BITS, PILANI – DUBAI CAPUS

FIRST SEMESTER 2011 – 2012

THIRD YEAR

<u>COMPREHENSIVE EXAMINATION</u>

Course Code: CHE C361 — Date: 11.01.12

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

1.(a) Water in the bottom of a narrow metal tube is held at a constant temperature of 20°C. The total pressure of air (assume dry) is 1 atm and the temperature is 20°C. Water evaporates and diffuses through the air in the tube, and the diffusion path is 0.1524 m. Calculate the rate of evaporation at steady state in kg mol/s m^2. The diffusivity of water vapor at 20°C and 1 atm pressure is 0.25×10^{-4} m^2/s. The vapor pressure of water at 20°C is 17.54 mm Hg. Assume that the system is isothermal. (R = 0.08205 L atm/g mol K) (8 m)

1.(b) Derive the equations for molecular diffusion in gases for the following cases. Discuss its significance. (8 m)

i) Steady state diffusion A through nondiffusing B

ii) Steady state equimolal counterdiffusion

2.(a) A solvent-recovery plant consists of a plate-column absorber and a plate-column stripper. Ninety percent of the benzene (B) in the gas stream is recovered in the absorption column. Concentration of benzene in the inlet gas is 0.06 mol B/mol B-free gas. The oil entering the top of the absorber contains 0.01 mol B/mol pure oil. In the leaving liquid, X = 0.19 mol B/mol pure oil. Operating temperature is 25°C.

Open, superheated steam is used to strip benzene out of the benzene-rich oil at 110°C. Concentration of benzene in the oil = 0.19 and 0.01 (mole ratios) at inlet and outlet, respectively. Oil (pure)-to-steam (benzene-free) flow rate ratio = 2.0. Vapors are condensed, separated, and removed. MW oil = 200 MW benzene = 78 MW gas = 32

(13 m)

Calculate,

(i) The molar flow rate ratio of B-free oil to B-free gas in the absorber;(4 m)

(ii) The number of theoretical plates in the absorber; and (4m)

(iii) The minimum steam flow rate required to remove the benzene from 1 mol of oil under given terminal conditions, assuming an infinite-plates column (5m)

Equilibrium Data at Column Pressures		
X in oil	Y in gas, 25°C	Y in steam, 110°C
0	0	0
0.04	0.011	0.1
0.08	0.0215	0.21
0.12	0.032	0.33
0.16	0.042	0.47
0.20	0.0515	0.62
0.24	0.060	0.795
0.28	0.068	1.05

2.(b) Compare and discuss the packed and plate towers. (3 m)

3.(a) A mixture of 40 mol% carbon disulfide (CS_2) in carbon tetrachloride (CCl_4) is continuously distilled. The feed is 50% vaporized (q = 0.5). The top product from a total condenser is 95 mol% CS_2, and the bottoms product from a partial reboiler is a liquid of 5 mol% CS_2. (14 m)

Calculate graphically the minimum reflux, the minimum boilup ratio from the reboiler, $\overline{V}/B$ and the minimum number of stages (including reboiler). The vapor-liquid equilibrium data at column pressure for this mixture in terms of CS_2 mole fraction are

x	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
y	0.135	0.245	0.42	0.545	0.64	0.725	0.79	0.85	0.905	0.955

3.(b) Define minimum reflux ratio. (2 m)

4. A mixture of 100 kg mol which contains 60 mol' n-pentane (A) and 40 mol% n-heptane (B) is vaporized at 1 atm under differential conditions until 40 kg mol are distilled. Use following equilibrium data. (16 m)

x	1	0.867	0.594	0.398	0.254	0.145	0.059	0
y	1	0.984	0.925	0.836	0.701	0.521	0.271	0

a) What is the avg composition of the total vapor distilled and the composition of the remaining liquid? (8 m)

b) If this same vaporization is done in an equilibrium distillation and 40 kg mol are distilled, what is the composition of the vapor distilled and of the remaining liquid? (8 m)

5.(a) 40 kg of solution containing 45% A (acetone) in S (water) are to extracted using 60kg of L (1,1,2-trichloroethane) in countercurrent operation. Determine the number of stages required to give a final raffinate of less than 1 % A. (12 m)

Extract wt fraction			Raffinate wt fraction		
A	L	S	A	L	S
0.6	0.13	0.27	0.6	0.13	0.27
0.5	0.04	0.46	0.5	0.43	0.07
0.4	0.03	0.57	0.4	0.57	0.03
0.3	0.02	0.68	0.3	0.68	0.02
0.2	0.015	0.785	0.2	0.79	0.01
0.1	0.01	0.89	0.1	0.895	0.05

5.(b) Compare and discuss the LLE and distillation operations. (4 m)

BITS, PILANI – DUBAI
FIRST SEMESTER 2011 – 2012
THIRD YEAR

Course Code: CHE C361 **Test 2** Date: 18.12.11
Course Title: Mass Transfer Operations Max Marks: 20
Duration : 50 minutes (Open Book) Weightage: 20%

Note : Permitted to use "<u>only prescribed Text book and original hand written notes</u>" for the open book evaluation component. <u>No photocopies of any sought shall be permitted</u>.

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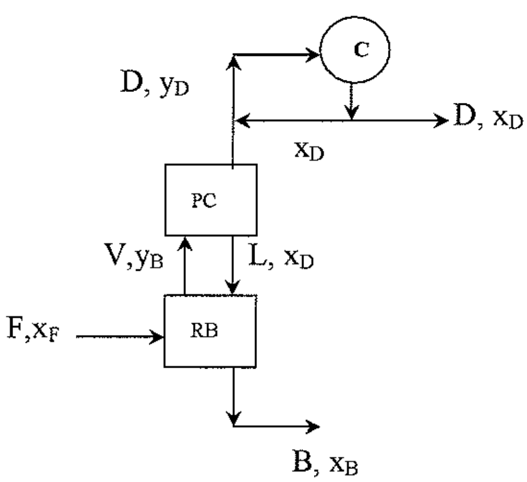
1. A saturated-liquid mixture of 69.4 mol% benzene (B) in toluene (T) is to be continuously distilled at atmospheric pressure to a produce distillate containing 90 mol% benzene, with a yield of 25 moles of distillate per 100 moles of feed. The feed is sent to, a steam heated still (reboiler), where residue is to be withdrawn continuously. The vapors from the still pass directly to a partial condenser. From a liquid separator following the condenser, reflux is returned to the still. Vapors from the separator, which is in equilibrium with the liquid reflux, are sent to a total condenser and are continuously withdrawn as distillate. At equilibrium the mole ratio of B to T in the vapor may be taken as 2.5 times the mole ratio of B to T in the liquid (relative volatility). Calculate analytically or graphically the total moles of vapor generated in the still per 100 mol of feed. (8 m)



PC: partial condenser, RB: Reboiler, C: Total condenser.

2. A mixture of benzene and toluene containing 45 mole % benzene is to be separated to give a overhead product of 95 mole % benzene and bottom product containing 5 mole % benzene. The fed is at its boiling point, and the vapor leaving the column is condensed but not cooled and provides reflux and products.

mole fraction of benzene in the vapor	0.9	0.77	0.632	0.486	0.261	0.039
mole fraction of benzene in the liquid	0.78	0.581	0.411	0.258	0.13	0.017

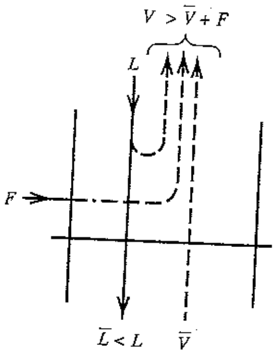
Using McCabe method, calculate:

a) Minimum reflux ratio (5 m)

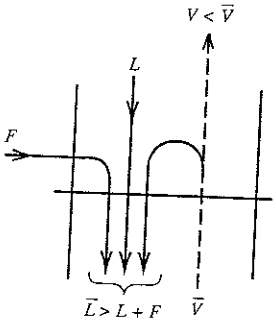
b) Number of theoretical plates required when total reflux is used (5 m)

3. Mention the type of the feed conditions from the following figures. (2 m)

a)



b)



BITS, PILANI – DUBAI
FIRST SEMESTER 2011 – 2012
THIRD YEAR
Test 1

Course Code: CHE C361
Course Title: Mass Transfer Operations
Duration : 50 minutes

(Closed Book)

Date: 23.10.11
Max Marks: 25
Weightage: 25%

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1. Sulphur dioxide (mw: 64) produced by the combustion of sulphur in air is absorbed in pure water. SO_2 is then recovered from the solution by steam stripping. The feed will be 5000 kg/h of gas containing 8 per cent v/v SO_2. The gas will be cooled to 20°C. A 95 per cent recovery of the sulphur dioxide is required. Equilibrium data for the above system at these conditions are:

SO_2	Percentage w/w solution	0.05	0.1	0.15	0.2	0.30	0.5	0.7	1.0	1.5
	Partial Pre. gas mm Hg	1.2	3.2	5.8	8.5	14.1	26	39	59	92

Calculate: (9 m)

(i) (L/G)min.

(ii) The number of equilibrium stages required using value of L/G of 1.5 times the minimum (3 m)

2. In petro chemical plant a gas containing 4% cyclo hexane and 96% inerts has to be treated with non absorption oil in packed tower. It is required to remove 98% of cyclo hexane of the feed gas. The feed is solvent free from cyclo hexane. If the feed gas rate is 80 mol/hr calculate the minimum solvent rate. The equilibrium relation is given as (12 m)

$$Y = \frac{0.2X}{1+0.8X}$$

3. Sketch the operating line for an absorber in terms of (0.5+ 0.5 m)
(a) mole fraction (x Vs y) (b) mole ratio (X Vs Y)

BITS, PILANI – DUBAI

FIRST SEMESTER 2011 – 2012

THIRD YEAR

Course Code: CHE C361 **QUIZ 2** Date: 07.12.11

Course Title: Mass Transfer Operations Max Marks: 07

Duration : 20 minutes (Closed Book) Weightage: 7%

Name: . . . . **ID No:** . . . . **Prog:** . . . .

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1. The relative volatility is defined as (1 m)

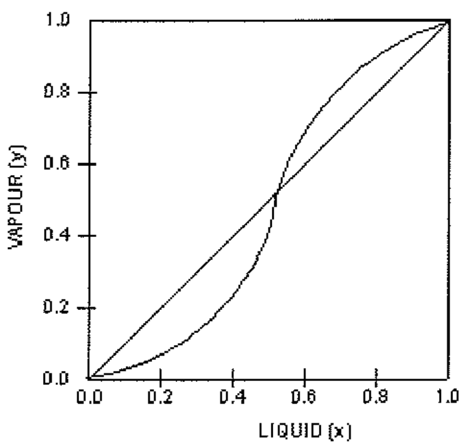
a) $\alpha = \dfrac{y^* /(1-x)}{x/(1-y^*)}$

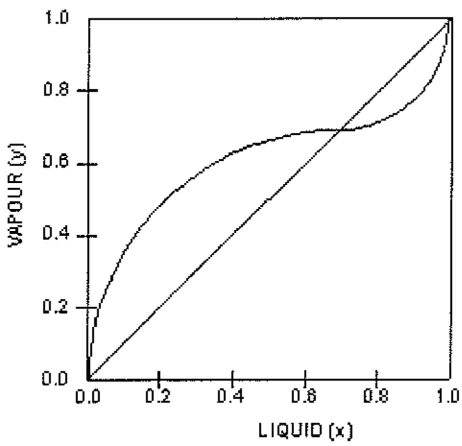
b) $\alpha = \dfrac{y^*(1-x)}{x(1-y^*)}$

c) $\alpha = \dfrac{y^* /(x-1)}{x/(y^*-1)}$

d) $\alpha = \dfrac{y^* /(x-1)}{x/(y^*-1)}$

2. The most intriguing VLE curves are generated by azeotropic systems. Name the categories of the two VLE plots shown below, which shows two different azeotropic systems. (2 m)





a) ____________________ b) ____________________

3. The following material balance equation is obtained for flash vaporization. (1 m)

a) $-\frac{W}{D}=\frac{y_D - z_F}{z_F - x_W}$ b) $\frac{D}{W}=\frac{x_W - z_F}{y_D - z_F}$

c) $-\frac{D}{W}=\frac{x_W - z_F}{y_D - z_F}$ d) $-\frac{W}{D}=\frac{x_W - z_F}{y_D - z_F}$

4. The Rayleigh equation is ___________ for simple distillation (1 m)

a) $-\int_F^W \frac{dL}{L}=\int_{x_W}^{x_F}\frac{dx}{y^* - x}$ b) $-\int_W^F \frac{dL}{L}=\int_{x_W}^{x_F}\frac{dx}{y^* - x}$

c) $\int_F^W \frac{dL}{L}=\int_{x_W}^{x_F}\frac{dy}{y^* - x}$ d) $\int_F^W \frac{dL}{L}=\int_{x_F}^{x_W}\frac{dx}{y^* - x}$

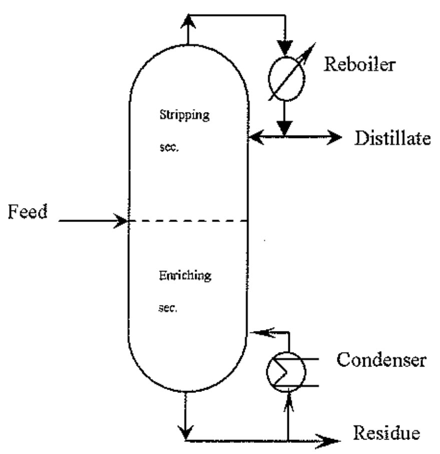
5. The Fenske equation is ___________ for total reflux (1 m)

a) $N_m + 1 = \frac{\log \frac{x_D}{1-x_D}\frac{1-x_W}{x_W}}{\log \alpha_{av}}$ b) $N_m + 1 = \frac{\log \frac{x_W}{1-x_W}\frac{1-x_D}{x_D}}{\log \alpha_{av}}$

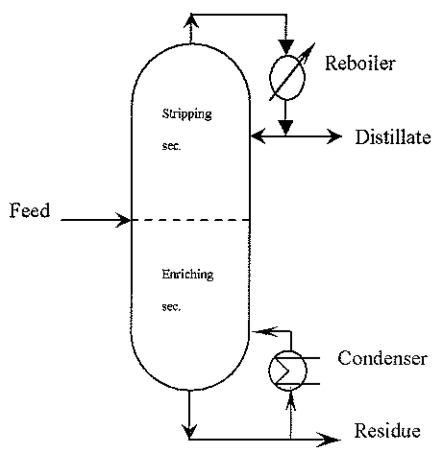
c) $N_m - 1 = \frac{\log \frac{x_D}{1-x_D}\frac{1-x_W}{x_W}}{\log \alpha_{av}}$ d) $N_m + 1 = \frac{\log \frac{x_D}{1+x_D}\frac{1+x_W}{x_W}}{\log \alpha_{av}}$

6. Choose the correct distillation column. (1 m)

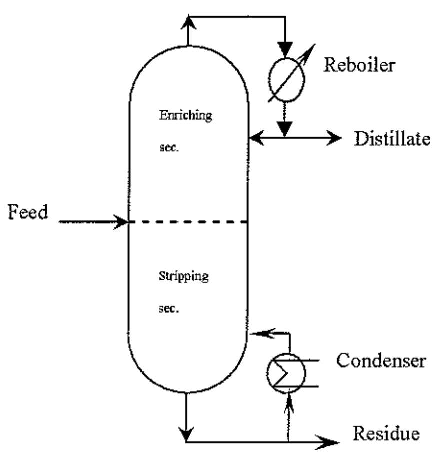
a)



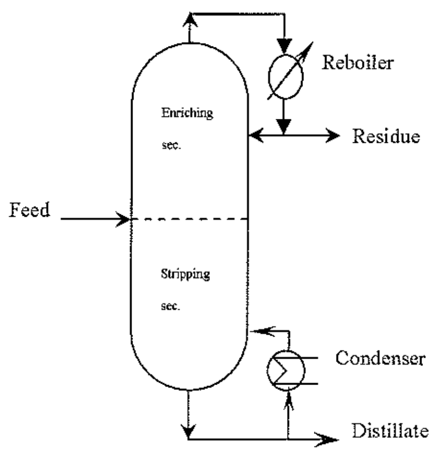
b)



c)



d)



BITS, PILANI – DUBAI

FIRST SEMESTER 2011 – 2012

THIRD YEAR

QUIZ 1

Course Code: CHE C361 | Date: 28.09.11

Course Title: Mass Transfer Operations | Max Marks: 08

Duration : 20 minutes | (Closed Book) | Weightage: 8%

Name: .... **ID No:** .... **Prog:** ....

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1. The diffusivity or diffusion coefficient for gases is aproperty of the system dependent upon ____________, __________________and ____________________(1.5 m)

2. Mention the two types fluxes which is used in mass transfer operations with its significance. (2 m)

3. Mention the difference between molecular diffusion and eddy diffusion. (2 m)

4. Derive an equation for the flux relative to a fixed location in space for the below said application.
If ammonia (A) were being absorbed from air (B) into water. In the gas phase, air does not dissolve appreciably in water, and neglect the evaporation of water, only ammonia diffuses. (2.5 m)