KATHMANDU UNIVERSITY
End Semester Examination
July/August, 2024

Marks Scored:

Level : B.E.
Year : III

Course : CHEG 313
Semester : II

Exam Roll No. :

Time: 30 mins.

F. M. : 10

Registration No.:

Date : 12 AUG 2024

SECTION "A"

[20 Q. × 0.5 = 10 marks]

Choose and encircle in the most appropriate option from each set of choices

1. Which of the following factors does NOT typically affect the convective mass transfer coefficient in a liquid-gas system?
   a. Temperatureof the gas phase
   b. Velocity of the gas phase
   c. Surface roughness of the solid
   d. Viscosity of the liquid

2. According in an experiment on mass transfer through the laminar boundary layer over a flat plate, 1 m long, the average mass transfer coefficient was found to be 0.00705 cm/s. What would be the average mass transfer coefficient ni cm/s if the plate length is doubled?
   a. 0.0141 b. 0.0035 c. 0.005 d. 0.1

3. The mass transfer coefficients obtained by the Reynolds and Prandtl analogies are the same if
   a. Sc=0 b. Sc=1 c. Sc=infinite d. Not applicable

4. The psychrometric ratio is defined as ____ where, h_G convective heat transfer coefficient, k_y is convective mass transfer coefficient and c_s is humid heat.
   a. h_G / k_y b. k_y / h_G c. $h_G / k_y \cdot c_s$ d. $k_y \cdot c_s / h_G$

5. The units of mass transfer coefficients could be
   a. Moles transferred/Time (area)(pressure)
   b. Moles transferred/Time (area) (mole fraction)
   c. Moles transferred/Time (area)(concentration)
   d. Any of these answers

6. Reboiler is considered as one theoretical plate, because
   a. Of the assumption that vapor and liquid leaving the reboiler are in equilibrium
   b. Vapor is recycled to the column
   c. Reboiler itself contains one plate
   d. Vapor is pure

7. The humidity at dry-bulb temperature of 20 °C is 40% and the humidity at dry-bulb temperature of 25 °C is 25%, what is the slope of adiabatic cooling line?
   a. -0.05 b. 0.05 c. -0.03 d. 0.03

8. Binary distillation involves the mass transfer by _____ at the gas-liquid interface.
   a. Unidirectional diffusion from liquid to gas phase
   b. Unidirectional diffusion from gas to liquid phase
   c. Non directional diffusion in either gas to liquid or liquid to gas phase
   d. A counter diffusion at an almost equal molar rate

9. Operating velocity in a packed tower is usually _____ the flooding velocity.
   a. equal to b. half c. one third d. twice

10. Minimum reflux ratio in a distillation column results in?
   a. Optimum number of trays b. Maximum condenser size
   c. Minimum reboiler size d. Minimum number of trays

11. For the absorption of a gas (like water) Henry's law states that partial pressure of the gas is proportional to the mole fraction of the gas in the liquid–gas solution with the constant of proportionality being Henry's constant. A bottle of soda pop (CO_2-H_2O) at room temperature has a Henry's constant of 17,100 kPa. If the pressure in this bottle is 120 kPa and the partial pressure of the water vapor in the gas volume at the top of the bottle is neglected, the concentration of the CO_2 in the liquid H_2O is
   a. 0.003 mol-CO_2/mol b. 0.007 mol-CO_2/mol
   c. 0.013 mol-CO_2/mol d. 0.022 mol-CO_2/mol

12. In a batch adsorption process, 5 g of fresh adsorbent is used to beat 1 liter on an aqueous phenol solution. The initial phenol concentration is 100 mg/L. The equilibrium relation is given by q = 1.3C, where q is the amount of phenol adsorbed in mg of phenol per gram of adsorbent and C is the concentration of phenol in mg/L in the aqueous solution. When equilibrium is attained between the adsorbent and the solution, the concentration of phenol in the solution is _____ mg/L.
   a. 13.33 b. 7.5 c. 0.5 d. 11.11

13. A binary distillation column is to be designed using McCabe Thiele Method. The distillate contains 90 mol% of the more volatile component. The point of intersection of the q-line with the equilibrium curve is (0.5,0.7). The maximum reflux ration for this operation is _____?
   a. 2 b. 1.5 c. 0.5 d. 1

14. A rubber object is in contact with nitrogen at 298 K and 250 kPa. The solubility of nitrogen gas in rubber is 0.00156 kmol/m^3·bar. The mass density of nitrogen at the interface is
   a. 0.049 kg/m^3 b. 0.064 kg/m^3 c. 0.077 kg/m^3 d. 0.109 kg/m^3

15. Find the Nitrogen gas at high pressure and 298 K is contained in a 2 m x 2 m x 2 m cubical container made of natural rubber whose walls are 4 cm thick. The concentra- tion of nitrogen in the rubber at the inner and outer surfaces are 0.067 kg/m^3 and 0.009 kg/m^3, respectively. The diffusion coefficient of nitrogen through rubber is 1.5 x 10^{-10} m^2/s. The mass flow rate of nitrogen by diffusion through the cubical container is
   a. 8.24 x 10^{-10} kg/s b. 1.35 x 10^{-10} kg/s
   c. 5.22 x 10^{-9} kg/s d. 9.71 x 10^{-9} kg/s

16. The correct expression for the Colburn factor for mass transfer that relates Sherwood number (Sh), Reynold number (Re) and Schmidt number (Sc) is

a. $\frac{Sh}{(Re)^{1/2}(Sc)}$ b. $\frac{Sh}{(Re)^{1/2}(Sc)^{1/3}}$ c. $\frac{Sh}{(Re)(Sc)}$ d. $\frac{Sh}{(Re)(Sc)^{1/3}}$

17. Choose the correct one

a. wet bulb temperature is always higher than dry bulb temperature
b. wet bulb temperature is identical to dry bulb temperature at 0% relative humidity
c. wet bulb temperature is identical to dry bulb temperature at 100% relative humidity
d. dry bulb temperature is the temperature of adiabatic saturation

18. If Prandtl number is greater than the Schmidt number, then the

a. thermal boundary layer lies inside the concentration boundary layer
b. concentration boundary layer lies inside the thermal boundary layer
c. thermal & concentration boundary layers are of equal thickness
d. hydrodynamic boundary layer is thicker than the other two

19. In a binary mixture containing components A and B, the relative volatility of A with respect to B is 2.5 when mole fractions are used. The molecular weights of A and B are 78 and 92 respectively. If the compositions are however expressed in mass fractions, the relative volatility will then be

a. 1.18 b. 2.5 c. 2.12 d. 2.95

20. At 25°C and 90 % relative humidity, water evaporates from the surface of a lake at the rate of 1 kg/m3.h. The relative humidity that will lead to an evaporation rate of 3.0 kg/m2.h with other conditions remaining the same is,

a. 30 % b. 50 % c. 60 % d. 70 %

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SECTION "B"
[5 Q. × 8 = 40 marks]

Attempt *ALL* questions.

1. A continuous fractionating column is to be designed for separating 10000 kg/hr for a liquid mixture containing 40 mole % methanol and 60 mole % water in to an overhead product containing 97 mole % methanol and a bottom product having 98 mole % water. A molar reflux ratio of 3 is used. Calculate
   a. Moles of overhead product obtained per hour [3]
   b. Number of ideal plates and location of the feed plate, if the feed is at its bubble point [5]

Equilibrium data:

x	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
y	0.417	0.579	0.669	0.729	0.78	0.825	0.871	0.915	0.959

Where, x and y are mole fraction of methanol in liquid and vapor phase respectively.
$(y=\frac{\alpha x}{1+(\alpha-1)x})$ $(y=(\frac{R}{R+1}x+\frac{x_D}{R+1})$ for rectifying section) $(y=(-\frac{q}{1-q}x+\frac{x_F}{1-q})$ for feed)

2. The SO_2 emission limit at a plant is 25 ppmv. The concentration in the uncleaned exhaust gas is 200 ppmv. A packed absorption tower (a scrubber) of circular cross-section is currently used to reduce the SO_2 concentration in the exhaust gas to 10 ppmv, i.e. well below the emission limit. The packed section of the scrubber has a height of 1 m. The solvent inlet concentration of SO_2 is 0. A production increase is planned at the plant, and as a consequence of this, the exhaust gas flow rate is expected to increase by 30 %. It is assumed that the mass transfer coefficient will not be significantly affected be the increased flow rate, and no operational problems with the scrubber are expected to occur. The pollutant concentration in the solvent outlet stream is very low, and as a simplification it can be set to 0.
   a. Is it possible to keep the existing equipment and still have SO_2 emissions below the emission limit after the production increase? (Hints: Check how HTUG will be affected by the production increase, simplify the NTUG equation and calculate a new NTUG while keeping Z constant.) [5]
   b. Are there potential operational bottlenecks, other than the emissions limit, that should be evaluated in connection with such a production increase? Explain. [3]

Henry's law: $y_A^* = \frac{H}{p}x_A$ $z = HTU_G \cdot NTU_G$ $HTU_G = \frac{G}{K_y a}$ $K_y = \frac{1}{\frac{1}{k_y}+\frac{m}{k_x}}$ $m = \frac{H}{p}$

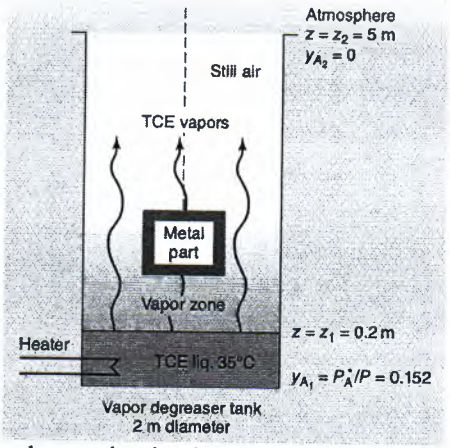
$NTU_G = \int_{out}^{in} \frac{dy_A}{y_A - y_A^*}$ $NTU_G = \frac{y_{A,in}-y_{A,out}}{(y_A-y_A^*)_{lm}}$ $(y_A - y_A^*)_{lm} = \frac{(y_{A,in}-y_{A,in}^*)-(y_{A,out}-y_{A,out}^*)}{ln\frac{y_{A,in}-y_{A,in}^*}{y_{A,out}-y_{A,out}^*}}$

P.T.O.

3.

a. Refer to the figure given. This is an example of a vapor degreaser set-up. Given a cylindrical tank containing trichloroethylene (TCE) with its level maintained at 0.2 m and temperature maintained at 35 °C. TCE has a molecular weight of 131.4 g/mol, a vapor pressure of 115.5 mmHg, and diffusivity in air of 0.088 cm2/s at the given temperature. Current regulations state that the degreaser cannot emit monre than 1 kg of TCE per day. Determine if the degreaser is in violation of the regulation.

[*Hint: Start from* $N_{A,z} = -cD_{AB}\frac{dy_A}{dz} + y_A(N_{A,z} + N_{B,z})$] [5]



b. Two very large tanks, maintained at 323 K and 1 atm total system pressure, are connected by a 0.1 m diameter circular duct which is 5 m in length. Tank 1 contains a uniform gas of 60 mol % acetone and 40 mol % air, whereas tank 2 contains a uniform gas of 10 mol % acetone and 90 mol % air. Determine the initial rate of acetone transfer between the two tanks. [$D_{AB} = 1.46 \times 10^{-5}$ m^2/s at 323 K] [3]

4. A waste strean of alcohol vapor in air from a process was adsorbed by activated carbon particles in a packed bed having a diameter of 4 cm and length of 14 cm containing 79.2 g of carbon. The inlet gas stream having a concentration c_o of 600 ppm and a density of 0.00115 g/cm^3 entered the bed at a flow rate of 754 cm^3/s. Data in the table give the concentrations of the breakthrough curve. The break-point concentration is set at c/c_o = 0.01. Do as follows:

Time,h	c/c_o	Time,h	c/c_o	Time,h	c/c_o
0	0	4.5	0.155	6.2	0.933
3	0	5	0.396	6.5	0.975
3.5	0.002	5.5	0.658	6.8	0.993
4	0.030	6	0.903		

a. Determine the break-point, the fraction of total capacity used up to the break point, and the length of the unused bed. Also, determine the saturation loading capacity of the carbon. [4]

b. If the break-point time required for a new column is 6.0 h, what is the new total length of the column required? [4]

[$t_b = t^*(1\text{-LUB/L}][\ t^* \propto L$]

5. Water exiting the condenser of a power plant at 45 °C enters a cooling tower with a mass flow rate of 15000 kg/s. A stream of cooled water is returned to the condenser from the cooling tower with the same flow rate. Make-up water is added in a separate stream at 20 °C. Atmospheric air enters the cooling tower at 30 °C with a wet bulb temperature of 20 °C. The volumetric flow rate of moist air into the cooling tower is 8000 m^3/s. Moist air exits the tower at 40 °C and 90% relative humidity. Assume an atmospheric pressure of 101.3 kPa.

[$H_{y,sat} = c_s(T - 32) + \lambda_0 H_s$][1ft equals 0.0283 m^3][(0°C × 9/5) + 32 = 32°F][λ_0=1075 Btu/lb]

a. the mass flow rate of dry air [4]

b. the temperature of the cooled liquid water exiting the cooling tower [4]