Exam Date & Time: 16-Jun-2022 (02:00 PM - 05:00 PM)

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

IV SEMESTER B.TECH END SEMESTER EXAMINATIONS, JUNE 2022

MASS TRANSFER - I [CHE 2254]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions.

Instructions to Candidates: Answer ALL the questions Missing data may be suitably assumed.

1) Calculate the rate of diffusion of acetic acid (A) across a film of nondiffusing water (B) solution with 3 mm thick at 17 ^{0}C when the concentrations on opposite sides of the film are 12 and 4 wt % respectively. D_{AB}=9.45x10^{-10} m^2/s, viscosity = 1 cP, M_A=60, and M_B=18 density of water is 1000 kg/m^3 and the density of solution increases linearly to the wt. percentage of acetic acid in water. (4)

B) Show that the calculated diffusivity of ethanol vapor in air at 103 ^{0}C and 1.5 atm is lower than the theoretical value which is 1.02x10^{-5} m^2/s [assume the boiling point of ethanol is 370 K]. (4)

C) Define liquid holdup and average liquid velocity in gas-liquid systems? (2)

2) Compare the following theories i) Film theory ii) Penetration theory iii) Film and penetration theory. (3)

A)

B) Prove that (overall mass transfer coefficient from the gas side)) $K_Y \sim k_y$ (individual mass transfer coefficient from the gas side) for the case of liquid phase control mass transfer coefficient in interphase mass transfer (3)

C) A wet sugar candy (cylindrical structure) with a radius of 12 mm and a height of 20 mm has an initial moisture content of 12 % (wt). At time t=0 the candy is exposed to air on all surfaces. Air contains 0.1% (wt) of moisture/water present. Evaluate the moisture content after 50 hrs of time in wet sugar candy. The diffusivity is 1x10^{-10} m^2/s. (4)

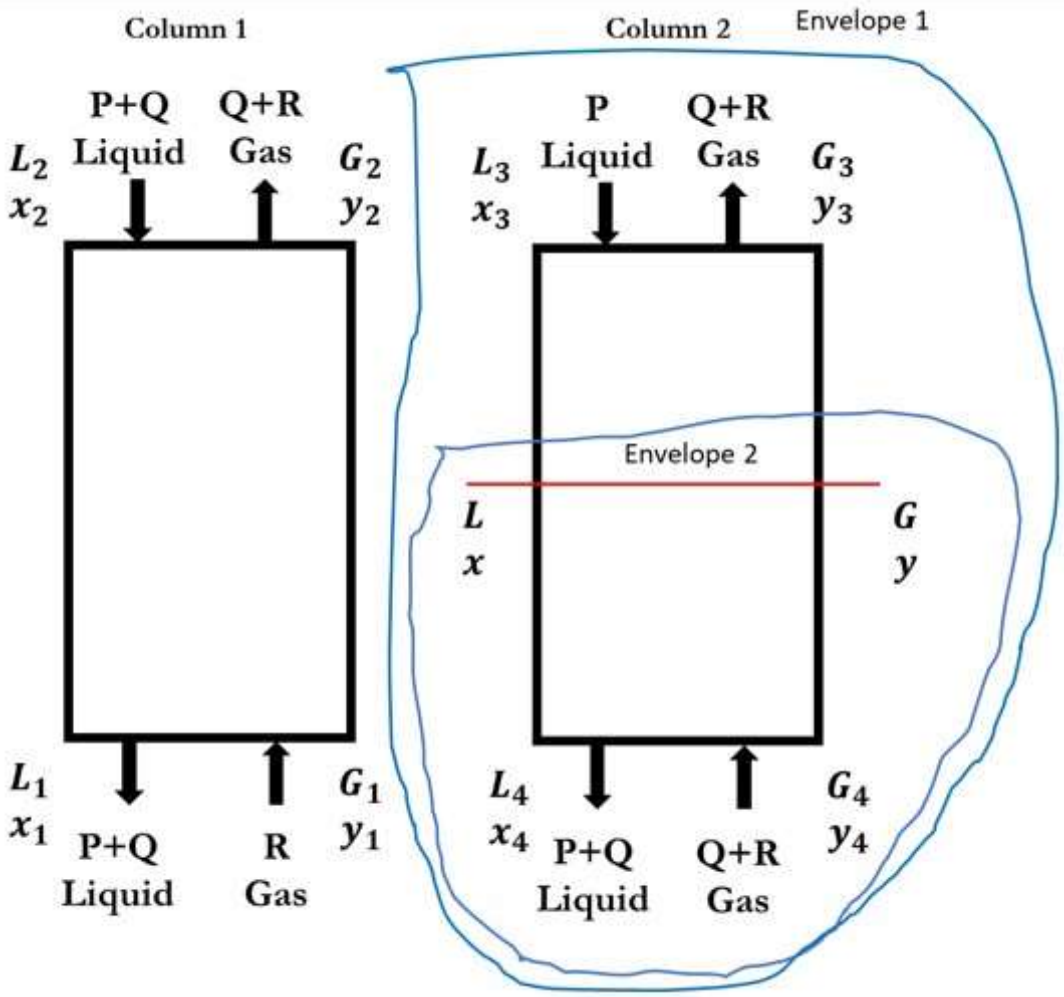
3) Estimate the mass transfer coefficient of pure oxygen at 1 atm and 25 ^{0}C into water flowing as a film down a vertical wall of 2 m high and 0.06 m width. The average velocity of the film is 0.0863 m/s and the film thickness is maintained at 1.6x10^{-4} m. Assume the diffusivity of oxygen in water 2.5x10^{-9} m^2/s and the concentration of oxygen in water at that temp and pressure is 0.0128 kmol/m^3. (5)

B) Write the material balance equations with a neat flow diagram and graphical representation of the counter-current flow of mass transfer with complete notation. (3)

C) Define dry and wet bulb temperature, percentage saturation, and dew point? (2)

4) (i) Calculate the partial pressure for N_2 gas with the mole fraction of 0.35 in the liquid solution at T = 303.2 K. (Henry's law constant = 9.3601 x 10^4 bar)

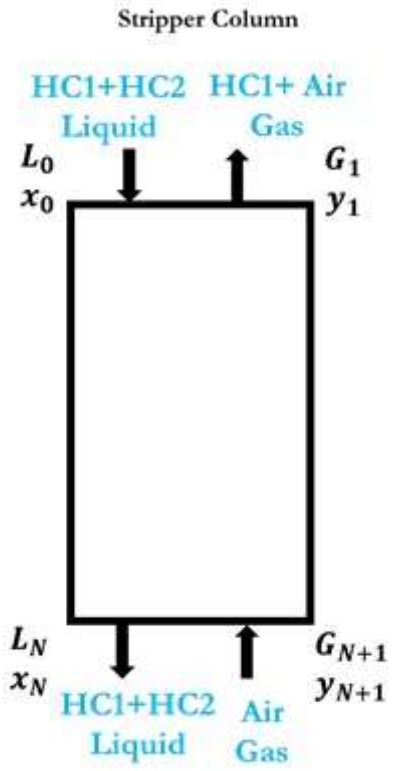
A) (ii) Write the operating line equation in terms of mole ratios for envelope 2 of the absorption column shown in the figure. (2)



B) In a stripper column operation, a liquid solution with a feed rate of 1000 kg/h containing hydrocarbon HC1 of 25% by weight (M.Wt. = 44) and hydrocarbon HC2 of 75% by weight (M.Wt. = 114) is sent. In the liquid mixture, 95 % of HC1 is stripped off by using air. Calculate the following: (3)

a. Mole fraction of HC1 and HC2 at the entrance and exit of the column.

b. Total liquid, HC1 (in liq. stream), and HC2 (in liq. stream) flow rates at the entrance and exit of the column in kmol/h.



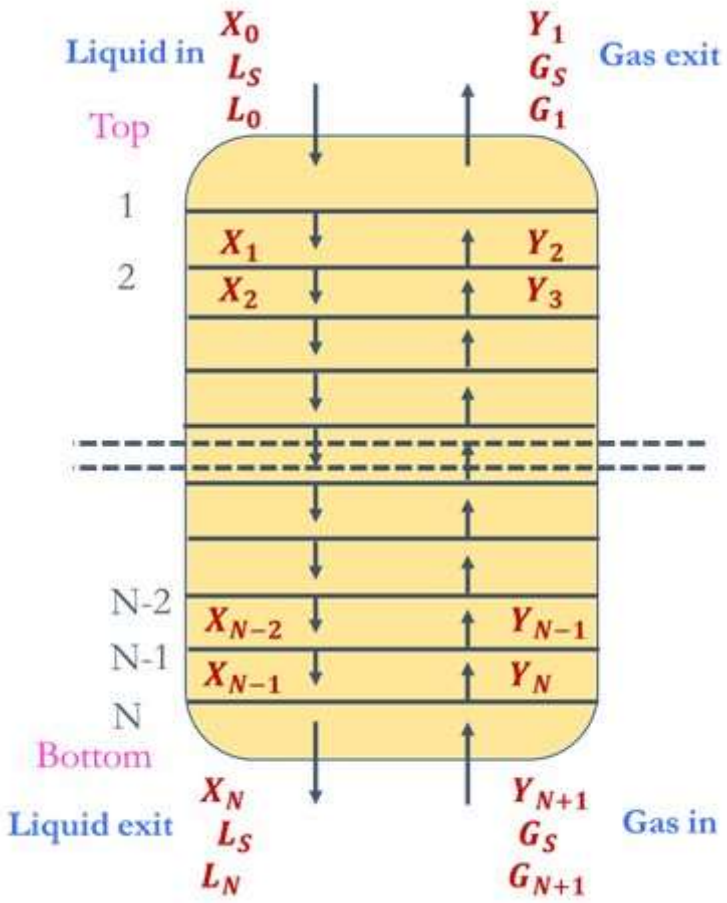
C) In the absorption column, the mixture of NH_3 and N_2 mixture is scrubbed with water to reduce NH_3 to 0.4%. The gas mixture stream enters the column with a flow rate of 2500 m^3/h at 310 K and 120 kPa and the partial pressure of NH_3 in the entering gas stream is 9 kPa. The water stream fed to the column is always solute free. The NH_3-Water solutions can be assumed to obey Raoult's law. The vapor pressure of NH_3 at 310 K is 48 kPa. Absorption factors: $A_1 = \frac{L_1}{mG_1} \approx \frac{L_0}{mG_1}$ $A_N = \frac{L_N}{mG_N} \approx \frac{L_N}{mG_{N+1}}$. Calculate the following: (5)

i. Minimum L_S/G_S ratio for (X_N)=0.2277 at the point of tangency to the equilibrium curve.

ii. Water circulation rate in kg/h, for the actual liquid-to-gas solvent rate is 1.4 times the minimum.

iii. Mole fraction of NH_3 in the exit liquid stream.

iv. Number of trays required for the desired separation using the Kremser equation.



5) In a spray drier, a wet solid with a weight of 500 kg is dried from the initial moisture content of 30% to the final product with a moisture content of 12% on a wet basis. The equilibrium moisture is 7% on a wet basis. Calculate the following for the given data:

A) (a) amount of moisture removed for 2500 kg of dry solid (b) free moisture content? (3)

B) Define the following and denote them in the moisture content vs. relative humidity graph:

(i) Bound moisture (ii) Unbound moisture (iii) Free Moisture (iv) Equilibrium Moisture? (3)

C) As an expert chemical engineer, you were assigned a task to design a process scheme with adsorber units to purify the liquid and gas streams for the chemical industry. Adsorber units can be designed using your choice of adsorbents for the following separation/ purification purposes. A liquid feed stream (contains petroleum products + water mixture) and a separate gas feed stream (contains hydrocarbon gases + water vapor mixture) are to be sent to adsorber units for separation/ purification. Choose the adsorbents for the adsorber units that can essentially do the purification/ separation for the respective liquid/ gas streams. The first adsorber unit will dehydrate the liquid feed stream following which the liquid mixture is sent to the secondary adsorber unit to decolorize the petroleum products. The gas feed stream with hydrocarbons gas mixture will be dehydrated in the third adsorber unit. Draw the flowsheet schematic for the following adsorption process with the feed streams and specify clearly the adsorber units (1, 2 & 3), feed stream (liquid mixture/ gas mixture), components of the stream (water/ vapor/ petroleum/ hydrocarbon products), and adsorbents used in adsorber unit. Provide a brief and concise report about your choice of adsorbents made for the adsorber units, your reason to select the adsorbent, and a description of the process flowsheet. (4)

-----End-----