BITS, PILANI – DUBAI

FIRST SEMESTER 2010 – 2011

THIRD YEAR

COMPREHENSIVE EXAMINATION

Course Code: CHE C361 Date: 30.12.10

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) In an experiment to determine the diffusity of the gas chloropicrin –air, a vertical glass tube is filled with chloropicrin to a depth of 30 mm from the top end. After long time it was observed that the level of chloropicrin dropped to 58 mm from the top end. The total pressure on the system is 760 mm of Hg and the temperature is 25°C. the vapour pressure of chloropicrin at this temperature is 23.81 mm of Hg and its molar flux of 3.9×10^{-7} kmole/m^2 S. Assuming steady state evaporation of chloropicrin into air and neglecting counter diffusion of air, compute the diffusivity of the chloropicrin-air (cm^2/s).

Derive the required equation (5 + 3 m)

1.(b) Explain the following;

(i) Efficiency of tray towers

(ii) Efficiency of random packed towers

(iii) Efficiency of structured packing in towers ($3 \times 2 = 6$ m)

2.(a) 100 kmol/h of feed gas containing 85 mole % air and 15 mole % acetone. 95% of acetone vapor is to absorbed by counter current contact with pure water in a valve tray column. The column will operate essentially at 20°C and 101 kps. Equlibrium data for acetone at these conditions are

Y (moles acetone / moles air) $\times 10^3$	41	90	126	156.8
X (moles acetone / moles water) $\times 10^3$	34	77	132.5	206.3

Calculate:

(i) The minimum value of L/G., the ratio of moles of water per mole air. (6 m)

(ii) The number of equilibrium stages required using value of L/G of 1.25 times the minimum (6 m)

2.(b) Compare absorption, stripping and distillation. (4 m)

3.(a) A distillation column having 7 theoretical stages (6 in the column + reboiler) is being used to separate a saturated liquid feed containing 50 mol% A into a product stream containing 90 mol % A. the liquid to vapour molar ratio at the top plate is 0.75. The saturated liquid feed is introduced in the column. Determine

(i) the composition of the bottoms (x_W and W) ($4 \times 3 = 12$ m)

(ii) the $\frac{\bar{L}}{\bar{V}}$ ratio in the stripping section

(iii) Unbeknown to the operators, the bolts holding last plate rust through, and the plates fall into the still pot. If no adjustments are made, what is the new top and bottom composition? (Use separate plot to determine, $\frac{L}{V}=\frac{\bar{L}}{\bar{V}}=0.75$)

y	0.19	0.37	0.5	0.62	0.71	0.78	0.84	0.9	0.96
x	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9

3.(b) A liquid feed of benzene and toluene is being distilled in a tray tower. The number of theoretical steps needed is calculated as 7.6. The feed composition x_F = 0.45, x_D = 0.95, and x_w = 0.1 (the average temperature is 94.4°C). At 94.4°C the viscosity of benzene is 0.26cp , and of toluene 0.295 cp. Calculate tray tower efficiency and tower height, assuming a tray spacing T of 0.6 m and α_{avg} = 2.465. (6 m)

4.(a) Estimate the minimum equilibrium stages by the Fenske equation and the corresponding products from the following data. Derive the required equation. (9 + 4 m)

Component	$z_F F$	$x_w W$	$y_D D$	α_{40}	α_{120}
C_a	0.03	-	0.03	100	31.9
C_b	0.07	-	0.07	23.3	10.43
LK C_c	0.15	0.003	0.147	8.34	5
C_d	0.33	0.1994	0.13	2.78	2.19
HK C_e	0.3	0.297	0.003	1	1
C_f	0.12	0.12	-	0.415	0.521

4(b) Sketch the schemes for separation of ternary system. (3 m)

5.(a) Furfural (A) is to continuously extracted from a solution in water (S) by toluene (L) at 25°C in a an agitated vessel. The feed 40 kg of solution containing 50% A in water are to be extracted using 60 kg of toluene in countercurrent operation. Determine the number of stages required to give a final raffinate of less than 5 % A from the following data. (10 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) Explain in detail about its operation, uses and its limitations for the following extractors: (3 + 3 m)

(i) Any column extractor

(ii) Centrifugal extractor

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FIRST SEMESTER 2010 – 2011

THIRD YEAR

Course Code: CHE C361 **TEST 2** Date: 12.12.10

Course Title: Mass Transfer Operations Max Marks: 20

Duration : 50 minutes (Open Book) 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. A continuous distillation operation with a reflux ratio (L/D) of 3.5 yields a distillate containing 97wt% B (benzene, mw : 78.11) and bottoms containing 98 wt% T (toluene, mw: 92.13). Due to weld failures, the 10 plates in the bottom section of the column are ruined, but the 14 upper plates are intact. It is suggested that the column still be used, with feed (F) as saturated vapor at the dew point, with F = 13,600 kg/hr containing 40wt% B and 60 wt% T. Assuming that the plate efficiency remains unchanged at 50%

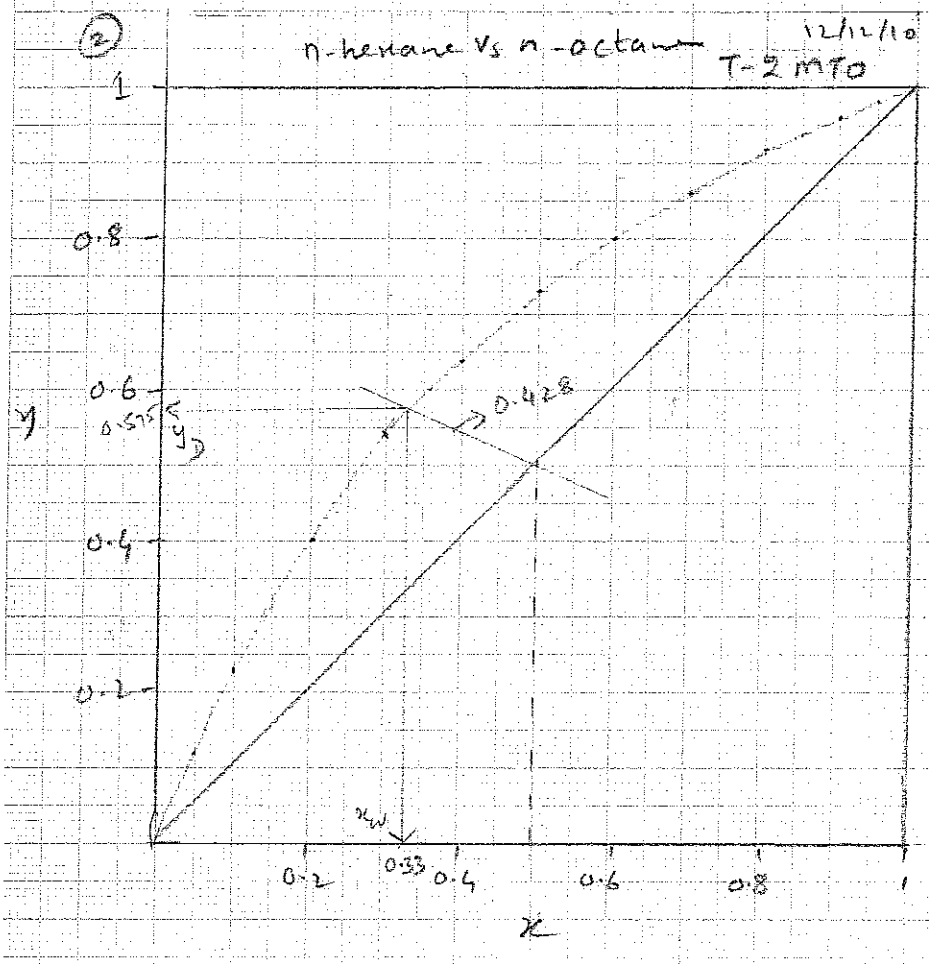
   a) Can this column still yield a distillate containing 97 wt% B (6 m)
   b) What will the composition of the residue (in kmol/hr) (2.5m)
   c) How much distillate can produce (in kg/hr) (1.5 m)

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

2. A liquid containing 50 mol% n hexane (A) and 50% n octane is continuously distilled in a single equilibrium stage unit at atmospheric pressure to vaporize 70 mol % of the feed. What will be the composition of the vapor and liquid in the separator? Assuming a constant relative volatility of 2.7. (7 m)

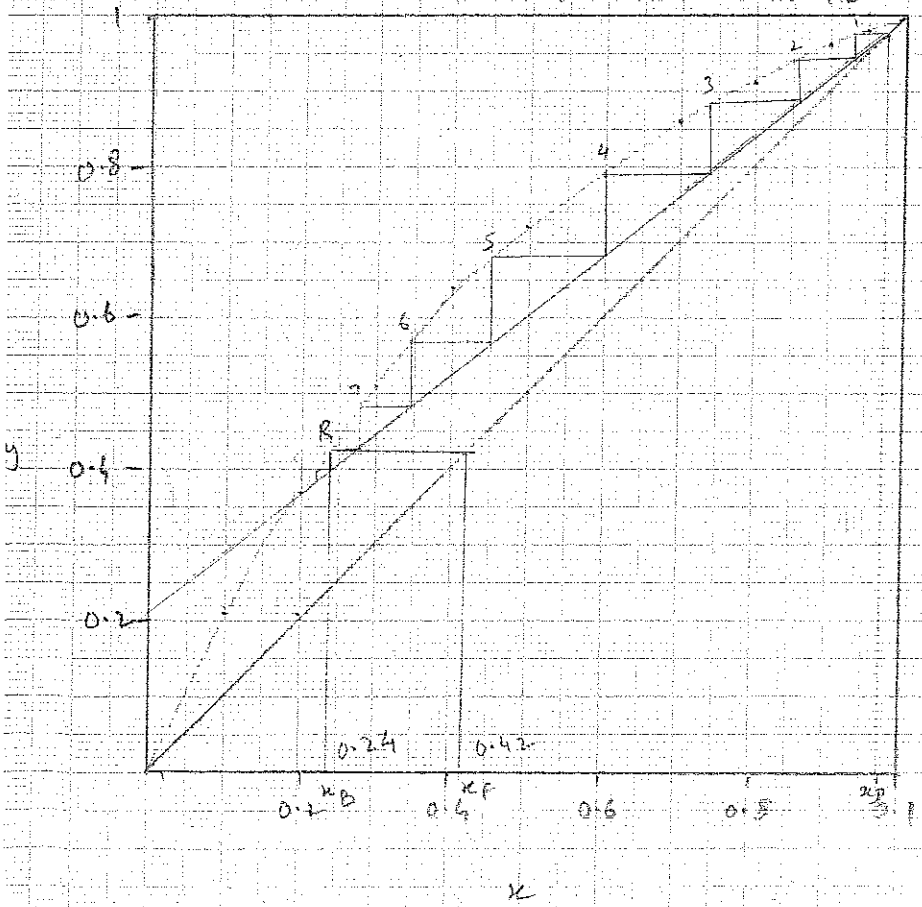
3. Explain azeotropic and extractive distillation with an example. (1.5 + 1.5 m)

② n-hexane Vs n-octane T-2 MTO 12/12/10



30/70 = 0.428 ملوب

① Benzene Vs Toulene T-2 MTO 12/12/10



BITS, PILANI – DUBAI

FIRST SEMESTER 2010 – 2011

THIRD YEAR

Course Code: CHE C361 **TEST 1** Date: 31.10.10

Course Title: Mass Transfer Operations Max Marks: 25

Duration : 50 minutes (Closed Book) Weightage:25%

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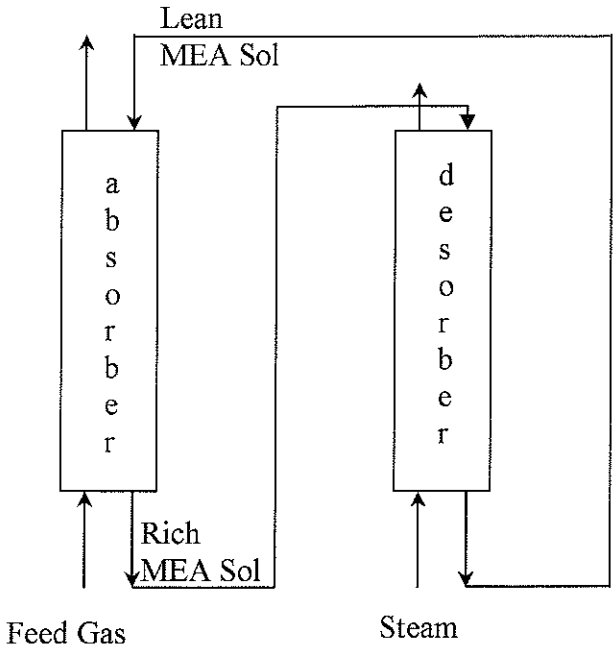
1. Some HCl gas diffuses across a film of air 0.1 in thick at 20°C. The partial pressure of HCl on one side of the film is 0.08 atm and it is zero on the other. Estimate the rate of diffusion, as mol HCl / sec cm^2, if the total pressure is 1 atm
   The diffusity of HCl in air at 20°C and 1 atm is 0.145 cm^2/sec
   Derive the required equation. (5 + 3 m)

2. A counter current plate absorber is to be installed for scrubbing of an air mixture containing 5% ammonia by volume. The scrubber is fed with water containing 0.002 mole NH_3 per mole of water. The scrubbing water flows at a rate of 1.0 mole water per mole air. It is necessary to absorb 85 percent of the ammonia present in the gas by operating the absorber at 200°C. Calculate the concentration of NH_3 in the outgoing liquid. (5 m)

3. Biogas, that is produced by the anaerobic fermentation of a biodegradable material like the cow dung, is a mixture of methane and CO_2. For enriching the biogas (i.e. for reducing its CO_2 content), the gas is scrubbed with 30% (weight) aqueous MEA (monoethanolamine) solution counter currently in a bubble cap tray tower at 25°C and 1 atm. The rich MEA solution discharged from the bottom of the absorber is stripped by steam and the resulting lean MEA solution is recycled back to the top of the absorber. The feed gas containing 30 % (by volume) CO_2 enters the absorption tower and its CO_2 content is to be reduced to 5%. The recycled lean MEA solution contains 0.058 moles of CO_2 per mole of solution. Assuming isothermal operation and neglecting the chemical reaction between CO_2 and MEA, compute
   a) The minimum liquid to gas ratio required (5 m)

b) The number of ideal trays if a liquid to gas ratio that is 1.2 times the minimum is being employed. (7 m)

Moles of CO_2 per mole of solution (x)	0.058	0.06	0.062	0.064	0.066	0.068	0.07
Partial pressure of CO_2, mm Hg	5.6	12.8	29	56	98.7	155	232



BITS, PILANI – DUBAI

FIRST SEMESTER 2010 – 2011

THIRD YEAR

Course Code: CHE C361 **QUIZ 2** Date: 22.11.10

Course Title: Mass Transfer Operations Max Marks: 07

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

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

Each question carries one mark

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1. What is the process used to separate the different components of oil?

   1) Deadly Distillation 2) Simple Distillation 3) Fractional Distillation

   4) Destructive Distillation

2. Which of these components of crude oil has the highest boiling point?

   1) bitumen 2) kerosene 3) petrol 4) diesel

3. Separation of components by distillation is not possible for

   1) $\alpha > 1$ 2) $\alpha < 1$ 3) $\alpha = 1$ 4) none

4. In batch distillation with constant reflux, the overhead product purity

   1) decreases with time 2) increases with time 3)does not vary with time

   4) none of the above

5. In flash vaporization, the product vapor

   1) is always in equilibrium with the liquid leaving the flash chamber

   2) is never in equilibrium with the liquid leaving the flash chamber

   3) may be in equilibrium with the liquid leaving the flash chamber and the extent of equilibriation depends on the vapor – liquid contact time in the chamber

   4) is 100% pure.

6. Fenske's equation is used to calculate number of plates in a distillation column

   1) at total reflux 2) for system having constant relative volatility 3) at minimum reflux 4) for both (1) and (2)

7. Azeotropic distillation is a special case of

1) molecular distillation 2) differential distillation 3) flash vaporization

4) multicomponent distillation

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FIRST SEMESTER 2010 – 2011

THIRD YEAR

Course Code: CHE C361 **QUIZ 1** Date: 06.10.10

Course Title: Mass Transfer Operations Max Marks: 08

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

Each question carries one mark (1Q to 6Q)

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

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1. The concentration can be defined as

   a) $C_A = \frac{P_A}{RT}$ b) $C_A = \frac{\rho_A}{M_A}$ c) $C_A \neq \frac{P}{RT}$ d) all of the above

2. Diffusivity of liquids in cm^2/s is of the order of

   a) 0.1 b) 0.01 c) 10 d) 1×10^{-5}

3. Diffusivity of liquids varies with temperature according to the relation,

   a) $D \propto T^{1.75}$ b) $D \propto T^{0.75}$ c) $D \propto T$ d) $D \propto T^{1.5}$

4. The equilibrium relation for distribution of a solute between a gas and liquid phase is given by $y = mx$ (at a particular temperature). If k_y and k_x are individual gas and liquid phase mass transfer coefficients, respectively, the overall gas phase mass transfer coefficients is given by the relation,

   a) $1 / K_y = 1 / k_y + m / k_x$

   b) $1 / K_y = m / k_y + 1 / k_x$

   c) $1 / K_y = 1 / mk_y + 1 / k_x$

   d) $1 / K_y = 1 / k_y + 1 / mk_x$

5. Knudsen diffusivity is

   a) directly proportional to total pressure

   b) inversely proportional to total pressure

   c) independent of total pressure

   d) directly proportional to the square root of total pressure

6. A good solvent for a gas absorption should have

a) high vapor pressure and low viscosity

b) high vapor pressure and high viscosity

c) low vapor pressure and low viscosity

d) low vapor pressure and high viscosity

7. A binary gaseous mixture of components A and B at a pressure of 1 bar and temperature of 300K undergoes steady state equimolar counterdiffsuin along a 1 mm thick diffusion path. At one end of the path the mole fraction of component A is 70%, while at the other end it is 20%. Under these conditions, $D_{AB} = 0.1$ cm^2/s. Calculate the molar flux of component A. (2 m)