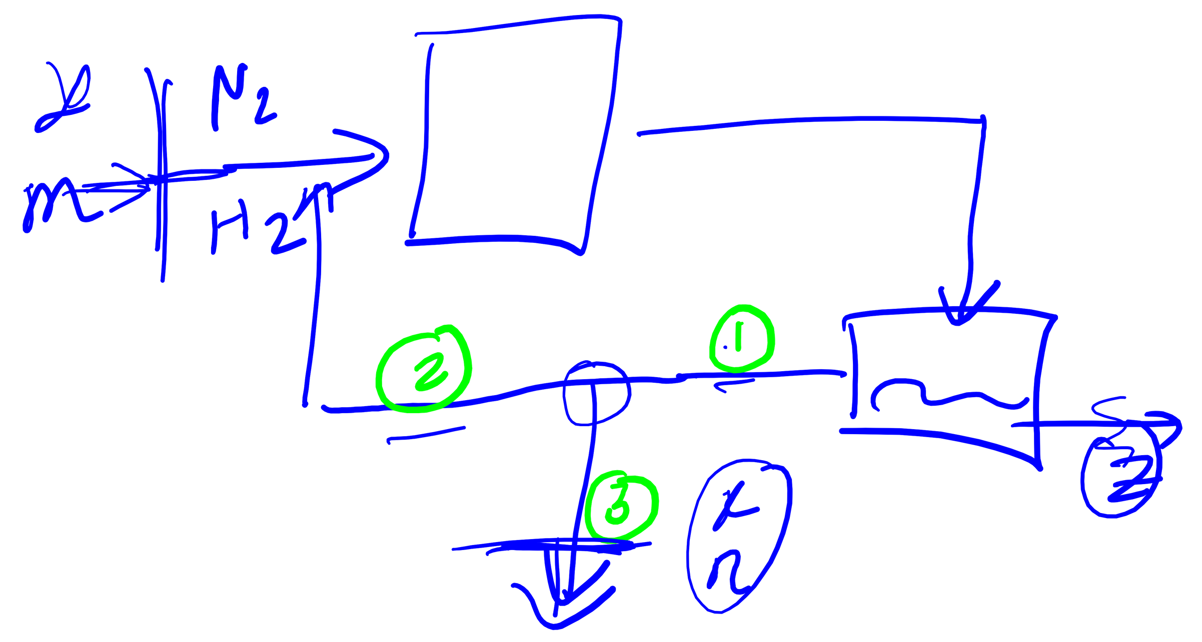
M → # unknowns + $\underbrace{\text{\# indep rx}^n\text{s}}_{\xi}$ − # indep balances − other data = DOF

A → # υ − # atomic balance − # inert − +/− = +/−

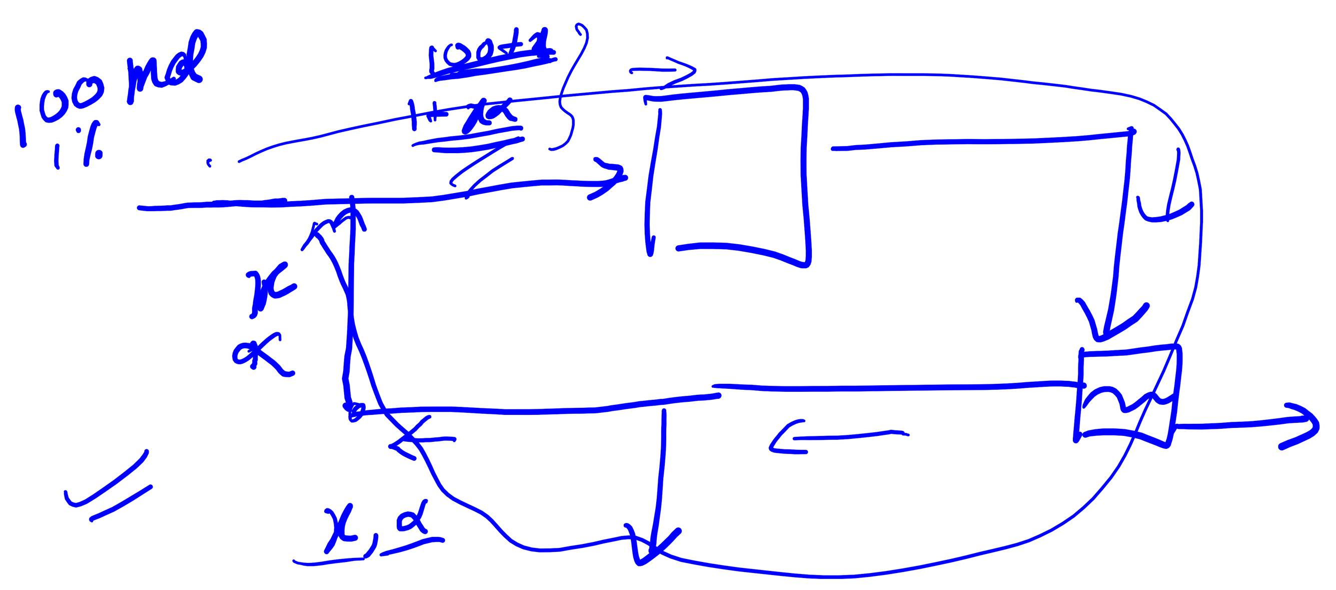
Extent → # υ + # extent − # indep balanc − other = DOF

Purge

1) composit^n → 1 = 2 = 3



Dry basis
Wet basis



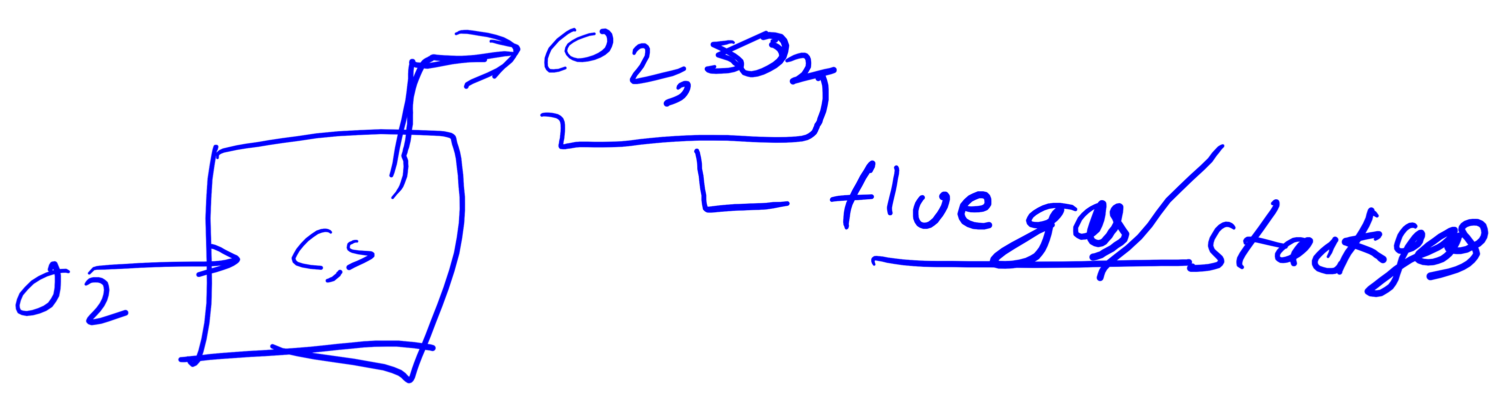
O_2 , N_2 , $H_2O(v)$

20 mol O_2
80 mol N_2
~~10 mol H_2O~~

$\left.\begin{array}{l} 20\%\ O_2 \\ 80\%\ N_2 \end{array}\right\}$ DB

$\frac{20}{80+20+10} = \frac{20}{110} \times 100$ ← % O_2 WB

→ $f(x,\alpha) = x$
→ $g(x,\alpha) = \alpha$



2 inerts → 2 purges in depen

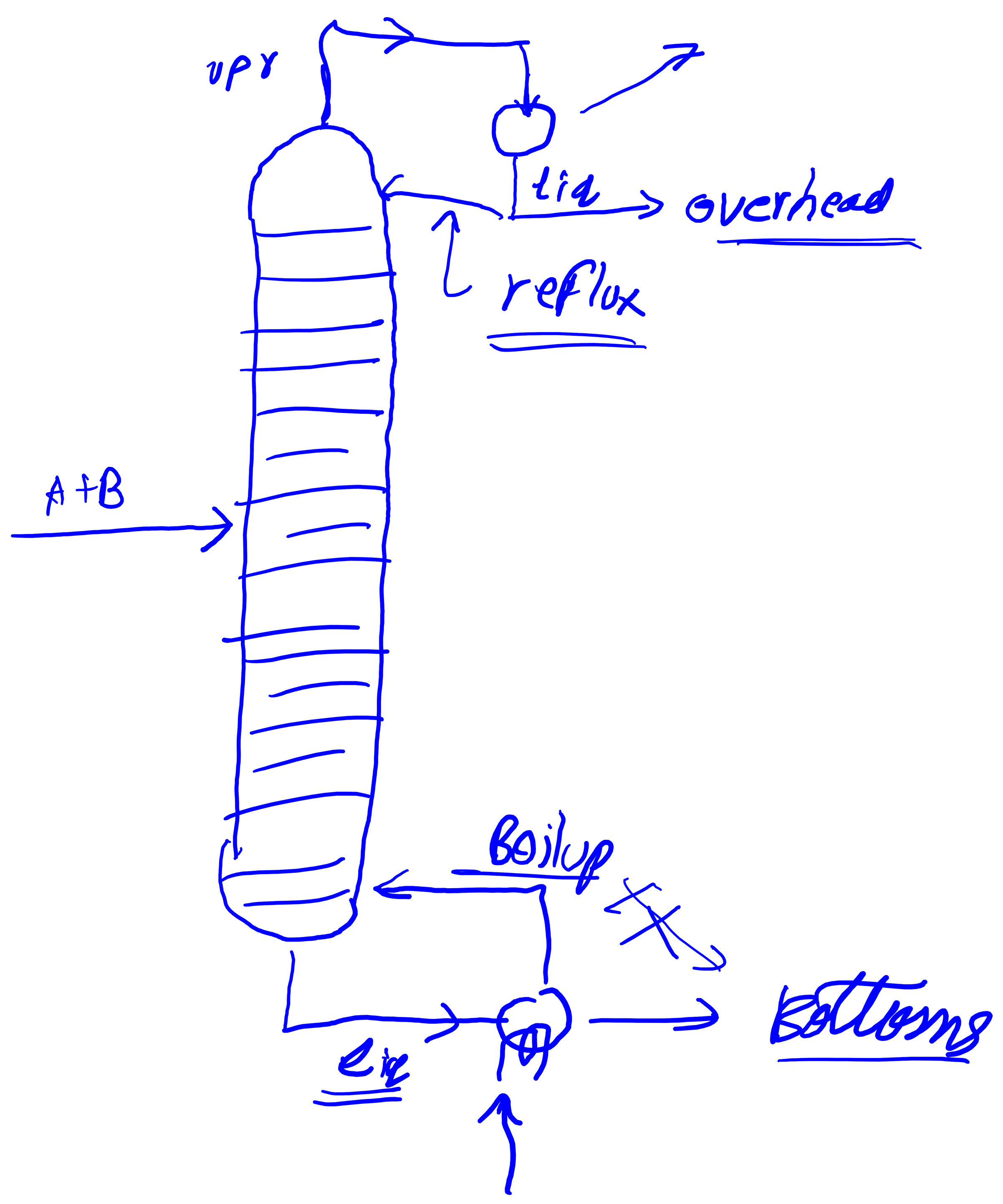
- low flow
- high flow ✓

④

Separations

- Liq – Liq Extractⁿ ← solub
- Crystallizatⁿ ← solub
- Leaching
- Stripping ← solub
- Rectificatⁿ
- Distillatⁿ ← volatility
- Absorptⁿ ← solub
- Chromatography — Permeability
- Membrane
- Adsorptⁿ — affinity to adsorbent

Distillatⁿ



Raoult's Law

$$y_i P_T = x_i \, VP_i$$

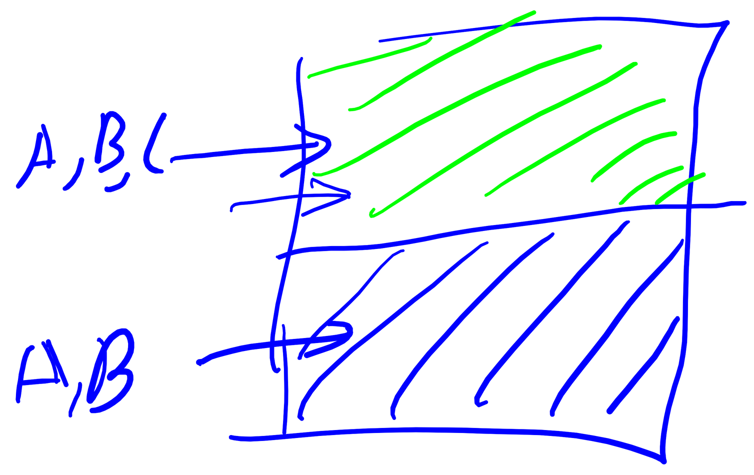
x_1 = mol fractⁿ in liq × VP_{temp} → Antoine

$x_i \neq y_i$

$$P_T = P.P_A + P.P_B + P.P_C$$

$y_i P_T$

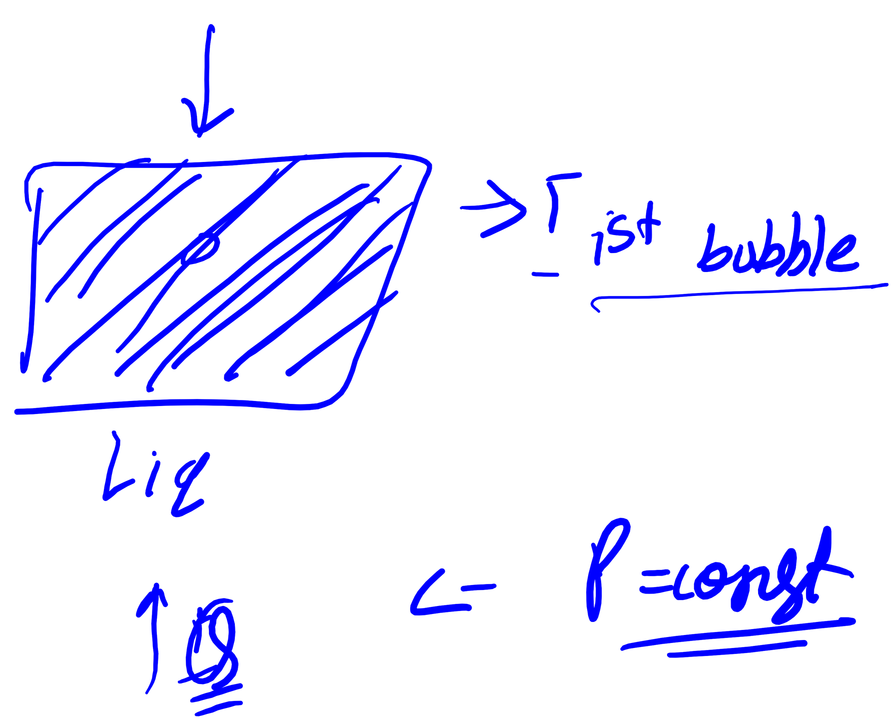
$$\log VP = A - \frac{B}{T+C}$$

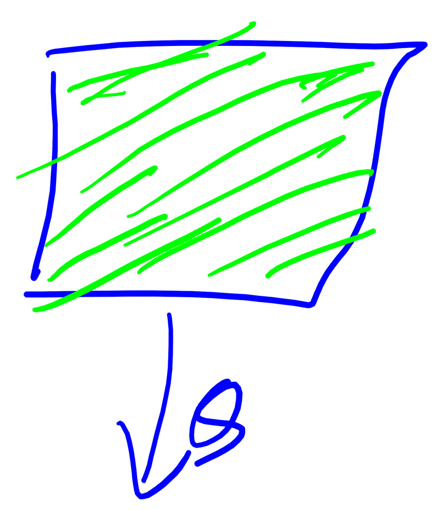


Equilibrium

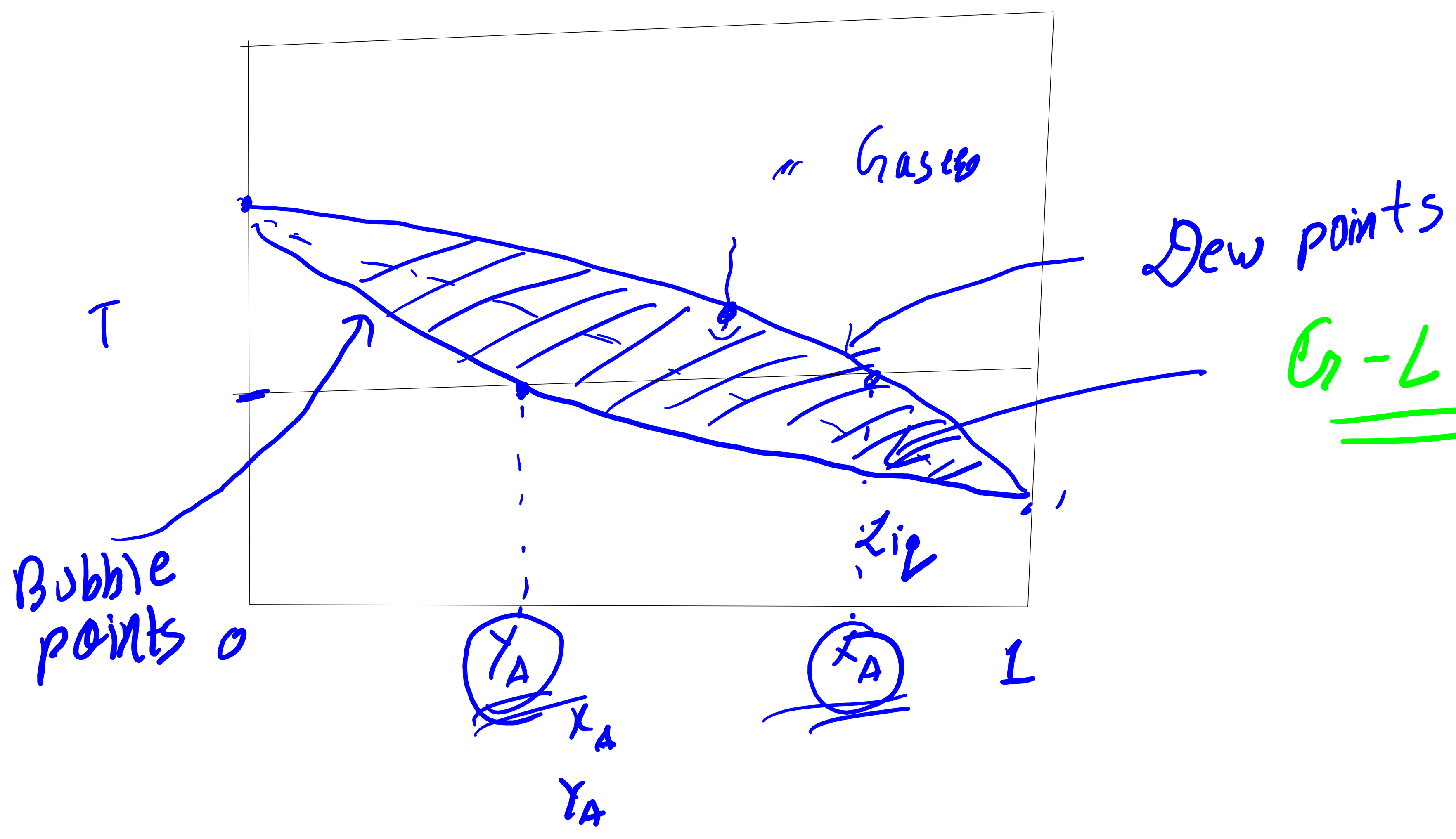
$PP_{H_2O} = 1 \times VP_{H_2O}$ → lab → boiling

★ Bubble point – Dew point

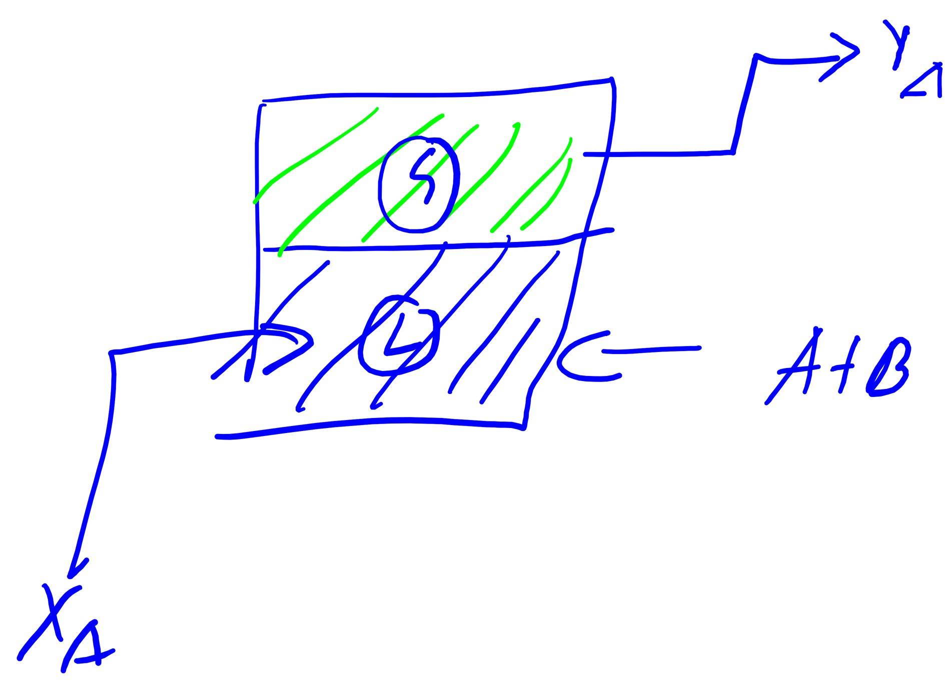




T_{max} 1st drop



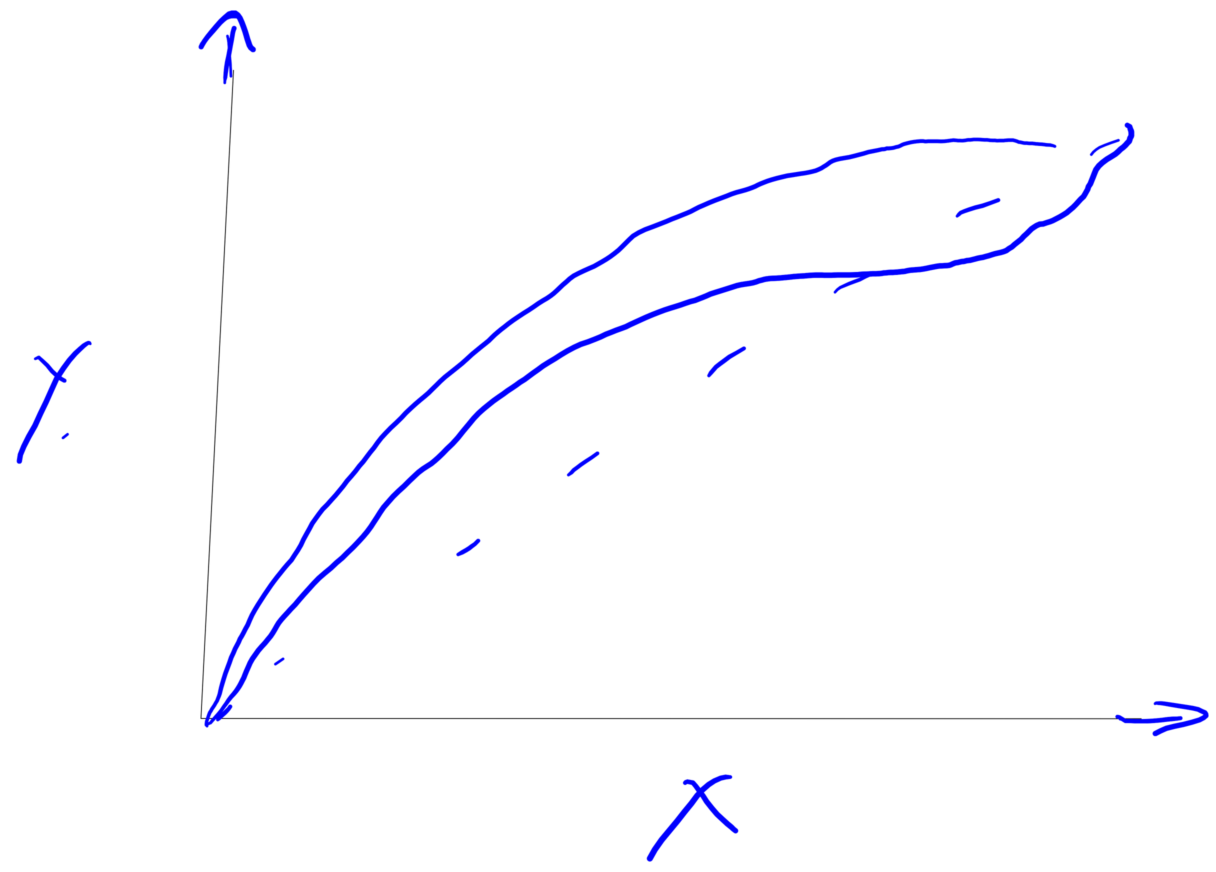
G-L Eq



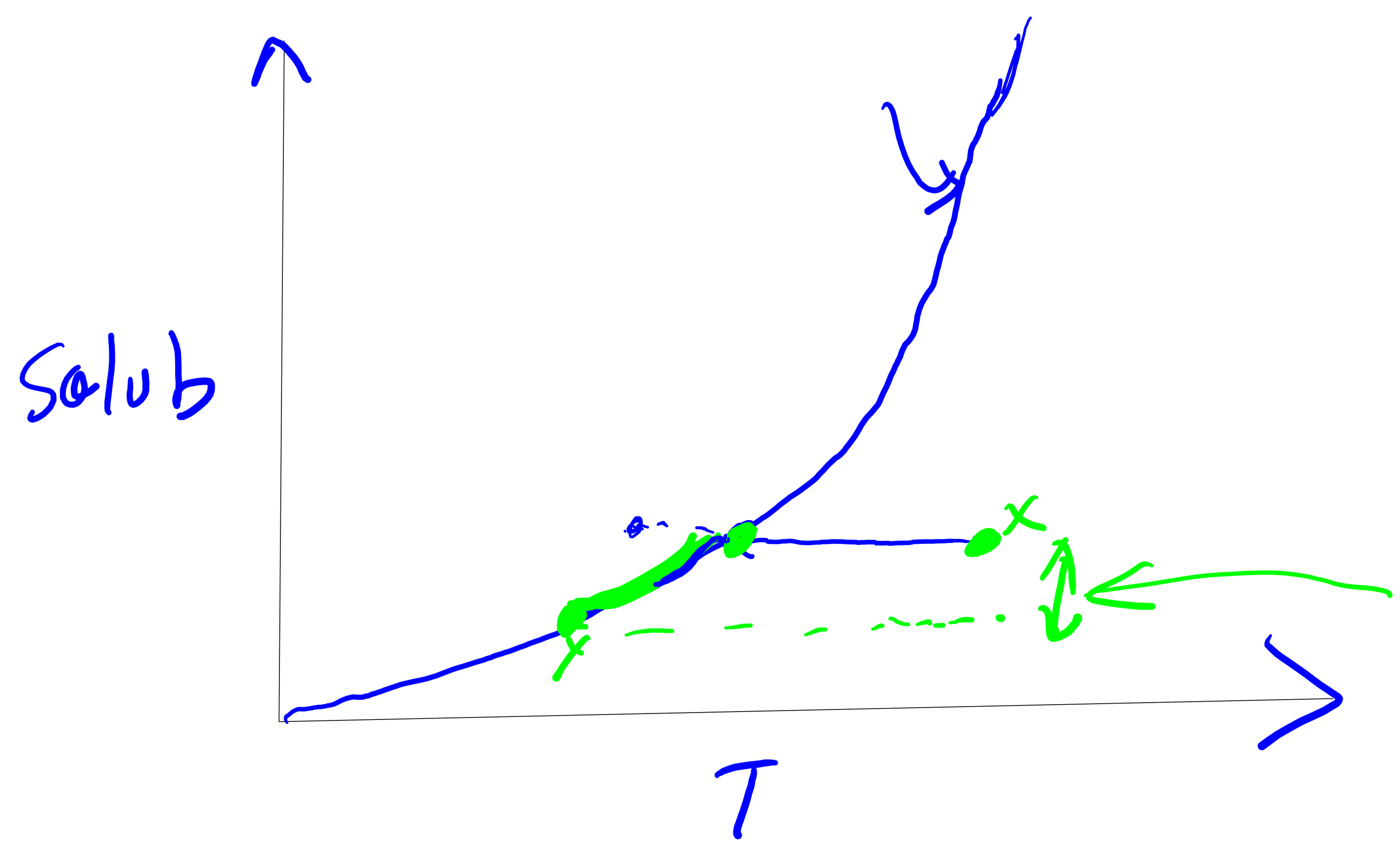
$y_A P_T = x_A VP$

$\frac{y_A}{x_A} = \frac{VP}{P_T}$

L → V



SLE → Solub ← Henry's Law.



← solubility

Crys.

come out of soln ← Crystallized

Gibbs Phase Rule

$P + F = C + 2$

Phases Freedom Components

water → LV eqn

1

$2 + F = 1 + 2$

$F = 1$ → T, P

$F \to x_i, y_i, T, P$

2

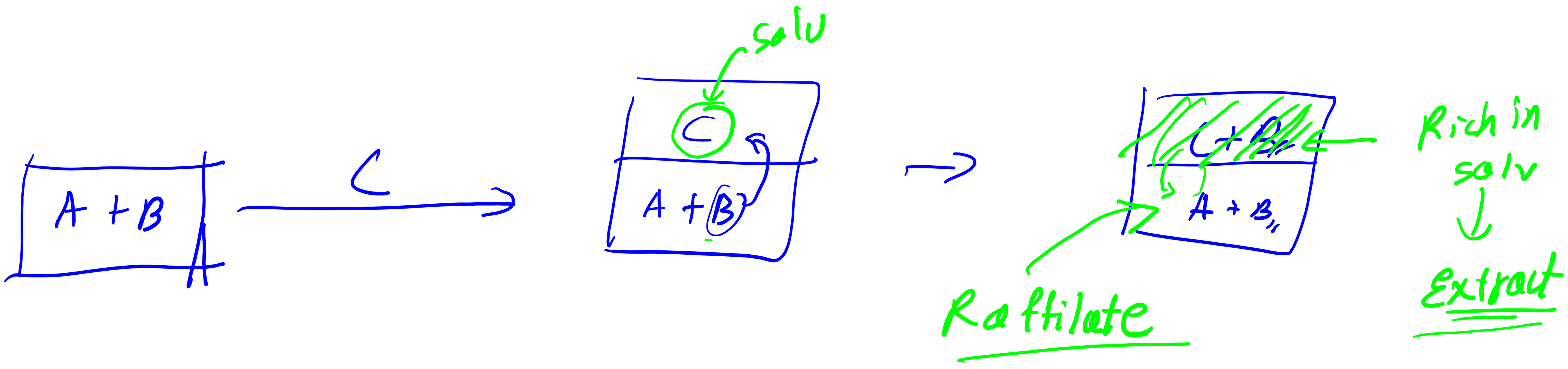
Triple Point $F = 0$, $P = 3$, $C = 1$ (s, L, V)

$3 + 0 = 1 + 2$

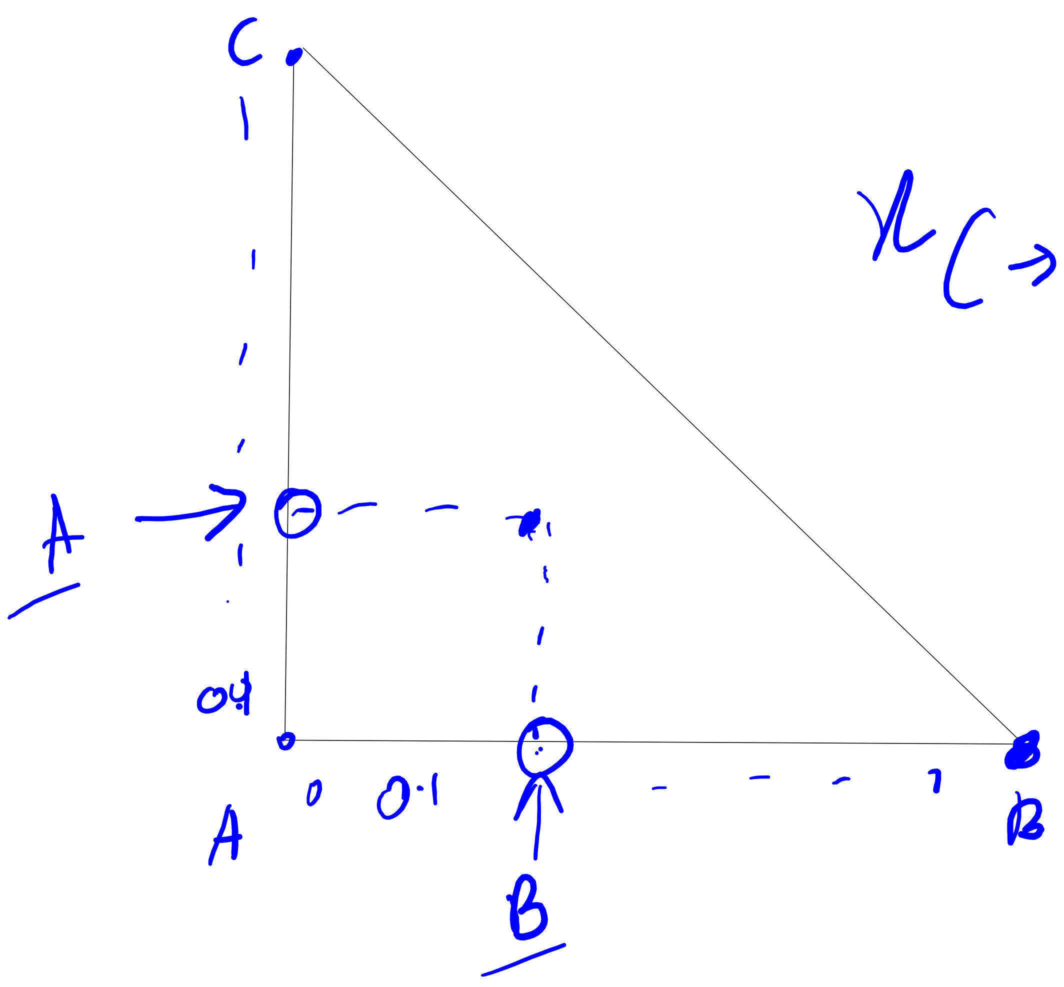
$P + F = C + 2$

Partition Coeff / Diff. coeff (L-L sep)

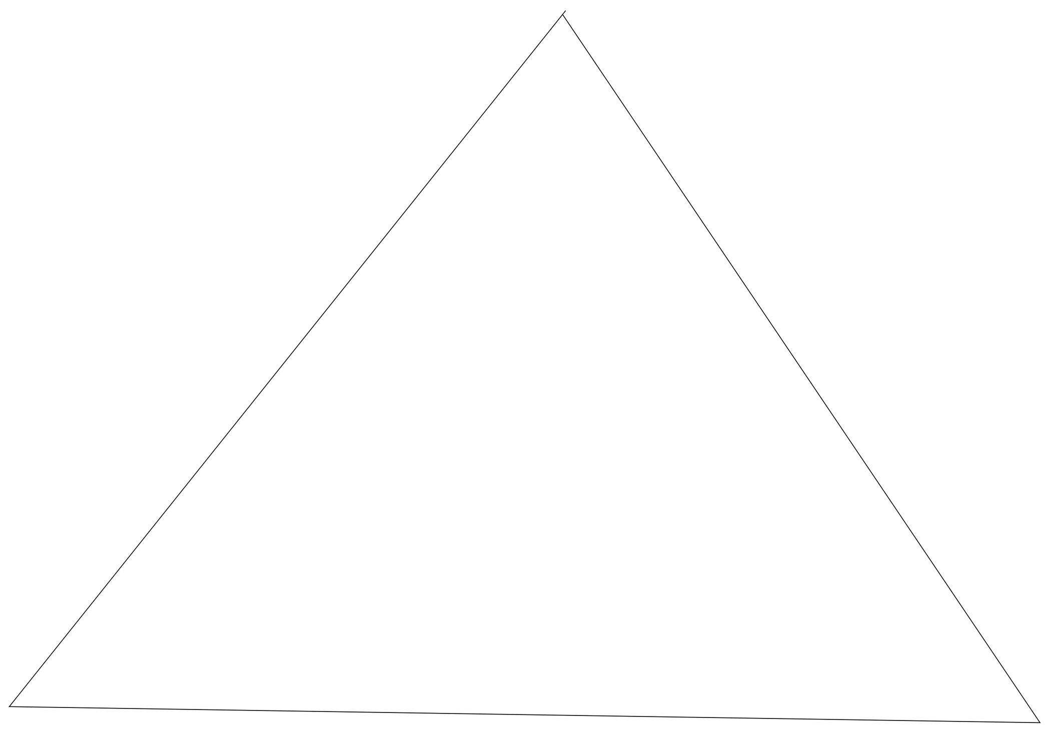
$$= \frac{\text{conc. of B in org}}{\text{'' '' '' '' aq}}$$

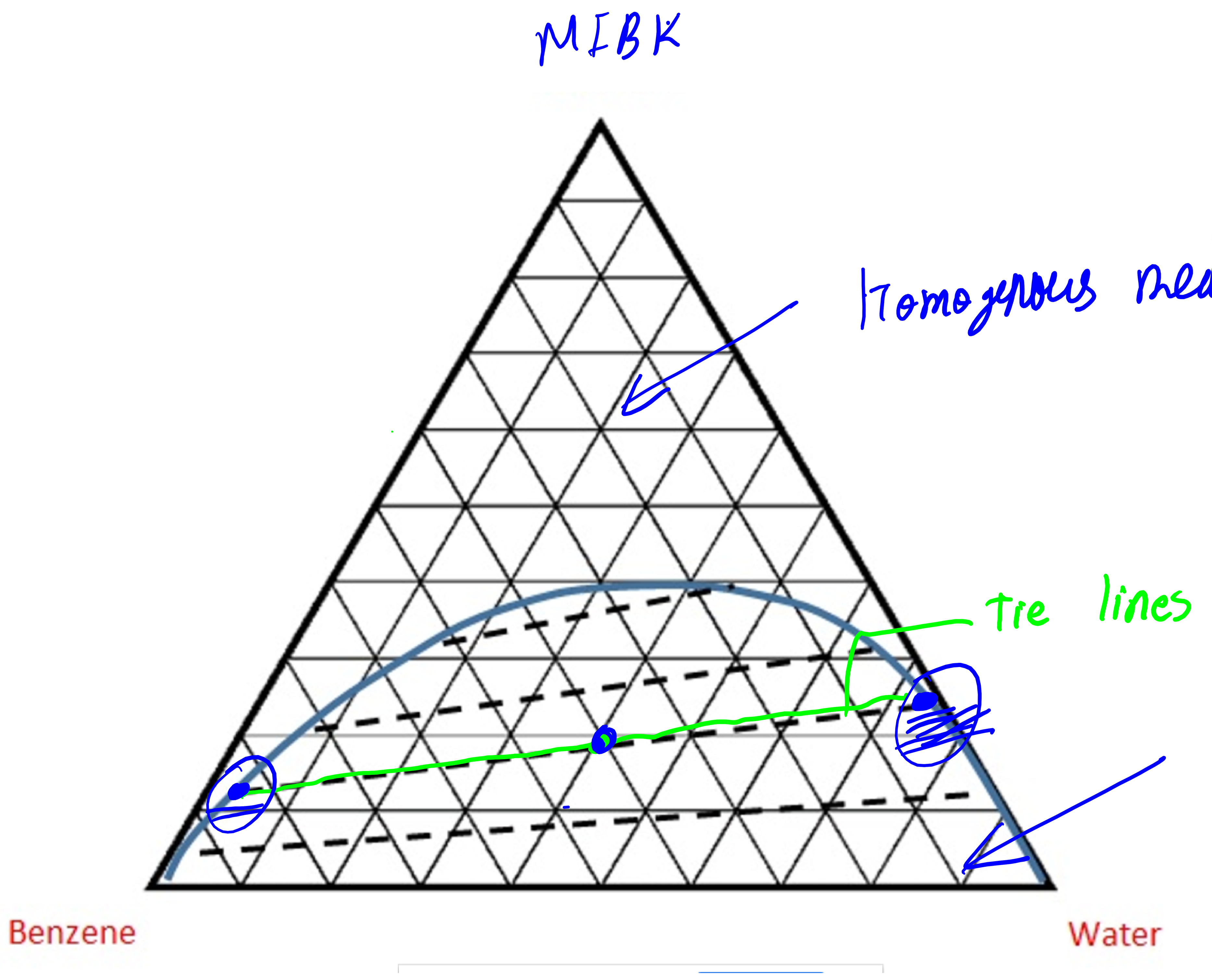


Triangular Diag



$x_C \to \underline{1 - x_A - x_B}$





End pts of TL → composi^n of 2 phase

2 V separat^n & Eq

Colligative properties

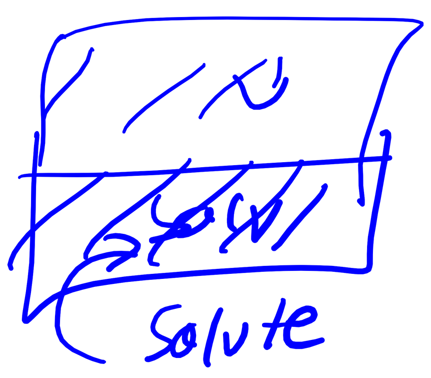
$$\Delta T_B = T_{B_S} - T_{B_0} = \frac{R T_b^2}{\Delta H_{vap}} \times x_{solute}$$

$$\Delta T_F = T_{F_0} - T_{F_S} = \frac{R T_f^2}{\Delta H_{fusion}} \times x_{solute}$$

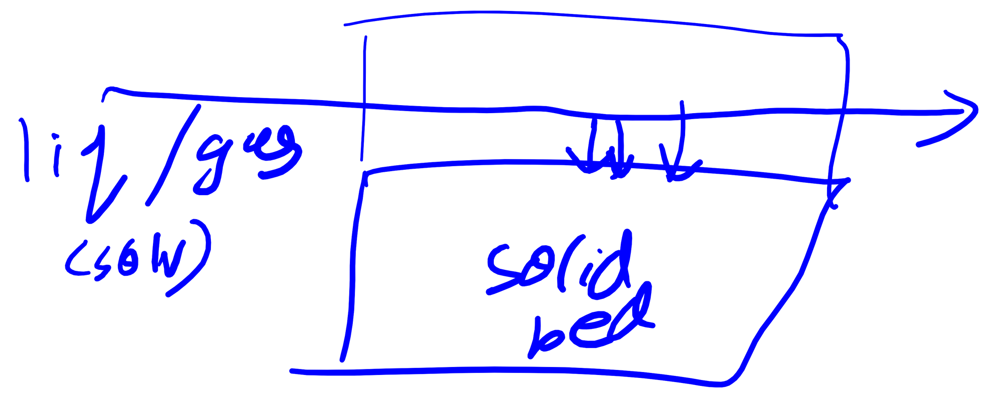
RLVP

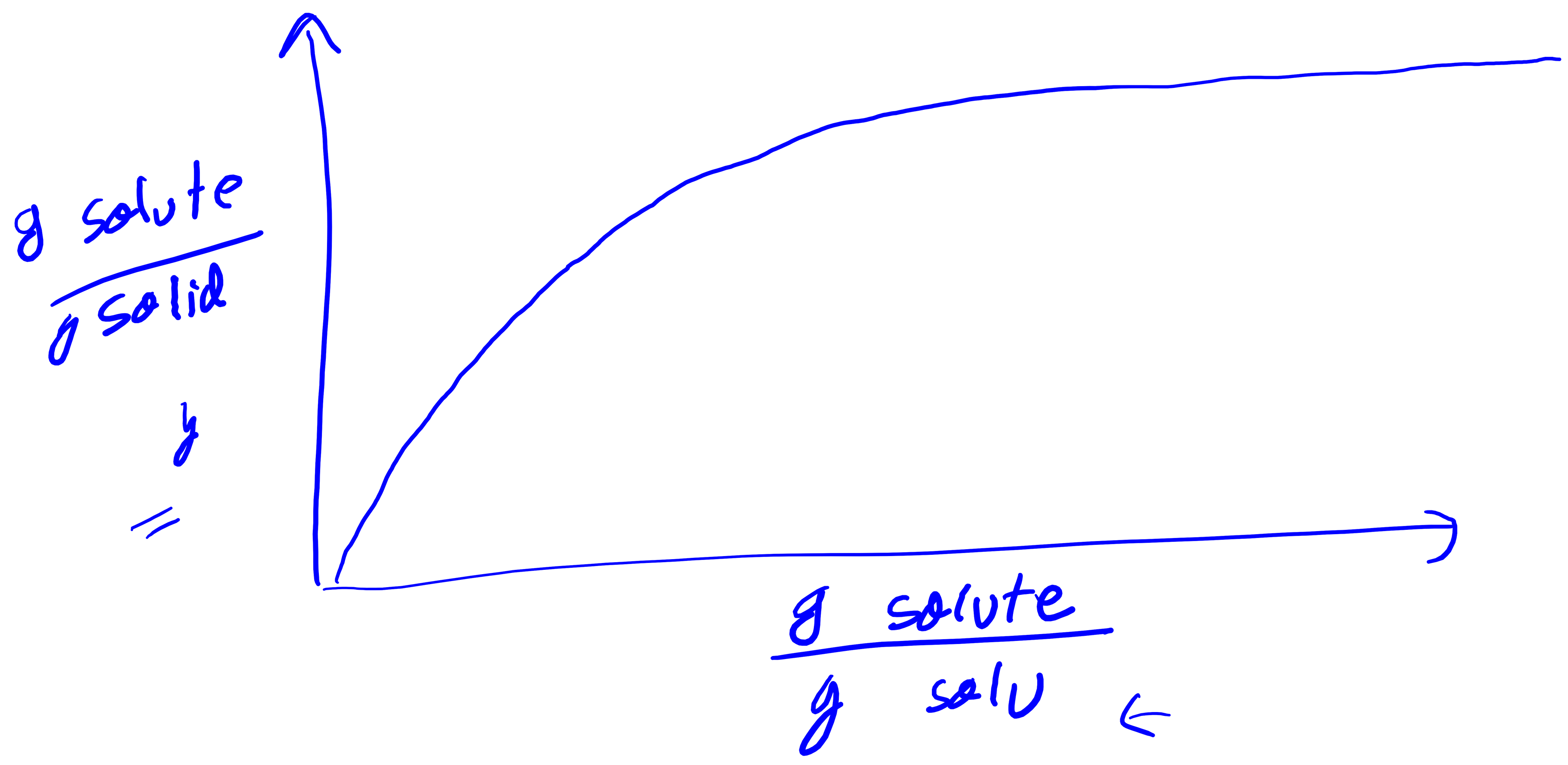
$$PP = (x(VP))$$

$\neq 1$



Adsorpt^n isotherm

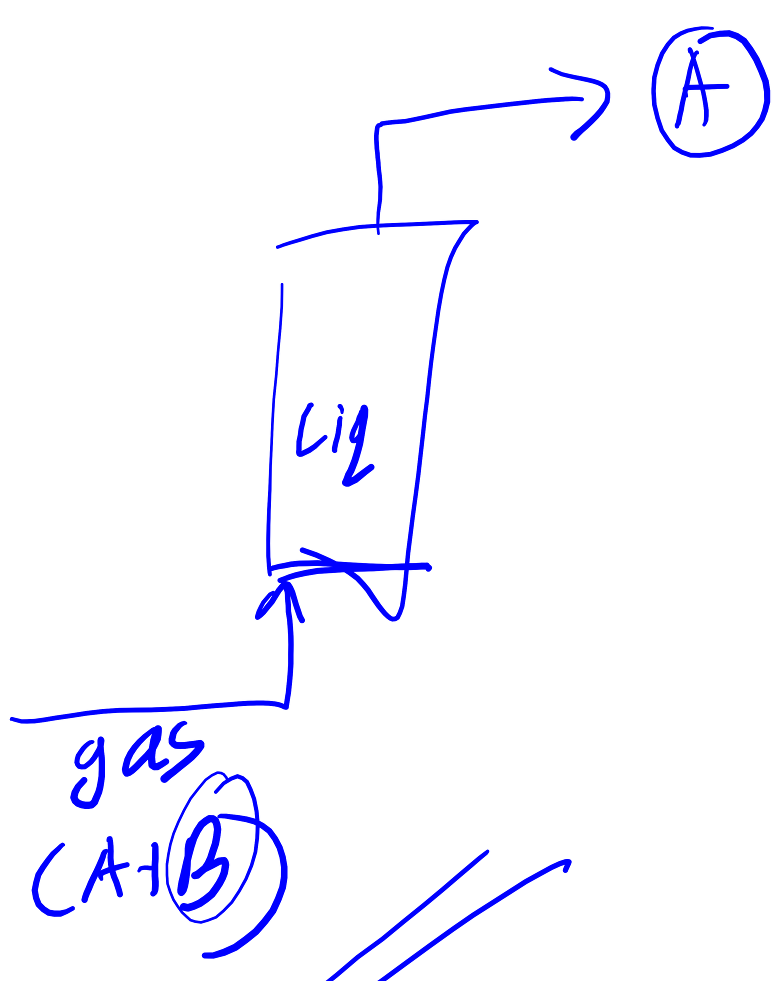


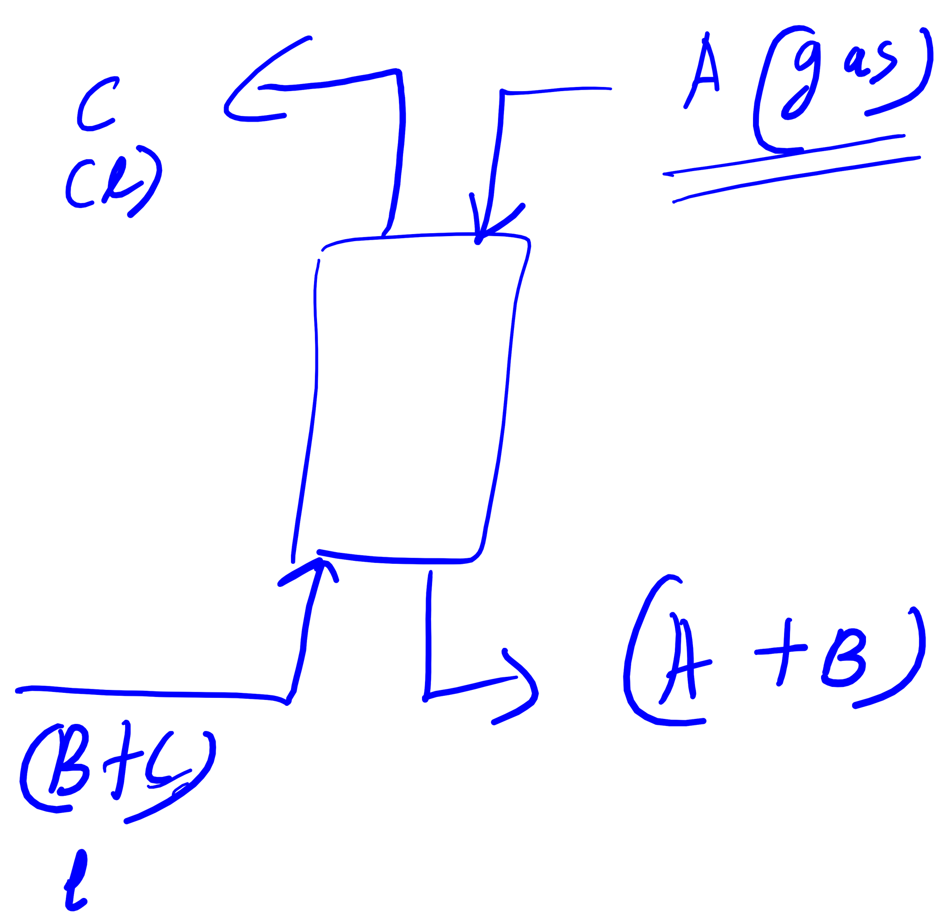


Langmuir $y = \frac{k' x}{1 + kx}$

Frenudlich $\to y = kx^n$

absorpt^n v/s stripping





Energy Balances

$$\sum(\Delta U + \Delta E_k + \Delta E_p) = Q - W_s - W_{fl}$$

$W_s \to$ rotatin

$Q \to$ +ve when Heat into system

$W \to$ +ve when done by the system

$\to \quad \to \quad \hat{U} = \frac{U}{\dot{m}}$ & $\underset{W_{fl}}{U + PV} = \underset{\text{enthalpy}}{H}$

$$\underbrace{\Delta U + W_f}_{} = Q$$

$$\boxed{\Delta H = Q}$$

Steam tables (water vap)

$T, P \to \hat{H}, \hat{U}$

$H_2 - H_1 = \Delta H$

$H_2 - H_1$

$(\cancel{H_{0,f}} + \Delta H_{g,f\to 2}) - (\cancel{H_{0,i}} + \Delta H_{g,i\to 1})$

$U_T = U_{T_0} + \Delta U_{T\to T_0}$

$T_0 \to U_{T_0} = 0$

$U_T = \Delta U$

$\Delta H, \Delta U$

$\to U_f, U_i$

$H_f, H_i \leftarrow$ same reference

Liq $\to \rho$, $\quad \Delta U = Q = 0$, $W_s = 0$

$$\frac{1}{2}(v_2^2 - v_1^2) + g(z_2 - z_1) + \frac{P_2 - P_1}{\rho} = 0$$

$\leftarrow$ Bernoulli Eq^n

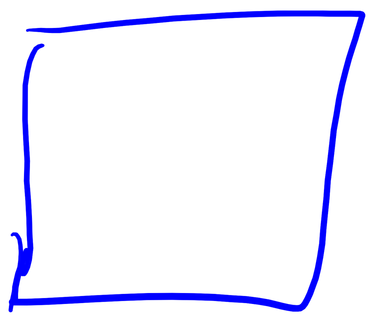
ΔP

Ideal gases $H(T) \Rightarrow$ no effect of P

Real gases $\not\Rightarrow P$

$H \rightarrow P, T$

Solids & liq $\Rightarrow$ $\boxed{\Delta H = V\Delta P}$



Fixed boundary $\Rightarrow \Delta P \neq 0$

$W_{fl} = 0$

$\Delta V \neq 0$

$\boxed{C_p = C_v + R}$

$$\Delta H = \int C_p \, dT$$

$$\Delta U = \int C_v \, dT$$

7

Psycometric charts

H

77 KJ/kg DA

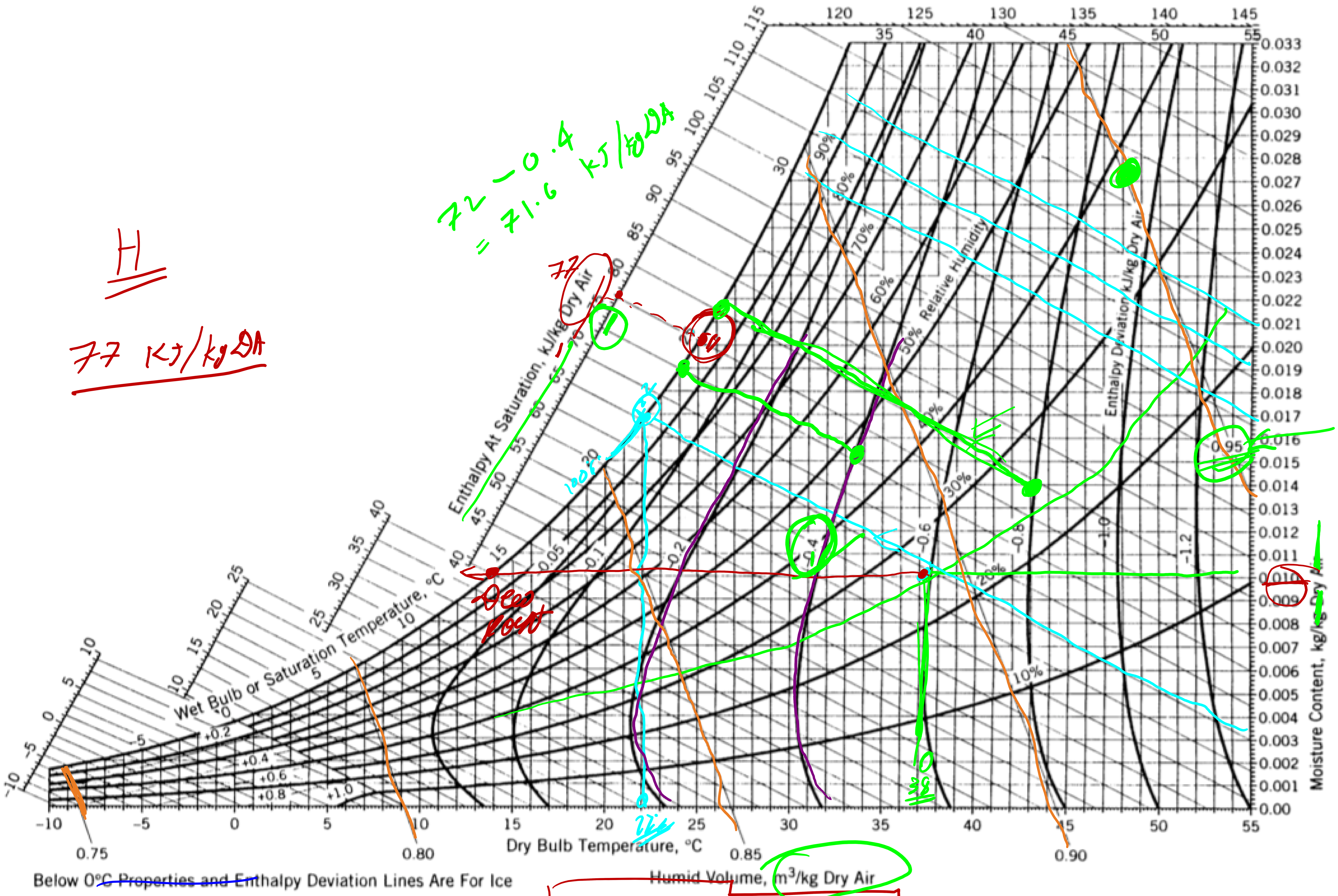


Figure 8.4-1 Psychrometric chart—SI units. Reference states: H_2O (L, 0°C, 1 atm), dry air (0°C, 1 atm). (Reprinted with permission of Carrier Corporation.)

- wet bulb temp
- Dry bulb ""
- Dew pt ←
- Enthalpy
- RH ←
- Abs H ←
- Humid volume
- Adiabatic cooling

θ

w

wet cloth

Air

30 ← θ

25 ← w

water

air

air

WT

Dry bulb temp → eq

Water Temp ↓

Raoult's Law

VP = 88

min water

Air in → water → Air mass sat

(sensible) → Temp diff in H_2O ⇐ H_{vap}

8

Enthalpy of Mixing & Reactions

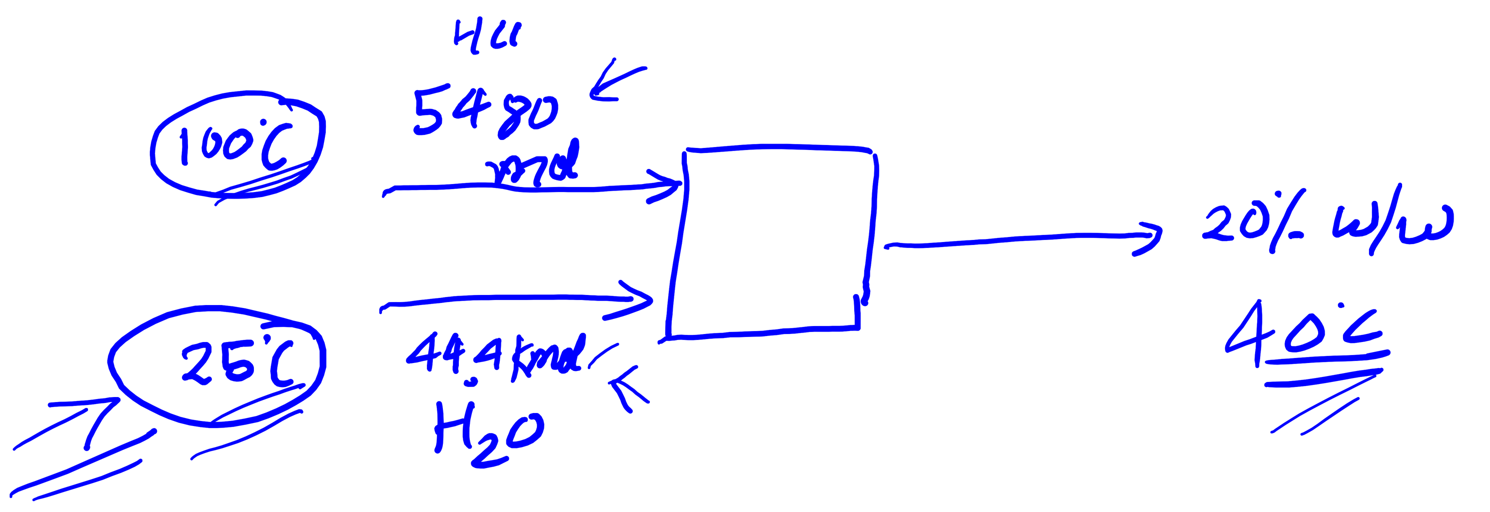
ΔH_{mix} depends on

- → Conc. ✓
- → Nature of solvents ✓
- → $\frac{\text{Solvent}}{\text{Solute ratio}}$ } (moles) ← 1

Units

ΔH_{mix} → $KJ/\text{mol of solute}$

Q.



1000 kg/hr ← Felder

$r \simeq 8.1$ ≃ $69 \ KJ/\text{mol HCl}$ ← 25°C

Subs	in n	in $\hat{H}$	out n	out $\hat{H}$
HCl (g)	5480	$\hat{H}_1$	—	—
H_2O (l)	44400	0	44400	⊗
HCl (aq)	-	-	5480	$\hat{H}_2$

$\Delta H = H_{out} - H_{in}$

$= \hat{H}_2 \times 5480 - \hat{H}_1 \times 5480$

$\hat{H}_1 = \int_{25°C}^{100°C} C_p \, dt = x$

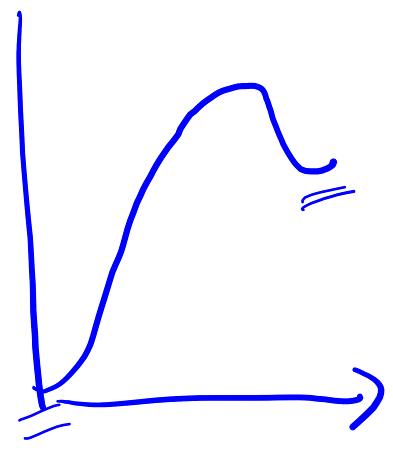
$\hat{H}_2$ = Mixing at water temp 25°C → Heating the mix T 40°C

ΔH_{mix} at 25°C

water C_p, HCl C_p, $C_{p,soln}$

$69 \cdot \times 5480 + \int_{25°C}^{40} C_{p,soln} \, dT$

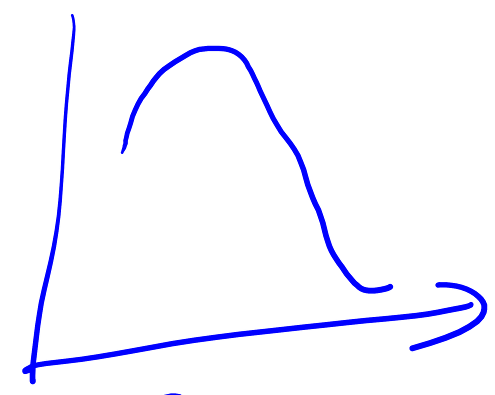
$H_2 - H_1$



Endo

↓

$\Delta H > 0$



Exo

↓

$\Delta H < 0$

$2A_{(l)} + 6B \rightarrow 8C + 6D$ → $\Delta H_{rxn} = -100$ KJ/mol

$A_{(g)}$

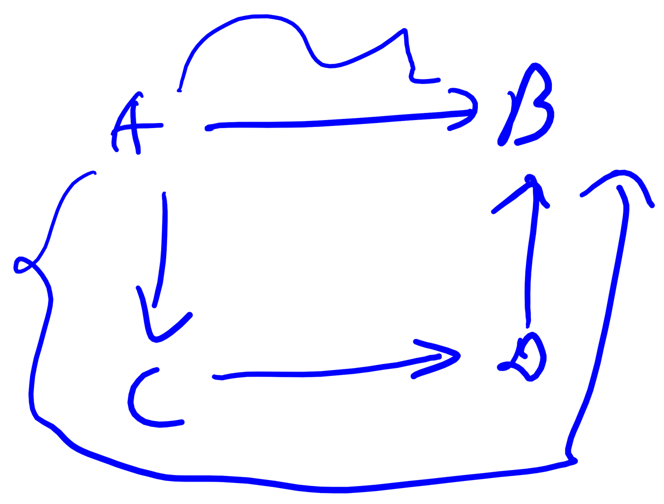
Heat of rxⁿ per-mol of A → $\frac{100}{2}$ = 50 KJ/mol of A

C → $\frac{100}{4}$ = 25 ... C

Heat of formatⁿ

$H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O$ ΔH_{form} 25°C, 1atm

Hess's Law

→ 

$\Delta H_1 = \Delta H_2$

Q

i) Material Balance

ii) What is the ref

iii) Enthalpy table

iv) ΔH

2 ways
- → ΔH_{rxn} → ref = molecules/compounds at std Temp
  - ↳ $\Delta H = \Sigma H_{out} - \Sigma H_{in} + \Delta H_{rxn}$
- → H_f → ref = Elements at 25°C, 1atm
  - ↳ $\Delta H = \Sigma H_{out} - \Sigma H_{in}$ *