Zaid

NR414 - (25)

INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR
End-Spring Semester Examination, 2022-2023

Subject : Mass Transfer - I *Subject No.*: CH21202/CH31001
Date: 21.04.2023 (AN) *Time*: 3 Hrs *Full Marks*: 50

Specific charts, graph paper, log book etc., required: Normal graph paper (≥ 3 nos. per candidate)

Instructions : (1) Use relevant equations and diagrams, wherever necessary.
(2) Any missing data may be assumed suitably giving proper justification.
(3) Answer all parts of a question at one place only.

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1. **(a)** What are 'Dumping' and 'Priming' of a Sieve Tray Tower?
(b) When is split flow tray preferred over cross flow tray?
(c) A tray tower is to be designed to absorb CO_2 from a flue gas stream by scrubbing into an aqueous amine solution at 25°C. Approximately, 180 m^3/h (at 25°C and 1 atm) of gas is to be processed and the CO_2 content of the gas is to be reduced from 15 mol% to 2 mol%. The scrubbing liquid, which is recycled from a stripper, will contain 0.058 mol CO_2/mol solution. Determine (i) the minimum liquid rate, kmol/h and (ii) the number of real trays required for a liquid rate 1.2 times the minimum. Assume an overall tray efficiency of 53%.

Equilibrium Data:

Mole CO_2/mole amine 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

[2+1+(4+3)]

2. **(a)** For dilute mixtures and cases where Henry's law applies, prove that the number of overall gas phase transfer units for co-current gas absorption in packed towers is given by

$$N_{toG} = \frac{A}{A+1} \ln\left[\frac{y_1 - mx_1}{y_2 - mx_2}\right]$$

where the notations have their usual meanings.

(b) 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°C 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°C, 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 $K_G a$ is given as 265 kmol/m^3 h atm.

OR

(a) What are the factors that influence N_{tOL} and H_{tOL} of a packed desorption tower?

(b) A relatively nonvolatile hydrocarbon oil containing 3.5 mol% benzene is being stripped at a rate of 160 kmol/h by direct superheated steam in a packed tower to reduce the benzene content to 0.1%. The gas-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 height of the packing if the diameter of the tower is 1.5 m. The steam rate is 270 kg/h and $K_x a$ is 150 kmol/m^3 h (Δx^*).

[4+6]

P.T.O.

3. (a) How is butadiene separated from C_4-stream of naphtha cracker?
(b) Why are the heat-sensitive high-boiling materials not degraded during purification by steam distillation?
(c) A liquid mixture containing 50 mol% ethanol (*A*) and 50 mol% n-propanol (*B*) is subjected to differential distillation at atmospheric pressure with 50 mol% of the liquid distilled. What will be the compositions of the composited distillate and the residue? The vapour pressures of A and B at 80°C are given as 787 mm Hg and 364 mm Hg, respectively.

OR

(c) A liquid mixture containing 50 mol% ethanol (A) and 50 mol% n-propanol (B), at 80°C, is to be continuously flash vaporized at atmospheric pressure to vaporize 50 mol % of the feed. What will be the composition of the vapour and liquid if the vaporizer is an ideal one? The vapour pressures of A and B at 80°C are 787 mm Hg and 364 mm Hg, respectively.

[3+2+5]

4. (a) How does the cost of a distillation column vary with reflux ratio?
(b) A mixture of diethylamine (DEA) and triethylamine (TEA) containing 50 mol% of DEA is to be continuously fractionated at a rate of 8700 kg/h and at a total pressure of 113.3 kPa. The top product should have 98% more volatile component and the bottom product 2%. The feed will be 50 mol% vaporized before it enters the tower. A total condenser will be used and the reflux will be returned at the bubble point. Determine (i) the product rates, kg/h; (ii) the minimum reflux ratio; (iii) the number of theoretical trays required at a reflux ratio 1.5 times the minimum and (iv) the location of the feed tray.

The equilibrium data for the system are given below:

x	0.02	0.104	0.227	0.34	0.428	0.52	0.65	0.79	0.90	0.95
y	0.052	0.231	0.45	0.6	0.694	0.765	0.845	0.915	0.963	0.982

[2+ (2+2+3+1)]

5. (a) Draw model operating line and equilibrium line diagrams on X-Y plane for (i) co-current absorption and (ii) counter-current stripping processes.
(b) Derive the relationship between the nucleation rate, growth rate and the population density function of vanishingly small size.
(c) The crystal growth rate in an MSMPR crystallizer under a given set of condition is 5×10^{-8} m/s. The holdup of the suspension is 10 m^3 and the suspension withdrawal rate is 4 m^3/h. The zero-size population density is 5×10^{10}/cm. liter. Calculate the total number of crystals, and mass of the crystal in the size range of 0.5 mm to 1 mm per unit volume of the product. Volume shape factor and the density of the crystals can be taken as 0.6 and 2700 kg/ m^3.

[2+2+6]

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