Department of Chemical Engineering, Veer Surendra Sai University of Technology Burla

MASS TRANSFER
(Lab Manual)

List of Experiments:-

1. To determine the Liquid phase mass transfer mass transfer coefficient in a wetted wall column

2. (a) To determine the diffusion coefficient of an organic vapour i.e. CCl_4 in Air

    (b) To study the effect of temperature on the diffusion co-efficient

3. To determine the mass transfer coefficient in Humidification and Dehumidification

4. To determine the Vapour-Liquid Equilibrium (VLE) curve for theCCl_4toluene mixture(Computerized)

5. To determine the Vapour-Liquid Equilibrium (VLE) curve for the CCl_4 toluene mixture

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Experiment 1

AIM OF THE EXPERIMENT

To determine the Liquid phase mass transfer mass transfer coefficient in a wetted wall column

INTRODUCTION

A wetted wall column is essentially a vertical tube with means of admitting liquid at the top and causing it to flow downwards along the inside wall of the tube, under the influence of gravity and means of admitting gas to the inside of the tube, where it flows through the tower in contact with the liquid. In absence of ripple formation at the liquid surface, the interfacial area, A,is known and form drag is absent.

THEORY

The mass transfer coefficient, Ka, can be measured in a wetted wall column in which the area of contact between two phases is known and boundary layer separation does not take place. A wetted wall column also provides useful information on mass transfer to and from fluids in turbulent flow.

Various dimensionless groups that control the phenomenon are:

Reynolds number, N_{Re} $\qquad = \dfrac{d\,G}{\mu}$

Schmidt Number, N_{Sc} $\qquad = \mu/\rho\,D$

Sherwood Number $\qquad = Kd/D$

$\qquad$ G $\quad = \quad$ Gas mass velocity, $kg/m^2\ s$

$\qquad$ D $\quad = \quad$ diffusivity Coeff., m^2/s

$\qquad$ d $\quad = \quad$ tube diameter, m

$\qquad$ Ka $\quad = \quad$ Mass transfer coeff.

For turbulent flow mass transfer to pipe wall-involving evaporation of liquids in wetted wall towers, Gillard and Sherwood proposed the correlation:

$$K_G = \left(\frac{D\pi}{Pd}\right)(0.023)\left(\frac{dV\rho}{\mu}\right)^{0.81}\left(\frac{\mu}{\rho d}\right)^{0.44}$$

For $\quad$ N_{Re} $\quad\Rightarrow\quad$ 2000 - 3500

N_{SC} $\quad\Rightarrow\quad$ 0.6 - 2.5

P $\quad\Rightarrow\quad$ 0.1 to 3 atm

The known flow rate of air at a measured humidity is brought into contact with a film of water at a certain temperature and vapor pressure. Moisture is absorbed by the air from water film and the resultant humidity of the exit air and the temperature and vapor pressure of the entry water measured.

DESCRIPTION

In this system the air is firstly heated by passing through a heated chamber and then directed to the column from bottom. Water pumped in from the top and flows down in the form of a thin film. The moisture is absorbed from the wetted wall as the air travels up through the column and then discharged to the atmosphere. Water is recycled in the sump tank through the pump. The temperature of the air dry bulb and wet bulb are measured by RTD 100 are provided.

UTILITIESREQUIRED

1. Electrical supply: Single-phase, 220VAC, 50Hz, 0.5kWwith earth connection.
2. Water Supply
3. Drain required.
4. Compressed Air Supply at 2 Bar, 4CFM.

EXPERIMENTALPROCEDURE

1. Feed Water to the column from top at a rate at which complete wetting with minimum of ripple formation takes place.

2. Commence the operation with minimum airflow and after 15-20 minutes, the humidity of the inlet air and the outlet air at this flow rate of air is noted and read corresponding vapor partial pressure, from the psychometric chart. Simultaneously the temperatures of the water in and out are noted and flow rates Measured. From steam tables obtain Vapour pressure of water corresponding to these temperatures.

3. Repeat step 3 for 3-4 airflow rates.

4. Calculate experimental value of K_G by using humidity chart data.

5. Calculate predicted value of K_G using Sherwood-Gilliland correlation.

6. Compare the experimental and predicted Value of K_G.

OBSERVATION &CALCULATION

DATA:

Id = 48mm
Od = 55mm

L = 750mm

P = 1.025atm

W = ----------

ρ = ---------- kg/m^3

From Psychometric chart

a = -------------

b = ------------ (from data book)

From steam tables, corresponding to water inlet and outlet temperature, calculate the Vapour

pressure.

P_1 = ----------- bar

P_2 = ----------- bar

OBSERVATION TABLE

S.no	F, LPM	T_1, ºC	T_2ºC	BOTTOM SECTION		TOP SECTION	
				T_3ºC	T_4ºC	T_5ºC	T_6ºC
1							
2							
3							

CALCULATIONS:

ACTUAL VALUE OF K_G

$Y_1 =$ (a/18) /[(a/18)+(1/29)]

Y_2= (b/18) / [(b/18) +(1/29)]

$(P_{AV)} = \dfrac{P_1 + P_2}{2}$ = ——— bar

$y = \dfrac{(P)_{AV}}{P}$ ———= ----------------

$A = \pi d\,L$, cm^2= --------------------------------- cm^2

$M = F \times \rho$, kg/hr= ------------------------------------- kg/hr

$V = \dfrac{M}{W}$, g mole/hr = ------------- g mole/hr

$\dfrac{K_G P A}{V} = \dfrac{1}{1 - y_i} \ln\left[\left(\dfrac{y_i - y_2}{y_i - y_1} \right)\left(\dfrac{1 - y_1}{1 - y_2} \right) \right]$ = ------------------

K_G = -------------------- g mole/h cm^2 atm

THEORETICAL VALUE OF K_G

$K_G = \left(\dfrac{D\pi}{Pd} \right)(0.023)\left(\dfrac{dV\rho}{\mu} \right)^{0.81} \left(\dfrac{\mu}{\rho D} \right)^{0.44}$ = ----------------------- g mole/h cm^2 atm

Then Compare the actual & theoretical value of K_G

NOMENCLATURE

A	=	Area, cm^2
a, b	=	Inlet & Outlet humidity of air
D	=	Diffusivity coefficient
d	=	Column diameter, cm
F	=	Flow rate of air, m^3/h
K_G	=	Mass transfer coefficient, g mole/h cm^{2}atm
L	=	Column effective length, cm
M	=	Mass flow rate, kg/hr

P	=	Atmospheric pressure, atm
P_1, P_2	=	Vapor pressure of water at inlet outlet temperature, bar
$(P)_{AV}$	=	Average vapor pressure, bar
T_1	=	Water inlet temperature, °C
T_2	=	Water outlet temperature, °C
T_3	=	Dry bulb temperature of inlet air, °C
T_4	=	Wet bulb temperature of inlet air, °C
T_5	=	Dry bulb temperature of outlet air, °C
T_6	=	Wet bulb temperature of outlet air, °C
V	=	Mass velocity of air, g mole/hr
W	=	Molecular weight of air
y_1, y_2	=	Mole fraction of water
ρ	=	Density of air, kg/m^3
μ	=	Viscosity of air, kg/m h

PRECAUTIONS & MAINTENANCEINSTRUCTIONS:

1. For condenser the cold water supply should be constant.

2. Don't switch on the pump at low voltage.

3. Air should be moisture free.

4. Wet bulb temperature should be properly contacted with water.

TROUBLESHOOTING

1. If any type of suspended particles are come in the Rota meters. Remove the Rota meters, clean the tube and fit that at its place.

2. If there is any leakage tight that part or remove that and refix that again after wrapping Teflon tape.

3. If Rota meters fluctuating more than average tight control knob of that.

4. IfD.T.Idisplay'1'ondisplayboarditmeanssensorsconnectionarenotOKtight that.

5. If switch ON the heater but temperature can't rise but panel LED is ON it means bath heater had burned replace that.

REFERENCES

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Experiment 2

AIM OF THE EXPERIMENT

a) To determine the diffusion coefficient of an organic vapour i.e. CCl_4 in Air

b) To study the effect of temperature on the diffusion co-efficient

INTRODUCTION

If two gases are inter-diffusing with continual supply of fresh gas and removal of the products of diffusion, this diffusion reaches an equilibrium state with constant concentration gradients. This is known as steady state diffusion. If also there is no total flow in either direction the rates of diffusion of A & B, N_A and N_B are equal but of opposite sign.

According to Dalton's law the total concentration of the two components C_A and C_B is constant

$$\frac{dC_A}{dx} = -\frac{dC_B}{dx}$$

Then using the integrated form of the Fick Diffusion equation with appropriate constants

$$N_A = -D_{AB}\frac{dC_A}{dx}$$

$$N_B = -D_{BA}\frac{dC_B}{dx}$$

Where, $D_{AB} = D_{BA}$ = Diffusivity coefficient

Molar concentration of a perfect gas C_A is related to partial pressure P_A by the gas law:

$$C_A = P_A / RT$$

Then $N_A = \dfrac{D}{RT}\dfrac{dp_A}{dx}$

Integration of this equation yields:

$$N_A = D/RTx\,(P_{A1} - P_{A2}) = N_B\, D/RTx\,(P_{B2} - P_{B1})$$

Where P_{A1} & P_{A2} are the partial pressure of boundaries of the zone of diffusion and x is the distance over which diffusion occurs.

In case where gas A is diffusing through stagnant gas B (non- diffusing) the flow carries both components in proportions to their partial pressure.

$$(N_A P_A / P) + (N_B P_B / P)$$

The total transfer of A is the sum of this position of the flow and the transfer by diffusion $N_A = N_A\,(P_A/P) - D.\,dp_A\,/\,RT.\,dx$

$N_A = N_A (1 - P_B/RT) + D. dp_B / RT. dx$

This is the expression used for the experimental determination of vapor diffusion co-efficient in gases by evaporation from a liquid surface in a narrow bore tube and measuring the fall of level of the surface. The distance of the liquid surface below the open end of the tube is measured before and after evaporation over a definite period of time. If the variation in level is small then arithmetic mean of these two readings is taken as the value of x.

In case there is appreciable change of level, the value of x is determined by integration between the initial and final readings of level.

The rate of evaporation is thus given by:

$$N_A = \frac{D_P \ln P_{B2}}{P_{B1}} = \frac{\rho_l dx RTx}{M \, d\theta}$$

where, M = mol. wt. of evaporating liquid, ρ_l is the density of evaporating liquid

Integration of this expression yields

$$\frac{DP}{RT} \ln \frac{P_{B2}}{P_{B1}} \frac{M}{\rho_l} \int_0^\theta d\theta = \int_{x1}^{x2} x dx$$

$(DP/RT) \ln (P_{B2}/P_{B1}) M\theta/\rho_l = (x_2^2 - x_1^2) / 2$

Therefore,

$D = [RT / \{P \ln (P_{B2}/P_{B1})\}]. (\rho_l /M) .(x_2^2 - x_1^2) / 2\theta$ (θ is the time of evaporation)

Other form this equation that is convenient to use is: $D_{AB} = [\rho_A(x^2 - x_0^2)RTp_{BM}] / 2P (p_{A1} - p_{A2})M_A\theta$......Eq.1

Where,

ρ_A is the density of CCl_4

x is the final height from top end of the tube after time θ

x_o is the initial height from top end of the tube

$x - x_o$ is the drop in liquid (CCl_4) level in time θ

R is gas law constant = 8314 m^3 Pa / kg mol – K = 82.057×10^{-3} – atm / kg mil –

K R = 82.057 cm^3 – atm / g mol –K

T is the operating temp., K

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M_B is the mol. Wt. of air (component B) = 28.97 g / g mol

M_A is the mol. Wt. of CCl_4 (diffusing component A) = 153.84 g / g

mol P is the total pressure, atm, Pa

P^{BM} is the log mean partial pressure of inert component (B, air)

= $[p_{B2} - p_{B1}]$ / In (p_{B2} / p_{B1}) = $[p_{A1} - p_{A2}]$ / In $[(P-p_{A2})/ (P-p_{A1})]$

Where, p_{A1} is the partial pressure of diffusing component (A) (i.e. CCl_4) at the liquid-air interface (position 1) = vapor. Pressure of CCl_4 at temp T / total pressure, P

Where, p_{A2} is the partial pressure of diffusing component (A) (i.e. CCl_4) in air at the vapor-air interface (position 2 i.e. top of the tube), for pure air p_{A2} = 0.0In terms of concentration terms the expression for D is:

$(x^2 - x^2_o) = (2\theta M_A D_{AB} C_A C_T) /(\rho C_L{}_{Bm})$ Eq. 2

Where, $C_{BM} = (C_{B1} - C_{B2})$ / In (C_{B1}/ C_{B2})

C_A and C_B are the molar concentrations of A and B; C_T is the total molar concentration

Usually, x_o will not be measured accurately nor is the effective distance for diffusion, x, at time θ. Accurate values of $(x - x_o)$ are available, however, and hence:

Re-writing Eq.2 as:

$\theta / (x-x_o) = (\rho_l C_{Bm} / 2M_A D_{AB} C_A C_T) (x-x_o) +(\rho_l C_{Bm} / 2M_A D_{AB} C_A C_T)x_o$ **Eq. 3**

A graph between $\theta / (x-x_o)$ against $(x-x_o)$ should yield a straight line with slope =

$$S = (\rho_l C_{Bm} / 2M_A D_{AB}C_A C_T)$$ Eq. 4

Or $D_{AB} = (\rho_l C_{Bm} / 2M_A C_A C_T S)$ Eq.5

If we take the kilogram molecular volume of a gas as 22.4m³, then

C_T = 1x273.15 / 22.4xT = 12.19 /T kmol/ m³ at operating temperature of T K

If the vapor pressure of the evaporating liquid (A) is V.P (kN/m^2) at the operating temperature of T K

Then C_A = [(V.P.) $_A$ / total pressure in $kN/^{m2}$ (P)]

*C_T(E.g. vapor pressure of CCl_4 at 321 K = 37.6kN/m^2) C_{B1} shall be equal to $C_T$and

C_{B2} = C_T [P – (V.P.)$_A$] / P , kmole/m^3

Effect of temperature and pressure on co-efficient of diffusion, D is expressed as:D = const. $T^{1.5}$/ P

   Eq.6

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Experimental values of Diffusion co-efficient are

System	Temp. , K	D, cm^2 /s
Air- Ethanol	298	0.119
	315	0. 145
Air-n-Hexane	294	0.080
Air- Benzene	298	0.0962
Air- Toluene	298.9	0.086
Air-n Butanol	298.9	0.087
Air- Water	298	0.260
	315	0.288
Air- Methanol	298	0.159
Air- Propanol	298	0.100
Air- Butanol	298	0.090
Air-CS_2	298	0.107

APPARATUS SPECIFICATIONS

The main components of the experimental set up are:-

Glass T-Tube with 4mm capillary bore, heater nichrome wire type, stirrer for uniform temperature distribution

Constant temperature water bath capacity 8-10 liters approximate.

Air Pump and Magnifier/ travelling microscope 0-150*0.1mm

PROCEDURE

1. Set the water bath temperature at the desired level (between 25^0C to $50\ ^0$C) and wait till the bath attains the set temperature. Note the capillary dimensions and the steady temperature of thebath.

2. Fill the T-Tube with CCl 4 to within 2 cm's of the top of capillary leg. Note down the initial diffusion height of liquid in the capillary from the top end (x_0).

3. Make the connection with the air or vacuum pump and allow a gentle current of air to flow over the capillary.

4. Record the height of liquid (x) from the top of the capillary bore after every 30 min. (record the complete variation of x with time θ). Calculate the diffusion coefficient (D) corresponding to the bath temperature. (Using Eq.-1). Prepare the table as shown in table.

5. Repeat the steps for four different water bath temperatures(25^0, $30^{0,}45^0,55^0$C)Calculate D_{AB} at each temperature using equations 3, 4 &5. 1

6. Plot diffusion coefficient against absolute temperature on a log-log graph and

determine the slope. It should be between 1.5 and1.75.

7. Compare the experimental values with that of Gilliland's correlation (Eq.7).

8. Use different organic liquids like: ethanol, toluene, acetone, hexane etc. and tabulate the results anddiscuss.

RECORD AND OBSERVATIONS

Bath temperature, T $\qquad$ = $\qquad$ K

Capillary Radius $\qquad$ = $\qquad$ r, cm.

Liquid in the capillary $\qquad$ = $\qquad$ CCl_4

Density of CCl_4 at T & K $\qquad$ = $\qquad$ ρ_1, kg/cm^3

Diffusing component is CCl_4 (A).

Non diffusing component is air (B).

Partial pressure of CCl_4 at position 2 (top of the tube where air is in large excess)=0.0 CCl_4 vapor at the surface of the liquid (position 1) will have partialpressure P_{A1}/P,

where P_{A1} =vapor pressure of CCl_4 at T K /total pressure.

Height of interface from top atθ=0 $\qquad$ = $\qquad$ x_0,mm

Height of interface from topat θ=0 $\qquad$ = $\qquad$ x ,mm

DIFFUSION CO-EFFICIENT (D)

Using equations 3, 4 & 5 at temperature= T, K.

Record the values of (D) corresponding to four different temperatures and plot D vs. T on a log-log plot to represent the equation: (Eq. 6).

D= const. $T^{1.5}$ / P.

And determine the slop of the straight line.

Plot T vs D*P on a log-log graph

R-square = 0.999 # pts = 3
Temp., T, K=5.55e-007x^1.29

1

Experiment 3

AIM OF THE EXPERIMENT

To calculate the mass transfer coefficient in the Humidification and Dehumidification column

THEORY:-

In the processing of materials, it is often necessary either to increase the amount of vapour present in a gas stream, an operation known as humidification; or to reduce the vapour present, a process referred to as dehumidification. In humidification, the vapour content may be increased by passing the gas over a liquid which then evaporates into the gas stream. This transfer into the main stream take place by diffusion, and the interface simultaneous heat and mass transfer take place according to the system. In the reverse operation, that is dehumidification. The most widespread application of humidification and dehumidification involves the air-water system. Drying of wet solids is an example of a humidification.

The mass transfer coefficient, Ka, can be measured in a humidification & dehumidification column in which the area of contact between two phases is known and boundary layer separation does not take place. A humidification & dehumidification column also provides useful information on mass transfer to and from fluids in turbulent flow.

Method of increasing humidity:

Water is sprayed into the gas at such a rate that on complete vaporization it gives the required humidity. In this case the temperature of the gas will fall as the latent heat of vaporization must be supplied from the sensible heat of the gas and liquid.

Method of decreasing humidity:

Dehumidification of air can be effected by bringing it into contact with a cold surface, either liquid or solid. If the temperature of the surface is lower than the dew point of the gas, condensation takes place and the temperature of the gas falls. The temperature and humidity are reduced simultaneously throughout the whole process.

A humidification column is essentially a vertical tube with means of admitting liquid at the top and causing it to flow downwards along the inside wall of the tube, under the influence of gravity and means of admitting gas to the inside of the tube, where it flows through the tower in contact with the liquid. In absence of ripple formation at the liquid surface, the interfacial area, A, is known and form drag is absent.

Various dimensionless groups that control the phenomenon are:

Reynolds number, N_{Re} = dG/μ

Schmidt Number, NSc = $\mu/\rho D$ Sherwood

Number N_{Sh} = Kd/D G = Gas

mass velocity,Kg/m^2-s

D   = diffusivity Co-eff., $m^2/$-s

d   =   tube diameter,m

K_a =   mass transfer co-efficient.

For turbulent flow mass transfer to pipe wall involving evaporation of liquids in wetted wall towers, Gilland and Sherwood proposed the correlation:

$$N_{Sh} = 0.023 N Re^{0.81} N_{sc}^{0.44} \qquad (1)$$

For, $N_{Re} \Rightarrow 2000$ -3500

$N_{SC} \Rightarrow 0.6$ - 2.5

P $\Rightarrow 0.1$ to3atm

The known flow rate of air at a measured humidity is brought into contact with a film of water at a certain temperature and vapor pressure. Moisture is absorbed by the air from water film and the resultant humidity of the exit air and the temperature and vapor pressure of the entry water measured. The rate of diffusion through the gas film, N_A, is givenby:

N_A, kgmol/h $= KaA(\Delta P)_m$ (2)

Ka   = gas film coefficient, kg mole of water transferred. m^2/h per atmospheric partial
        pressuredifference.

A   = Wetted surface of column $= \pi dL$

$(\Delta P)_m$ = Log mean partial pressure driving force across the ends of the column.

The value of Ka obtained experimentally can be compared with that predicted from Sherwood - Gillilandcorrelation:

$K_a = (D*d/RT)(d*V*\rho/\mu)(\mu/\rho*d)$ (3)

d = Column diameter

DESCRIPTION

The setup consists of two glass columns with packing of rasching ring and silica gel. Air flow rates can be set and measured by Rota meter and temperature by RTD. The setup studies in volumetric mass transferco-efficient.

Features:

1. CompactModel

2. SafeOperation

3. Digital temp.Indication

In this system the air is firstly free from moisture by passing in the heated chamber and then inserted in the column from the bottom and water is from the top and comes down with the packing wall. The moisture is absorbed from the glass column and goes up in the cooling for dehumidification and then passed into the silica gel filled glass column for complete dehumidification and then passed into the atmosphere. Water is recycled in the sump tank through the pump. The temperature of the air dry bulb and wet bulb are measured by RTD 100 areprovided.

UTILITIES REQUIRED

Compressed Air Supply at 2 Bar

Water supply

Drain

Electricity Supply: 1 Phase, 220 V AC, 0.5 kW.

EXPERIMENTAL PROCEDURE

1. Fill the sump tank with water and also connect the air supply to the pointprovided.

2. Connect the plug to mains and start heating the chamber and also start the air and maintain air flowrate.

3. Fill the wet bulb thermometer bottle with water and weight for 30 min and control the air temperature by regulating the voltage variac provided.

4. Commence the operation with minimum airflow and after 15-20 minutes, the humidity of the inlet air and the outlet air at this flow rate of air is noted and read corresponding vapor partial pressure, from the psychometric chart. Simultaneously the temperature of the water in and out is noted and flow rates measured. From steam tables obtain Vapour pressure of water corresponding to thesetemperatures.

5. Repeat step 3 for 3-4 air flowrates.

6. Calculate experimental value of Ka using equation(2)

7. Calculate predicted value of Ka using Sherwood-Gilliland correlation, eq.(3).

8. Compare the experimental and predicted Value of Ka

9. Plot   KaRT/Dd   Vs (dvρ)

    and

              $(\mu/\rho D)^{0.44}$ Vs   μ

  On log-log scale and check the slope approximates to 0.8.

SPECIFICATION:

Column	=	50 mm dia x 500 mm height
Shell and tube condenser	=	114 dia x 500 mm S.S.
Tanks	=	25 Lit S.S. (2 NO.)
Heater Box	=	2 kW
Pump	=	FHP
Compressor required	=	1 CFM
Temperature measurement	=	RTD
Air Flow measurement	=	Rota meter
Humidification measurement	=	Wet and Dry bulb
Control Panel	=	Electrical
Structure	=	M.S.
Space	=	1000 L x 500 W x 1500 H
Utilities required	=	230 V AC

FORMULAE:

$$\text{Humidity} = \frac{18 p_{H2O}}{29 (p_T - p_{H2O})}$$

From steam tables, corresponding to water inlet and outlet temperature calculate the Vapour pressure.

Calculate $(\Delta P)_m$ as:

$$(\Delta P)_m = \frac{(þ_{B1} - þ_B)}{\ln(þ_{B1} / þ_B)}$$

Where P_{B1} = $(P_T - þ_{a1})$

$þ_B$ = $(P_T - þa)$

OBSERVATION & CALCULATION:

Column diameter	=	d
Effective column height	=	L
Room temperature	=	
Atmospheric Pressure	=	P_T
Surface area	=	πdL

OBSERVATION TABLE

SR. NO	Air Flow Rate LPM	Air Temperature ^{0}C				Water Temperature ^{0}C		Humidity	
		In		Out		In	Out	Inlet	Outlet
		Dry bulb	Wet bulb	Dry bulb	Wet bulb				
1									
2									
3									
4									
5									

From   Psychometric chart = Note inlet and outlet humidity of air

-Calculate, NA

-Calculate air partial pressures from:

$$\text{Humidity} = \frac{18 p_{H2O}}{29 (p_T - p_{H2O})}$$

From steam tables, corresponding to water inlet and outlet temperature calculate the Vapour pressure.

Calculate $(\Delta P)_m$ as:

$$(\Delta P)_m = \frac{(p_{B1} - p_B)}{\ln (p_{B1} / p_B)}$$

where P_{B1} = $(P_T - p_{a1})$

$\overline{p_B}$ = $(P_T - p_a)$

P_{a1} = partial pressure of diffusing component, a, at the boundary.

$\overline{P_a}$ = main value of partial pressure of component, a, in the flowing stream.

D for air at 40°C = 0.288 cm²/sec.

Calculate K_a

Plot $N_{sh} / N_{sc}^{0.44}$ V_s N_{Re}

On log-log scale and determine the slope and intercept.

PRECAUTIONS & MAINTENANCE INSTRUCTIONS

1.   For condenser the cold water supply should be constant.

2.   Don't switch on the pump at low voltage.

3.   Air should be moisture free.

4. Wet bulb temperature should be properly contacted with water.

TROUBLESHOOTING

1. If any type of suspended particles are come in the Rotameters. Remove the Rota meters clean the tube and fit that at its place.

2. If there is any leakage tight that part or remove that and refix that again after wrapping Teflontape.

3. If Rota meters fluctuating more than average tight control knob of that.

   (Procedure: two nuts are there lose first nut and tight the second slightly, and then first also. Both nuts are on Rota meters)

4. IfD.T.Idisplay'1'ondisplayboarditmeanssensorsconnectionarenotOKtightthat.

5. If switch ON, the heater but temperature can't rise but panel LED is ON it means bath heater had burned replace that.

Experiment 4

AIM OF THE EXPERIMENT

To determine the Vapour-Liquid Equilibrium (VLE) curve for the CCl_4 toluene mixture (Computerized)

APPARATUS

VLE still, Refractrometer and test tubes

CHEMICALS

Carbon tetrachloride, Toluene

THEORY

The design of distillation and other contacting equipment requires reliable VLE data. Although relatively few ideal solutions are known whose equilibrium relations can be calculated from vapor pressure - temperature data of the pure components, by far the larger numbers of systems of industrial importance are non-ideal; and attempt to predict the equilibrium compositions of such mixtures from theoretical considerations alone have not proved successful. It has been the practice to determine such data experimentally under various conditions.Vapor liquid diagram shows relationship between the composition of the vapor and that of liquid in equilibrium with the vapor for a binary mixture at constant pressure or constant temperature. If liquid and vapor behave ideally, such curves are calculated as follows:

From Raoult' law:

$P_1 = P_1 X_1$

$P_2 = P_2 X_2$

where p_1 and p_2 are partial pressures of components 1 and 2 in the mixture,

P = total pressure

P_1 and P_2 are vapor pressure of pure components at the same temperature as mixture.

From Dalton's law of partial pressures:

$P_1 = P y_1$

$P_2 = P y_2$

y_1 and y_2 are the mole fractions of components in vapor

From these equations we have:

$$x_1 = \frac{P - P_2}{P_1 - P_2} \quad y_1 = \frac{P_1 x_2}{P}$$

Theoretical VLE curve can thus be calculated by choosing various boiling points of the mixture and calculate x and y as shown above. Carbon tetrachloride - toluene system closely follows ideal behavior.
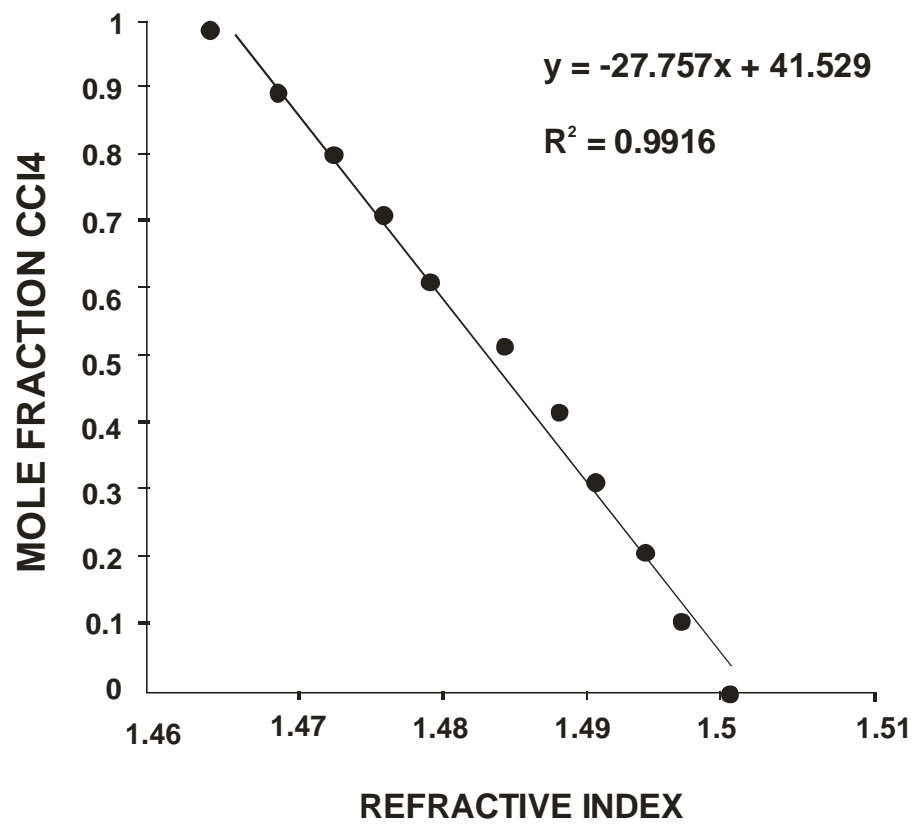
PROCEDURE

The vapor - liquid equilibrium still containing about 15O ml to 200 of known mixture (with low composition of high boiling component) is heated gently. The toluene – CCL_4 mixture being distilled over and the vapor being re-cycled for at least 45 to 60 minutes before any samples are taken, to allow equilibrium between liquid and gaseous phases to be attained (temperature of vapor, t, and remains constant)

The liquid and vapor are then sampled at noted temperature (t) and analyzed for molar composition of more volatile component in vapor (y) and liquid (x) .The heating is stopped and the feed liquid replaced by another feed mixture (increasing gradually the amount of high boiling liquid), the liquid and vapor once more allowed to come to equilibrium (indicated by constant temperature) and collecting the samples of liquid from the still and the condensate. The still liquid being hot, should be collected in an ice cooled test tube to avoid any change in composition due to vaporization. The above procedure should be repeated for at least six feed compositions.

The samples are viewed under a high precision refractometer, and their composition determined from the pre-determined calibration chart for CCl_4 - toluene mixture, which converts refractive index to mole fractions. This way t-x-y and x-y diagrams can be plotted.

The calibration curve (n_D vs. mole fraction of more volatile component, x) should be generated at a specific temperature (say 25^0C) by taking different mixtures of CCl_4 - toluene of known molar composition and recording the refractive index of the mixture. The samples collected should also be evaluated at the same temperature.
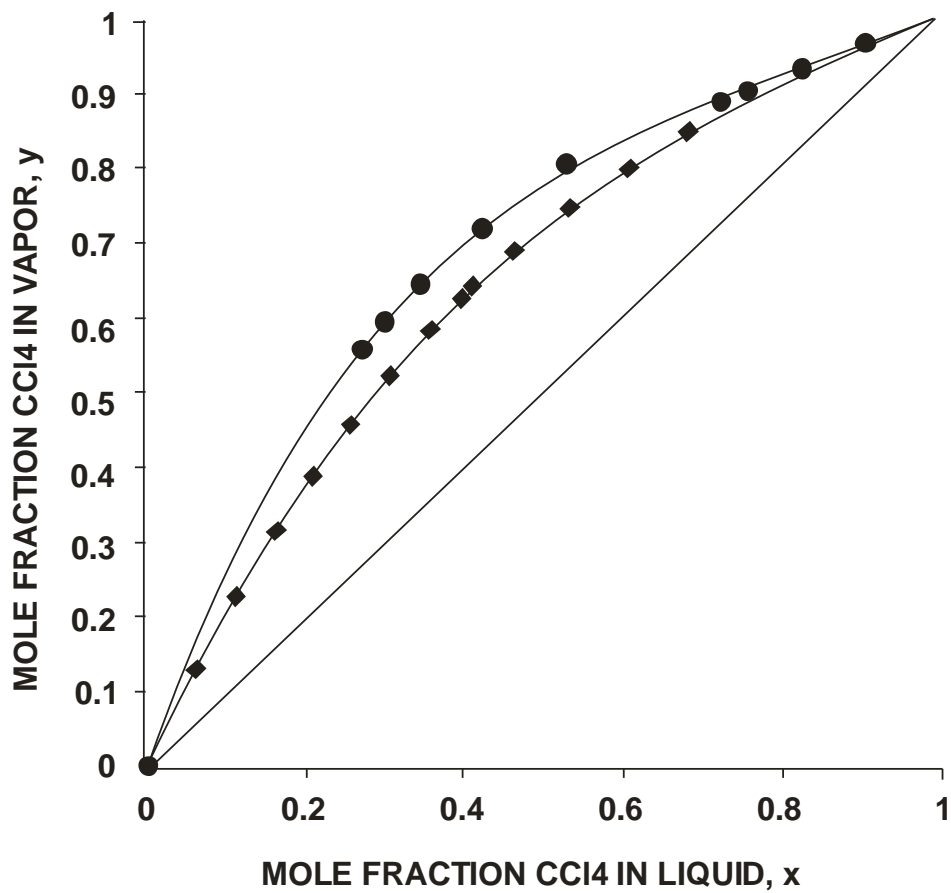
CALIBRATION CURVE FOR CCI4-TOLUENE AT 16° C

$y = -27.757x + 41.529$

$R^2 = 0.9916$
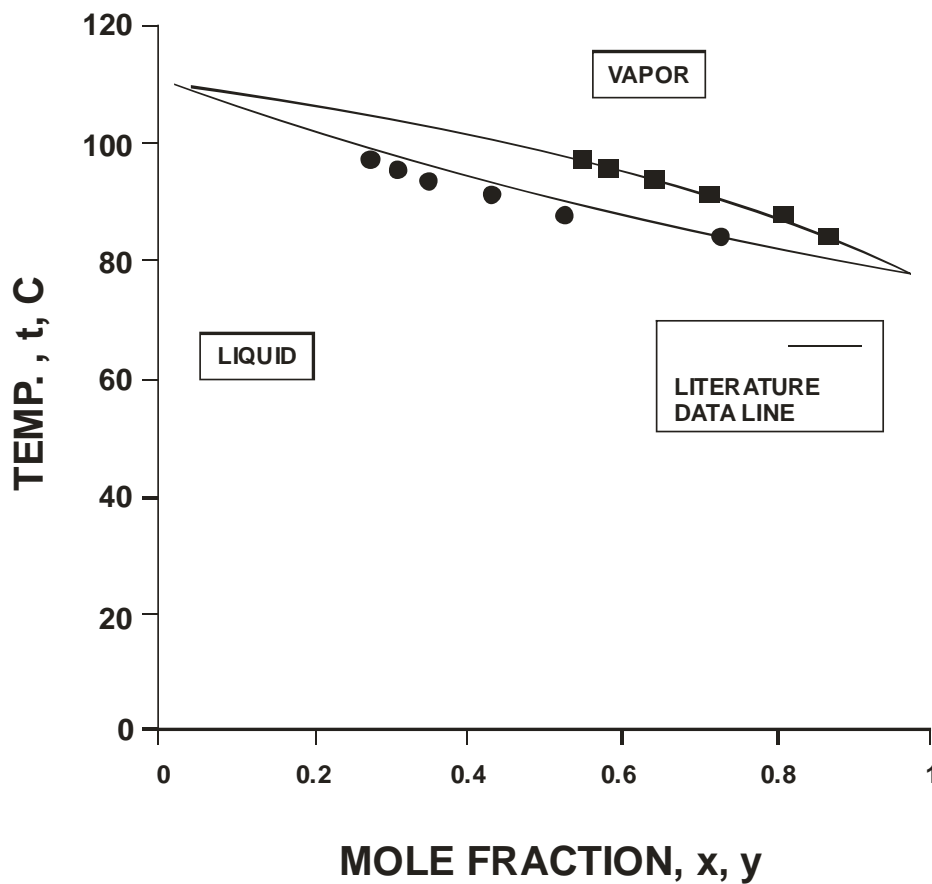
AVAILABLE LITERATURE DATA

- **PRESENT DATA**

<u>VLE DIAGRAM FOR CCI4-TOLUENE SYSTEM AT 760 mm Hg</u>

- ▪ t vs. y , PRESENT DATA

- ● t vs. x , PRESENT DATA

SOFTWARE INSTALLATION/OPERATION

The power input to the VLE can be controlled by PC interface via software. Please read the steps for installing and operating the software

1. Insert the CD in CD/DVDdrive

2. Click on software folder "USB Drivers" and install utility drivers as perPC

   Configuration 32/64 Bit

3. Click on CDM v2.08.30 WHQL …. And followinstructions

4. After driver installation is complete connect one end of the USB cable
   at front port of VLE LCD panel and the other end to USB port onPC.

5. Install software by clicking on Folder named"Software".

6. Click on Vapor liquid…… set up and followinstructions.

7. After software installation is complete, right click on "My computer" iconon desktop, and go to properties.

8. Click on device manager and see the port number selected by computer (COM & LPT).

9. Click on VLE software shortcut created ondesktop.

10. On the software screen and select the COM port previously detected or press refresh button a few times to select the respective COMport.

11. For detecting the COM port of computer the user can also press the"Device Manager" button on the softwarescreen.

12. On the LCD panel of the unit (VLE) select mode of operation by pressing mode button.

13. On the LCD screen Manual/Computer mode willappear.

14. Select Computer by pressing the mode button. This will allow the user to give power input to the VLE heater bycomputer.

15. Press start button to begin the heatingprocess.

16. Press (+) sign to increase voltage and (-) to decrease voltage to the VLE heater the above feature is useful for operating the heater in different feedmixtures.

17. To stop the heating process press "STOP" button.

Experiment 5

AIM OF THE EXPERIMENTS

To determine the Vapour-Liquid Equilibrium (VLE) curve for the CCl_4 toluene mixture

APPARATUS REQUIRED

VLE still, Refractrometer and test tubes

CHEMICALS

Carbon tetrachloride, Toluene

THEORY

The design of distillation and other contacting equipment requires reliable VLE data. Although relatively few ideal solutions are known whose equilibrium relations can be calculated from vapor pressure - temperature data of the pure components, by far the larger numbers of systems of industrial importance are non-ideal; and attempt to predict the equilibrium compositions of such mixtures from theoretical considerations alone have not proved successful. It has been the practice to determine such data experimentally under various conditions.

Vapor liquid diagram shows relationship between the composition of the vapor and that of liquid in equilibrium with the vapor for a binary mixture at constant pressure or constant temperature. If liquid and vapor behave ideally, such curves are calculated as follows:

From Raoult' law:

$P_1 = P_1 X_1$

$P_2 = P_2 X_2$

where p_1 and p_2 are partial pressures of components 1 and 2 in the mixture,

P = total pressure

P_1 and P_2 are vapor pressure of pure components at the same temperature as mixture.

From Dalton's law of partial pressures:

$P_1 = P y_1$

$P_2 = P y_2$

y_1 and y_2 are the mole fractions of components in vapor

From these equations we have:

$$x_1 = \frac{P - P_2}{P_1 - P_2}$$

$$y_1 = \frac{P_1 x_2}{P}$$

Theoretical VLE curve can thus be calculated by choosing various boiling points of the mixture and calculate x and y as shown above. Carbon tetrachloride - toluene system closely follows ideal behavior.
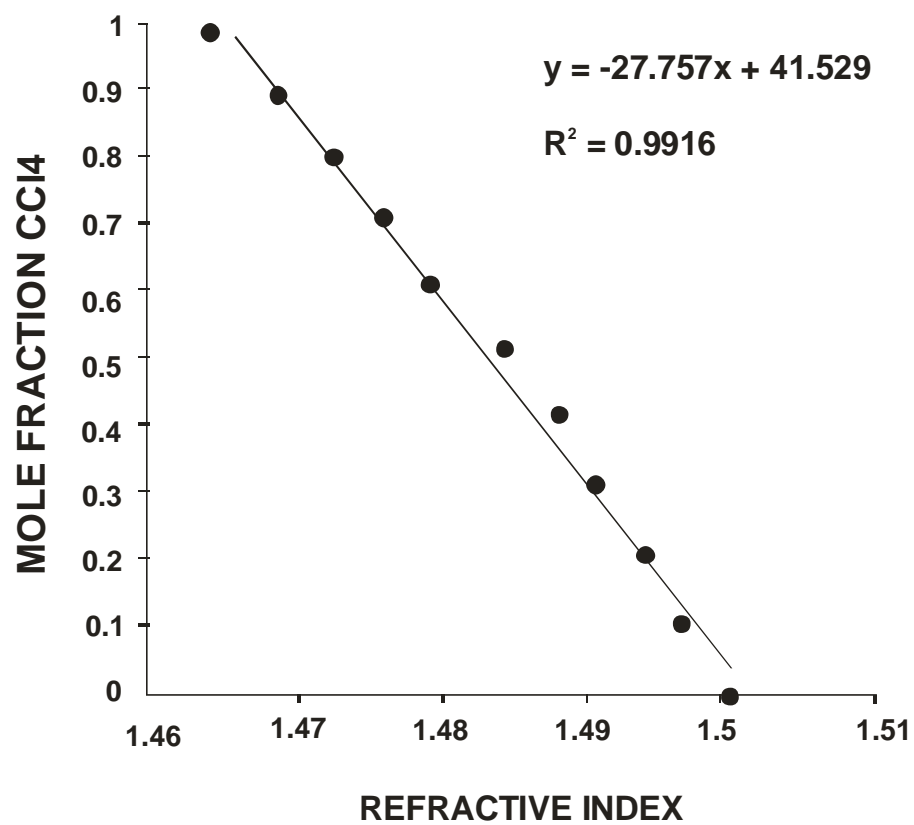
PROCEDURE:

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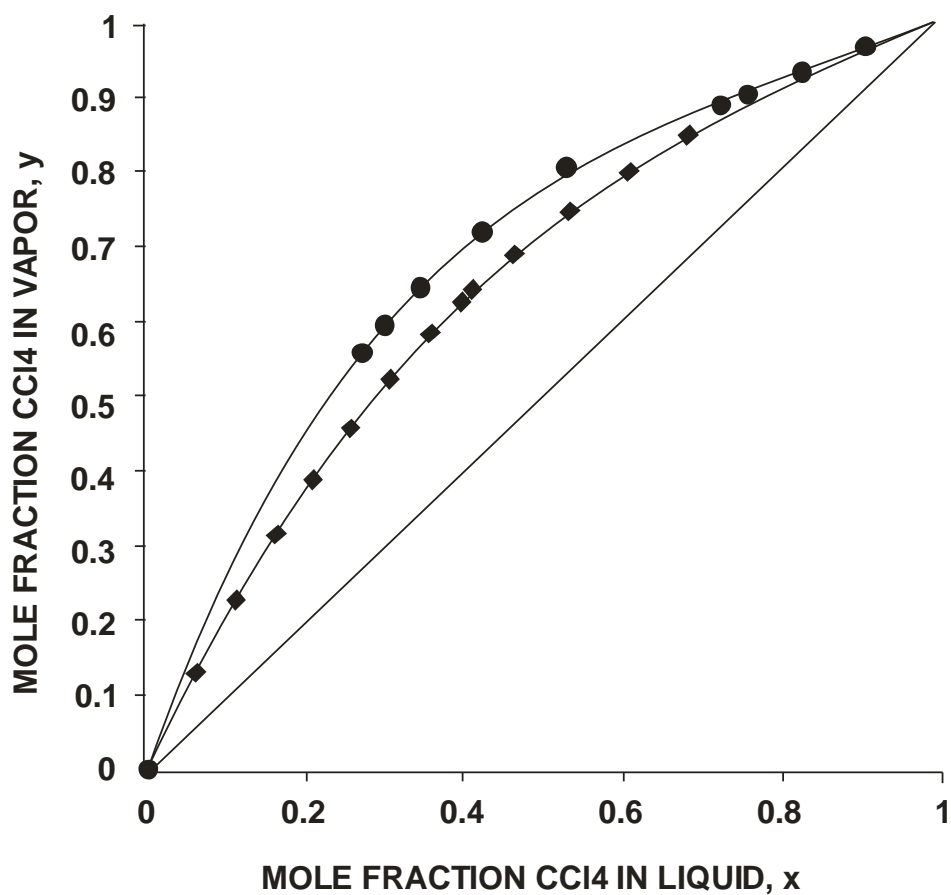
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CALIBRATION CURVE FOR CCI4-TOLUENE AT 16⊙ C

$y = -27.757x + 41.529$

$R^2 = 0.9916$

X-axis: **REFRACTIVE INDEX**

Y-axis: **MOLE FRACTION CCI4**

- ■ **AVAILABLE LITERATURE DATA**
- ● **PRESENT DATA**

VLE DIAGRAM FOR CCI4-TOLUENE SYSTEM AT 760 mm Hg

- ■ t vs. y , PRESENT DATA