# BITS, PILANI – DUBAI CAMPUS

**FIRST SEMESTER 2012 – 2013**

**THIRD YEAR (Chemical)**

Course Code: CHE F244 **COMPREHENSIVE EXAMINATION** Date: 10.06.13

Course Title: Separation Processes 1 (Closed Book) Max Marks: 80

Duration: 3 hr Weightage: 40%

Note: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct. Cleary show all calculation steps. Use graph sheets if needed.

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1.(a) Carbon dioxide and oxygen experience equimolar counter diffusion in a circular tube whose length and diameter are 1 m and 50 mm respectively. The system is at a total pressure of 10 atm. and a temperature of 25°C. The ends of tube are connected to large chambers in which the species concentrations are maintained at fixed values. The partial pressure of $CO_2$ at one end is 190 mm Hg while at the other end is 95 mm Hg. Estimate the rate of mass transfer. Diffusivity under given condition is 2.1 × 10-5 $m^2/s$ (7 m)

1.(b) Sketch concentration gradients for the two resistance theory: (2 × 2 = 4 m)

(i) Film theory

(ii) More realistic gradients

2.(a) Discuss the following tray efficiencies for tray towers. (2 × 3 = 6 m)

(i) Overall tray efficiency

(ii) Murphree tray efficiency

(iii) Point efficiency

2.(b) Sketch the operating lines for an absorber for the following conditions. (4 m)

(i) Infinite absorbent rate

(ii) 2 × minimum absorbent rate

(iii) 1.5 × minimum absorbent rate

(iv) Minimum absorbent rate

3.(a) A equimolar feed mixture containing A and B is differentially distilled such that 70% of the feed is distilled out. Estimate the composition of the distillate and residue.

Equilibrium Data:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| x | 1 | 8 | 14 | 21 | 29 | 37 | 46 | 56 | 66 | 97 | 100 |
| y | 3 | 16 | 28 | 39 | 50 | 59 | 65 | 76 | 83 | 99 | 100 |

x,y mole fraction of benzene in liquid and vapour phase respectively. (12 m)

3.(b) Discuss briefly: (2 × 2 = 4 m)

(i) Binary batch rectification with constant reflux and variable distillate composition

(ii) Binary batch rectification with constant distillate composition and variable reflux

4.(a) A continuous distillation column is used to separate a feed mixture at its boiling point, containing 24 mole% acetone and remaining is methanol into a distillate product containing 77 mol% acetone and a residue product containing 5 mol% acetone. A reflux ratio of twice the minimum is to be used. The overall plate efficiency is 60 %.

(i) Determine the number of plates required for the above separation.

(ii) Determine the number of plates at total reflux operation.

Equilibrium Data: (6 + 6 =12 m)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| x | 0.05 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1 |
| y | 0.102 | 0.186 | 0.322 | 0.428 | 0.513 | 0.586 | 0.656 | 0.725 | 0.82 | 0.9 | 1 |

x,y mole fraction of acetone in liquid and vapour phase respectively.

4.(b) Discuss in brief with an example: (2 × 2 = 4 m)

(i) Extractive Distillation

(ii) Salt Distillation

5.(a) 50 kg of solution containing 50% A (pyridine) in S (water) are to be extracted using 60 kg of L (chlorobenzene) in multiple contact operation. Determine the number of stages required to give a final raffinate of less than 2 % A from the following data. (8 m)

| Extract% | | | Raffinate % | | |
|---|---|---|---|---|---|
| A | L | S | A | L | S |
| 0 | 99.9 | 0.1 | 0 | 0.1 | 99.9 |
| 11 | 88 | 1 | 5 | 0.2 | 94.8 |
| 19 | 80 | 1 | 11 | 0.3 | 88.7 |
| 24 | 74 | 1.5 | 19 | 0.4 | 80.6 |
| 29 | 69 | 2 | 25 | 0.6 | 74.4 |
| 32 | 64.7 | 3.3 | 37 | 1.5 | 61.5 |
| 35 | 61 | 4 | 45 | 4 | 51 |
| 40 | 53 | 7 | 53 | 10 | 37 |
| 47 | 43 | 10 | 54 | 20 | 26 |
| 50 | 37 | 13 | 50 | 37 | 13 |

5.(b) Discuss Graesser raining bucket extractor working principle, advantages and limitations. (6 m)

6.(a) One hundred and fifty kg per hour of a feed containing 1/3 water soluble $Na_2CO_3$, and the balance insoluble ash to be leached and washed with 400 kg/h of water at 30°C in a 2 stage counter current system. The leaching stage consists of an agitated vessel that discharges the slurry into a thickener. The washing stage consists of a second thickener. Experiments show that the sludge underflow from each thickener will contain 2 kg of liquid (water and carbonate) per kg of insoluble ash. Assume ideal stages. At 30°C, the solubility of the carbonate in water is 38.8 kg/100 kg of water. (4+4 = 7 m)

(a) Calculate the percent (%) recovery of carbonate in the final extract

(b) If a third stage is added, calculate the amount of additional carbonate that will be recovered.

6.(b) Discuss any leaching equipments working principle, advantages and limitations. (6 m)

# BITS, PILANI – DUBAI CAMPUS

**FIRST SEMESTER 2012 – 2013**
**THIRD YEAR (Chemical)**

Course Code: CHE F244 **COMPREHENSIVE EXAMINATION** Date: 10.06.13
Course Title: Separation Processes 1 (Closed Book) Max Marks: 80
Duration: 3 hr (Answering Scheme) Weightage: 40%

Note: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct. Cleary show all calculation steps. Use graph sheets if needed.

---

1.(a) Carbon dioxide and oxygen experience equimolar counter diffusion in a circular tube whose length and diameter are 1 m and 50 mm respectively. The system is at a total pressure of 10 atm. and a temperature of 25°C. The ends of tube are connected to large chambers in which the species concentrations are maintained at fixed values. The partial pressure of $CO_2$ at one end is 190 mm Hg while at the other end is 95 mm Hg. Estimate the rate of mass transfer. Diffusivity under given condition is 2.1 × 10-5 $m^2/s$ (7 m)

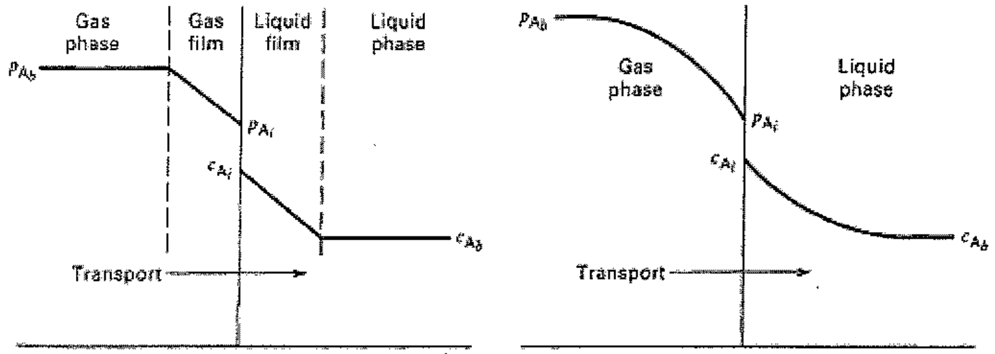
$$N_A = \frac{D_{AB}\left[p_{A1} - p_{A2}\right]}{ZRT}$$

$$R = \frac{PV}{T} = \frac{760 \times 22.414}{273} = 62.4\,(mmHg)(m^3)/K(kmol)$$

$$N_A = \frac{2.1\times10^{-5}}{1\times 62.4\times298} = (190-95) = 1.073\times10^{-7}\,kmol/m^2 s$$

$$Rtaeof\,MassTransfer = 1.073\times10^{-7}\times\pi r^2 = 1.073\times10^{-7}\times\pi\left(\frac{50\times10^{-3}}{2}\right)^2 = 2.107\times10^{-10}\,kmol/s$$

1.(b) Sketch concentration gradients for the two resistance theory: (2 × 2 = 4 m)
(i) Film theory
(ii) More realistic gradients



2.(a) Discuss the following tray efficiencies for tray towers. (2 × 3 = 6 m)

(i) Overall tray efficiency
(ii) Murphree tray efficiency
(iii) Point efficiency

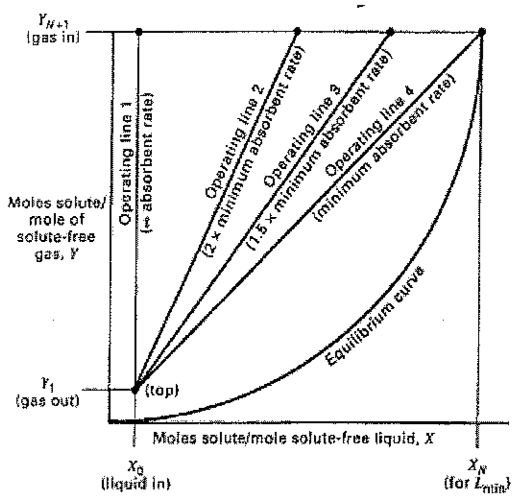
$$E_o = \frac{number\ of\ ideal\ trays}{number\ of\ actual\ trays}$$

$$E_M = \frac{y_n - y_{n+1}}{y_n^* - y_{n+1}}$$

$$E_{MP} = \frac{y_n' - y_{n+1}'}{y_n^* - y_{n+1}'}$$

2.(b) Sketch the operating lines for an absorber for the following conditions. (4 m)

(i) Infinite absorbent rate
(ii) 2 × minimum absorbent rate
(iii) 1.5 × minimum absorbent rate
(iv) Minimum absorbent rate




3.(a) A equimolar feed mixture containing A and B is differentially distilled such that 70% of the feed is distilled out. Estimate the composition of the distillate and residue.

Equilibrium Data:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| x | 1 | 8 | 14 | 21 | 29 | 37 | 46 | 56 | 66 | 97 | 100 |
| y | 3 | 16 | 28 | 39 | 50 | 59 | 65 | 76 | 83 | 99 | 100 |

x,y mole fraction of benzene in liquid and vapour phase respectively. (12 m)

WKT, $\int_{x_w}^{x_f} \frac{dx}{(y-x)} = \ln\left[\frac{F}{W}\right]$

Let F = 100 moles, D = 70 moles; W = 30 moles

$$\int_{x_w}^{x_f} \frac{dx}{(y-x)} = \ln\left[\frac{F}{W}\right] = \ln\left[\frac{100}{30}\right] = 1.204$$

$$by\, trial\, and\, error\, locate\, x_W\, such\, that \int_{x_w}^{x_f} \frac{dx}{(y-x)} = 1.204$$

$$Draw\left(\frac{1}{y-x}\right) Vs = x$$

$x_w = 0.23$; $y_D = 0.616$

3.(b) Discuss briefly: (2 × 2 = 4 m)
(i) Binary batch rectification with constant reflux and variable distillate composition
(ii) Binary batch rectification with constant distillate composition and variable reflux
Refer class notes

4.(a) A continuous distillation column is used to separate a feed mixture at its boiling point, containing 24 mole% acetone and remaining is methanol into a distillate product containing 77 mol% acetone and a residue product containing 5 mol% acetone. A reflux ratio of twice the minimum is to be used. The overall plate efficiency is 60 %.
(i) Determine the number of plates required for the above separation.
(ii) Determine the number of plates at total reflux operation.
Equilibrium Data: (6 + 6 =12 m)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| x | 0.05 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1 |
| y | 0.102 | 0.186 | 0.322 | 0.428 | 0.513 | 0.586 | 0.656 | 0.725 | 0.82 | 0.9 | 1 |

x,y mole fraction of acetone in liquid and vapour phase respectively.

From graph $x_D/(R_{min}+1) = 0.19$; $R_{min} = 3.053$;
Ractual = 2 × 3.053 = 6.106;
number of theoretical plates 13; actual plates 13/0.6 = 22 plates

4.(b) Discuss in brief with an example: (2 × 2 = 4 m)
(i) Extractive Distillation
(ii) Salt Distillation

Refer class notes

5.(a) 50 kg of solution containing 50% A (pyridine) in S (water) are to be extracted using 60 kg of L (chlorobenzene) in multiple contact operation. Determine the number of stages required to give a final raffinate of less than 2 % A from the following data. (8 m)

| Extract% | | | Raffinate % | | |
|---|---|---|---|---|---|
| A | L | S | A | L | S |
| 0 | 99.9 | 0.1 | 0 | 0.1 | 99.9 |
| 11 | 88 | 1 | 5 | 0.2 | 94.8 |
| 19 | 80 | 1 | 11 | 0.3 | 88.7 |
| 24 | 74 | 1.5 | 19 | 0.4 | 80.6 |
| 29 | 69 | 2 | 25 | 0.6 | 74.4 |
| 32 | 64.7 | 3.3 | 37 | 1.5 | 61.5 |
| 35 | 61 | 4 | 45 | 4 | 51 |
| 40 | 53 | 7 | 53 | 10 | 37 |
| 47 | 43 | 10 | 54 | 20 | 26 |
| 50 | 37 | 13 | 50 | 37 | 13 |

5.(b) Discuss Graesser raining bucket extractor working principle, advantages and limitations. (6 m)

Refer class notes

6.(a) One hundred and fifty kg per hour of a feed containing 1/3 water soluble $Na_2CO_3$, and the balance insoluble ash to be leached and washed with 400 kg/h of water at 30°C in a 2 stage counter current system. The leaching stage consists of an agitated vessel that discharges the slurry into a thickener. The washing stage consists of a second thickener. Experiments show that the sludge underflow from each thickener will contain 2 kg of liquid (water and carbonate) per kg of insoluble ash. Assume ideal stages. At 30°C, the solubility of the carbonate in water is 38.8 kg/100 kg of water. (4+4 = 7 m)

(a) Calculate the percent (%) recovery of carbonate in the final extract

(b) If a third stage is added, calculate the amount of additional carbonate that will be recovered.

N = 1 (L is the leaching stage)

S =2/3(150) = 100 kg/h of insoluble ash

$Na_2CO_3$ in entering solids = 1/3 (150) = 50 kg/h

$V_2$ = entering solvent = 400 kg/h

$L_L = L_1 = 2S = 200$ kg/h

By total liquid material balances on Stage 1 and Stage L,

$V_1 = V_2 + L_L - L_1 = 400 + 200 - 200 = 400$ kg/h

$V_L = V_1 + 50 - L_L = 400 + 50 - 200 = 250$ kg/h

$Na_2CO_3$ *material balance around Stage* 1:

$x_L L_L = y_1 V_1 + x_1 L_1$
$200\, x_L = 400\, y_1 + 200\, x_1$
But, $y_1 = x_1$ (for an ideal stage.)
$x_L = 3\, x_1$
$Na_2CO_3$ *material balance around Stage* L:
$y_1 V_1 + 50 = x_L L_L + y_L V_L$
$400\, y_1 + 50 = x_L 200 + y_L 250$
But, $y_1 = x_1$ ; $y_L = x_L$ (for an ideal stage.)
Combining above equations:
$x_L = 0.158 = y_L$
$x_1 = 0.0526$
Recovery of $Na_2CO_3 = y_L V_L / 50 = (0.158)(250)/50 = 79\%$

*B)* $N = 2$ washing stages
$V_3 = 400$ kg/h
$L_L = L_1 = L_2 = 2S = 200$kg/h
$V_2 = V_1 = 400$ kg/h
$V_L = 250$ kgh
$Na_2CO_3$ *material balance around Stage* 2:
$x_1 L_1 = y_2 V_2 + x_2 L_2$
$x_1 200 = y_2 400 + x_2 200$
But, $y_2 = x_2$ (for an ideal stage.)
$x_1 = 3\, x_2$
$Na_2CO_3$ *material balance around Stage* L:
$y_2 V_2 + x_L L_L = x_1 L_1 + y_1 V_1$
$y_2 400 + x_L 200 = x_1 200 + y_1 400$
But, $y_2 = x_2$ ; $y_1 = x_1$ (for an ideal stage.)
Combining above equations;
$x_L = 3x_1 - 2x_2$
$Na_2CO_3$ *material balance around Stage* L:
(Which is same as part a)
$x_L = 0.1795 = y_L$
$x_1 = 0.0769$; $x_2 = 0.0256$
Recovery of $Na_2CO_3 = y_L V_L / 50 = (0.1795)(250)/50 = 89.8\%$
From Part (a), for two stages, recovery of $Na_2CO_3$ is $= 0.158(250) = 39.5$ kg/h
For three stages, recovery is $0.1795(250) = 44.9$ kg/h
Recover 44.9 - 39.5 = 5.4 kg/h more $Na_2CO_3$ with 3stages.

6.(b) Discuss any leaching equipments working principle, advantages and limitations. (6 m)
Refer class notes

# BITS, PILANI – DUBAI CAMPUS
## FIRST SEMESTER 2012 – 2013
### THIRD YEAR (Chemical)

Course Code: CHE F244 **TEST 2** Date: 06.05.13
Course Title: Separation Processes 1 Max Marks: 20
Duration: 50 minutes (Open Book) Weightage: 20%

**Note: only prescribed text book and own handwritten notes are allowed, physical and chemical property tables are allowed**

1. It is desired to separate a mixture of 50% vapor and 50% saturated liquid in a plate type distillation column. The feed contains 45 mole% A and the top product is to contain 96 mol% A. the bottom product is to contain 5 mole% A. Determine the minimum reflux ratio and the number of theoretical plates needed if a reflux ratio of twice the minimum is used.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| x | 0.1 | 0.16 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| y | 0.215 | 0.3 | 0.52 | 0.625 | 0.725 | 0.78 | 0.85 | 0.89 | 0.95 |

Calculate total number of plates empirically as well as by graphical method for total reflux condition with average relative volatility of 2.2. (3.5 × 4 = 14 m)

2. A feed mixture containing 50 mol% hexane and 50 mol% octane is fed in to a pipe still through a pressure reducing valve and flashed into a chamber. The fraction of feed converted to vapor is 0.6. Find the composition of the distillate and residue. (6 m)

| | | | | | | |
|---|---|---|---|---|---|---|
| x | 0 | 4.5 | 19.2 | 40 | 69 | 100 |
| y | 0 | 17.8 | 53.8 | 78 | 93.2 | 100 |

x, y mole percent of hexane in liquid and vapor phase respectively.

# BITS, PILANI – DUBAI CAMPUS

**FIRST SEMESTER 2012 – 2013**

**THIRD YEAR (Chemical)**

Course Code: CHE F244 **TEST 2** Date: 06.05.13

Course Title: Separation Processes 1 Max Marks: 20

Duration: 50 minutes (Open Book) Weightage: 20%

**(Answering Scheme)**

**Note: only prescribed text book and own handwritten notes are allowed, physical and chemical property tables are allowed**

1. It is desired to separate a mixture of 50% vapor and 50% saturated liquid in a plate type distillation column. The feed contains 45 mole% A and the top product is to contain 96 mol% A. the bottom product is to contain 5 mole% A. Determine the minimum reflux ratio and the number of theoretical plates needed if a reflux ratio of twice the minimum is used.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| x | 0.1 | 0.16 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| y | 0.215 | 0.3 | 0.52 | 0.625 | 0.725 | 0.78 | 0.85 | 0.89 | 0.95 |

Calculate total number of plates empirically as well as by graphical method for total reflux condition with average relative volatility of 2.2. (3.5 × 4 = 14 m)

Wkt q = 0.5

Slope of the q line = 05/(05-1) = -1

For $R_{min}$ draw top operating line from $x_D$ = 0.96 through the meeting pt of feed line and equ. Line and find intercept $x_D/(R_{min}+1)$ = 0.35; $R_{min}$ = 1.74

$R_{actual} = 2 \times R_{min} = 3.48$

Fix the value in y axis $x_D/(R_{actual}+1)$ =0.199, join the feed point with bottom operating line and number stages are 9+1

At total reflux, number of stages from graph = 6+1 stages

Number of stages from Fenske's equ = 7 stages

2. A feed mixture containing 50 mol% hexane and 50 mol% Octane is fed in to a pipe still through a pressure reducing valve and flashed into a chamber. The fraction of feed converted to vapor is 0.6. Find the composition of the distillate and residue. (6 m)

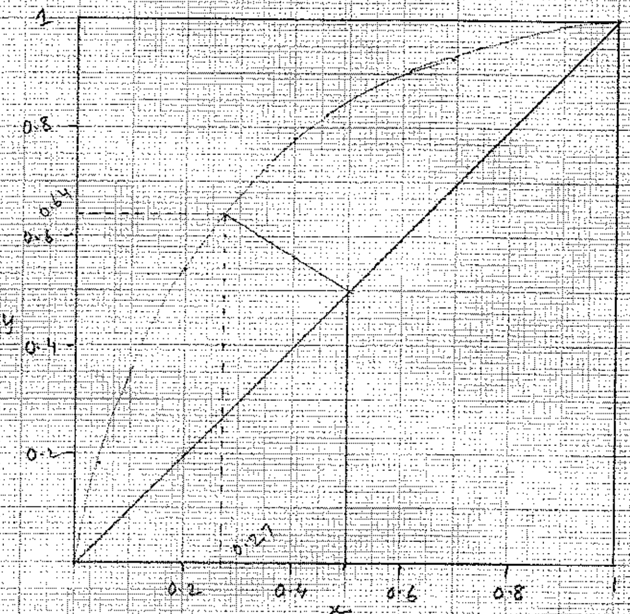
| | | | | | | |
|---|---|---|---|---|---|---|
| x | 0 | 4.5 | 19.2 | 40 | 69 | 100 |
| y | 0 | 17.8 | 53.8 | 78 | 93.2 | 100 |

x, y mole percent of hexane in liquid and vapor phase respectively.

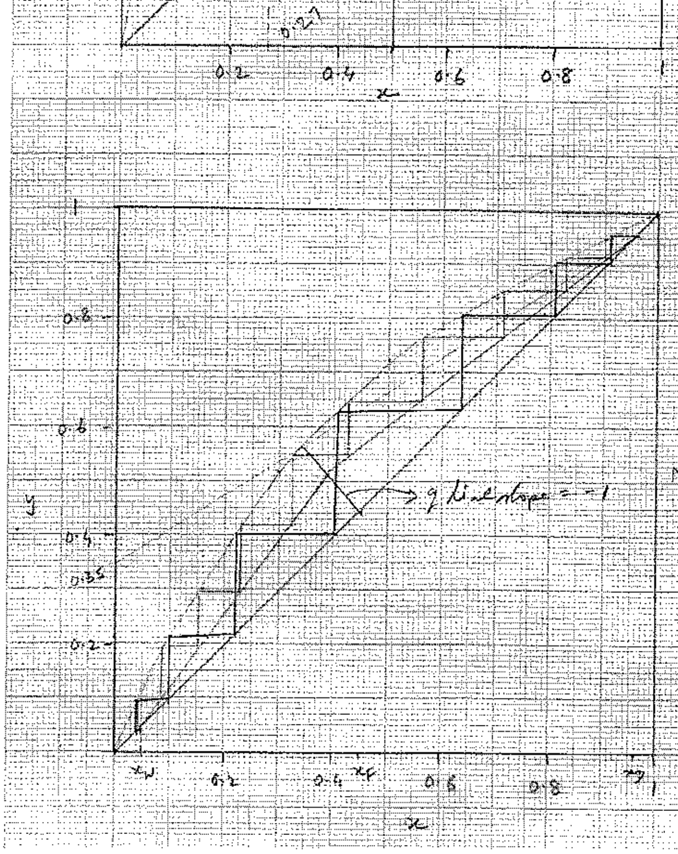
From the equ. Diagram, draw the line with following slope from the feed point.

[-W/D] = - 0.4/0.6 = 0.667

From the graph $x_W$ = 0.27; $y_D$ = 0.64 which is the required answer.




$$\frac{W}{D} = -\frac{0.4}{0.6} = -0.667$$




$$\frac{x_D}{R_{min}+1} = 0.35$$

$R_{min}$ 0.35 + 0.35 = 0.96

$R_{min}$ = 1.74 , No of plates = 9+1

Min no plates = 6+1 from graph.

$$N_{min} = \frac{\ln\left[\frac{0.96(0.95)}{0.05(0.04)}\right]}{\ln 2.2} - 1$$

$$= \frac{6.12}{\ln 2.2} - 1 = 6.7 \approx 7$$

=

## BITS, PILANI – DUBAI CAMPUS
### SECOND SEMESTER 2012 – 2013
### SECOND YEAR (Chemical)

Course Code: CHE F244 **TEST 1** Date: 18.03.13
Course Title: Separation Processes I Max Marks: 25
Duration : 50 minutes (Closed Book) Weightage: 25%

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1. An air-$NH_3$ mixture containing 5% $NH_3$ (MW: 17) by volume is absorbed in water using a packed tower at 20°C and 1 atm pressure to recover 98% $NH_3$. Gas flow rate is 1200 Kg/h $m^2$. Calculate

   (a) The molar total gas flow rate (4m)

   (b) The minimum water-to- $NH_3$ molar flow rate ratio. (7 m)

   (c) The maximum $NH_3$ concentration possible in the aqueous solution. (4 m)

Data for x-y at 20°C (in $NH_3$mole fractions):

| | | | | | |
|---|---|---|---|---|---|
| x | 0.0099 | 0.02 | 0.03 | 0.04 | 0.05 |
| y | 0.01146 | 0.02267 | 0.036 | 0.04434 | 0.0548 |

2. Oxygen is diffusing in a mixture of oxygen-nitrogen at 1 std. atm, 25°C. Concentration of oxygen at planes 2 mm apart is 10 and 20-volume % respectively. Nitrogen is non-diffusing. (5 + 5 =10 m)

   (i). Derive the appropriate expression to calculate the flux of oxygen. Define units of each term clearly.

   (ii). Calculate the flux of oxygen. Diffusivity of oxygen in nitrogen = 0.206 $cm^2\ s^{-1}$. (R = 8314 $m^3$ Pa/ mol K)

# BITS, PILANI – DUBAI CAMPUS
## SECOND SEMESTER 2012 – 2013
### SECOND YEAR (Chemical)

Course Code: CHE F244 | **TEST 1** | Date: 18.03.13
Course Title: Separation Processes I | Max Marks: 25
Duration : 50 minutes | (Closed Book) | Weightage: 25%

(Answering Scheme)

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1. An air-$NH_3$ mixture containing 5% $NH_3$ (MW: 17) by volume is absorbed in water using a packed tower at 20°C and 1 atm pressure to recover 98% $NH_3$. Gas flow rate is 1200 Kg/h m$^2$. Calculate
   (a) The molar total gas flow rate (4m)
   (b) The minimum water-to- $NH_3$ molar flow rate ratio. (7 m)
   (c) The maximum $NH_3$ concentration possible in the aqueous solution. (4 m)

   Data for x-y at 20°C (in $NH_3$mole fractions):

| | | | | | |
|---|---|---|---|---|---|
| x | 0.0099 | 0.02 | 0.03 | 0.04 | 0.05 |
| y | 0.01146 | 0.02267 | 0.036 | 0.04434 | 0.0548 |

a) $y_{N+1} = 0.05$; $x_o = X_o = 0$
$Y_{N+1} = 0.05/(1-0.05) = 0.0526$
Gas flow rate $G_{N+1} = 1200$ kg/h m$^2$
Avg Mol.Weight = $(0.05 \times 17) + (0.95 \times 29) = 28.4$
$G_{N+1} = 1200/28.4 = 42.25$ kmol/h m$^2$.
$Gs = G_{N+1}(1-y_{n+1}) = 42.25(1-0.05) = 40.1375$
$Y_1 = 0.02 \times 0.0526 = 0.001052$
$y_1 = 0.001052/(1-0.001052) = 0.00105$
$G_1 = Gs/(1-y_2) = 40.1375/(1-0.00105) = 40.179$ kmol/h m$^2$

$$\left(\frac{L_s}{G_s}\right)_{\min} = \left(\frac{Y_{N+1}-Y_1}{X_N - X_0}\right) = \frac{0.0526-0.001052}{X_N - 0}$$

| | | | | | |
|---|---|---|---|---|---|
| $X \times 10^{-3}$ | 10 | 20.4 | 30.9 | 41.66 | 52.63 |
| $Y \times 10^{-3}$ | 11.33 | 23.19 | 37.34 | 46.39 | 57.97 |

b,c) From graph (Ls/Gs) min = 1.074; $X_N = 45.5 \times 10^{-3}$,
WKT Gs = 40.1375
From the above equation Ls min = $40.1375 \times 1.074 = 43.1076$ kmol/hr m$^2$
The maximum $NH_3$ concentration possible in the aqueous solution = $45.5 \times 10^{-3}$

2. Oxygen is diffusing in a mixture of oxygen-nitrogen at 1 std. atm, 25°C. Concentration of oxygen at planes 2 mm apart is 10 and 20-volume % respectively. Nitrogen is non-diffusing. (5 + 5 m)
   (i). Derive the appropriate expression to calculate the flux of oxygen. Define units of each term clearly.
   (ii). Calculate the flux of oxygen. Diffusivity of oxygen in nitrogen = 0.206 cm$^2$ s$^{-1}$. (R = 8314 m$^3$ Pa/ mol K)

Derivation refer class notes ; $N_A = \dfrac{C\,D_{AB}}{Z_2 - Z_1}\ln\left(\dfrac{1-x_{A2}}{1-x_{A1}}\right)$

$D_{AB} = 0.206 \times 10^{-4}$ m$^2$/s Z = 2 mm = $2 \times 10^{-3}$ m
$C = P/RT = 1.013 \times 10^5 / 8314 \times 293 = 0.04158$ mol/m$^3$

$$N_A = \frac{0.04158 \times 0.206 \times 10^{-4}}{2 \times 10^{-3}} \ln\left(\frac{1-0.1}{1-0.2}\right) = 5.04 \times 10^{-5}\ kmol/m^2 s$$

# BITS, PILANI – DUBAI CAMPUS
## SECOND SEMESTER 2012 – 2013
## SECOND YEAR (Chemical)

Course Code: CHE F244 **QUIZ 2** Date: 22.04.13
Course Title: Separation Processes I Max Marks: 07
Duration : 20 minutes (Closed Book) Weightage: 07%
(Answering Scheme)

**Name: ............................ ID No: ...................... Sec / Prog: ...........**

1. Fenske equation determines the

   a) maximum number of ideal plates.
   b) height of the distillation column.
   c) **minimum number of theoretical plates.**
   d) optimum reflux ratio
   e) number of theoretical plates when feed at is boiling point.

2. Total reflux in a distillation operation requires minimum

   a) reboiler load
   b) **number of plates**
   c) condenser load
   d) all (a), (b) and (c)

3. In distillation, overhead product contains

   a) only one component
   b) two components
   c) **any number of components**
   d) only saturated liquid

4. Where in a distillation column is the temperature the lowest?
   a) At the bottom of the column, because the heat rises to the top due to natural convection of the hot gas flow.
   b) At the feed position, because the stream has to be cooled down before entering the column.
   c) There are no temperature differences over the whole column.
   **d) At the top of the column. In fact the more volatile components (lower boiling point) are withdrawn at the top of the column.**

5. What happens in a distillation column if the reflux ratio is zero?
   a) If no liquid is recycled back to the column, the internal liquid and vapour flow-rates can not be controlled and the design of the column gets more difficult.

   b) In this case a partial condenser should be used since we don't need any liquid for the recycle.

c) The entire product is withdrawn as Distillate and moreover we save the investment costs for recycle piping and pump. This is the best configuration possible for a distillation column.

**d) No liquid is recycled back to the column. Step by step the only vapour phase will be present in the rectification section and no mass transfer is possible anymore.**

6. The simplest case of batch distillation corresponds to the condensation of a vapor rising from a boiling liquid, called ________________
(**simple distillation**, complex distillation, flash distillation, fractional column distillation, equilibrium distillation)

7. Overall efficiency of the distillation column is
a) **the ratio of number of ideal plates to actual plates**.
b) the ratio of number of actual plates to ideal plates.
c) same as the Murphree efficiency.
d) always more than the point efficiency.

# BITS, PILANI – DUBAI CAMPUS

**SECOND SEMESTER 2012 – 2013**

**SECOND YEAR (Chemical)**

Course Code: CHE F244 **QUIZ 2** Date: 22.04.13

Course Title: Separation Processes I Max Marks: 07

Duration : 20 minutes (Closed Book) Weightage: 07%

**Name: ......................... ID No: ..................... Sec / Prog: ...........**

1. Fenske equation determines the

   a) maximum number of ideal plates.
   b) height of the distillation column.
   c) minimum number of theoretical plates.
   d) optimum reflux ratio
   e) number of theoretical plates when feed at is boiling point.

2. Total reflux in a distillation operation requires minimum

   a) reboiler load
   b) number of plates
   c) condenser load
   d) all (a), (b) and (c)
   e) none

3. In distillation, overhead product contains

   a) only one component
   b) two components
   c) any number of components
   d) only saturated liquid

4. Where in a distillation column is the temperature the lowest?

   a) At the bottom of the column, because the heat rises to the top due to natural convection of the hot gas flow.
   b) At the feed position, because the stream has to be cooled down before entering the column.
   c) There are no temperature differences over the whole column.
   d) At the top of the column.

5. What happens in a distillation column if the reflux ratio is zero?

   a) If no liquid is recycled back to the column, the internal liquid and vapour flow-rates can not be controlled and the design of the column gets more difficult.

   b) In this case a partial condenser should be used since we don't need any liquid for the recycle.

c) The entire product is withdrawn as Distillate and moreover we save the investment costs for recycle piping and pump. This is the best configuration possible for a distillation column.

d) No liquid is recycled back to the column. Step by step the only vapour phase will be present in the rectification section and no mass transfer is possible anymore.

6. The simplest case of batch distillation corresponds to the condensation of a vapor rising from a boiling liquid, called ____________________
(simple distillation, complex distillation, flash distillation, fractional column distillation, equilibrium distillation)

7. Overall efficiency of the distillation column is
a) the ratio of number of ideal plates to actual plates.
b) the ratio of number of actual plates to ideal plates.
c) same as the Murphree efficiency.
d) always more than the point efficiency.

# BITS, PILANI – DUBAI CAMPUS
## SECOND SEMESTER 2012 – 2013
### SECOND YEAR (Chemical)

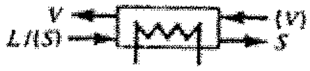
Course Code: CHE F244 | **QUIZ 1** | Date: 28.02.13
Course Title: Separation Processes I | Max Marks: 08
Duration : 20 minutes | (Closed Book) | Weightage: 08%

**Name:** .............................. **ID No:** ...................... **Sec / Prog:** ...........

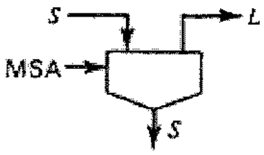
1. Explain how mass transfer diffusion occurs at the surface of the human lungs. (2 m)

2. Name the separation operation with an example for the following symbols: (2 m)

a)




b)




MSA: mass separating agent

3. Express Fick's law of diffusion in terms of mass density in the positive z direction. (1 m)

4. Match the ordinary molecular diffusion of a solute in various phases: (3 m)

| | |
|---|---|
| a) Gas | 1 $cm^2/g$ |
| b) Solid | $1\times 10^{-9}$ $cm^2/g$ |
| c) Liquid | $1\times 10^{5}$ $cm^2/g$ |
| | 0.10 $cm^2/g$ |
| | $1\times 10^{-5}$ $cm^2/g$ |
| | $1\times 10^{9}$ $cm^2/g$ |
| | 10 $cm^2/g$ |

# BITS, PILANI – DUBAI CAMPUS
## SECOND SEMESTER 2012 – 2013
### SECOND YEAR (Chemical)

Course Code: CHE F244 **QUIZ 1** Date: 28.02.13
Course Title: Separation Processes I Max Marks: 08
Duration : 20 minutes (Closed Book) Weightage: 08%
(Answering Scheme)

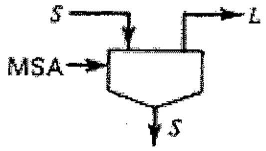
**Name:** . . . . . . . . . . . . . . . . . . . . . . . . . **ID No:** . . . . . . . . . . . . . . . . . . . . . **Sec / Prog:** . . . . . . . . . . .

1. Explain how mass transfer diffusion occurs at the surface of the human lungs. (2 m)

   At the surface of the lungs – oxygen (solute) from air diffuses to blood while inhaling, Carbon di oxide from blood diffuses to air stream while exhale

2. Name the separation operation with an example for the following symbols: (2 m)

   a) 
   
   Drying: removal of water from solid materials with hot air (Ex: removal of water from PVC with hot air in a fluid bed dryer)

   b) 
   
   Leaching : Extraction of solute from a solid using a solvent (Ex: Removal of oil from sunflower seeds using hexane as solvent)

   MSA: mass separating agent

3. Express Fick's law of diffusion in terms of mass density in the positive z direction. (1 m)

$$j_A = -\rho D_{AB} \frac{dw_A}{dz}$$

4. Match the ordinary molecular diffusion of a solute in various phases: (3 m)

| | |
|---|---|
| a) Gas | 0.10 $cm^2/g$ |
| b) Liquid | $1\times 10^{-5}$ $cm^2/g$ |
| c) Solid | $1\times 10^{-9}$ $cm^2/g$ |