BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI, PILANI CAMPUS
CHEMICAL ENGINEERING DEPARTMENT
Course Title: Separation Process I (CHE F244)
Mid Sem Test (Closed-Book): Make-up Marks: 90 Date: 06/03/18 Time: 90 minutes

---

Note: Answers all parts of Question No. 1 together and make suitable assumptions if necessary.

1. **(5+4+6 = 15 Marks)**
Give precise answers of the following questions.
(a) Generally, great liquid depths and high gas velocities are desired for higher tray efficiency. What operational difficulties would you encounter under these conditions. Provide proper explanation for your answer.
(b) What is the difference between *N* type and *J* type flux?
(c) Derive an expression of overall mass transfer coefficients based on mole fraction (K_x and K_y) for the gas-liquid mass transfer in a concentrated solution. (Write all steps clearly)

2. **(15 Marks)**
A feed, *F*, of 100 kmol/h of air containing 21 mol% O_2 and 79 mol% N_2 is to be partially separated by a membrane unit according to each of four sets of specifications. Compute the amounts, in kmol/h, and compositions, in mol%, of the two products (retentate, R, and permeate, P) for the following cases:
(a) 85 mol% purity of N_2 in the retentate and a split ratio of O_2 in the permeate to the retentate equal to 1.1.
(b) 85 mol% purity of N_2 in the retentate and 50 mol% purity of O_2 in the permeate.
The membrane is more permeable to O_2.

3. **(20 Marks)**
In a typical chemical process, component A is desorbed from an aqueous solution into an air stream in a mass transfer tower at a certain operating temperature and pressure. At a particular point in the tower, analysis report shows that partial pressure of A is 12 mmHg and liquid phase concentration of A is 4 kmol/m^3. The overall mass transfer coefficient, K_G = 0.269 kmol A/(m^2.hr.atm). If Henry's law is applicable to this system and if 56% of the total mass transfer resistance is encounterd in gas film. Calculate:
(a) the gas film coefficient.
(b) the liquid film coefficient
(c) the overall liquid mass transfer coefficient
(d) the interfacial gas and liquid phase concentration of ammonia.
(e) Molar flux of component A.
Data: Henry's law constant = 7.5×10^{-3} atm/(mole A/m^3 solution)

4. **(25 Marks)**
A rotary film washer is used for the removal of ammonia from coal gas at 20ºC. The washer is made up of eight brush compartments and is designed to treat 3700 m^3/hr of gas with 1.5 times the theoretical amount of wash water. If the coal gas contains 1.3% NH_3 on entering the scrubber and 0.3% NH_3 on leaving, calculate the mass of water used per hour, number of theoretical stages (Using Graphical method) and overall stage efficiency. Equilibrium data at 20ºC: $y^* = 0.8x$

5. **(15 Marks)**
A service attendant accidently spills 50 liters of gasoline which quickly spreads over a level surface of area 8 m^2. Estimate the time required for the gasoline to evaporate into the stagnant air above the surface of the liquid. The diffusivity of gasoline in air is 0.65 m^2/h. The air temperature is 298 K. Evaporation may be assumed to take place through a film of air of 2 m thickness. Vapor pressure of gasoline at 298 K is 76 mm Hg. The density of gasoline is 720 kg/m^3 and the molecular weight of gasoline is 200. The operation takes place at 1 atm pressure.

ALL THE BEST

TEST – 1 (Solutions) CHE F244

(a) J-type flux is due to the molecular diffusion which is mainly due to the concentration difference driving force. Hence, to measure the J-type flux, molar average velocity of the mixture is taken as reference. Due to this, we able to measure the transfer of species which is mainly due to molecular diffusion. N-type flux is total net transfer of molecules (bulk flow due to velocity + molecular diffusion due to concentration difference) which can be measured only relative to a fixed plane or stationary plane.

(b) The assumption of phase equilibrium at the phase interface, while widely used, may not be valid when gradients of interfacial tension are established during mass transfer between two fluids. These gradients give rise to interfacial turbulence resulting, most often, in considerably increased mass-transfer coefficients. This phenomenon, the Marangoni effect.

(c) Great liquid depths on the tray and high gas velocities, both result in high pressure drop for the gas in flowing through the tray. Due to high pressure drop (large pressure difference in the space between trays). The level of liquid leaving a tray at relatively low pressure and entering one of high pressure. Must necessarily assume an elevated position in the downspouts. As the pressure difference is increased, the level in the downspout will rise further to permit the liquid to enter the lower tray. Ultimately, the liquid level may reach that on tray above. Further increase in either flow rate then aggravates the condition rapidly. The liquid will fill the entire space between the trays and the tower is then flooded.

(d) If the height of packing is more than about 20 ft, liquid channeling may occur, causing the liquid to flow down near the wall, and gas to flow up the center of the column. Thus greatly reducing the extent of vapor–liquid contact. It also lead to high pressure drop. In that case, liquid redistributors need to be installed.