Principle 1 Summary

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Chapter "2" Introduction to Engineering Calculations

Chemical Engineering

raw material → processes → product

* amount and properties of the raw material
* amount and properties of the product

Units & dimensions

dimention [numerical value
unit

Calculated
volum
density
velocity

mesured
mass
time
length
tempreture

Force & weight

natural force unit [
- SI unit $Kg \cdot m/s^2 = 1$ newton
- CGS unit $g \cdot cm/s^2 = 1$ dyne
- Am Eng. unit $lbm \cdot ft/s^2 = \frac{1}{32.174}$ lbf

$$lbf = 32.174\ lbm \cdot ft/s^2$$

Estimate of Measured value:

Sample mean $\bar{x} =$ مجموع القيم / عددهم

- Range: $R = x_{max} - x_{min}$
- variation: $S_x^2 = \frac{1}{n-1}[(x_1-\bar{x})^2 + (x_2-\bar{x})^2 + \dots]$
- deviation: $S_x = \sqrt{S_x^2}$

pressure :- $\frac{\text{force}}{\text{Area}}$ $\frac{N}{m^2}$ $\frac{lbf}{in^2}$ $\frac{dyne}{cm^2}$

$$\rho = \rho_0 + gh\rho$$

$$P_{abs} = P_{gauge} + P_{atm}$$

Open end gauge — differential Δ — sealed end abs

Temperature — C & K نفسه — الفرق بين

R & F نفسه

* density = mass / volume ≥ g/cm^3, kg/m^3, lbm/ft^3
  sub sub

* Specific volume = volume / mass

✓ $\frac{g}{cm^3}$ ≡ Specific gravity → kg * 1000
→ lbm 62.43

* G mole ⟶ 6.02×10^{23} (Avogadro's number)

* X mass fraction = mass of A / total mass

* y mole fraction = moles of A / total moles

mass fraction $\xrightarrow[\text{\& table}]{\text{Basis of calcu}}$ mole fraction.

* Avergge molecular weight

$$\frac{1}{M} = \sum \frac{X}{M} \qquad M = yM$$

* Mass conc = m of sub / V of solution

* mol conc = n of sub / V of solution

* molarity = mol of solute / V solution (l

* 1 ft = 12 Inch

* 1 yd = 3 ft

* 1 N = kg.m/s²

* 1 dyne = g.cm/s²

* 1 lbf = 32.174 $\frac{lbm \cdot ft}{s^2}$

$g = 9.8066\ m/s^2$

$= 980.66\ cm/s^2$

$= 32.174\ ft/s^2$

Dimention less groups

* Exponents $x^{②}$
* Transcendental (log, e, sin)
* arguments of transcendental

$\sin(x)$

Interpolation estimate y between 2 points

$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1} \rightarrow (x_2 - x_1)(y - y_1) = (y_2 - y_1)(x - x_1)$$

$$y = y_1 + \frac{x - x_1}{x_2 - x_1}$$ common !

Fitting a stright line & non linear line (Linearization)

Least Square methode

$S_x = \frac{1}{n}\Sigma x$ $S_y = \frac{1}{n}\Sigma y$ $S_{xx} = \frac{1}{n}\Sigma x^2$ $S_{xy} = \frac{1}{n}\Sigma xy$

Best Line

$$a = \frac{S_{xy} - S_x S_y}{S_{xx} - (S_x)^2}$$

$$b = \frac{S_{xx} S_y - S_{xy} S_x}{S_{xx} - (S_x)^2}$$

4 sig fig or 5 sig fig after linearrization

Best line through the origin

$$a = \frac{S_{xy}}{S_{xx}}$$ intercept (0,0)

Balances :- (Balance on conserved quantities (mass & energy) momentum

① General Balance equation

A

(+) accumulation

G C

Total mass input + generation − output − consumption =

(−) depletion

non reative total mas: input − output = accumulation

G = 0 C = 0

Steady state total mass A = 0: input + generation − output − consumption = 0

Total mass non reactive & steady state: input = output

② Balance on continuous steady state process

A = 0

rate

input + generation − out put − consumption = 0

③ Balamee on batch process

initial input + generation = final output + consumtion

Material Balaice & calculations.

* The number of independent equations = number of chemical species

* labiling
* أكتبي مطلوب السؤال بالمتغيرات
* degree of freedom

unknow species

process constrant

Dof = Uhknown − indep

Material Balances:-

* مبدأ حفظ الكتلة :-

الكتلة في نظام مغلق ستبقى ثابتة مهما حدث داخل النظام

mass can't be created or destroyed

Total mass input = Total mass output

* When do I say that my system is complete ??

① input & output of the entire process

② each individual unit sastify Balance equation.

System
- closed system ⟶ no mass crosses system boundaries (Batch)
- opened system ⟶ mass cross system boundaries (continuous)

Chemical processes:-

Batch
- كل feed مرة وحدة *
- كل prod مرة وحدة *
- زي طنجرة الفشفوط
- * Baking a cake

Semibatch
any process that is neither batch nor continuous

Continuous
input & out put flow continuously

Steady state
all the variables in a process doesn't change with time
- * Temp
- * pressure
- * volume
- * flowrate

transient
If any of variables change with time
- * Batch (لا يكون في تفاعل كيميائي)
- * semi batch

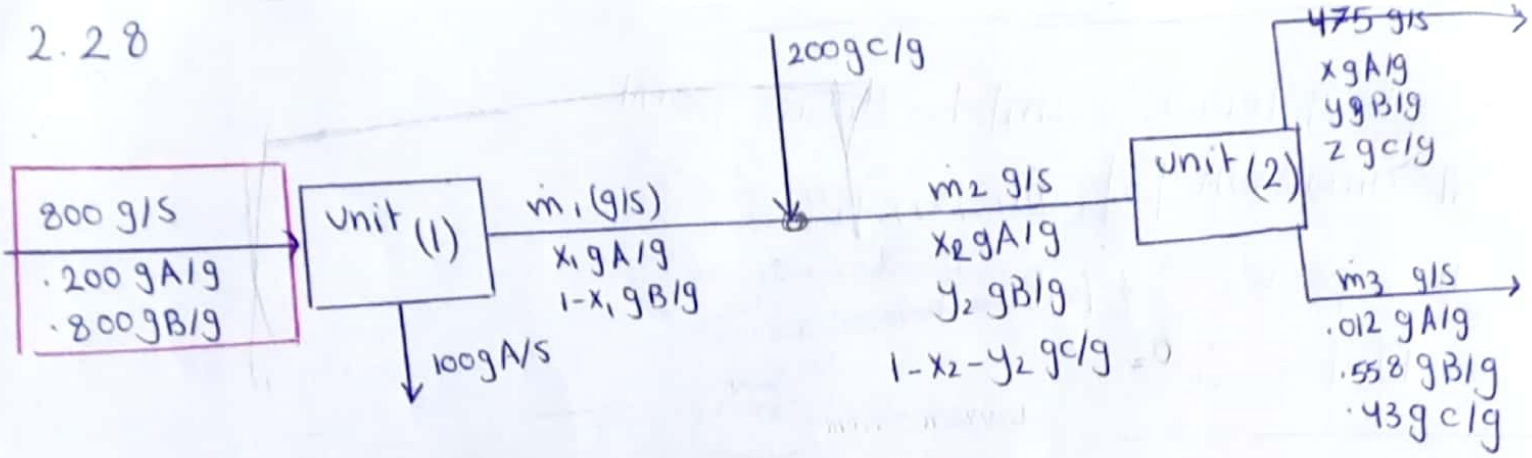
↑ continuous

في بدخل نفس rate إلى بيطلع عشان ضمان ما يغير تغيير

Types of balances

- Differential
  - rate
  - continuous
- Integral
  - amount
  - batch

2.28



Step (1) Choose a Bais of calculation

Step (2) Draw a flowchart and fill all known variables & label unknown stream variables

Step (3) Express what the problem statment ask

Step (4) if you are given mixed mass and mole units for a stream, convert all quantities to one bais (mole ↔ mass)

Step (5) Do Dof analysis

Dof = 0 ← System أحدثي وليبأ منعنده

subSystem "1" : unit 1 ✓✓

unknowns = 2 {$\dot{m}_1$, x_1}

species = 2 {A, B}

Dof = 0

subsystem "2": unit 2

unknowns = 7 {x_2, y_2, $\dot{m}_2$, x_1, y, z, $\dot{m}_3$}

species = 3 {A, B, C}

physical constraints = 1

Dof = 7 - 3 - 1 = 3

Sub system "3": mixing point

unknowns: 5 {$\dot{m}_1$, x_1, $\dot{m}_2$, x_2, y_2}

species: 3 {A, B, C}

Dof = 5 - 3 = 2

Subsystem "4" : Overall process ✓✓

#unkowns: 4 {x, y, z, $\dot{m}_3$}

#species: 3 {A, B, C}

physical constraints: 1

Dof = 4 - 3 - 1 = 0

Subsystem "5": unit 1 + Mixing point

unknown: 3 {$\dot{m}_2, x_2, y_2$}

species: 3 {A, B, C}

Dof = 3 - 3 = 0

subsystem "6": unit 2 + Mixing point

unknowns: 6 {$\dot{m}_1, x_1, x, y, z, \dot{m}_3$}

species: 3 {A, B, C}

physical constraints: 1

Dof = 6 - 3 - 1 = 2

Step '6' write the equations in an efficient order

(minimizing simultaneous equations)

Start with system that has [Dof = 0]

* unit 1
* overall process
* unit 1 + Mixing point

Just valid for mols

تفاعلين

Balances on Reactive Processes

more favorouble

Molecular Species Balances	Atomic Species Balances	Extent of Reaction
تفاعل واحد		
No. *degrees of freedom* (DOF) =	No. *degrees of freedom* (DOF) =	No. *degrees of freedom* (DOF) =
+ No. Unknowns	No. Unknowns	No. Unknowns
+ No. independent Chemical reactions	- No. independent Atomic species	+ No. independent Chemical reactions
- No. independent Molecular species	- No. independent Nonreactive (inert) species	- No. independent Reactive species
- No. process information	- No. process information	- No. independent Nonreactive (inert) species
		- No. process information
*Best for single reaction	*Best choice when have multiple reactions	*Convenient for chemical equilibrium problems
*Need stoichiometric equation	*Most robust الأقوى	*Good when equation-solving software to be used
	*Don't need to know the reaction is some cases	*Somewhat cumbersome

Input + generation = output + consumption

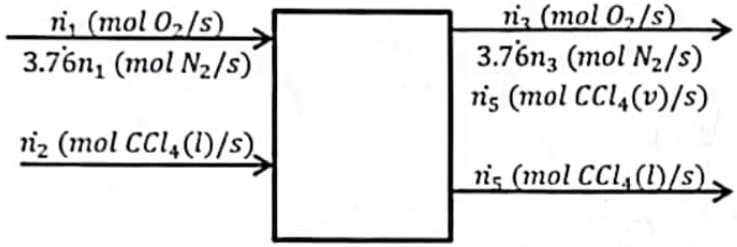
Input = output

حددنا التفاعلات وبينا ظهروا لنا النسبة

$n_i = (n_i)_0 + \varepsilon \nu_i \xi$

Maximum 3 reactions

- If 2 molecular species are in the same ratio to each other wherever they appear in a process, balances on these species will not be independent equations. Example:



  - N_2 and O_2 appear in the same ratio, 3.76 mol N_2/mol O_2, they cannot be counted as 2 independent molecular species;
    (you can write a balance on either N_2 or O_2)
  - Atomic C and Cl are always in the ration of 1:4, so they are not independent atomic species;
    (you can write a balance on either C or Cl)

- If the stoichiometric ratio of a reaction can be obtained by adding/subtracting multiples of other equations, it is not independent chemical reaction. Example:

[1] A → 2B
[2] B → C
[3] A → 2C

Now, [3] = [1] + 2*[2] → it's not independent → those 3 reactions have only 2 independent chemical reactions.

Chapter 5 : Single phase system

In the system only one phase
(solid or liquid or gas)

§§ 5.1: Liquid & Solid densities :

* Solids & liquids densities are independent of Temprature & pressure.

* mixture of pure components

$$\overline{\rho} = \Sigma x_i \rho_i \qquad \Sigma \frac{1}{\rho} = \Sigma \frac{x_i}{\rho_i}$$ (volum additivity)

* $\dot{V}(STP) \longrightarrow \dot{n}$ وإنما طريقة أخرى للتعبير عن $\dot{V}$ ليست للتعبير عن

IDEAL GASES (depends on T&P)

$$PV = nRT \longrightarrow \rho = \frac{P\bar{M}}{RT} \qquad \bar{M} = \Sigma x_i M$$ mixture of gases

assumtion:

① negligible volume

② exert no forces on each other

③ Collide elastically with the walls of Contanier

Conditions :

high T ↑ low pressure P ↓

make sure that it IDEAL GAS ??

$$\frac{V}{n} = \frac{RT}{P}$$ [diatomic > 5 L/mol ; other > 20 L/mol]

Same gas different conditions

$$\frac{PV}{P_s V_s} = n \frac{T}{T_s}$$

Dattons law $P_A = y_A P$

Amagat's law $V_A = y_A V$

Volum fraction of a substance in an ideal gas mix ⇔ mol fraction of this sub

Non IDEAL GASES

Verial equation of state:

$$\frac{P\hat{V}}{RT} = 1 + \frac{B}{\hat{V}}$$ (not for polar compounds)

P → stright forword

◊ → quadratic equation

① P_c & T_c
② ω
③ T_r P_r
④ B

reffer to book!

Van der waals equation of state:

$$P = \frac{RT}{\hat{v} - b} - \frac{a}{\hat{v}^2}$$

He & H_2
+ 8 K
+ 8 atm

Soave - Redlich SRK

$$P = \frac{RT}{\hat{V} - b} - \frac{\alpha a}{\hat{V}(\hat{V}+b)}$$

Compressibility factor

$$Z = \frac{P\hat{V}}{RT} \qquad V_r^{ideal} = \frac{\hat{V}}{V_c} = \frac{P_c \hat{V}}{RT_c}$$

Mixture of gases (Kay's rule)

$T_c = y_A T_{cA} + y_B T_{cB}$ $\qquad T_r = T/T_c$

$P_c = y_A P_{cA} + y_B P_{cB}$ $\qquad P_r = P/P_c$

$\hat{V} = \frac{Z_m RT}{P}$

* Batch process V is constant

* Complete reaction is one where all of at least one of avaliable reactants is used up to converted into products (when it reached equilbrium) reversiable (irrevesiable)

* fractional convarsion normaly for L.R except if he says some thing else.

* hydrogeneton is reversable

* combustion : complete يتفاعل 100% خلص او incomplete ما حرق

* @ STP $\dot{n}$ طريقة أخرى للتعبير عن

* $\underline{\dot{V}}$ Volumetric flow rate $\underline{\hat{V}} = \frac{\underline{\dot{V}}}{\dot{n}}$ منها نقدر اطلع عدد المولات

* Vr مستخدم (Z) وبدنا نطلع قيمة $\underline{T}$ عايكون معطينا

$$Vr = \frac{P_c \hat{V}}{R T_c}$$

Chapter "6" :- MULTIPHASE SYSTEM

Phase change operations :-

* freezing * melting * evaporation * condensation

Separation & purification prosses :-

* leaching * absorbtion * Distillation

* adsorbtion * crystallization * liquid extraction.

difference between evaporation & boiling

evaporation (surface) → $p^* < p$ ⇝ Total pressure

boiling (entire liquid) → $p^* = p$

difference between saturation & humidity

saturation gas - vaper

humidity air - water

* vapor prussure → liquid - Gas equilibrum carve
* number of mols cond = number of mol in gas if it completly cond

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* Humidity :- water vapor thats in the air
* relative humidity = $\frac{p_{H_2O}}{p^*(H_2O)}$ * 100%. (dependent on T)

p_{H_2O} → gives an idea of the amount of H_2O in the air

$p^*_{H_2O}$ → maximum amount of water that can be in the air at a given (T)

* absolute humidity = $\frac{\text{mass of } H_2O \text{ in the air}}{\text{mass of dry air}}$
* molal humidity = $\frac{\text{mol of } H_2O \text{ in air}}{\text{mol of dry air}}$

Single Component phase equilibrum

* Volatility :-
species tends to transfer from liquid or (solid) to vaper

Volatility ↑ → vaper
Volatility ↓ → condensed form (liquid or solid)

* Vapor prussure :- P^*
*measure it's volatility
* vapor liquid equilibrum curve
Vapor prussure ↑ volatility ↑

① P^*
Clausius - claperyon equat

$$\ln P^* = \frac{-\Delta H_v}{R(T)_{abs}} + B$$

(heat of vaporization)

$\ln P^*$ vs $\frac{1}{T}$

② Cox chart

③ Antoine equation

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

④ Interpolation (°C)

$$y = y_1 + \frac{x - x_1}{x_2 - x_1}(y_2 - y_1) \qquad \frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}$$

error ↑

GIBBS phase equilibrum

Dof multiple phase system

Intensive variables at equilibrium if there is no reaction

$$DF = 2 + (C) - (\pi)$$

C: number of Chemical species
π: phases in the system

equilibrium State :-

* Temperatures & pressures of both phases are the Same
* The composition of each phase no longer change

To describe the system :-
① Temperature & pressure
② masses of each phase
③ mass or mol fraction for each phase

Gas - Liquid system

One Condensable component (Sm, Sa, Sr Sp)

Saturated :
Solution holds all material that it can hold at the system Temperature & pressure.

$$p_i^*(T) = y_i P = p_i^\circ$$

Valid : ① saturated
② only one species that can condensate (condensable)

*gas in equilibrium liquid is saturated with volatile component
* partial pressure of vaper at equilibrum can't exceed the vaper pressure of pure component
* Super heated $p_i = y_i P < p_i^*$
* dew point :- $P_i = y_i P = p_i^*$
The temperature at which the vaper becomes saturated
* degrees of superheat
difference between the system Tem & dew point of gas

MULTIComponent Gas-Liquid Systems

*composition of components in 2 phases are not indepen

IDEAL Solutions

Raoults low

gas liquid
$y_i P = x_i P^*$

* x_i nearly 1
* mixture of similar subs

Henry's low

gas liquid
$y_i P = x_i H_i(T)$

* x_i nearly 0.
* non condensable gases

Bubble point tempreture

liquid heated slowly at const P → first vaper bubble form

$P = (x_A) P^*(T_P) + (x_B) P^*(T_P)$

gas $(y_i) = P_i / P_{bp}$

dew point tempreture

gas cooled → first liquid droplet

$$P_{dp} = \frac{1}{\frac{y_1 P}{P_1^*} + \frac{y_2 P}{P_2^*}} \qquad 1 = \frac{x_{1dp}}{\frac{y_1 P}{P_1^*}} + \frac{x_{2dp}}{\frac{y_2 P}{P_2^*}}$$

$$x_i^\circ = \frac{P_i / P_{dp}}{}$$