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

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

1. (5+5+5 = 15 Marks)

Give precise answers of the following questions.

(a) Under what conditions, mechanical entrainment phenomena occurred in trayed absorption column. How it affect the tray efficiency?

(b) When stepping off stages on an *Y–X* plot for an absorber or a stripper, does the process start and stop with the operating line or the equilibrium curve? Justify your answer.

(c) In the two film theory of mass transfer between gas and liquid phase, at what circumstances, the assumption of phase equilibrium at the phase interface, while widely used may not be valid?

2. (15 Marks)

An open tank, 4 m in diameter containing toluene at 25ºC, is exposed to air at 100 kPa in such a manner that the surface of the liquid is covered with a stagnant air film estimated to be 5 mm thick. The concentration of toluene beyond the stagnant flim is negligible. The vapor pressure and density of liquid toluene at 25ºC are 3.8 kPa and 862 kg/m^3, respectively. The diffusivity of toluene in air at 0ºC is 0.071 cm^2/s. **Estimate the loss of toluene per day from this tank in kmol toluene/day.**

3. (20 Marks)

In an experimental study of absorption of ammonia by water from an air-ammonia mixture in a wetted-wall column, the overall gas phase mass transfer coefficient was estimated to be 93.25×10^{-2} kmol NH_3/m^2.h.atm. The operating pressure and temperature of the tower are 2 atm and 288 K, respectively. For dilute solutions of ammonia in water at 288 K, the equilibrium partial pressure is given by: $p_A^* = 4\ c_A$. where, p_A^* = equilibrium partial pressure of ammonia, atm and c_A = concentration of ammonia in water at equilibrium, kmol NH_3/m^3 solution. At the top of the tower, the outlet gas contained ammonia 1% by volume and inlet liquid which is in contact with gas phase is pure water. Assuming 85% of the total resistance to mass transfer was contributed by the gas phase, 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.

4. (25 Marks)

A plate absorption column is used to reduce the concentration of a pollutant "A" in an air stream from 5.4% to 0.3% by volume in a counter-current scrubbing with solvent "S". This solvent is fresh on entering the top of column and the gas stream enters at the bottom of the column at a flow rate of 2.4 m^3/s at the column operation conditions of 293 K and 1 atmoshphere. Equilibrium data is given by:

X (kmol A/kmol S	0	0.005	0.010	0.020	0.030	0.040	0.045
Y (kmol A/kmol air)	0	0.002	0.005	0.015	0.032	0.053	0.065

(a) Determine the minimum flow rate in kmol/s needed for fresh solvent S.

(b) If the actual fresh solvent flow rate is 1.1 times the minimum, estimate the number of ideal plates required using **Graphical method**.

5. (15 Marks)

5000 kg/h of a SO_2-air mixture containing 5% by volume of SO_2 is to be scrubbed with 2,00,000 kg/h of fresh water in a packed tower. The exit concentration of SO_2 is reduced to 0.15%. The tower operates at 1 atm. The equilibrium relation is given by: $Y = 30\ X$, where Y = mole SO_2/mole air and X = mole SO_2/mole water. If the packed height of tower is 0.42 m, calculate the height of transfer unit. Molecular weight of SO_2, air and water are 64, 29 and 18, respectively.

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(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.