

BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI

FIRST SEMESTER 2007-2008

CHE UC361 Mass Transfer Operations

Comprehensive Examination (Closed Book)

DATE: 07.01.2008

DURATION: 3 hours

MAXIMUM MARKS: 120

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.

Attempt questions from each section in different answer sheets.

Section - 1

Give brief and to-the-point answers to following questions. Answer all the parts sequentially.

[35 marks]

1. What is meant by equimolar counterdiffusion? In what separation operation is it closely approached? [3]
2. For a binary mixture, under what conditions is the diffusivity of A in B equal to the diffusivity of B in A, independent of composition? [3]
3. What is the q -line on a y - x phase equilibrium diagram? [3]
4. Can absorption be accompanied by a temperature change? Why? [3]
5. On a Y - X plot for an absorber, is the operating line above or below the equilibrium curve? Explain. [3]
6. When should the use of an algebraic method, rather than a graphical method be considered for determining stage requirements for an absorber or stripper? [3]
7. How is q related to the feed condition? What are the five possible feed conditions? [6]
8. Starting with the relationship

$$N_A = \frac{N_A}{(N_A + N_B)} \frac{D_{AB} P_t}{RTz} \ln \frac{N_A / (N_A + N_B) - y_{A2}}{N_A / (N_A + N_B) - y_{A1}}$$

derive to show that for the steady state diffusion of gas A through non-diffusing

gas B, $N_A = \frac{D_{AB} P_t}{RTz \bar{p}_{B,M}} (\bar{p}_{A1} - \bar{p}_{A2})$ [6]

9. In a conventional distillation column with reflux, what are the directions of (i) net flow of heat, (ii) net flow of the more volatile component, and (iii) net flow of the less volatile component? [3]
10. How an equilibrium stage is defined in case of solid-liquid extraction? [2]

Section – 2

Solve following questions, clearly showing each step in calculation, and mention all the assumptions you make. [85 marks]

1. A chalcocite ore was carefully roasted to convert CuS_2 to CuSO_4 . The roasted ore containing 10% CuSO_4 and 90% gangue material was extracted with water in an extraction unit. Quantity of water used in each stage is 15 times the weight of CuSO_4 in the feed (ore). The weight of solution carried out in the underflow is equal to the weight of gangue. Calculate graphically the percentage recovery after 3 stages in a cross-current operation. [20]
2. A liquid mixture containing 30 mol% benzene and 70 mol% toluene at 40 °C and 1 atm pressure is subjected to differential distillation with 80 mol% of the feed distilled. Calculate the composition of the composited distillate and the residue, if the relative volatility of benzene to toluene is 1.9. [10]
3. The exit gas from an alcohol fermenter consists of an air- CO_2 mixture containing 10 mol% CO_2 that is to be absorbed in a 5.0-N solution of triethanolamine, containing 0.04 mole of CO_2 per mole of amine solution. If the column operates isothermally at 25 °C, if the exit solution contains 78.4% of the CO_2 in the feed gas to the absorber, and if the absorption is carried out in a six-theoretical-plate column, calculate: (a) moles of amine solution required per mole of feed gas, and (b) exit gas composition. [15]

Equilibrium Data:

Y	0.003	0.008	0.015	0.023	0.032	0.043	0.055	0.068	0.083	0.099	0.12
X	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11

4. Liquid mixture containing 25 mol% benzene and 75 mol% ethyl alcohol, in which components are miscible in all proportions, is heated at a constant pressure of 1 atm from a temperature of 60 °C to 90 °C. Using following T-x-y experimental data, prepare a T-x-y diagram and find out the composition of the residual liquid when 25 mol% has evaporated. Assume that all vapor formed is retained within the apparatus and that it is completely mixed and in equilibrium with the residual liquid. Also find out azeotropic composition and temperature at this pressure.

[5+5+3+2=15]

Temperature, °C	78.4	77.5	75	72.5	70	68.5	67.7	68.5	72.5	75	77.5	80.1
Mole percent benzene in vapor	0	7.5	28	42	54	60	68	73	82	88	95	100
Mole percent benzene in liquid	0	1.5	5	12	22	31	68	81	91	95	98	100

5. A solution of carbon tetrachloride (mol. Wt. 154) and carbon disulphide (mol. Wt. 76) containing 60 wt% CCl_4 and 40 wt% CS_2 is to be continuously fractionated at standard atmospheric pressure at the rate 4000 kg/h. The distillate product is to contain 90 wt% CS_2 and residue no more than 2.5 wt% CS_2 . The feed will be 40 mol% vaporized before it enters the tower. A total condenser will be used and reflux will be returned at the bubble point. The equilibrium data in terms of mole fraction CS_2 are given below:

x	0	0.03	0.06	0.11	0.14	0.26	0.39	0.53	0.66	0.75	0.86	1.0
y*	0	0.08	0.155	0.26	0.33	0.50	0.63	0.74	0.83	0.87	0.93	1.0

Determine the top and bottom product rates (in kg/h), minimum reflux ratio and number of theoretical stages required at a reflux ratio equal to 1.5 times the minimum and the position of the feed plate. [25]

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FIRST SEMESTER 2007-2008**

CHE UC361 Mass Transfer Operations

**Test - 2
(Open Book)**

DURATION: 50 MINUTES

**DATE: 09.11.2007
MAXIMUM MARKS: 45**

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.

1. A binary mixture of benzene (A) and toluene (B) containing 60 mol% benzene is to be distilled at 1 std atm pressure to vaporize 80% of the feed. Estimate the composition of the distillate obtained, if the distillation is carried out by
 - a) Equilibrium flash vaporization, [10]
 - b) Differential distillation collecting all the distillate together. [20]

2. a liquid mixture containing 25 mol% benzene and 75 mol% ethyl alcohol, in which components are miscible in all proportions, is heated at a constant pressure of 1 atm from a temperature of 60 °C to 72 °C. Using following T-x-y experimental data, find out: [15]
 - a) At what temperature does the vaporization begin?
 - b) What is the composition of the first bubble of equilibrium vapor formed?

Temperature, °C	78.4	77.5	75	72.5	70	68.5	67.7	68.5	72.5
Mole percent benzene in vapor	0	7.5	28	42	54	60	68	73	82
Mole percent benzene in liquid	0	1.5	5	12	22	31	68	81	91

BITS, PILANI-DUBAI CAMPUS, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2007-2008
CHE UC361 Mass-Transfer Operations

TEST - 1
(Closed Book)

DURATION: 50 MINUTES

DATE: 28.10.2007
MAXIMUM MARKS: 75

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.

Question 1: [Total marks = 55]

The equilibrium adsorption of benzene vapor from a mixture of benzene vapor and nitrogen on a certain activated charcoal at 33.3 °C is reported as follows:

Benzene vapor absorbed, cm ³ (STP)/ g charcoal	65	80	90	100
Partial pressure benzene, mm Hg	0.251	1.00	2.81	7.82

- a) Define "phase E" and "phase R" for this system. [02]
- b) Plot equilibrium data as $X = \text{g mol benzene/ kg charcoal}$ and $Y = \text{g mol benzene/ kg mol nitrogen}$. [16]
- c) A nitrogen-benzene vapor mixture containing 1.0% benzene by volume is to be passed counter-currently at the rate $4.72 \times 10^{-2} \text{ m}^3/\text{s}$ to a moving stream of activated charcoal so as to remove 90% of the benzene from the gas in a continuous process. The entering charcoal contains 65 cm³ benzene vapor (at STP) adsorbed per gram charcoal. The temperature and total pressure are to be maintained at 33.3 °C and 1 std atm, respectively, throughout. Nitrogen is not adsorbed. What is the minimum amount of charcoal which can be used per second? [22]
- d) If charcoal used is twice as that of the minimum amount, what will be the concentration of benzene adsorbed upon the charcoal leaving? To how many equilibrium stages will the process be equivalent? [15]

Question 2: [Total marks = 20]

- a) What do you understand by "stage" as used in mass-transfer? [05]
- b) Discuss the various properties which have important consideration in choice of solvent for absorption. [15]

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