Mass Transfer – I (CH21202)
Tutorial Sheet No.: MT-I/NCP/2023/1

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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. The hydrotreater off gas of a refinery processing sour crude contains 20% H_2S. The gas is sent to the amine treating unit of the refinery where it is blown into a sieve-tray tower operated at 1.0 std atm, 30°C and scrubbed with a 25 wt% diethanol amine (DEA) solution in water. The scrubbing liquid, which is recycled from a stripper, contains 0.01 mol H_2S/mol solution. The gas leaving the absorber is to contain 1.4% H_2S. Assuming isothermal operation, determine (a) the minimum liquid/gas ratio, mol/mol; (b) the number of theoretical trays required for a liquid/gas ratio 1.2 times the minimum. The equilibrium partial pressures of H_2S over aqueous solutions of diethanol amine (25 wt%) are given below:

Moles H_2S/mole DEA solution (x)	0.0225	0.0366	0.052	0.063	0.067	0.071	0.076
P_{H2S} (mm Hg)	14	35	72	110	133	152	175

[Ans. (a) 2.9, (b) 3.6]

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]

P.T.O.

5. A relatively nonvolatile hydrocarbon oil contains 3 mol% benzene and is being stripped by direct superheated steam in a sieve tray tower 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. Determine the number of theoretical trays required for this stripping operation.

[Ans. 3.5]

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