

BITS, PILANI – DUBAI
FIRST SEMESTER 2009 – 2010
THIRD YEAR
COMPREHENSIVE EXAMINATION

Course Code: CHE C361

Date: 29.12.09

Course Title: Mass Transfer Operations

Max Marks: 80

Duration: 3 hr

(Closed Book)

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. Clearly show all calculation steps. Use graph sheets if needed.

1. (a) 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 = $1.89 \times 10^{-5} \text{ m}^2 \text{ s}^{-1}$.
- (b) Define the following (2 + 2 m)
- (i) Kremser Graph (ii) Stage efficiency
2. (a) A vent gas stream in a chemical plant is 15 wt% A; the rest is air. The local pollution authorities feel that A is a priority pollutant and require a maximum exit concentration of 0.5 wt %. It is decided to build an absorption tower using fresh water (on an A free basis) as the absorbent. The inlet water is pure and at 25°C. At 25°C, the laboratory has found that the equilibrium data can be approximated by $y = 0.5x$ (where y and x are mass fractions of A in vapour and liquid respectively) (6 + 6 m)
- (i) Find $(L/G)_{\min}$ (on an A free basis) 6 m
- (ii) With an $L/G = 1.5(L/G)_{\min}$, find the total number of equilibrium stages. 6 m
- (b) State Raoult's law and Henry's law. (4 m)
3. A liquid mixture containing 50 mol% n heptane (A), 50 mol% n-octane(B), at 30°C, is to be continuously flash vaporized at 1std atm pressure to vaporize 60 mol% of the feed. What will be the composition of the vapour and liquid and the temperature in the separator for an equilibrium stage? Given data: (P_A = Vapor pressure of A) (10 + 2 m)

t°C	98.4	105	110	115	120	125.6
P_A mmHg	760	940	1050	1200	1350	1540
P_B mmHg	333	417	484	561	650	760

4. A mixture of benzene and toluene containing 40 mole percent benzene is to be separated to give a product containing 90 mole percent benzene at the top and a bottom product containing not more than 10 mole percent benzene. The feed enters the column at its boiling point and the vapor leaving the column which is condensed and not cooled, provides the reflux and product. It is proposed to operate the unit with a reflux ratio of 3 kmol/kmol product. It is required to find the number of theoretical plates needed and position of entry for the feed using McCabe and Thiele method. (10 + 2 m)

x	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
y	0.21	0.37	0.51	0.64	0.72	0.79	0.86	0.91	0.96	0.98

5. (a) A methanol – water solution containing 50 mole percent methanol at 26.7°C is to be continuously rectified at 1 std atm pressure to provide a distillate containing 95 mole % methanol and a residue containing 1 mole % methanol. The average relative volatility is 2 for the above said system. Determine minimum number of plates using Fenske's equation and derive the required equation. (3 + 7 m)

- (b) What is the significance of reflux in distillation operation? (2 m)

6. 40 kg of solution containing 50% A (pyridine) in S (water) are to be extracted using 60 kg of L (chlorobenzene) in countercurrent operation. Determine the number of stages required to give a final raffinate of less than 1 % A from the following data. Deduce the required equation from mass balance. (12 + 2 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

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Course Title: Mass Transfer Operations
Duration : 50 minutes

TEST 2
(Open Book)

Date: 16.12.09
Max Marks: 20
Weightage:20%

Note : Permitted to use “only prescribed Text book and original hand written Notes” for the open book evaluation component. No photocopies of any sought shall be permitted.

1. Specify the condition of the feed, when the heat supplied in the reboiler is approximately equal to that removed in the condenser. (2 m)

2. 100 moles of a binary mixture F containing 60 mol% A (more volatile) and 40 mol% B is treated in a batch distillation still. After 1 hour, 70 moles of the distillate D is collected leaving behind the residue W. Relative volatility α is 2. The governing equation is

$$\log \frac{F x_F}{W x_w} = \alpha \log \frac{F(1-x_F)}{W(1-x_W)}$$

Determine the mole fraction of A in the distillate (5 m)

3. A tray tower is to be designed to continuously distill binary mixture of 54.5% benzene in chlorobenzene at its bubble point. The column is equipped with a partial reboiler and a total condenser, to give the product containing 90 mole percent benzene at the top. Sufficient heat is supplied to the reboiler to give $\bar{V}/F = 0.855$ and L/V in the top of the column is kept constant at 0.5. (10 m)

Equilibrium data are given below;

x	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
y	0.314	0.508	0.64	0.734	0.806	0.862	0.905	0.943

Determine

- a) Quality of bottom product (3 m)
b) Number of theoretical stages for the above said conditions by McCabe and Thiele method (4 m)
c) Number of theoretical stages at total reflux. (3 m)
4. Define Murphree and local efficiencies for the tray columns. (3 m)

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Duration : 50 minutes

TEST 1
(Closed Book)

Date: 01.11.09
Max Marks: 25
Weightage:25%

1. In a gas mixture of hydrogen and oxygen, steady state equimolar counter diffusion is occurring at a total pressure of 100 kPa and temperature of 20°C. If the partial pressures of oxygen at two planes 0.01 m apart, and perpendicular to the direction of diffusion are 15 kPa and 5 kPa, respectively and the mass diffusion flux of oxygen in the mixture is 1.6×10^{-5} kmole/m².s. Calculate the molecular diffusivity for the system. Derive the desired equation. (5 + 5 m)

2. Carbon disulphide is to be absorbed from a dilute gas mixture of CS₂ – N₂ into a pure nonvolatile oil at atmospheric pressure in a counter current absorber. The mole fraction of CS₂ in inlet gas stream is 0.05 and the flow rate of gas stream, G is 1500 kmol/hr. The equilibrium relation is given by; $y = 0.5x$, where x is the mole fraction of CS₂ in liquid stream. It is desired to reduce the mole fraction of CS₂ in the gas stream to 0.005.
 - (a). Calculate the minimum value of L/G, where L is the liquid flow rate in kmol/hr. (5 m)
 - (b). Derive the equation for the operating line if L/G is equal to 1.5 times the minimum values with substituting the given mole fractions. (5 m)

3. Define the absorption factor and discuss its significance. (2.5 + 2.5 m)

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QUIZ 2
(Closed Book)

Date: 09.12.09
Max Marks: 07
Weightage: 7%

Name: ID No: Sec / Prog:

1. If x_D is the mole fraction of the more volatile component in the overhead product and R is the reflux ratio, the intercept and slope of the enriching section operating line in a McCabe –Thiele diagram is
 - a) $x_D/(R+1)$ and $(R+1)/R$
 - b) $R/(R+1)$ and $x_D/(R+1)$
 - c) $x_D/(R+1)$ and $R/(R+1)$
 - d) $R/(x_D+1)$ and $x_D/(x_D+1)$

2. Fenske's equation is used to calculate number of plates in a distillation column
 - a) at total reflux
 - b) for system having constant relative volatility
 - c) at minimum reflux
 - d) for both (a) and (b)
 - e) none

3. In flash vaporization, the product vapor
 - a) is always in equilibrium with the liquid leaving the flash chamber
 - b) is never in equilibrium with the liquid leaving the flash chamber
 - c) may be in equilibrium with the liquid leaving the flash chamber and the extent of equilibration depends on the vapor – liquid contact time in the chamber
 - d) is 100% pure.
 - e) none

4. In the McCabe-Thiele diagram for binary distillation, vertical feed line represents _____ feed and horizontal feed line represents _____ feed.

5. Minimum number of ideal stages is required in a fractionating column when the reflux ratio is equal to,
- a) Minimum reflux ratio.
 - b) Optimum reflex ratio.
 - c) Zero
 - d) Infinity
 - e) One
 - f) None
6. The condition under which the operating lines for both stripping and rectifying sections coincide with the diagonal in McCabe-Thiele method is:
- a) 1.2 times minimum reflux
 - b) minimum reflux.
 - c) total reflux
 - d) no reflux
7. When feed to a distillation column is a mixture of 50% vapor and 50% liquid, determine the slope of the feed line.

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QUIZ 1
 (Closed Book)

Date: 14.10.09
 Max Marks: 08
 Weightage: 8%

Name: ID No: Sec / Prog:

1. Diffusivity of gases at atmospheric pressure in cm^2/s is in the range of (1 m)
 - a) greater than 1
 - b) less than 1
 - c) greater than 10
 - d) greater than 100
 - e) none

2. Diffusivity of a gas varies with temperature and pressure according to the relation (1 m)
 - a) $D = T^{1.5} / P^2$
 - b) $D = T / P^{1.5}$
 - c) $D = T^{1.5} / P$
 - d) none of the above

3. Diffusivity of liquids can be estimated by (1 m)
 - a) Hirschfelder-Bird-Spotz equation
 - b) Gilliland equation
 - c) Lewis relation
 - d) Wilke–Chang equation
 - e) none

4. Mass transfer coefficient is defined as (1 m)
 - a) Flux =(coefficient) / (concentration difference)
 - b) Flux =(coefficient) (concentration difference)
 - c) Flux =(concentration difference) / (coefficient)
 - d) none of these

5. Mole fraction, y , is related to the mole ratio, Y , by the relation (1 m)
 - a) $y = Y / 1 - Y$
 - b) $y = Y / 1 + Y$
 - c) $y = 1 - Y / 1 + Y$
 - d) $y = 1 - y / Y (1+Y)$

6. Draw graphs between concentration in phase R Vs concentration in phase E with operating lines for (a) steady state countercurrent process (solute transfer from R to E) (b) steady state co current process (solute transfer from E to R) (1.5 + 1.5 m)

