BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI

Second Semester 2012-2013
CHE F244 Separation Processes-I
Mid-Semester Examination

Date: 26.02.2013 **Time: 2:00-3:30 PM** **Maximum Marks: 100**

Note: The question paper consists of two parts. Answer **Part A** and **Part B** in separate answer books. Collect answer book for **Part B** after submitting **Part A** answer book.

PART – A (Closed Book)

Time: 2:00 – 2.20 P.M.

Marks: 20

1. (2 Marks) What are the five general separation techniques and what do they all have in common?
2. (2 Marks) Why is mass transfer a major factor in separation processes? What limits the extent to which the separation of a mixture can be achieved?
3. (2 Marks) List at least five property differences that can be exploited to develop a separation process.
4. (2 Marks) What are the two agents that can be used to create a second phase in the separation of a chemical mixture? Which is the most common?
5. (2 Marks) How does the mechanism of separation for a microporous membrane differ from that of a nonporous membrane?
6. (2 Marks) What is osmosis? Why can't it be used to separate a liquid mixture?
7. (2 Marks) How do reverse osmosis and dialysis differ? What do they have in common?
8. (3 Marks) Give examples for separation through effusion, liquid permeation, dialysis and reverse osmosis.
9. (3 Marks) Define split fraction (SF), split ratio (SR) and separation power (SP).

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PART – B (Open Book)

Time: 2:20 – 3:30 P.M. **Marks: 80**

Note: Only Text Book and hand-written Class Notes are allowed. Photocopy (Xerox) of Text Book or Class Notes are not allowed.

1. (20 *Marks*)

Unimolar diffusion can be used to estimate the binary diffusivity of a binary gas pair. Consider the evaporation of CCl_4 (A) into a tube containing O_2 (B). The distance between the CCl_4 level and the top of the tube is 16.5 cm. The total pressure in the system is 760 mm Hg and the temperature -5°C. The vapor pressure of CCl_4 at that temperature is 29.5 mm Hg. The area of diffusion path in the diffusion tube may be taken as 0.80 cm^2. Determine the binary diffusivity, D_{AB}, in cm^2/s, when in an 11-hour period after steady state 0.026 cm^3 of CCl_4 is evaporated.

2. (30 *Marks*)
In a distillation operation, one of the components transfers from a binary vapor mixture of A+B into the liquid, during which other component transfers from liquid to vapor. At one section of the equipment, the mole fractions of component A in liquid and vapor are measured as 0.25 and 0.32 respectively.
a) Obtain the interfacial concentrations and the overall mass transfer coefficients based on overall gas and liquid films.b) Calculate the percentage resistances in liquid and vapor phases and the molar flux of A based on overall gas and liquid films.

The individual mass transfer coefficients for liquid and vapor phases were calculated at the operating conditions from the appropriate correlations as:

$$k_x' = 3\times10^{-4}\,kmol/m^2s \qquad k_y' = 1.5\times10^{-4}\,kmol/m^2s$$

The equilibrium relationship within the operating range is linear and expressed as y =1.8 x, where y and x are the mole fractions of component A in vapor and liquid respectively.

3. (30 *Marks*)

A 150 kmol/h gas consisting of ammonia (A) and air (C) will be washed with water (S) in a plate column operating at 20°C and 800 mmHg. Gas contains 20 percent ammonia by volume and this will be reduced to 1.96 percent. The water, which is ammonia-free, will be supplied at a flow rate of 2581 kg/h. Calculate:

a) The concentration of liquid solution leaving the column,
b) The percentage recovery of ammonia,
c) The number of the equilibrium plates needed,

The equilibrium data (in mole ratios) is given below:

X	0.212	0.159	0.106	0.079	0.053	0.042	0.032	0.021
Y	0.262	0.167	0.095	0.067	0.042	0.032	0.024	0.015

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BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI

SECOND SEMESTER 2012-2013
COMPREHENSIVE EXAMINATION
CHE F244 SEPARATION PROCESSES-I

DATE: 04.05.2013 **Maximum Marks: 130**

***Note*: The question paper consists of two parts. Part A is of 40 marks and of 60 minutes duration. Part B question paper can be collected only after submission of Part A answer sheet.**

PART – A

Time: 8.00 – 9.00 A.M. **Marks: 40**

Write your answers on the Answer Sheet provided at the back side of this question paper. Rough work can be done on the main answer book. Only final answer will be evaluated.

1. What is the diffusivity D_{AB} (in cm^2/s) for O_2–C_6H_6 system at 1 atm, 25°C? Given $M_A = 32$, $M_B = 78$, $\Sigma v_A = 16.3$, and $\Sigma v_B = 90.96$. Use F-S-G equation.
2. Obtain the height of one transfer unit and number of transfer units when NH_3-Air mixture containing 5 % ammonia by volume is absorbed in water in a packed column operated at 20°C and 1 atm pressure if Gs = 40 kmol/h.m^2, Ls = 3000 kmol/h.m^2, K_Ga = 190 kmol/h.m^3.atm, recovery = 90% and $Y^* = 0.20\ X$.
3. In Ponchon-Savarit enthalpy-concentration plot, the feed point is located at (0.4, 20000). If a vertical line passing through this point crosses the saturated liquid enthalpy at 5000 kJ/kmol and saturated vapor enthalpy at 45000 kJ/kmol, what is the percentage of vapor in the feed?
4. In Ponchon-Savarit enthalpy-concentration plot, the Δ_D point is located at (0.96, 112000). If a vertical line passing through this point crosses the saturated liquid enthalpy at 8000 kJ/kmol and saturated vapor enthalpy at 41000 kJ/kmol, what is the reflux ratio when a total condenser is used?
5. What is the Murphree tray efficiency in an absorption column if G_s = 90 kmol/h, L_s = 100 kmol/h, $y_{n+1} = 0.12$, $x_n = 0.078$, $x_{n-1} = 0.06$, and $Y^* = 1.01\ X$.
6. A mixture of benzene (A) and toluene (B) containing 40 mol% benzene is to be separated continuously in a tray tower at a rate of 200 kmol/h. The top product should have 94 mol% benzene and the bottom must not contain more than 4 mol% of it. The reflux is saturated liquid and a reflux ratio of 2.0 is maintained. For a 60% vaporized feed, obtain the followings:
   a) Distillate and bottoms flow rates in kmol/h.
   b) Latent heat of vaporization at the top and bottom if λ_A =30,770 kJ/kmol and λ_B = 32,120 kJ/kmol.
   c) Vapor rates in kmol/h at the rectifying and stripping sections.
   d) Equations of operating lines in the rectifying and stripping sections.
   e) Condenser and reboiler heat duties in kW for constant molar overflow.
   f) Volumetric vapor flow rates at the top and bottom in m^3/h assuming boiling points of benzene and toluene to be78°C and 100°C at 1 atm pressure.

[Q1 to Q5: 4 marks each; Q~~4~~6a to Q~~4~~6d: 3 marks each; Q~~4~~6e to Q~~4~~6f: 4 marks each]

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BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI

SECOND SEMESTER 2012-2013

COMPREHENSIVE EXAMINATION

CHE F244 SEPARATION PROCESSES-I

DATE: 04.05.2013 **Maximum Marks: 130**

Time: 9.00 – 11.00 A.M. **PART – B** **Marks: 90**

1. (30 *Marks*)

A distillation column receives two feeds: (i) 200 kmol/h, 80% liquid and 20% vapor, with 42.86 mole% methanol and rest water; (ii) 100 kmol/h, saturated liquid, with 17.65 mole% methanol and rest water. The top product must have a purity of 96.1 mole% and the bottoms must not have more than 3.1 mole% of the alcohol. A liquid side stream having 66.67 mole% methanol is to be withdrawn at a rate of 35 kmol/h. The reflux is returned to the top tray as a saturated liquid at a reflux ratio of 2.0. (a) Find the number of ideal trays required for the separation. (b) Identify the feed trays and also the tray from which the side stream should be withdrawn. Vapor-liquid equilibrium data at the operating pressure of 1 atm is as follows:

x	0	0.02	0.04	0.06	0.08	0.10	0.20	0.30	0.40
y*	0	0.134	0.23	0.304	0.365	0.418	0.579	0.665	0.729
x	0.50	0.60	0.70	0.80	0.90	0.95	1.0		
y*	0.779	0.825	0.87	0.915	0.958	0.979	1.0		

Hint: Take scale: 2 cm = 0.1 on both axes.

2. (20 *Marks*)

Roasted copper ore containing copper as $CuSO_4$ is to be extracted in a counter current extractor. The feed charge to be treated per hour comprises 10 tons of gangue, 1.2 tons of $CuSO_4$ and 0.5 ton of water. The strong solution produced is to consist of 95% water and 5% $CuSO_4$ by weight. The recovery of $CuSO_4$ is to be 90% of that in the ore. Pure water is to be used as the fresh solvent. After each stage, one ton of inert gangue retains 2 tons of water plus the copper sulphate dissolved in that water. How many equilibrium stages are required? Assume no solid is lost in the overflow so that the rate of gangue remains constant in all the stages.

Hint: Take scale, for solute axis: 2 cm = 0.01, for solvent axis: 1 cm = 0.1

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3. (40 *Marks*) Answer the following questions together and in sequence.

(a) Briefly discuss on effusion, permeation, dialysis and reverse osmosis with respect to separating agent and the principle of separation. What is the difference between osmosis and reverse osmosis?

(b) Explain why operating line for stripping section starts from the point (x_w, 0.0) rather than (x_w, x_w) point when open steam is used instead of a reboiler.

(c) If y-coordinate of feed pinch point becomes greater than or equal to the distillate composition, what should be the value of minimum reflux ratio, and why? In case of tangent pinch, how can you find the minimum reflux ratio?

(d) What is total reflux? Explain why number of stages are minimum at total reflux?

(e) Using component balance equations at rectifying and stripping sections, obtain the equation for feed line.

(f) Using simple distillation, explain how you can obtain the relative volatility of a system.

(g) With a neat diagram show the different parts of a tray tower. Indicate the functions of weir and the slanting downspout.

(h) In case of binary gas system total concentration is constant, but in case of binary liquid system it is not so. Explain.

(i) Explain why total cost passes through a minimum as we go on increasing the reflux ratio for a given condition of separation.

(j) In leaching, when the overflow and underflow are in equilibrium, how are the respective solute concentrations related? Define plait point and outline the significance of phase envelope in liquid-liquid extraction.