BACHELOR OF ENGINEERING IN CHEMICAL ENGINEERING EXAMINATION, 2019

(3rd Year, 1st Semester)

SEPERATION PROCESSES - I

Time : Three hours (50 marks for each Part) Full Marks : 100

Use a separate answerscript for each Part

PART I

Answer any two questions
Symbols carry their usual meaning
Assume any missing data

1(a) A staged column is used to remoter contains toluene from water by stripping with air. The water contains 60×10^{-6} g/g of toluene. The concentration needs to be reduced to 5×10^{-6} g/g. The average pressure within the column is 1.1 atm. The equilibrium relationship is $P_{tol}(atm) = 256x$, where P_{tol} is the partial pressure of toluene in the and x is the mole fraction of toluene in the liquid phase.

(i) Determine the minimum air flow rate in gmol/min for water flow rate of 100 L/min

(ii) Calculate the number of stages for an air flow rate of twice the minimum?

(iii) Determine the concentration of the streams entering and leaving the 2nd stage from the top of the column?

(b) Distinguish between axial dispersion and back mixing? [22 + 3]

2(a) Derive the relation $F = k_y \frac{P_{BM}}{RT} = k'_y$ [12]

(b) Acetone (A) is diffusing through nitrogen (B) under steady state condition, with the latter non-diffusing. The total pressure is 1.5 bar and temperature 300 K. The partial pressure of acetone at two planes 1 mm apart is 15000 and 5000 N/m^2 respectively. The diffusivity of mixture is 2×10^{-7} m^{2}s^{-1}. Estimate the rate of diffusion of acetone? [6]

© For fluid flow perpendicular to a circular cylinder, the average heat transfer coefficient in the fluid is given by $Nu = (0.35 + 0.34Re^{0.5} + 0.15Re^{0.58})Pr^{0.3}$

Estimate the rate of sublimation of a cylinder of naphthalene 5 mm in diameter and 5 cm in length, exposed to an air stream flowing at a velocity of 10 m/s and temperature 38 °C. The bulk air is at 1 std atm.

The density and viscosity of air is 0.114 kg/m^3 and 1.85×10^{-5} kg/m.s respectively. The vapor pressure of naphthalene and its diffusivity in air is 1.0×10^{-4} bar and 0.09 cm^{2}s^{-1} respectively. [7]

3(a) The liquid phase (x) and vapor phase (y) mole fraction of a component at a cross section in a mass transfer equipment is 0.2 and 0.04 respectively. The magnitude of individual liquid phase and vapor phase mass transfer coefficient is 1.6×10^{-3} kmol m^{-2}s^{-1} and 1.4×10^{-3} kmol m^{-2}s^{-1} respectively.
The equilibrium relation is given by $y = x^{3.2}$

(i) Determine the direction of mass transfer?

(ii) Estimate the overall gas phase mass transfer coefficient and overall liquid phase mass transfer coefficient respectively from the above data. [3+9]

(b) A mixture of acetone and nitrogen is flowing (average velocity = 5.0 m/s) through a duct of rectangular cross section 0.5m by 0.6m. The pressure and temperature at one point in the duct is 800 mm Hg and 45 °C. A wet bulb temperature at that point was measured to be 30 °C. The following data are given

The value of Lewis number, heat capacity of acetone and nitrogen, latent heat of vaporization are 0.9, 96 J/mol K, 1040 J/kg °C, 31.3 kJ/mol respectively. For flow past cylinders

$$\frac{h_G}{k_Y C_S} = Le^{0.567}$$

The vapor pressure of acetone is given by $log_{10}(mm\ Hg) = 7.1327 - \frac{1219.97}{T(oC)+230.653}$

Estimate the water vapor flowing through the duct in kg/s? [13]

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(3rd Year, 1st Semester)
SEPARATION PROCESSES I
Use Separate answer script for each part
Part: II
Answer any **two**
Assume any missing data

1.a) Nicotine is to be extracted from a liquor by using a solvent in a three-stage crosscurrent device. The feed rate is 2000 kg/h, containing 10 mass% nicotine. 95% of the solute has to be recovered. The solvent has 0.001 mass% nicotine in it. The equilibrium of the system can be expressed as $W_I = 0.85W_S$, where W_I is kg nicotine per kg nicotine-free feed and W_S is kg nicotine per kg nicotine free solvent. If equal amounts of solvent are used in each stages, calculate the total solvent requirement for the job.

b) Which of the following three common trays (a) offers the lowest pressure drop, (b) offers the maximum turndown ratio, (c) enjoys the maximum share of the market?

i) Bubble-cap tray

ii) Sieve tray

iii) Valve tray

c) Describe the underlying assumptions of penetration theory of mass transfer.

d) Indicate the category to which each of the following devices belongs by mentioning either gas dispersed in the liquid or liquid dispersed in the gas or both the gas and liquid are continuous:

i) tray tower; ii) spray tower; iii) packed tower; iv) falling film absorber;

v) bubble column; vi) agitated vessel.

16+3+3+3

2.a) 1000 kg dry weight of non-porous solid with area 55 m^2 is dried under constant drying condition when air flows parallel to the surface with a rate of 0.75 m/s. The critical moisture content of solid is 0.125 kg water/kg dry solids and equilibrium moisture content is negligible.

(i) if the rate in constant rate drying period is 0.3 kg/m^2-s; how long it will take to dry the material from 0.15 to 0.025 kg water/kg dry solid. Consider that the rate of drying in the falling rate period is directly proportional to the free moisture content.

(ii) If the air velocity were increased to 4 m/s, what would be the anticipated saving in time if surface evaporation is controlling. N_c is directly proportional with $G^{0.71}$, where G is the mass flux of air in kg/m^2-s and N_c is the drying rate in constant drying condition.

b) What are the differences between critical moisture content and equilibrium moisture content of a solid?

c) The H_2 gas at 17°C and 0.01 atm partial pressure is diffusing through a vulcanized neoprene rubber 0.55 mm thick. The pressure of hydrogen on the other side of membrane is zero. Calculate the steady-state flux, assuming that the only resistance to diffusion is in the membrane. The solubility of hydrogen in membrane solid at 17°C is 0.051 m^3/ m^{3}solid-atm and diffusivity is 1.03×10^{-10} m^2/s at same temperature.

15+4+6

3.a) A stream of air (dry-bulb temperature = 80°C; wet bulb temperature = 27°C; 4000 kg/h-m^2, dry basis) is contacted with water maintained at adiabatic saturation temperature of the gas. The gas leaves the tower 95% saturated. Calculate the overall gas-phase transfer units and makeup water to be supplied.

b) The warm water from the condenser of power plant enters the cooling tower at 40°C at the rate of 45 kg/s. The water is cooled to 25°C in the cooling tower by air which enters the tower at 23°C and relative humidity 60% and leaves as saturated air at 32°C. Make-up water enters the tower at 25°C.

i) Determine the fan capacity installed at the top of the tower in terms of m^3/s.

ii) Determine the flow rate of make-up water.

$(p_s)_{20°C}$ = 2.339 kPa, $(p_s)_{23°C}$ = 2.837 kPa, $(p_s)_{32°C}$ = 4.799 kPa

10+15

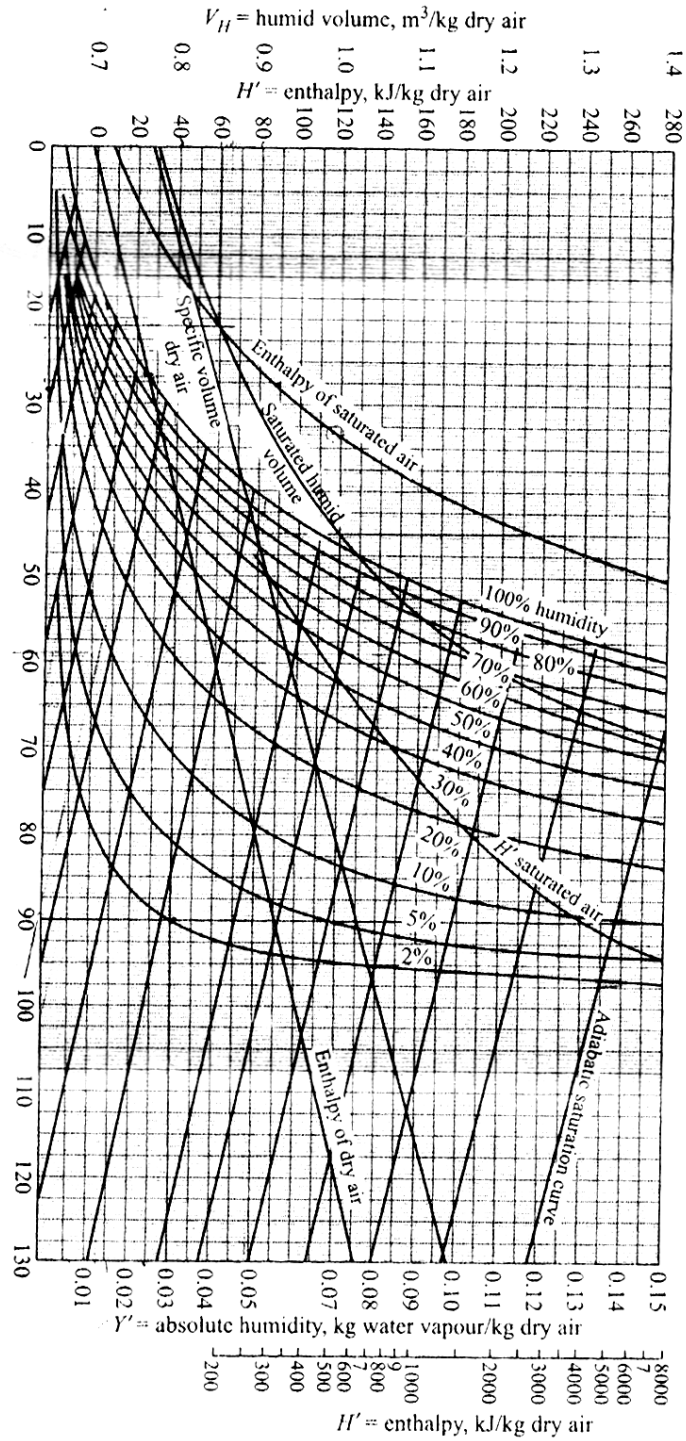

Figure 10.6 (a) Psychrometric chart for the air–water system at 1 atm total pressure.