Mass Transfer – I (CH31001)
Tutorial Sheet No.: MT-I/NCP/2019/1

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1. A tray tower is to be designed to absorb SO_2 from an air stream by using pure water at 20°C. Approximately 180 m^3/h (at 20°C and 1 atm) of gas is to be processed and the SO_2 content of the gas is to be reduced from 20 mol% to 2 mol%. Determine (a) the minimum water rate and (b) the number of real trays required for a water rate 1.2 times the minimum. Assume an overall tray efficiency of 50%.

Equilibrium Data:

x	0.0	5.640 x 10^{-4}	8.420 x 10^{-4}	1.403 x 10^{-3}	1.965 x 10^{-3}	2.790 x 10^{-3}	4.200 x 10^{-3}	6.980 x 10^{-3}
y	0.0	0.0112	0.0185	0.0342	0.0513	0.0775	0.121	0.212

[Ans. (a) 3786 kg/h (b) 10]

2. A flue gas stream containing 15% CO_2 is blown into a sieve-tray tower operated at 1.0 std atm, 25°C and scrubbed with a 30% monoethanol amine (Mol Wt. = 61) solution in water. The scrubbing liquid, which is recycled from a stripper, will contain 0.058 mol CO_2/mol solution. The gas leaving the scrubber is to contain 2% CO_2, Assuming isothermal operation, determine (a) the minimum liquid/gas ratio, mole/mole; (b) the number of kilograms of solution to enter the absorber per cubic meter of the entering gas for an L/G ratio of 1.2 times the minimum and (c) the number of theoretical trays required for the conditions of part (b). The equilibrium partial pressures of CO_2 over aqueous solutions of monoethanol amine (30 wt%) are given below:

Mole CO_2/mole solution	0.058	0.060	0.062	0.064	0.066	0.068
p_{CO2} (mm Hg)	5.6	12.8	29.0	56.0	98.7	155.0

[Ans. (a) 14.53, (b) 17.11, (c) 2.7]

3. Carbon dioxide evolved during the production of ethanol by fermentation contains 0.01 mole fraction of alcohol vapour. It is proposed to remove the alcohol by absorption into water in a bubble-cap plate tower. Absorption may be assumed to occur isothermally at 30°C and 1 atm pressure. The water for absorption is supplied from the subsequent distillation step for alcohol recovery and may be assumed to contain 0.0001 mole fraction alcohol. To be processed are 240 kmol of gas per hour. Over the conditions of operations, the solubility of alcohol in water may be approximated by the relation $y = 1.0682\ x$ (where y and x are the gas phase and liquid phase mole fractions).

(a) Calculate the minimum water rate for 98% absorption of the alcohol vapour.

(b) Calculate the number of theoretical plates required for 98% absorption at a water rate twice the minimum.

(c) Calculate the percentage absorption which would be obtained in one equilibrium stage at the flow rates of part (b).

[Ans. (a) 251.4 kmol/h; (b) 5.78; (c) 65%]

4. A rich absorption oil containing 5% propane is being stripped by direct superheated steam in a tray tower to reduce the propane content to 0.5%. A total of 25 kmol of direct steam is used for 600 kmol of total entering liquid. The vapour-liquid equilibrium may be represented by $\boldsymbol{y = 26\ x}$, where $\boldsymbol{y}$ is the mole fraction of propane in the steam and $\boldsymbol{x}$ is the mole fraction of propane in the oil. Steam can be considered as inert gas and will not condense. Determine the number of theoretical trays needed for the stripping operation.

[Ans. 2.8]

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5. Ammonia is to be removed from an ammonia-air mixture by water scrubbing in a 0.786 m diameter tower packed with 25 mm Raschig rings. The gas mixture is available at the rate of 600 m^3/h (at 25^oC and 1 atm) with 10% ammonia by volume. Pure water will be used as solvent at a rate twice the minimum. Film coefficients are $k_y a$ = 150 kmol/m^3 h Δy and $k_x a$ = 325 kmol/ m^3 h Δx. The equilibrium relation may be expressed y^* = 1.02 x/(1 - x). Calculate the depth of the packing required for 98% removal of ammonia.

[Ans. 3.2 m]

6. Ammonia is to be removed from an ammonia-air mixture by water scrubbing in a 0.30 m diameter tower packed with 25 mm Berl saddles. The gas mixture is available at the rate of 150 m^3/h (at 25^oC and 1 atm) with 6% ammonia by volume. Calculate the depth of the packing required for a final ammonia content of 0.05% by volume. At 25^oC, ammonia-water solutions follow Henry's law up to 6 mole% ammonia in liquid and m = 1.4. The water rate is 250 kg/h and K_Ga is given as 265 kmol/m^3 h atm.

[Ans. 3.906 m]

7. Acetone is being absorbed by water in a packed tower having a cross-sectional area of 0.186 m^2 at 20^oC and 1 atm pressure. The inlet air contains 2.6 mol% acetone and the outlet air contains 0.5 mol% acetone. The gas flow rate is 14.0 kmol/h. The pure water flow rate 820 kg/h. Film coefficients for the given flows in the tower are $k_y a$ = 0.0378 kmol/m^3 s Δy and $k_x a$ = 0.0616 kmol/ m^3 s Δx. The equilibrium relation may be expressed as y = 1.186 x. Determine the height of the tower.

[Ans. 1.96 m]

8. A relatively nonvolatile hydrocarbon oil contains 3 mol% benzene and is being stripped by direct superheated steam in a packed tower having a cross-sectional area of 0.86 $m^2$to reduce the benzene content to 0.2%. A total of 20 kmol of direct steam is used for 260 kmol of total entering liquid. The vapour-liquid equilibrium may be represented by y = 22.5 x, where y is the mole fraction of benzene in the steam and x is the mole fraction of benzene in the oil. Steam can be considered as inert gas and will not condense. Film coefficients for the given flows in the tower are $k_y a$ = 0.04 kmol/m^3 s Δy and $k_x a$ = 0.06 kmol/ m^3 s Δx. Determine the height of the tower for the stripping operation.

[Ans. 6.74]

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