BITS, PILANI – DUBAI CAMPUS

FIRST SEMESTER 2012 – 2013

THIRD YEAR (Chemical)

Course Code: CHE C361 **COMPREHENSIVE EXAMINATION** Date: 08.01.13

Course Title: Mass Transfer Operations (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.

1.(a) A crystal of copper sulphate $CuSO_4.5H_2O$ falls through a large tank of pure water at 0°C. Estimate the rate at which the crystal dissolves by calculating the flux of $CuSO_4$ from the crystal surface to the bulk solution. Molecular diffusion occurs through a film of water uniformly 0.0305 mm thick surrounding the crystal. At the inner side of the film, adjacent to the crystal surface, the concentration of $CuSO_4$ (MW:160) is 0.0229 mole fraction $CuSO_4$ (solution density = 1193 kg/m^3). The outer surface of the film is pure water. The diffusivity of $CuSO_4$ is 7.29×10^{-10} m^2/s. Assume water is non diffusing. (8 m)

1.(b) Derive equations for steady state cocurrent process and counter current process, where the transfer of solute from R to E phase. (8 m)

2.(a) An air-C_6H_6 mixture containing 5% benzene enters a countercurrent absorption tower where it is absorbed with pure hydrocarbon oil Gs = 600 kmol/h. The solubility follows Raoult's law. Temperature at 26.7° C and 1 atm pressure are the operating conditions. The average molecular weight of oil is 200. The equilibrium equation is y* = 0.1355 x. Find: (6.5 × 2 = 13 m)

i) Ls_{min} to recover 90 % of entering C_6H_6

ii) The number of theoretical stages if 1.5 times the minimum liquid rate used.

2.(b) Discuss the significance of $(Ls/Gs)_{min}$ in absorption operations. (3 m)

3.(a) An equimolar mixture of A and B (A being more volatile) is flash distilled continuously at a feed rate of 100 kmol/h, such that the liquid product contains 40 mol % of A. If the relative volatility is 6, determine the vapor product (kmol/h). (6 m)

3.(b) A charge of 50 kmol of a mixture of benzene (A) and chlorobenzene (B) having 55 mol% of the less volatile is to be batch-distilled. The relative volatility of benzene in the mixture is 4.15 (5 + 5 = 10 m)

i) If 25 moles of the solution is vaporized and condensed as the distillate, calculate the concentration of the accumulated distillate.

ii) If the concentration of the accumulated product is found to be 72 mol % benzene (with same feed conditions), calculate its amount.

4.(a) A stream of aqueous methanol having 45 mol % CH_3OH is to be separated into a top product having 96 mol% methanol and a bottom liquid with 4 mol% methanol. The feed at its bubble point and the operating pressure is 101.3 kPa. A reflux ratio of 1.5 is suggested (4 × 3 = 12 m)

i) Determine the number of ideal trays

ii) Find the number of real trays if the overall efficiency is 40%. On which real tray should the feed to be introduced?

iii) Determine the temperature for first, last and feed trays for the ideal system.

x	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95	1
y	0.418	0.579	0.665	0.729	0.779	0.825	0.87	0.915	0.958	0.979	1
temp °C	87.7	84.4	78	75.3	73.1	71.2	69.3	67.6	66	65	64.5

4.(b) A mixture of benzene and toluene having 40% benzene is to be separated at the rate of 200 kmol/h into a top product containing 95% benzene and a bottom product with 4% of it. It is a common practice to run a column at total reflux for some time for the purpose of stabilization during startup. Determine the number of ideal trays required for this separation if the column is operated at total reflux using Fenske equation. Assume α =2.5. (4 m)

5.(a) One thousand kilograms of an aqueous solution containing 50% acetone (A) is contacted with 800 kg of pure chlorobenzene (L) in a simple multiple contact extraction unit at 25°C. Determine the number of stages required to give a final raffinate of less than 25 % A from the following data. (10 m)

Extract%			Raffinate %		
A	L	S	A	L	S
0	99.82	0.18	0	0.11	99.89
10.79	88.72	0.49	10	0.21	89.79
22.23	76.98	0.79	20	0.31	79.69
37.48	60.8	1.72	30	0.58	69.42
49.44	47.51	3.05	40	1.36	58.64
59.19	33.57	7.24	50	3.72	46.28
61.07	15.08	23.85	60	12.59	27.41
60.58	13.76	25.66	60.58	13.76	25.66

5.(b) Explain in detail about any two extractors operation, uses and its limitations (6 m)

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THIRD YEAR (Chemical)

Course Code: CHE C361 — **TEST 2** — Date: 13.12.12

Course Title: Mass Transfer Operations — 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

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1. A distillation unit consists of a partial reboiler, a bubble-cap column, and a total condenser. The overall plate efficiency is 65%. The feed is a liquid mixture, at its bubble point, consisting of 50 mol% benzene (MW: 78.11) in toluene (MW: 92.14). This liquid is fed to the optimal plate. The column is to produce a distillate containing 95 mol% benzene and bottoms of 95 mol % toluene. (4 ×4 = 16 m)

Calculate for an operating pressure of 1 atm:

(a) Minimum reflux ratio $(L/D)_{min}$ (from graph)

(b) Minimum number of actual plates to carry out the desired separation, (from graph)

(c) Using a reflux ratio (L/D) of 50% more than the minimum, the number of actual plates needed, (from graph)

(d) The kilograms per hour of product and residue, if the feed is 907.3 kg/h,

Equilibrium data in mole fraction benzene-toluene system, 1 atm

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. Define the following terms which used in distillation operations: (2 ×2 = 4 m)

a) Cold reflux

b) Entrainer

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Course Code: CHE C361 | **TEST 1** | Date: 21.10.12

Course Title: Mass Transfer Operations | Max Marks: 25

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

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1. Exit gas from a chlorinator consists of a mixture of 20 mol% chlorine in air. This concentration is to be reduced to 1% chlorine by water absorption in a packed column to operate isothermally at 20°C and atmospheric pressure. Using the following equilibrium x-y data, calculate for 100 k mol/h of feed gas: (12 m)

(a) The minimum water rate in kilograms per hour. 7 m

(b) Number of equilibrium stages for twice the minimum water rate. 5 m

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

x	0.0001	0.00015	0.0002	0.00025	0.0003	0.00045	0.000576	0.000695
y	0.006	0.012	0.024	0.04	0.06	0.132	0.197	0.263

2. You are asked to design a packed column to recover acetone from air continuously, by absorption with water at 60°F. The air contains 3 mol% acetone, and a 97% recovery is desired. The gas flow rate is 8 kmol/hr at 60°F, 1 atm. It may be assumed that in the range of operation, $Y^* = 1.75X$, where Y and X are mole ratios for acetone. Calculate: (11 m)

(a) The minimum water-to-air molar flow rate ratio. (7 m)

(b) The maximum acetone concentration possible in the aqueous solution. (4 m)

3. Sketch the operating and equilibrium lines for a stripper in terms of (1+ 1 m)
(a) mole fraction (x Vs y) (b) mole ratio (X Vs Y)

Acetone in entering liquid = 0.

Acetone in existing liquid = 0.24 - 7.2× 10^{-3} = 0.2328 kmol/hr

Y_1 = 3/9 = 0.03, Y_2 = 7.2× 10^{-3}/7.76 = 9.27 × 10^{-4} kmole of acetone/kmole of air,

X_1 = 0.03/1.75 = 17.14× 10^{-3}

$$\left(\frac{L_s}{G_s}\right)_{min} = \left(\frac{Y_1 - Y_2}{X_1 - X_2}\right) = \frac{0.03 - 9.27\times10^{-4}}{0.01714 - 0} = 1.69$$

b) X_1 = 17.14× 10^{-3}; mole fraction $x_1 = X_1/(1+X_1)$ = 16.85 × 10^{-3}

3. Sketch the operating and equilibrium lines for a stripper in terms of (a) mole fraction (x Vs y) (b) mole ratio (X Vs Y) (1+ 1 m)

Refer class notes

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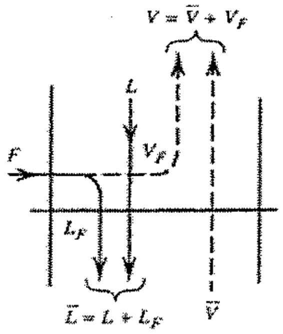
Course Code: CHE C361 — **QUIZ 2** — Date: 27.11.12
Course Title: Mass Transfer Operations — Max Marks: 07
Duration : 20 minutes — (Closed Book) — Weightage: 07%

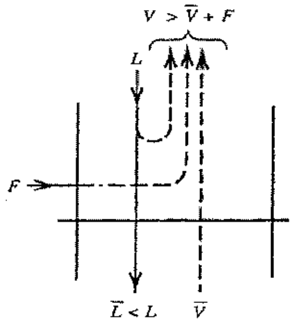
Name: .... **ID No:** .... **Sec / Prog:** ....

1. State the situation when equilibrium distillation becomes differential distillation. (1 m)
2. Sketch the vapor liquid compositions on a sieve tray. (1 m)
3. Define a theoretical stage in distillation. (1 m)
4. Specify the possible feed conditions for the following figures: (2 m)

a)



b)



5. In batch distillation with constant reflux, the overhead product purity (1 m)

   a. decreases with time
   b. increases with time
   c. does not vary with time
   d. can't predict
   e. decreases, then increases
   f. parabola profile
   g. none of the above

6. At total reflux the reflux ratio is (1 m)

   a. zero
   b. one
   c. infinite
   d. neither zero nor one, but finite
   e. 1.1
   f. None
   g. 1.2
   h. 1.5

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

Course Code: CHE C361 **QUIZ 1** Date: 09.10.12
Course Title: Mass Transfer Operations Max Marks: 08
Duration : 20 minutes (Closed Book) Weightage: 08%

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

1. Virtually mass transfer operations are used for the
a) separation of products from its by-products
b) purification of raw materials
c) both a and b
d) none
e) producing a new product by a reaction
f) producing a new product by absorption

2. For steady state molecular diffusion a gas A through non-diffusing B, the ratio $N_A/(N_A + N_B)$ is
a) 0
b) 0.1
c) ½
d) ∞
e) 2
f) none
g) 0.2

3. The unit of mass transfer coefficient could be
a) moles transferred /Time(area)(pressure)
b) a, c and d
c) moles transferred/Time(area)(mole fraction)
d) mole transferred/Time(area)(concentration)
e) area/time
f) none
g) c and d only

4. Name the separation process for the following (1 × 5 = 5 m)
a) Removal of SO_2 from natural gas using zeolities -
b) Removal of H_2S from natural gas using alkali solution -
c) Removal of volatile substances from wastewater by steam -
d) Production of salt -
e) Desalination of water –