INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Date: **20.04.2013 (AN)** Time: **3 hours** Full Marks **50** No. of students: **5**
Spring Semester 2013 Deptt. **AgFE** Subject No.: **AG60100**
V year Dual Degree/RS Subject: **Mass Transfer Operations in Food Processing**

Section-A

(Attempt any four questions from this section)

Q 1 a) Derive the operating line equation for countercurrent multiple-stage gas liquid system. **[4]**

b) It is desired to absorb 80% of the acetone in a gas containing 1.0 mol % acetone in air in a countercurrent stage tower. The total inlet gas flow to the tower is 32.0 kg mol/h, and total inlet pure water flow to absorb the acetone is 88 kg mol H_2O/h. The process is to operate isothermally at 300 K and a total pressure of 101.3 kPa. Equilibrium relation for acetone (A) in the gas-liquid is $y_A = 2.53x_A$. Determine the number of theoretical stages required for this separation. **[6]**

Q 2 Solute A is being absorbed from a gas mixture of A and B in a wetted-wall tower with the liquid flowing as a film downward along the wall. At a certain point in the tower the bulk gas concentration y_{AG} =0.420 mol fraction and bulk liquid concentration x_{AL} = 0.120. Tower is operating at 298 K and 1.013 x 10^5 Pa and equilibrium data are as follows:

x_A	0	0.05	0.10	0.15	0.20	0.25	0.30	0.35
y_A	0	0.022	0.052	0.087	0.131	0.187	0.265	0.385

Solute A diffuses through stagnant B in the gas phase and then through a non-diffusing liquid. Using correlations for dilute solutions, mass transfer coefficients for A in the gas and liquid phases are predicted as 1.435 x 10^{-3} and 1.927 x 10^{-3} kg mol/s.m^2.mol fraction respectively. Calculate the interface concentrations and the flux. **[10]**

Q 3 A packed countercurrent water-cooling tower using a gas flow rate of G = 1.658 kg dry air/s.m^2 and a water flow rate of L = 1.658 kg water/s.m^2 is to cool the water from 42.2 °C to 27.0 °C. The entering air at 27.0 °C has a wet bulb temperature of 22.9 °C. Volumetric mass transfer coefficient in gas phase is 1.273 x 10^{-7} kg mol/s.m^3.Pa and $h_L.a/k_G.a.M_B.P$ is 4.187 x 10^4 J/kg.K. The tower operates at a pressure of 1.013 x 10^5 Pa. Calculate the height of packed tower. **[10]**

Q 4 a) Derive Lever-Arm Rule for graphical application. **[4]**

b) An original mixture weighing 200 kg and containing 50 kg of isopropyl ether, 20 kg of acetic acid and 130 kg of water is equilibrated in a mixer-settler and the phases separated. Determine the amounts and compositions of the raffinate extract layers using equilibrium data tabulated below:

Water Layer %	Acetic Acid	0	0.69	1.41	2.89	6.42	13.3	25.5	36.7	44.3	46.4
	Water	98.8	98.1	97.1	95.5	91.7	84.4	71.1	58.9	45.1	37.1
	Ether	1.2	1.2	1.5	1.6	1.9	2.3	3.4	4.4	10.6	16.5
Ether Layer %	Acetic Acid	0	0.18	0.37	0.79	1.93	4.82	11.4	21.6	31.1	36.2
	Water	0.6	0.5	0.7	0.8	1.0	1.9	3.9	6.9	10.8	15.1
	Ether	99.4	99.3	98.9	98.4	97.1	93.3	84.7	71.5	58.1	48.7

[6]

Q 5. Write short notes on any four of the following:

- Operating line equation for countercurrent leaching
- Tie lines
- Triangular coordinates and equilibrium data
- Hildebrand extractor
- Prediction of time for batch leaching [2.5x4]

Section-B

Q 1 An acetic acid – water solution in the form of a stagnant film 2.0 mm thick at 300 K is in contact at one surface with an organic solvent (ethanol) in which acetic acid is soluble and water is insoluble. Let at point 1 in the stagnant film the concentration of acetic acid is 15 wt % and the solution density is 970.5 kg/m^3. At point 2, the concentration of ethanol is 5 wt % and density is 982.7 kg/m^3. Calculate the rate of diffusion of acetic acid at steady state. Given molecular weight of acetic acid is 60 and that of water is 18, diffusion coefficient of acetic acid in water is 0.750 x 10^{-9} m^2/s. [6]

Q 2 A gas mixture of N_2 = 3%, H_2 = 12%, NH_3 = 78% and Ar = 2% flows through a pipe of 22.4 mm diameter at a total pressure of 4 bar. The velocities of the respective components are 0.02m/s, 0.024m/s, 0.02 m/s and 0.015m/s. Calculate the mass average and molar average velocities of the mixture. [4]

Hint equations for Section B:

$$N_A = \frac{D_{AB} c_{av}}{(z_2 - z_1) x_{BM}} (x_{A1} - x_{A2}) \qquad v^* = \frac{\sum_{i=1}^{n} C_i v_i}{\sum_{i=1}^{n} C_i} \qquad v = \frac{\sum_{i=1}^{n} \rho_i v_i}{\sum_{i=1}^{n} \rho_i}$$

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(Wishing all the students "best of luck")