Subject:

* Measuring ⇝
* Estimation : Correlations

① Clapeyron Equation :

$$\frac{dP^*}{dt} = \frac{\Delta\hat{H}_v}{T(\hat{V}_g - \hat{V}_L)} \quad \text{---- ①}$$ From measuring

P^* : vapor pressure

T : absolute temp. (K, °R)

$\Delta\hat{H}_v$: Latent heat of vaporization

$\hat{V}_g$: specific molar volume of Gas ($\frac{\text{Volume}}{\text{mole}}$)

$\hat{V}_L$: " " " " Liquid

⇝ at low to moderate pressure

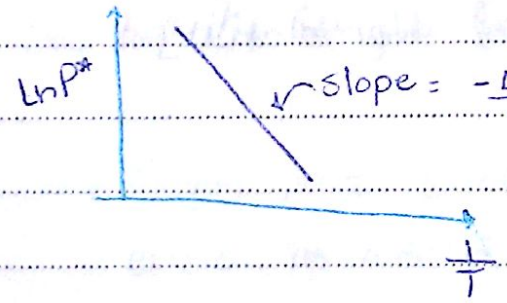
$\hat{V}_g \gg \hat{V}_L \Rightarrow \hat{V}_g - \hat{V}_L = \hat{V}_g$

Ideal Gas Law $\Rightarrow \hat{V} = \frac{RT}{P^*}$ ⇝ نعوض بـ $(\hat{V}_g - \hat{V}_L)$

$$\frac{dP^*}{dT} = \frac{\Delta H_v}{T * \frac{RT}{P^*}} \rightsquigarrow \frac{d(\ln P^*)}{d(1/T)} = \frac{-\Delta\hat{H}_v}{R} \quad \text{---- ②}$$

to get this

derive this



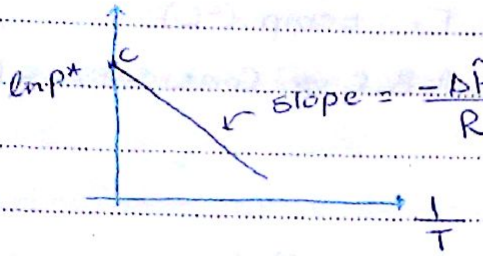
Subject: .....

* Suppose that $\Delta\hat{H}_v \neq f(T)$

Integrate eq. ②

$$\ln P^* = \frac{-\Delta\hat{H}_v}{RT} + C$$ Clausius - Clapeyron Equ

C ⇝ Const. depends on substance



① if you have single pt (P^*, T) & $\Delta\hat{H}_v$

⇝ intercept ⇝ C

② if you have set of P^* VS T

⇒ slope ⇒ $\Delta\hat{H}_v$

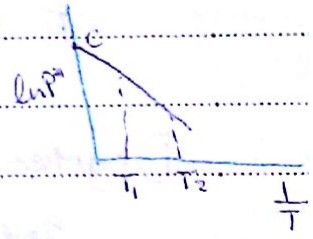
⇒ intercept ⇒ C

Ex ⇝ 6.1-1 ⇝ at $T_1 = 7.6\,^\circ C$ ⇝ $P^* = 40$ mmHg

at $T_2 = 15.4\,^\circ C$ ⇝ $P^* = 60$ mmHg

a) ⇝ $\Delta\hat{H}_v$ & B

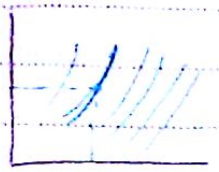
b) $T = 42.2\,^\circ C$ ⇒ $P^* = ??$



Subject: ..... 9 /Dec / 2015

* Vapor pressure (P^*)

Cox Chart Fig. 6-1-4 P. 247



P^*_{VP} = vapor pressure (mmHg)

T = Temp (°C)

A, B, C ⇒ Constants ⇒ Table B.4

* Antoine Equation

$$\log_{10} P^* = A - \frac{B}{T + C}$$

Sec 6-2 ⇝ Gibbs Phase Rule

Equilibrium between 2- Phases

T, P & composition in each phase no longer changes with time

T_1	Phase II
a	P_1
b	
c	Composition
T_1	Phase I
a	P_1
b	composition

Variables

Intensive	Extensive
do not depend on size of system	do depend on size of system
T, ρ, $\hat{V}$, P, x, y	m, U

Degrees of Freedom ⇝ # of intensive variables that must be specified for a system at equ before the remaining intensive variables can be calculated.

$$DF = 2 + C - R$$ (non-Reactive)

C = # of components

R = # of phases

Subject:..... / /

DF = 2 + C − π − r , r = # of rxns occur

Ex. 6.2-1 → 1. DF = 2 + C − π

2 + 1 − 1 = 2

2. DF = 2 + 1 − 3 = 0

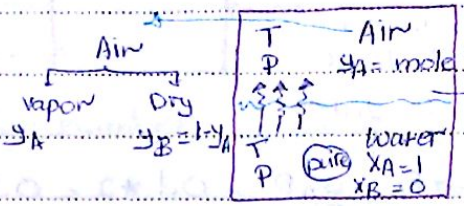
3. DF = 2 + 2 − 2 = ∅ 2

Sec 6.3 → Gas - Liquid Systems = One Condensable Component.

Terms → Saturation = Equilibrium

DF = 2 + C − π

= 2 + 2 − 2 = 2



mole of vap / moles of Air

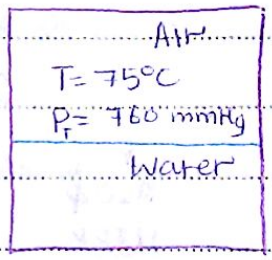
* Raoult's law :- water

$P_A = y_A P = P_A^*(T)$

- Gas - liquid System
- Saturated Vapor (at equilibrium)
- One condensable Component

"the vapor is the only species that would condense"

Ex → 6.3-1



DF = 2 + 2 − 2 = 2

$y_A P = P_A^*(T)$

$y_A = \frac{P_A^*(T)}{P}$

Table B.3 ← $= \frac{P_A^*(75°C)}{P_t} = \frac{229}{760} = 0.38$ ← y_A

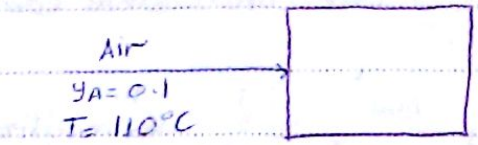
$y_{DA} = 1 - y_A$

Subject: ..... / /

* IF $P_i = y_i P = P_i^*$ ⇒ the vapor is sat.
P_i can not exceed P_i^*

* If $P_i < P_i^*$ ⇒ the vapor is superheated vapor
Cooling ($T\downarrow$) at const. P (isobarically)
OR P↑ at const T (isothermally)

* Degrees of Superheat = T - T_{sat}



$P_A = y_A P = 0.1 * 2 = 0.2$ atm

P_A^* | 110°C = 1.5 atm

$P_i < P_i^*$ (dew point ↑)

$P_i = 0.2 atm = P_i^*(T_{sat})$

$\log P_A^* = A - \frac{B}{T+C}$

$T = 80°C$

Degree = 110 - 80 = 30°C

* Ex 6.3-2 / P (251) * very impor

6.6 Equilibrium between two liquid Phases.

6.6 a) دایتین سیوا

دایتین ببنگل جزئی ① Partially misible ⇝ Water & MIBK

2 liquid Phases
- H_2O & MIBK
- H_2O & MIBK

② immiscible ⟶ water & Chloroform

3) Extraction ⟶ water & acetone ⟶ solute
immiscible ⟶ Chloroform

4) distribution coefficient, K:
A & S ⟶ Two nearly immiscible liquids
B ⟶ solute distributed between the 2 liquid

$$K = \frac{\text{mass Fraction of B in S phase}}{\text{mass Fraction of B in A phase}}$$

Perry's Handbook ⟶ list of K for number of ternary liq. component

Example 6.6-1 ⟶ very important

6.6b Phase Diagrams for Ternary Systems

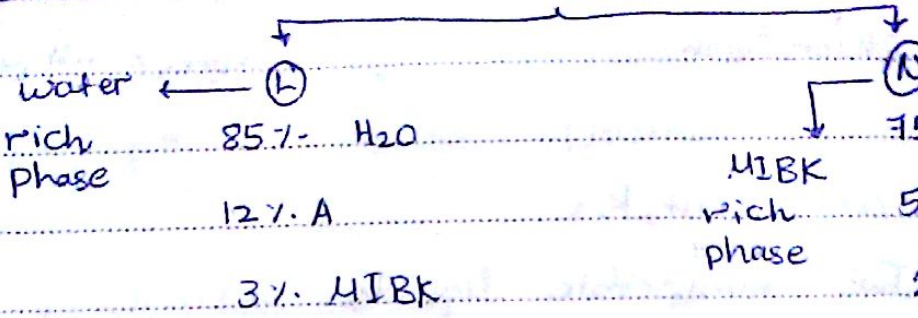
* Triangular Phase Diagram ⟶ behaviour of partially miscible ternary system
  * 3-components
    * equilateral triangle ⟶ مثلث متساوي الأضلاع
    * right triangle ⟶ مثلث قائم الزاوية

* each apex ⟶ pure component
* each edge ⟶ binary system

Subject: .....

give ~ 80% Acetone , 10% H_2O , 10% MIBK] كيف نحدد هذه النقطة

give point M : 55 wt% H_2O , 15% A , 30% MIBK



tie line ~> connects phases at equilibrium

Subject:

6.4] Multi components Gas - liq. System.

6.4a] → Vapor - Liquid Equilibrium Data (VLE Data)

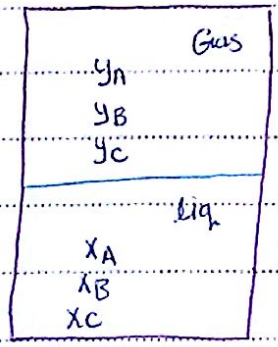
Perry's Chemical Engineering handbook.

6.4b] Raoult's law & Henry's law

Distribution of components between phases

↓

mole fraction



Gas - liq. at equilibrium ⇒ T, P

x_A: mole Fraction of A in liq. phase

y_A: " " " " gas phase

P_A: partial pressure of A in gas phase

Raoult's law ⇒ $P_A = y_A P = x_A P^*(T)$

$P_A^*(T)$: Vapor pressure of pure A at T

Valid when:

(1) $x_A \sim 1$ ⇒ the liquid phase is almost pure of A

$x_A \sim 1$ ⇒ pure liquid of A

↳ one condensable comp.

(2) Similar compounds :-

toulene & benzene

Subject:

Henry's law :-

$P_A = y_A P = x_A H_A(T)$

$H_A(T)$: Henry's law Constant for A in a specific solvent.

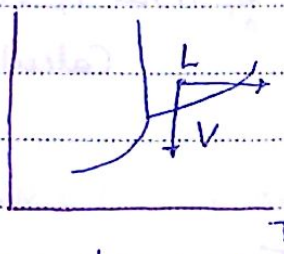
valid when :-

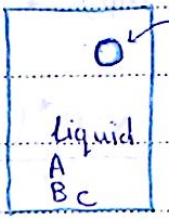
$x_A \sim 0$ ⇝ the solution is diluted.

Ideal solution ⇝ a solution for which Raoult's law or Henry's law is obeyed for all species at all solution composition

Example 6.4-2 ⇝ very important.

6.4C ⇝ V.L.E Calculations for ideal solution.





Pbp ↑ P ↓ تبدأ تتكون عند

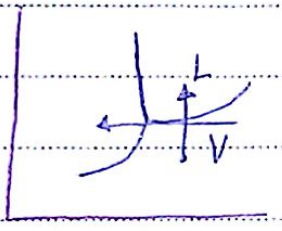
vapor A, B, C ○ bubble point

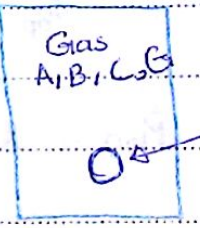
y_A
y_B
y_C

T ↑ ← Tbp

أول فقاعة تتكون تسمى Pbp أو Tbp

L → V decompression at const T OR heating at const P





أول قطرة dew pt

L
x_A
x_B
x_C

V → L compression at const T OR cooling at const P

Subject: / /

Def :-

Bubble pt. T ⇝ the temp at which the 1st vapor bubble forms when a liq. is heated slowly at const P.
T_{bp}

Bubble pt. pressure ⇝ the temp at which the 1st vapor bubble forms when a liq. decompressed at const T

bubble point temp Calculations.

T_{bp} ⇝ y_A , y_B , y_C

the liq. ⇝ ideal soln

the gas ⇝ ideal Gas

Raoult's law ⇝

$$P_i = y_i P = x_i P_i^* (T_{bp})$$

هون الtemp معي موجودة

$$P = \sum P_i = \sum (x_i P_i^* (T_{bp}))$$

$$P = x_1 P_1^* (T_{bp}) + x_2 P_2^* (T_{bp}) + \cdots$$ Trial & Error Calculation

$$y_i = \frac{x_i P_i^* (T_{bp})}{P}$$

bubble point pressure calculation :- T ✓

هون temp موجودة بالسؤال

Raoult's law ⇝ $P_i = y_i P = x_i P_i^* (T)$

$$P_{bp} = \sum P_i = \sum (x_i P_i^* (T))$$

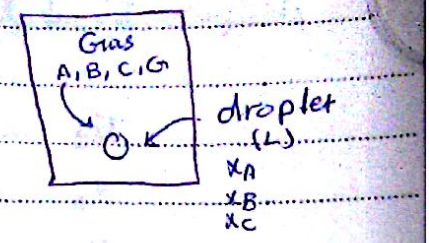
$$P_{bp} = x_1 P_1^* (T) + x_2 P_2^* (T) + \cdots$$

$$y_1 = \frac{x_1 P_1^* (T)}{P_{bbp}}$$

Subject: ..... / /

dew point Calculation (temp) (T_{dp})

Suppose a gas mixture contains A, B, C, ... & noncondensable G. at const P.



Raoult's Law $\Rightarrow$ $x_i = \dfrac{y_i P}{P_i^*(T_{dp})}$

$\sum x_i = 1 \Rightarrow \sum \dfrac{y_i P}{P_i^*(T_{dp})} = 1$

$\dfrac{y_1 P}{P_1^*(T_{dp})} + \dfrac{y_2 P}{P_i^*(T_{dp})} + \cdots = 1$ $\rightsquigarrow$ Trial & Error Calculation

* dew point pressure $\rightsquigarrow$ at const T

$x_i = \dfrac{y_i P_{dp}}{P_i^A(T)}$

$P_{dp} = \dfrac{1}{\frac{y_A}{P_A^*} + \frac{y_B}{P_B^*} + \cdots}$

Example 6.4-3 $\rightsquigarrow$ very important.

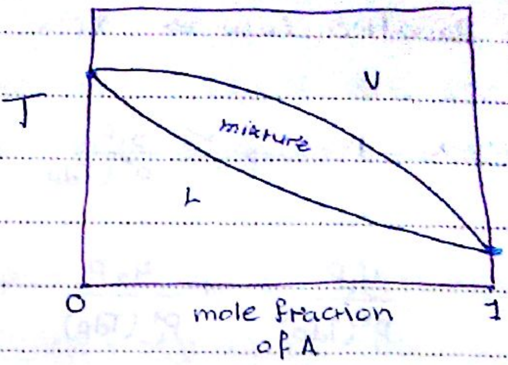
Subject: .... / /

6.4.d → Graphical Representions of Vapor-liquid Equilibrium

Txy & Pxy → VLE representions for {binary} system → 2-components

Txy → P = 1atm

x_A	T	y_A
0	→ _	□
⋮	→ _	□
⋮	→ _	□
1		

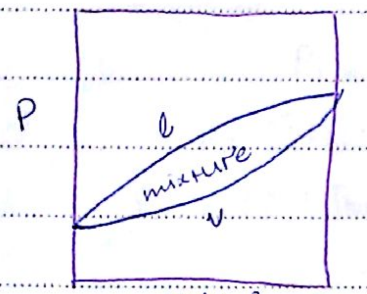


P = 1atm

Pxy x_A P dp y_A ⇒ const T = 100°C

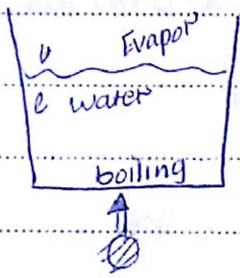
بدنا نطلع bubble point ← بنروح على خط L

بدنا نطلع dew poi ← بنروح على خط V



T = 100°C

+ Boiling Point of amixture



between 2 phases → Evaporation

between سطح غير of l → Boiling

→ boiling point → Tbp → boiling point

$$P = x_A \left(P_A^*(T_{bp})\right) + x_B P_B^*(T_{bp})$$

Subject:..... / /

6.1 ~ Adsorption on solid Surfaces.

↳ attraction of chemical species in gases or liquids to the surfaces of solid.

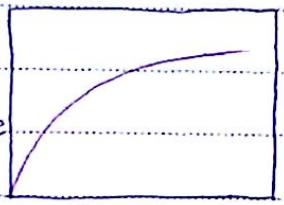
* adsorbent → solid

adsorbate → solute

* adsorption Isotherm ~ adsorbate eq. data on a specific adsorbent taken @ certain T

adsorbent ⇒ activated carbon

adsorbate ⇒ CCl_4



* can be held by unit mass of adsorbent

↳ Concentration

@ low adsorbate partial pressure/conc

linear ⇒ $X_i^* = KC_i$ or KP_i

for higher conc ⇒ Langmuir Isotherm

$$X_i^* = \frac{a K_L P_i}{1 + K_L P_i} \quad \text{or} \quad X_i^* = \frac{a K'_L C_i}{1 + K'_L C_i}$$