Water Cooling Tower (Humidification Operation)

Exp (3) — Reem

* To study the mass transfer. → study outlet Temp(s), HTU, NTU
* ≈ = ≈ effect of air flowrate on the mass transfer coeff.

(filled with film packing)

- Air flowrate can be measured by a orifice meter
- Water flowrate is measured by a flowmeter.

- Water flowrate is constant (180 L.H^{-1}) while the inlet air flowrate was change in each run (only var.)

↑ Humidity of air, ↑ Inlet air flowrate, Outlet enthapy of air ↓

↑ Inlet air flowrate, ↑ Mass transfer coeff. ($K_{y.a}$), ↑ N_{OG}, H_{OG} ↓ (Humidity of Air ↑)

→ Cooling Tower is packed with corrugated sheet to increase the surface area of contact between air & water & increase turbulance flow, as a result that's improves the mass & heat transfer operation

Dry Bulb Temp > Wet Bulb Temp

* Outlet dry & wet bulb Temps. were higher inlet's values. (Since air is humidified by water)

* St.st sys. Before Collecting Data.

The main disadvantages of cooling towers is their nee for careful maintenance to minimize the risk of wate fouling & water organisms.

if Outlet water Temp ↓ & HTU & NTU ↑

Cooling Tower Types: Forced (or blower for air), Natural

Means that air flows depending on density difference.

* Air flowrates was controlled by two opens
  - One in the fan that increase air flowrate by opening it.
  - One on the tube which decrease air flowrate by ~~opening~~ opening it.

* Our cooling Tower allows for complete control of the speed of the fan used in cooling the warm water by moving the air & use pump to return the cooled water to the water heater again.

All inlet temp(s) were almost const

- Outlet water temp (lower) < inlet values.

* when Inlet air flowrate ↑, The outlet enthalpy of air was decreased ↓

The humidity of air was increased because of increasing the inlet air flowrate.

* The tube that used to transfer air from outside to the tower is inverted, since it makes the flow turbulence & According to the pressure difference in manometer, air flowrate is recorded.

Equilibrium line & operating line ⟹ using the equation that relates to the inlet & outlet enthalpy of the air.

Exp. data

No. of transfer units is calculated

* By using the height of the tower, the height of each transfer unit was calculated

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* When the inlet air flow rate was increased
  - ✓ humidity of air was inc. ↑
  - ✓ Enthalpy of air was dec. ↓
  - ✓ The mass transfer coeff. ($K_y a$) was inc. ↑

  H_{OG} ↓

  N_{OG} ↑

sys. Running at stst

Before collecting data

if it wasnot ! stst

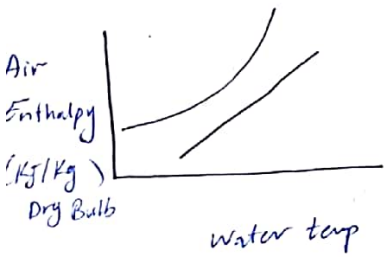
⇐

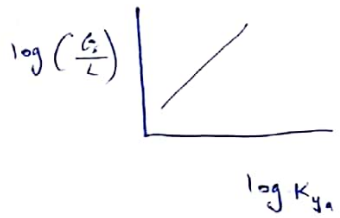
The different measurements that are being made are continually changing & to besure that the sys. was perfectly insulated with no energy losses & Thermometers were accurate to an infinite amount of sig. fig.

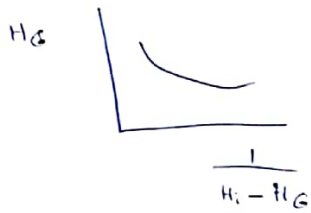
⇒ Then the two numbers would be the same

Errors

- Instrumental
- Personal
- Manometer







(area under curve)

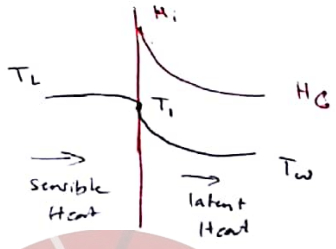
$$N_t = \int_{H_1}^{H_2} \frac{dH}{H^* - H}$$

H^* ↓ from equilib.

H ↓ operating line

$$H_1 : C_s (T_G - 0) + H_i \lambda_{T=0}$$

$$H_2 \quad \frac{L}{G}(43.3 - 29.4) + H_1$$



* transfer units ↑, Air flowrate ↑, height ↓

* packing ⇒ To inc. surface Area turbulent flow better mass & heat operations

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at exit $T_{dry} < T_w$ ⇒ Not sure !!

$$T_{(dry + wet)\,exit} > T_{(dry + wet)\,inlet}$$

* **Liquid Liquid Extraction (LLE)** → counter current

Exp (4) → (Separation mix. using two immiscible solvent)

lab(3)

(obj) → Examine the mass transfer coeff's dependence on Liquid Flowrate for counter liq-liq Extraction in a packed column by extracting benzoic acid from toluene using (water) solvent

→ imp. unit operation that allows one to separate fluids based on different Solutes being soluble to different degrees in different Solvent.

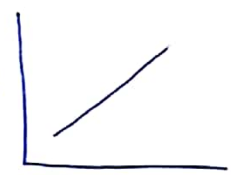
* بستخدم ال (LLE) لما ال distallation بيكون صعب أو غير فعّال

* بستخدمه لما B.P قريبة من بعض أو process under vacuum

بداي التجربة

• Benzoic Acid is extracted by contact with water (continous phase) from a feed stream containing unknown conc. of benzoic acid in toulene (disperesed phase), considering water (inorganic material) & toluene (organic material) to be insoluble in one another

* ↑ $\dot{V}$ (volumetric flowrate) → K_a ↑ (mass transfer coeff.)



* ↑ $\dot{V}$ leads to ⇒ ↓ Resistance of film in the continous phase as well as reduce benzoic acid conc. in water & toluene.

* Titration ⇝ Sodium hydroxide sol. (NaOH) & ethanolic Sodium hydroxide

or due to taking samples of water & toluene before acheiving the st st.

⇒ In LLE the solvent must nearly always be removed from extractor Raffinate or Both

↑ water flowrate, Mass transfer coeff ↑ of Benzoic & Benzoic Acid conc. in Raffinate ↓ which the solute is removed from

Flooding
طوفان _ فيضان

* The component (Benzoic acid) is dissolved in a suitable solvent (toluene) and second solvent that is immiscible with the first solvent is added (water).

(Ethanol added) ← • Raffinate ⇒ Ethanolic NaOH

• product ⇒ NaOH solution, by an indicator

Exp (4)

$V = \pi/4 \; D^2 \; h$ // $C_{sample} \cdot V_{sample} = C_{Titrant} \cdot V_{Titrant}$

$A = \pi r^2$

$C_{W(in)} = 0$ pure water

$C_W = \frac{C_{NaOH} \cdot V_{NaOH}}{V_{W(out)}}$

$C_{T(in)} = \frac{C_{sph} \cdot V_{sph}}{V_{T(in)}}$

sph = conc. of ethanolic NaOH

$C_{T(out)} = \frac{C_{sp} \cdot V_{sp}}{V_{T(out)}}$

$C_W^*(T_{in})$, $C_W^*(T_{out})$ ⟹ from equilb. curve

$K_E = \frac{L_E (C_{E_2} - C_{E_1})}{\Delta C_{E_{lm}}} * A * h$ (V)

mass transf. coeff

$\Delta C_2 = C_{W_2} - C_{E_2}$

⇒ Ethanol is added as a solvent to ensure that all benzoic acid will be titrated & it doesn't affect the titration.

⇒ Benzoic acid is transferred from Tol. → water
So, it's required to calc. mass transfer coeff. by determining the value of benzoic acid transferred.

→ packed column

LLE is a method used for the separation of a mixture using two immiscible solvents.

K_a

Results

↑ water flowrate , ↑ Mass transfer coeff → Benzoic acid conc. in product & ↑ NaOH ↑ is need as titrant

↑ NaOH titrat

water flowrate ↑

Benzoic Acid in Raffinate ↓

NaOH ↓ need as titrant.

Solvent

- يذوب بسرعة
- لا تتفاعل مع المادة
- رخيص
- high B.P

higher flowrate ↑ , higher Re ↑ , better turbulance , mix.

Water flowrate * $[(C_{W_2} - C_{W_1}) / \Delta C_E / Area / Height]$

C_{W_2}: Benzoic Acid conc. outlet; C_{W_1}: inlet.; ΔC_E: equilb. conc of Toluene

higher flowrate ↑ , conc. of Benzoic Acid ↓ Because higher water flowrate

(LLE) ①

* Feed : Toluene , Benzoic Acid
* Extract water , Benzoic Acid (Bottom of column) → Aqueous
* Raffinate Toluene , Remaining Benzoic Acid (Top of column) → organic layer
  (ethanolic NaOH)

* To determine composition of Benzoic Acid in each layer

* Feed, Raffinat (organic phase) titrate with ethanolic (0.24) Sodium hydroxide in addition of pure methanol.
  - To ensure the solution won't thicken (Become Jelly)

indicator ph-ph ⇒ colorless → pink

⇒ Extract (Aqueous phase) titrate with Sodium hydroxide ph-ph (0.5 M)
colorless ⇒ pink

Pumps used → ① water (centrifugal)
→ ② feed (piston)

→ Interface between organic & Aqueous phase should be on the top of the column to ensure maximum surface area, We can control the interface by using Solenoid valve. ⇒ normally closed & used for → control interface / To take sample

→ Keep the interface (phase) constant to achieve steady state conditions.

Calculations

$$C_{\text{Benzoic Acid (feed)}} = \frac{C_{\text{E NaOH}} * V_{\text{E NaOH}}}{V_{\text{feed}}}$$ moles/L

$$C_{\text{Benz. acid (ext)}} = \frac{C_{\text{E NaOH}} * V_{\text{NaOH}}}{V_{\text{ext.}}}$$

$$C_{\text{Benz. acid (Raffinate)}} = \frac{C_{\text{E NaOH}} * V_{\text{E NaOH}}}{V_{\text{Raffinate}}}$$

$C_{eq.}$ From the chart in [1 lbmol / ft³]

* you have to convert the above concentrations ⇒

نتائج calc. (4)

Cequ ① = (x : feed) , (y : inlet water)
↳ = zero (No Benzoic Acid at the beginning)

$\Delta C_{equ\,1} = C_{equ\,1} - C_{H_2O,\,in}$ (→ 0)

Cequ ② = (x : Raffinate / organic) (y : Extract / Aqueous)

$\Delta C_{eq\,2} = C_{eq\,2} - C_{in}$

$C_{eq\,2}$ → aqueous phase

C_{in} → Extract

$$\Delta C_{lm} = \frac{\Delta C_{eq\,1} - \Delta C_{eq\,2}}{\ln \dfrac{\Delta C_{eq,1}}{\Delta C_{eq\,2}}}$$

$$K = \frac{\Phi * (C_{BA}(\text{extract}) - C_{H_2O,\,in})}{V * \Delta C_{lm}}$$

Φ : volumetric flowrate of water

$C_{H_2O,\,in}$ → zero

V → eff. the column.

$$H = \frac{\Phi / A}{K} \quad (m)$$

* if the interface isn't occured at the top, there's a possibility for flooding to happen, & if the interface backs to the column, less efficient mass transfer will produce.

*Exp (5) **Determination of diffusion coeff.** (app. of mass transfer) Reem.

↳ To determine the diffusion coeff. of acetone vap. into air &
To 〃 the convective mass transfer coeff (K)

measured using vernier caliber. ⇙ نقيس بيه Diffusion path

* Diffusivity (Diffusion) depends upon the T, P_T, and nature of the components of the sys, surface area of mass transfer (Diffusion), velocity of non diffusing comp

↑ Time passes, ↓ Diffusion / ↑ path of diffusion, ↑ Diffusion

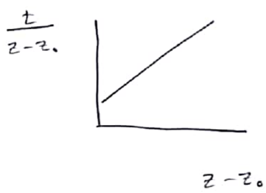
$$\text{Rate of transfer Process} = \frac{\text{Driving force}}{\text{Resistance}}$$

⇨ As the time passes the driving force decreases due to decrease of acetone conc. in the tube.

⇨ As the time passes the diffusion path length increases due to acetone evaporation & the diffusivity will decrease as result.

* D_{AB} is almost independent of composition.

high conc ⇒ low
capillary Tube



* Diffusion of Acetone is very fast which is a volatile Liq into another gas (Air)

* The partial pressure of Acetone at the diffusion surface is zero, due to the large volume of air passing by

$$P_{BM} = \frac{P_{B_2} - P_{B_1}}{\ln\left(\frac{P_{B_2}}{P_{B_1}}\right)}$$ (→ air)

$$D_{AB} = \left(\frac{\rho_A * C_{BLM}}{2 * Mw_A * C_A * C_t * (\text{slope})}\right) \rightarrow \left(\frac{t_F}{z_F - z_0}\right)$$ (time, length)

$$K_c = \left(\frac{D_{AB}\, P_T\, (P_{A_1} - P_{A_2})}{R\,T\, P_{BLM}\, (C_{A_1} - C_{A_2})\, (z - z_0)}\right)$$

↙ (m/s) وحدتها

Acetone

C_3H_6O → moderate volatility

Time ↑, Height ↑, Length of diffusion path ↑

Stagnant (Non diffusing Air) at st st — * بالعربي يعني Diff.

$$C_A = \left(\frac{P_A^*}{P_{tot}}\right) * C_t$$

↙ $Kmol/m^3$

$P.V = n.R.T$

⇨ Acetone vap. diffuses to air So, the heat necessary for evaporation is taken from sys. So it's temp decreases

Exp (7) (Adsorption of dye solutions by activated Carbon)

Recent solid (adsorbent)

Obj

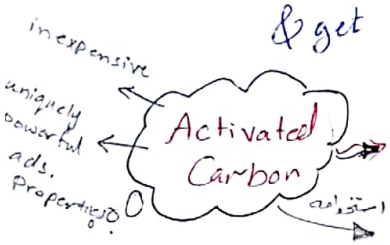
① To produce conc. – Time curve for the adsorption of dye solution by activated carbon. (Batch slurry ads.)

② To investigate the effect of initial dye conc. & speed of agitation on the conc. – Time curves.

③ To construct the equilibrium isotherm for the adsorption of solute on adsorbent. By using 30mL of 25 ppm initial conc. & leave it for a long time.

(si) activated carbon dye (I dye)

Ads. involves contacting a fluid (liq or gas) with a solid (adsorbent) ,, Then component in the fluid is attached to the surface of the solid & get separated from the fluid.



* Some features are imp. for selection of adsorbent:-
  - porosity & large surface Area that results in high capacity.
  - Selectivity.
  - low Solubility in the carrier solvent.
  - low cost.

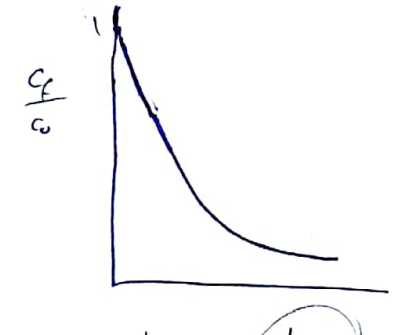
Procedures → isotherm, Kinetics

Equilib. isotherm

Represents the change of mass transferred with equilb conc. until it becomes const. due to saturation of the active site which don't further ads. to take place

At Kinetic of Ads.

The percentage of color removed increase with increasing adsorbent dosage, increase with contact time



* Conc. ↓ until it reaches around zero dye.

* Since Speed of agitation is (const.) ,, the only effected factor on adsorption is the mass of adsorbent.

mass of adsorbent ↑ , time need for ads. ↓ until it backs to clear solution

Freunlich ads

$$\frac{X}{m} = K \cdot P^{\frac{1}{n}}$$

(n = slope) ,, ($K = 10^{\text{intercept}}$) empirical const.

X = adsorbed quantity
m = mass of adsorbent
P = pressure = adsorbate

→ An accumulating time is determined to take sample during agitation in order to measure the transmittance using visible spectrophotometry which uses light in the visible & adjacent (Near UV & near infrared NIR) ranges

The Abs. or Reflectance in the visible range directly affects the perceived color of chemicals involved.

⇒ Transmittance is converted into conc. by a chart. (Transmittance value)

conc. ... curve ... % transmittance

Samples that are taken from the beakers are poured again into the beaker in order to keep the vol. const.

Calculation

Calibration curve

$M_1 * V_1 = M_2 * V_2$ (M_2 ?)

$\log x(C_0 - C^*)$ vs $\log C^*$

- Freundlich Isotherm

$W = K \cdot C^n$

$\log(q) = \log K + n \log(C)$

C^* ←

$\log C^*$

optimum agitation speed

No further increase in the adsorption capacity

Efficiency ↓,

↑ The initial conc. at the dye

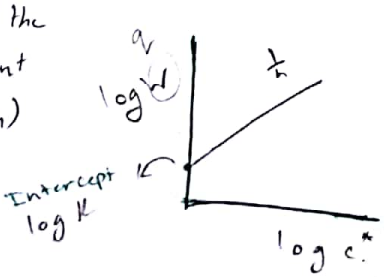
$V = \frac{\text{vol. of sol.}}{\text{Mass of Activated Carbon}}$

Agitation speed ↑, time ↓

agitated speed due turbulent mixing that decrease the boundary layer thickness around the adsorbent (Carbon)

$W = V(C_0 - C^*)$ ⇒ log ؟

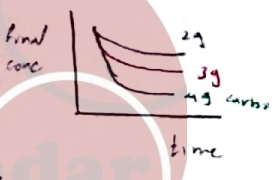
C_0 initial, C^* final equilib



plot $\log V(C_0 - C^*)$ vs $\log C^*$

Slope = $\frac{1}{n}$ =

Intercept = $\log K$ ⇒ K = ؟



* Adsorbent ⇝ activated Carbon
* Adsorbate ⇝ dye

* Mass adsorbent ↑, final conc ↓ at const initial conc. of dye solution

Gas Absorption

EXP ①

(counter current) ,, continous operation

lab ③ | Reem

* obj.

to study the hydrodynamics characteristics of packed column & establish a mass balance on the absorbed gas in the column. Moreover, to determine NTU, HTU and $K_{G.a}$

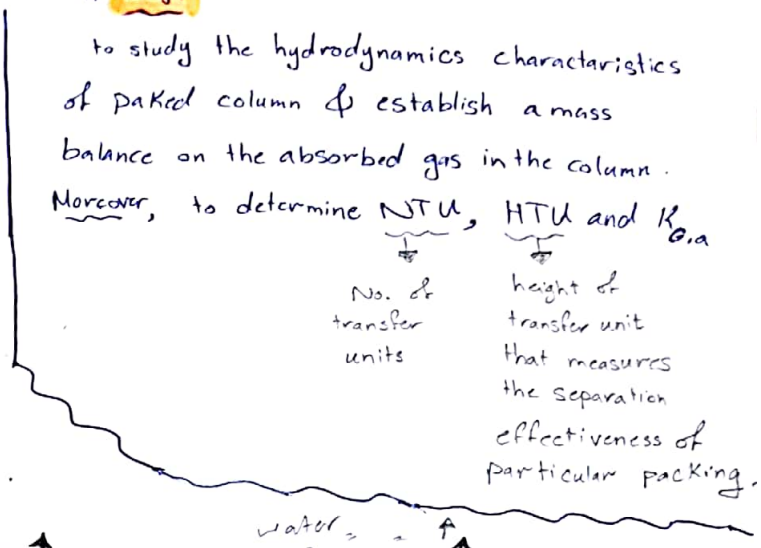
NTU: No. of transfer units

HTU: height of transfer unit that measures the separation effectiveness of particular packing.

Air Flowrate (L/min)	ΔP (mmH₂O)

* pressur drop => (mm Hg) @ low flow rates.

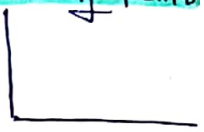
& measured in Hg @ high values of flowrates.



For dry packing the pressure drop ΔP ↑ as the air flow rate ↑ due to friction by high flowrates if air & the packing material.

ΔP in wet column > ΔP in dry column, since the pressure of water around the packing reduces the spaces around the packing that increased the resistance.

* The relationship between log ΔP & log ΔG is linear until we reach the flooding point at which the liquid starts to increase for wet column.



* Loading point: is the point where liquid starts to accumulate in column. (depends on the condition of the bed)
  - → velocity of gas is high enough to ...
  - → if gas flowrate remain constant => The ΔP will ↑ with an increase the liq. flowrate.

* The ΔP ↑ until the curve becomes vertical and this occurs when it reaches the flooding point as air flowrate increases ↑

* flowrate of water ↑ ,, the flooding point occurs at lower air flowrate ,, since water fills the voids with water faster than before.

* Mass transfer coeff. in the gas film > Mass - liq film ,, So it's the dominant one, Sice the viscosity of the liquid is higher & as aresult the resistance is greater that allow CO_2 to transfer from one phase to another.

↑ gas flow velocity ,, ΔP ↑

* Design Variables (must be considered)

① Air flow rate is from bottom ,, water flowrate is from top according to their densities that allow its free movement.

② Rashing rings are used as packing material in order to increase contact surface between air & water & provide a turbulance flow.

* Several Advs ... ① Economic ,, ② chemically inert ,, ③ Strong enough to ...

ans:

① A screen is used at the top of column in order to spread water equally on the packing material.

* St. st. time ≈ 254 min ,, then a sample of outlet water is taken to measure the conc. of CO_2 inside.

* Sample is quenched (Rapid Reaction) is excess HCL solution 0.2 M then the excess HCL that doesn't react is titrated with NaOH solution 0.2 M in the presence of indicator (Bromocresol green idicator).

* By increasing water flowrate ,, it's supposed to decrease amount of NaOH needed as titrant since most CO_2 reacted with HCL but this wasn't clearly happened in our experiement.

* Packing Material ⇒ is used to increase the efficiency of contact between two phases.

Solvent

- good absorber

→ selective: Absorbs the required solute & not any thing else.

→ Reasonable Cost:- Cheap & economic.

→ viscosity ★

→ Non toxic & chemically stable.

→ volatility ⇒ low v.p above the soln.

* In titration we indicate the neutral point when the solution change its color from Yellow (Acidic Medium) to pale pink (Basic Medium)

* Calculation

$\dot{V} = 30$,, $v_s = 22.4$,, $T_s = 273$

$z = 2$

- Dry column :-

$\Delta P = $ ← mm H_2O

$z = $ ←

$\frac{\Delta P}{z} =$ calculated

$\log(\Delta P/z)$

Assume Air Ideal gas behavior.

$A = \frac{\pi}{4} D^2$

$G_a = \text{Mwt} * \frac{P}{P_s} * \frac{\dot{V}}{v_s} * \frac{T_s}{T} * \frac{1}{A}$

$\log G_a$

- Wet column :-

$\Delta P = $ —

$\frac{\Delta P}{z} =$

$\log(\frac{\Delta P}{z})$

$G_a = $ - -

$\log G_a$

Gas velocity < Flooding point

in order to guarantee good operation for the absorber ,, otherwise will fill in the pores between packing & air will not be allowed to flow.

$\frac{\Delta P}{z}$ vs

$kg/m^2.min$

* Chemical part (Absorption part)

- Calculation of conc. of NH_3 in the outlet water:

M: mol/L
V: mL $\xrightarrow{*10^{-3}}$ L

$$(M*V)_{CO_2} + (M*V)_{NaOH} = (M*V)_{HCl}$$

? ; CO_2 ; 0.1 ; NaOH ; Avg. vol. used in titration = 9.7 ; 0.2 ; HCl ; 20 mL

M_{CO_2} = ... mol/L

Λ_w (given) from perry's Book

$$X_2 = M_{CO_2} \text{ (molarity / solution)} * 1000\ L/m^3 * \frac{m^3\ H_2O}{999.5\ Kg\ H_2O} * \frac{18\ Kg\ H_2O}{10^3\ mol} = \text{- -}\ \frac{mol\ CO_2}{mol\ H_2O}$$

$$x_2 = \frac{X_2 / Mwt_2}{(X_2/Mwt_2) + (1/Mwt_1)} \quad (Mwt_1 \to 18.02)$$

" Water is fresh $\therefore X_1 = 0$

$x_1 = 0$

G_a = molar flowrate / cross sectional Area mol/m².s

L_w = water vol. flowrate * ρ of water / Area

ρ of water → 999.5 Kg H_2O / m^3 H_2O

Area → $4.418 * 10^{-3}$ m^2

Y_2 = volumetric flow rate of ~~NH_3~~ CO_2 / vol. flowrate of Air

mole fraction of CO_2 = 150 / tot. mol

air = 150

$$Y_2 = \frac{\text{mole frac. of } CO_2}{\text{mole fraction of Air}}$$

$$y_2 = \frac{Y_2 / Mwt_2}{Y_2/Mwt_2 + (1/29)}$$

Mwt of water = 18.02

Mwt of Air = 29

$G_2 = G_a(1 + Y_2)$

$L_{w_1} = L_w(1 + X_1)$

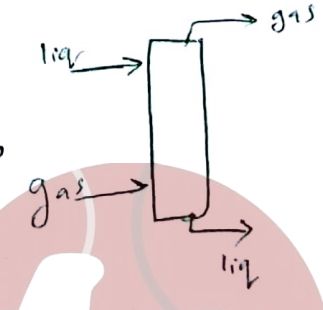
$L_{w_2} = L_w(1 + X_2)$

↑ liq. flowrate

↑ Resist for gas to overcome high pressure drop

water ↑

high height of the bed ↓



NaOH + HCl used for Titration

Material Balance

$$L_w(X_2 - X_1) = G_a(Y_2 - Y_1) \Rightarrow y_1 = \frac{Y_1/Mwt}{Y_1/Mwt + (1/29)}$$

? ← Y_1

$y_1' = 0$,, $y_2' = --$

$$NTU = \frac{y_2 - y_1'^{\to 0}}{(y - y')_{ln}}$$

$$y_1 = \frac{Y_1}{1 + Y_1}$$

$$(y - y')_{ln} = \frac{(y_1 - y_1') - (y_2 - y_2')}{\ln\left(\frac{y_1 - y_1'}{y_2 - y_2'}\right)}$$

$P = y' + P_{sat}$

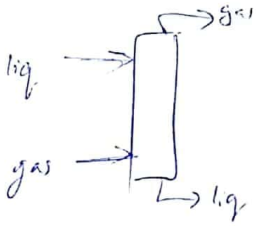
Exp ①

+ حل طويل . — — (ملف pdf على ccc يتعلم به)

Absorption of air into water

Abs. تعريف ⇐

* Mass transfer ~~coeff.~~ process in which a vap. solute in agas mixture is dissolved into a liquid phase which the solute is more or less



Air flowrate ↑ , ΔP ↑

Higher water flowrate ↑ , overall mass transfer ↑ , amount of ~~A~~ CO_2 ↑ , conc. ↓ (Because H_2O is increased) .

high recovery or content of NH_3 ← هدف *

HTU ↓ , efficient containing ↑ bi-

z = HTU * NTU

Loading point   بصير تكوم لل liq

بسبب سرعة الغاز الاضافية

↳ After this point the pressure drops at a much faster rate till another point known as the flooding point

↓ when all liq. is carried away by a the gas.

$$G_a = \frac{flow * \rho}{A}$$

$$\log \frac{\Delta P}{Z}$$

Z ← length at column = 2 cm

Dry → wet → water flowrate   2 ml/min → 3 ml/min → 4

Inc. ΔP at const. Airflowrate

Exp (6) **Wetted Wall column** → (app. of humidification)

- was applied to measure the Sherwood No. for mass transfer from the wall into turbulent air flow.

* Temp. of outlet water is < less than inlet temp (why → Because part of water has been evaporated and transfer to air)

wet Bulb temp < dry bulb Temp.

because when the air comes in contact with the wet cloth it absorbs some moisture & give up some heat So temp. of air reduces

- Humidity Value of outlet air > inlet air
- humidity value was decreased by increasing air flowrate (Eq 16)
- Reynolds No. is inc ↑ , By ↑ air flowrate (it depends on the type of Rate of flow)
- Sherwood No ↑ , Re ↑ (Re ∝ Sh)

Sh vs Re | Re vs Air flowrate | Kg vs Air flowrate

Schmidt No. can be determined using diff. analogies
- Van Karman
- Chilton Colburn
- Gilliland correlation.

Schimidt ↑ , Mass Transfer between Air & water ↑ , Air flowrate ↑

$$\frac{N_A}{\theta} = K_g \cdot A \cdot \Delta P_{lm}$$ (K_g: mass transfer coeff.)

$$Sh = a \cdot Re^{a} \cdot Sc^{0.6}$$

* Air & Liq Rates ⇒ are measured by flow meter
" " Temp. ⇒ " Thermometer

* The evap Rate may be measured by observing the rate of change of Liq level in the liq reservoir

Air flowrate ⇒ Variable *
water flowrate ⇒ const.

طريقة العمل → film of Liq cascades down the inside surface of tube by gravity while air is blown counter currently up the column, contact between water & Air happens along the column.

$Re = \frac{\text{inertial force}}{\text{viscous force}}$

Heat transfer wasn't sig. ← ai's inlet Air & water temp. was closed together ∴ Temp. gradient was v. small

Mass transfered ← according to conc. gradient

Exp (8) Soxhlet Extraction

→ effect of residence time
→ Leaching & solvent type
[Solid Liq Extraction]
oil extracted from solid (Bio mat.)

Recov

to calc. efficiency

in expensive & simple method

* ⇒ Solvent extract olive oil by extraction using organic solvent & the oil is separated later from the solvent by distillation

N-Hexane ⇒ Best extracting solvent ⇝ (High extraction Capacity), low B.P, high stability
low greasy residual effects
low corrosive
% 10.6 yeild

imp * [Parts of Soxhlet Extraction]

- Helix Type condenser is used to cool down the solvent vap. to back as a liq., helix shape is used to increase surface area of contact that increase heat transfer also amount of return solvent liq.
- porous container (Thimbe) is made from thick filler paper which allows the solvent vap. to extract the olive oil from olive cake.
- Soxhlet chamber where the condensate solvent is filled until it is emptied by siphon arm, These steps is considered as a one cycle.

No. of cycles ↑, Weight of solids & thimble after Exraction ↓, increasing in extracted oil & percentage (yeild) & in efficiency

Then Remain const. (Reach max.)

⇒ Optimum oil percentage can be ~~determined~~ obtained at the max. oil percentage (yeild)

$$\text{Extraction efficiency} = \frac{\text{Experiemental oil \%}}{\text{Theoritical \%}} * 100$$

- oil % percentage is the ratio between the weight of oil extracted to the weight of olive cake & thimble before extraction

Tap water is used as cooling water in condenser.

⇝ The extraction of oil depends on :
1. Moisture content.
2. Nature of solvent.
3. Time of extraction
4. Particle size of Solute.
5. Amount of Solvent

(↑ time, yeild ↑) طردي
(↓ size, oil yeild ↑) عكسي

طريقة التجربة ⇒ olive cakes samples ⇝ were dried in oven before being used in exp.

10 g of oil cake

100 mL n-Hexane

heated to b.p

& to enhance vaporization of Solvent

* Study effect of extraction time on the amount of extracted olive oil from olive cake (3, 6, 9, (12)) cycle
optm

Optm. No. of cycle ⇒ is No. of cycle it reaches max Yeild

optm. No. of cycle ⇒ The No. of cycles it reach max. yeild of oil extracted from the cake

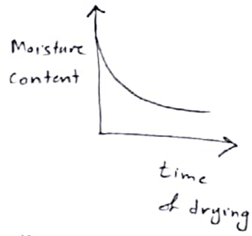
* Exp (9) Tray Dryer → Determine diffusion coeff. of Acetone into air

simple economic

→ Effect of air velocity on drying Rate & Perform heat & mass transfer anlysis of a ~~process~~ drying process.

- Removal of water or moisture (Drying تجفيف)

* Tray dryer is used for drying solids by air or removes the moist vapor which must be supported by trays. Trays are designed to force air to follow a longer zigzag route, which increases the ↑ contact time between solids & air, thus improve efficiency ↑



$$\text{Moisture of Content} = \frac{\text{mass of liq}}{\text{mass of dry solid}}$$

$$\text{Drying Rate} = \frac{dx}{dt} \cdot \frac{m_s}{A}$$

slope

$$\text{Heat transfer coeff. } h = \frac{R_e \cdot \lambda}{(T_{dry} - T_{wet}) \cdot A}$$

(R_e → Drying Rate)

$$\text{mass transfer coeff } h_d = \frac{R_e}{(H_{outlet} - H_{inlet}) \cdot A \cdot \rho_{air}}$$

(R_e → Drying Rate)

* Drawback of Tray dryer عيوب
  - Non uniformity in the desired moisture content of end product due to poor air flow distribution in the drying chamber.

طريقة التجربة
- Sand was placed in a tray with addition of water & was allowed to face an air duct by a motor

* Temp of air ↓, Humadity ↑, ↓ Moisture content

Tray dryer → اختيار رطوبته في نوع الـ solid المراد تجفيفه
↓ ثابت
→ can't be agitated

* Moisture Content ↓, Drying time ↑ until all free moisture removed (equilb. moisture content The minimum moisture content we can reach)

direct dryer (why?) ⇒ Because it's a direct contact between the hot air & the wet solid

* Water is ~~dry~~ dried from the outlet surface to inner surface So as time passes, drying rate decreases. ↓

* if solid porous ⇒ Impossible to remove all the moisture.

if unporous → possible to remove all moisture

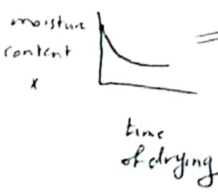
* Digital Anemometer for measurement of air velocity.

* Wet & dry bulb Temp. & mass of the air are measured using a aspirated psychrometer

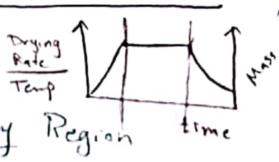
* Removing humidity of air → dehumidification

But * Removing Moisture of solid → Drying

71 min



⇒ 3 Regions



Drying Rate depends on ① Surface Area, ② Air speed, ③ Temp of air, ④ humadity of air

① Unsteady Region (Initial)

② Constant Rate Period → when the unbounded moisture (water on the surface) is removed while drying

③ Falling Rate period → when the bound moisture (water between sand particles) is removed while drying.

After all water on the surface vaporizes → Drying Rate falls down → Because surface Area dec.