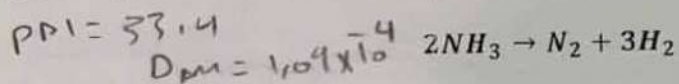


Q2) Ammonia is being cracked on a solid catalyst according to the reaction:



At one place in the apparatus where the pressure is 1 atm and the temperature is  $200^\circ\text{C}$  the analysis of the bulk gas is 33.33%  $\text{NH}_3$  (A), 16.67%  $\text{N}_2$  (B), and 50%  $\text{H}_2$  (C) by volume. The circumstances are such that  $\text{NH}_3$  diffuses from the bulk gas stream to the catalyst and the products of the reaction diffuse back as if by molecular diffusion through a gas film in laminar flow of 1 mm thickness. The diffusion is controlled (chemical reaction very rapid) with the concentration of  $\text{NH}_3$  at the catalyst surface equal to zero. Also at 1 atm and  $200^\circ\text{C}$ ,  $D_{AB} = 5.39 \times 10^{-5} \text{ m}^2/\text{s}$ ,  $D_{AC} = 1.66 \times 10^{-4} \text{ m}^2/\text{s}$ . Estimate the local rate of cracking ( $\text{kg NH}_3/\text{m}^2 \cdot \text{s}$ ).

Given:  $\text{Mwt}_{\text{NH}_3} = 17 \text{ kg/kgmol}$

$$N_A = 8.41 \times 10^{-4} \frac{\text{kgmol}}{\text{m}^2 \cdot \text{s}}$$

$$N_A = 0.0136 \frac{\text{kg}}{\text{m}^2 \cdot \text{s}}$$

(35 Marks)

# FACULTY OF ENGINEERING

MidTerm Examination  
Academic Year 2024-2025



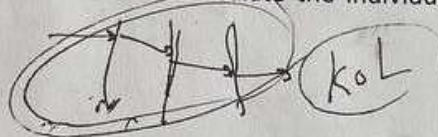
Department: Chemical Engineering  
Stage/ Level: 3  
Total Mark: 100

Course Title: Unit Operation  
Course Code: KOU20441  
Time Allowed: 90 minutes  
Attached Sheet: Non

Q1) A solute gas is absorbed from a dilute gas-air mixture by counter current scrubbing with a solvent in a packed tower. The equilibrium relation is  $Y = mX$ . If (99%) of the solute is to be recovered using a liquid rate of 1.75 times the minimum and the height of transfer unit is (1 m). What height of packing will be required?

(20 Marks)

Q2) In an experimental study of the absorption of ammonia by water in a wetted-wall column, the value of  $K_G$  was found to be  $2.75 \times 10^{-6} \text{ kmol/m}^2 \cdot \text{s} \cdot \text{kPa}$ . At one point in the column, the composition of the gas and liquid phases were 8.0 and 0.115 mole %  $\text{NH}_3$ , respectively. The temperature was 300 K and the total pressure was 1 atm. Eighty-five percent of the total resistance to mass transfer was found to be in the gas phase. At 300 K, ammonia-water solution follows Henry's law up to 5 mole % ammonia in the liquid, with  $H = 1.64$  when the total pressure is 1 atm. Calculate the individual film coefficients and the interfacial concentrations.



(20 Marks)

Q3) A soluble gas is to be absorbed from air in water in packed tower. The inlet and exit gas stream concentrations are 0.08 and 0.009 kgmole solute/kgmole air. The water enters the tower solute free and leaves with concentration 0.08 kg solute/kg water. The height of the liquid and gas phase transfer units are 0.5 m and 1 m respectively and the equilibrium relationship is given by  $Y^* = 0.06X$ . Drive an expression for the packed height in the tower and calculate the height of the packed tower.

$$\left(\frac{L_s}{G_s}\right)_a$$

$$N_G = m \frac{G_s}{L_s}$$

$$\frac{m}{\left(\frac{L_s}{G_s}\right)_{min}}$$

(25 Marks)

Q4) The gas  $\text{CO}_2$  is diffusing at steady state through a 20 cm long tube with a diameter of 1 cm. The tube contains  $\text{N}_2$  at 350 K and the total pressure is constant at 101.32 kPa. The  $\text{CO}_2$





## FACULTY OF ENGINEERING

MidTerm Examination  
Academic Year 2024-2025



Department: Chemical Engineering  
Stage/ Level: 3  
Total Mark: 100

Course Title: Unit Operation  
Course Code: KOU20441  
Time Allowed: 90 minutes  
Attached Sheet: Non

gas has a composition of 60 vol.% at one end of the tube and 10 vol.% at the other end. The diffusivity  $D_{AB}$  is  $0.16 \text{ cm}^2/\text{s}$  at 298 K.

- (a) Calculate the mass rate of  $\text{CO}_2$ .
- (b) If the total pressure was doubled calculate the time required for  $\text{CO}_2$  to diffuse through the tube.

(35 Marks)

Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

Course Title: Transport phenomena  
Course Code: KOU20441  
Time Allowed: 90 minutes  
Attached Sheet: Non

Q1) A solute gas is absorbed from a dilute gas-air mixture by counter current scrubbing with a solvent in a packed tower. The equilibrium relation is  $Y = mX$ . If (99%) of the solute is to be recovered using a liquid rate of 1.75 times the minimum and the height of transfer unit is (1 m). What height of packing will be required?

(20 Marks)

Q2) Drive an expression for the diffusion of an ideal gas in unsteady state conditions.

(15 Marks)

Q3) A packed tower operating at 101 kPa, recovers 95% of solute gas initially is presented at low concentration in an inert gas. The inert gas rate is  $0.16 \text{ kmol/m}^2 \cdot \text{s}$  and the tower is supplied with solute free liquid at the rate of  $0.23 \text{ kmol/m}^2 \cdot \text{s}$ . Calculate the height of the tower given:

$$y_A^* = 0.8 \cdot x_A$$

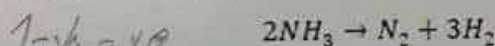
$$KOG.a = 50 + KOL.a$$

Where  $KOG.a$ , and  $KOL.a$  are in  $\text{kmol/m}^3 \cdot \text{h}$

$$x_A + x_B + x_C = 1 - x_A$$

(30 Marks)

Q4) Ammonia is being cracked on a solid catalyst according to the reaction:



At one place in the apparatus where the pressure is 1 atm and the temperature is  $200^\circ\text{C}$  the analysis of the bulk gas is 33.33%  $\text{NH}_3$  (A), 16.67%  $\text{N}_2$  (B), and 50%  $\text{H}_2$  (C) by volume. The circumstances are such that  $\text{NH}_3$  diffuses from the bulk gas stream to the catalyst and the products of the reaction diffuse back as if by molecular diffusion through a gas film in laminar flow of 1 mm thickness. The diffusion is controlled (chemical reaction very rapid) with the concentration of  $\text{NH}_3$  at the catalyst surface equal to zero. Also at 1 atm and  $200^\circ\text{C}$ ,  $D_{AB} = 5.39 \times 10^{-5} \text{ m}^2/\text{s}$ ,  $D_{AC} = 1.66 \times 10^{-4} \text{ m}^2/\text{s}$ . Estimate the local rate of cracking ( $\text{kg NH}_3/\text{m}^2 \cdot \text{s}$ ).

Given:  $\text{Mwt}_{\text{NH}_3} = 17 \text{ kg/kmol}$

$$n = 14$$

$$0.1667$$

$$n = \frac{m}{\text{mol}}$$

(35 Marks)

$$\frac{P_{\text{NH}_3}}{P_{\text{total}}} = \frac{P_{\text{NH}_3}}{P_{\text{total}}}$$

$$\frac{P_{\text{NH}_3}}{P_{\text{total}}} = \frac{P_{\text{NH}_3}}{P_{\text{total}}}$$

$$6029.1$$

$$3092.2$$



Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

Course Title: Unit Operation I  
Course Code: UOP5521  
Time Allowed: 180 minutes  
Attached Sheet: Non

(a) Calculate the number of theoretical plates when  $L = 0.65 \text{ kg/m}^2 \cdot \text{s}$  and  $G = 0.4 \text{ kg/m}^2 \cdot \text{s}$ .

(b) Calculate  $(L/G)$  if the actual number of plates = 12 and overall column efficiency = 0.5.

Given: M.wt  $\text{NH}_3 = 17 \text{ kg/kgmol}$

(25 Marks)

Q5) A continuous rectifying column handles a mixture consisting of 40 per cent of benzene by mass and 60 per cent of toluene at the rate of  $4 \text{ kg/s}$ , and separates it into a product containing 97 per cent of benzene and a liquid containing 98 per cent toluene. The feed is liquid at its boiling-point.

(a) Calculate the mass flows of distillate and waste liquor.

(b) If a reflux ratio of 3.5 is employed, how many plates are required in the rectifying part of the column?

Given: M.wt Benzene =  $78 \text{ kg/kgmol}$ ,

M.wt toluene =  $92 \text{ kg/kgmol}$

(25 Marks)

Mole fraction of benzene in liquid	Mole fraction of benzene in vapour
0.1	0.22
0.2	0.38
0.3	0.51
0.4	0.63
0.5	0.7
0.6	0.78
0.7	0.85
0.8	0.91
0.9	0.96

The feed is at liquid at boiling point. The q line is a vertical line as drawn as

$W = 2.4$   
 $D = 1.6$

intercept of top operation line on the y axis is given by

Good Luck

$$\frac{x_d}{R+1} = 0.716$$

The plate stripped off as shown as 10 theoretical are required

# FACULTY OF ENGINEERING

Final Examination  
Second Attempt - 2020-2021



Faculty: Engineering  
Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

Course Title: Transport Phenomena  
Course Code: KOU20441  
Time Allowed: 120 minutes  
Attached Sheet: Non

## Answer All Questions

Q4) A mixture containing 52% pentane is to be distilled continuously to give a top product of 95% pentane and a bottom product of 10%. Determine the minimum number of plates by graphical and analytical methods. Also for the same conditions determine the liquid composition on the second plate from the top by using Lewis Sorel method with a reflux ratio of 2 kgmol/kgmol product.

Given:

(25 Marks)

$$\alpha_{AB} = 3.47$$

x	y
0.1	0.21
0.2	0.41
0.3	0.54
0.4	0.66
0.5	0.745
0.6	0.82
0.7	0.875
0.8	0.925
0.9	0.975

Good Luck

$$\frac{G}{L} = \frac{x_1 - x_2}{y_1 - y_2} = L(x_1 - x_2)$$

Q3

A mixture of ammonia and air is scrubbed in a plate column with fresh water. If the ammonia concentration is reduced from 5% to 0.5% and the equilibrium equation is given as  $y^* = 2 * x$ . Calculate  $(L/G)$  if the actual number of plates = 12 and overall column efficiency = 0.5

$$\frac{\text{kmol}}{\text{hr}} \times \frac{1 \text{ hr}}{3600}$$

$x_1 =$

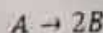
(25 Marks)



Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

Course Title: Transport Phenomena  
Course Code: KOU20441  
Time Allowed: 90 minutes  
Attached Sheet: Non

Q2) A species of A in a gas mixture diffuses through a 3 mm thick film and reaches a catalyst surface where the reaction below takes place:



If the partial pressure of (A) in the bulk of the gas is  $8.5 \text{ kN/m}^2$  and the diffusivity of (A) is  $2 \times 10^{-5} \text{ m}^2/\text{s}$ , find the mole flux of (A). The pressure and temperature of the system are  $101.3 \text{ kN/m}^2$  and  $297 \text{ K}$  respectively.

92.8

(25 Marks)

Q3) In an experimental study of the absorption of ammonia by water in a wetted-wall column, the value of KG was found to be  $2.75 \times 10^{-6} \text{ kmol/m}^2 \cdot \text{s} \cdot \text{kPa}$ . At one point in the column, the composition of the gas and liquid phases were 8.0 and 0.115 mole %  $\text{NH}_3$ , respectively. The temperature was  $300 \text{ K}$  and the total pressure was  $1 \text{ atm}$ . Eighty-five percent of the total resistance to mass transfer was found to be in the gas phase. At  $300 \text{ K}$ , ammonia-water solution follow Henry's law up to 5 mole % ammonia in the liquid, with  $H = 1.64$  when the total pressure is  $1 \text{ atm}$ . Calculate the individual film coefficients and the interfacial concentrations.

(25 Marks)

Q4) Through the accidental opening of a valve water has been spilled on the floor of an industrial plant in a remote difficult area of  $1 \text{ ft}^2$ . It is desired to estimate the time required to evaporate the water in the surrounding air. The water layer is  $0.04 \text{ in.}$  thick and may be assumed to remain at a constant temperature of  $75^\circ\text{F}$  and  $1 \text{ atm}$  with a molal humidity of  $0.0032 \text{ lbmol H}_2\text{O/lbmol air}$ . The evaporation is assumed to take place by molecular diffusion through a gas film  $2 \text{ in.}$  thick at  $75^\circ\text{F}$ , saturated molal humidity is  $0.0303 \text{ lbmol H}_2\text{O/lbmol air}$ . The diffusivity of water vapour in air is  $0.0084 \text{ ft}^2/\text{s}$ .

Given:

$$R = 0.73 \frac{\text{atm} \cdot \text{ft}^3}{\text{lbmol} \cdot ^\circ\text{R}}$$

$$p_{\text{water}} = 62.4 \frac{\text{lb}}{\text{ft}^3}$$

(35 Marks)



Q2) The gas  $\text{CO}_2$  is diffusing at steady state through a tube 20 cm long having diameter of 1 cm and containing  $\text{N}_2$  at 350 K. The total pressure is constant at 101.32 kPa. The partial pressure of  $\text{CO}_2$  at one end is 456 mmHg and 76 mmHg at the other end. The diffusivity  $D_{AB}$  is  $0.167 \text{ cm}^2/\text{s}$  at 298 K. Calculate the mass rate of  $\text{CO}_2$ . If the partial pressure remains constant calculate the total pressure to double the transfer rate.

Given:

$$1 \text{ cm} = 0.01 \text{ m}$$

$$\frac{\text{cm}^2}{\text{s}}$$

$$M.wt_{\text{CO}_2} = 44 \text{ kg/kgmol}$$

(25 Marks)

Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

Course Title: Transport Phenomena  
Course Code: KOU20441  
Time Allowed: 90 minutes  
Attached Sheet: Non

Q1) The experimental value of the gas diffusivity of oxygen (A)/benzene (B) at 38 °C and 1atm is 0.101 cm<sup>2</sup>/s. Estimate the diffusion coefficient for oxygen (A)/benzene (B) at 38 °C and 1 atm using the method of Fuller et al and compare it with the given experimental value. Also if the temperature was raised to 200 °C how can this affect the given experimental value of the gas diffusivity of oxygen (A)/benzene (B).

Given :  $M_{Bz} = 78 \text{ kg/kgmol}$

(15 Marks)

Atomic Diffusion Volumes  
and Structural Diffusion-Volume Increments

C	15.9	F	14.7
H	2.31	Cl	21.0
O	6.11	Br	21.9
N	4.54	I	29.8
Aromatic ring	-18.3	S	22.9
Heterocyclic ring	-18.3		

Diffusion Volumes of Simple Molecules

He	2.67	CO	18.0
Ne	5.98	CO <sub>2</sub>	26.7
Ar	16.2	N <sub>2</sub> O	35.9
Kr	24.5	NH <sub>3</sub>	20.7
Xe	32.7	H <sub>2</sub> O	13.1
H <sub>2</sub>	6.12	SF <sub>6</sub>	71.3
D <sub>2</sub>	6.84	Cl <sub>2</sub>	38.4
N <sub>2</sub>	18.5	Br <sub>2</sub>	69.0
O <sub>2</sub>	16.3	SO <sub>2</sub>	41.8
Air	19.7		

$$N_A = (c_{O_2} y_A - k_{O_2} y_A')$$

$$N_A - k_{O_2} y_A = - (c_{O_2} y_A') \quad \text{STATE} \rightarrow \text{DAP} \rightarrow \text{RATE}$$

$$-\frac{N_A}{k_{O_2}} + y_A = y_A'$$

$$y_A' = 0$$



Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

Course Title: Unit Operation I  
Course Code: UOP5521  
Time Allowed: 90 minutes

Q3) An open bowl 0.3 m diameter contains water at 350 K evaporating into the atmosphere. If the air current is sufficiently strong to remove the water vapour as it formed and the resistance to its mass transfer in air is equivalent to that of 1 mm thick layer for conditions of molecular diffusion, what will be the rate of cooling due to evaporation? The water can be considered as well mixed and the water equivalent in the system is equal to 10 kg. The diffusivity of water in air can be taken as  $0.2 \text{ cm}^2/\text{s}$ , and the kilogram molecular volume is  $22.4 \text{ m}^3$ .

Given:

$P^*_{\text{water at 350 K}} = 41.8 \text{ kPa}$ ,

latent heat of vaporization = 2466 KJ/kg,

$C_p \text{ water} = 4.184 \text{ KJ /kg.k}$

$$\text{Rate of heat loss} = m C_p \frac{dT}{dt}$$

(35 Marks)

Faculty: Engineering  
Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

Course Title: Transport Phenomena  
Course Code: KOU20441  
Time Allowed: 120 minutes  
Attached Sheet: Non

**Answer All Questions**

Q4) A mixture containing 52% pentane is to be distilled continuously to give a top product of 95% pentane and a bottom product of 10%. Determine the minimum number of plates by graphical and analytical methods. Also for the same conditions determine the liquid composition on the second plate from the top by using Lewis Sorel method with a reflux ratio of 2 kgmol/kgmol product.

Given:

(25 Marks)

$$\alpha_{AB} = 3.47$$

x	y
0.1	0.21
0.2	0.41
0.3	0.54
0.4	0.66
0.5	0.745
0.6	0.82
0.7	0.875
0.8	0.925
0.9	0.975

Good Luck



Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

Course Title: Unit Operation I  
Course Code: UOP5521  
Time Allowed: 90 minutes

Q1)

(A) In a packed column operating at atmospheric pressure and 295 K, 10% ammonia – air mixture is scrubbed with water and the concentration is reduced to 0.1%. If the whole of the resistance to mass transfer may be regarded as lying within a thin laminar film on the gas side of the gas liquids interface, drive from the first principle an expression for the rate of absorption at any position in the column. At some intermediate point where the ammonia's concentration in the gas phase has been reduced to 5%, the partial pressure of ammonia is in equilibrium with the aqueous solution is  $660 \text{ N/m}^2$ , and the transfer flux is  $10^{-3} \text{ kgmol/m}^2 \cdot \text{s}$ . What is the thickness of the hypothetical gas film if the diffusivity of ammonia in air is  $0.24 \text{ cm}^2/\text{s}$ ?

(25 Marks)

(B) Drive an expression for the diffusion of an ideal gas in unsteady state conditions.

(15 Marks)

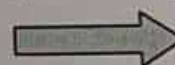
Q2) For a system in which component (A) is transferring from the liquid to the gas phase, the equilibrium is given by  $y_A^* = 0.75 X$ . At one point in the apparatus the liquid contain 90 mol% of (A) and gas contain 45 mol% of (A). The individual gas film mass transfer coefficient at this point in the apparatus of  $0.02716 \text{ kmol/m}^2 \cdot \text{s}$ , and 70% of the overall resistance to mass transfer is known to be encountered in the gas film: determine:

1. The molar flux of (A).
2. The interfacial concentration of (A).
3. The overall mass transfer coefficient for liquid and gas phases.

$$N_A = K_g (y_A - y_A^*)$$

$$N_A = k_g (y_A - y_A^*)$$

(25 Marks)



Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

Course Title: Unit Operation I  
Course Code: UOP5521  
Time Allowed: 180 minutes  
Attached Sheet: Non

**Q1)** A packed tower operating at 101 kPa, recovers 95% of solute gas initially is presented at low concentration in an inert gas. The inert gas rate is  $0.16 \text{ kmol/m}^2 \cdot \text{s}$  and the tower is supplied with solute free liquid at the rate of  $0.23 \text{ kmol/m}^2 \cdot \text{s}$ . Calculate the height of the tower given:

$$y_A^* = 0.8 \cdot x_A$$

$$KOG \cdot a = 50 + KOL \cdot a$$

Where  $KOG \cdot a$ , and  $KOL \cdot a$  are in  $\text{kmol/m}^3 \cdot \text{h}$

$$0.0694$$

$$3600$$

$$HOG = \frac{1}{a} HOB$$

$$Z = 11.6 \text{ m}$$

$$N_{OG} = 6.06$$

$$N_{OL} = 12.306$$

(15 Marks)

**Q2)** A Tube has 2 mm diameter and 2 cm long is closed at one end. This tube is filled with acetone to a depth of 1 cm. How long would the acetone take to evaporate completely if the tube was maintained at a temperature of  $20^\circ \text{C}$  in a current of air?

Given:

$$P_{\text{acetone}}^* = 180 \text{ mmHg,}$$

$$P_t = 760 \text{ mmHg,}$$

$$D_{AB} = 0.1 \text{ cm}^2/\text{s,}$$

$$M.wt_{\text{acetone}} = 58 \text{ kg/kmol,}$$

$$\rho_{\text{acetone}} = 790 \text{ kg/m}^3$$

$$t = 23415.33 \text{ s}$$

$$= 390 \text{ min}$$

(20 Marks)

**Q3)** Calculate the rate of burning of a carbon particle 2.54 cm diameter in an atmosphere of pure oxygen at 1000 K and 1 atm. Drive an expression to describe the process assuming a very large blanking layer of  $\text{CO}_2$  has formed around the particle. Given the diffusivity of oxygen in carbon dioxide is  $1.032 \text{ cm}^2/\text{s}$ , and

$$\text{At the carbon surface: } P_{\text{CO}_2} = 1 \text{ atm}$$

$$P_{\text{O}_2} = 0 \text{ atm}$$

$$\text{At very large radius: } P_{\text{CO}_2} = 0$$

$$P_{\text{O}_2} = 1 \text{ atm}$$

$$ND = 9.8 \times 10^5$$

(15 Marks)

**Q4)** A mixture of ammonia and air is scrubbed in a plate column with fresh water. If the ammonia concentration is reduced from 5% to 0.5% and the equilibrium equation is given as  $y^* = 2 \cdot x$

$$x_1 = 0.0174$$

$$Q = 0.775$$

$$C_1 = -0.0174$$

$$C_2 = 0.0671$$



# FACULTY OF ENGINEERING

Faculty: Engineering  
Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

Final Examination  
First Attempt - 2021-2022



Course Title: Transport Phenomena  
Course Code: KOU20441  
Time Allowed: 120 minutes  
Attached Sheet: Non

Answer All Questions

Q1) A relatively non-volatile hydrocarbon oil contains 4 mol % propane and being stripped by direct superheated steam in stripping tray tower to reduce the propane content to 0.2 mol %. The temperature is held constant at 422 K by internal heating in the tower at a pressure of  $2.026 \times 10^5$  Pa. Twice the minimum of direct steam is used for 300 kmol of total interning liquid. The vapour liquid equilibrium can be given by  $y = 25x$ , where  $x$  and  $y$  are mole fractions. Determine the number of theoretical trays.

$$63.138$$

$$2.43 \times 10^{-3}$$

$$-0.038$$

(20)



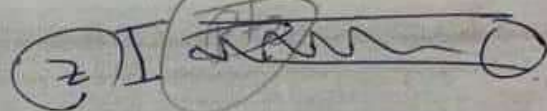
(25 Marks)

Q2) The gas  $\text{CO}_2$  is diffusing at steady state through a tube 20 cm long having diameter of 1 cm and containing  $\text{N}_2$  at 350 K. The total pressure is constant at 101.32 kPa. The partial pressure of  $\text{CO}_2$  at one end is 456 mmHg and 76 mmHg at the other end. The diffusivity  $D_{AB}$  is  $0.167 \text{ cm}^2/\text{s}$  at 298 K. Calculate the mass rate of  $\text{CO}_2$ . If the partial pressure remains constant calculate the total pressure to double the transfer rate.

Given:

$$1 \text{ cm} = 0.01$$

$$\frac{\text{cm}^2}{\text{s}}$$



(25 Marks)

$$M.W_{\text{CO}_2} = 44 \text{ kg/kmol}$$

$$\frac{G}{L} = \frac{y_1 - y_2}{x_1 - x_2} = \frac{(1 - y_2)}{(1 - y_1)}$$

$\frac{G}{L} = 1$

Q3) A mixture of ammonia and air is scrubbed in a plate column with fresh water. If the ammonia concentration is reduced from 5% to 0.5% and the equilibrium equation is given as  $y^* = 2x$ . Calculate  $(L/G)$  if the actual number of plates = 12 and overall column efficiency = 0.5

$$\frac{\text{kmol}}{\text{hr}} \times \frac{1 \text{ hr}}{3600}$$

$$x_1 =$$

(25 Marks)

Q4) 100 kmol/hr of a feed of 60% benzene and 40% heptane is to be separated by distillation. The distillate is to be 90 mol% benzene and the bottoms 10 mol% benzene. The feed enters the column as 30 mol% vapor. Use the reflux 1.5 times the minimum.

$$C_1 = 0.10$$

$$C_2 = -C_1$$

(0.1)

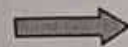
$$DAB2 = \frac{DAB1 + 1}{P + 2}$$

(-C1)

$$(1 + \theta) C_1$$

$$-6.78$$

$$\pi 0.2 \times 0.1$$



# FACULTY OF ENGINEERING

Final Examination  
Second Attempt - 2020-2021



Faculty: Engineering  
Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

Course Title: Transport Phenomena  
Course Code: KOU20441  
Time Allowed: 120 minutes  
Attached Sheet: Non

## Answer All Questions

Q1) A gas stream contains 4 mol %  $\text{NH}_3$  and this ammonia concentration is needs to be reduced to 0.5 mol % in a packed tower operating at 298 K and 101 kPa. The tower diameter is 750 mm. The inlet pure water flowrate is 68 kmol/h and the inlet gas flowrate is 57.8 kmol/h. The individual gas film mass transfer coefficient  $k_g a = 0.074 \text{ kmol/m}^3 \cdot \text{s}$  and the individual liquid film mass transfer coefficient  $k_l a = 0.17 \text{ kmol/m}^3 \cdot \text{s}$ . Calculate the height of tower if the equilibrium relationship is given as  $P_A^* = 1.46 C_A$ .

(25 Marks)

Q2) In a packed column operating at atmospheric pressure and 295 K, 10% ammonia – air mixture is scrubbed with water and the concentration is reduced to 0.1%. If the whole of the resistance to mass transfer may be regarded as lying within a thin laminar film on the gas side of the gas liquids interface, derive from the first principle an expression for the rate of absorption at any position in the column. At some intermediate point where the ammonia's concentration in the gas phase has been reduced to 5%, the partial pressure of ammonia is in equilibrium with the aqueous solution is 660 N/m<sup>2</sup>, and the transfer flux is  $10^{-3} \text{ kgmol/m}^2 \cdot \text{s}$ . What is the thickness of the hypothetical gas film if the diffusivity of ammonia in air is  $0.24 \text{ cm}^2/\text{s}$ ?

(25 Marks)

Q3) A 1 wt% solution of benzene in oil is to be stripped with steam at 1 atm and 100 °C to reduce the benzene content to 0.05 wt%.

(a) Calculate the steam usage per 100 kg of feed and the number of theoretical stages required for stripping tower where the steam composition is 1.8 times the minimum.

(b) If the efficiency is equal to 65% based on gas phase, calculate the actual number of trays required.

Given:  $y = 1.842 x$

M.wt oil = 300 kg/kgmol,

M.wt benzene = 78 kg/kgmol

(25 Marks)





Faculty: Engineering  
Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

Course Title: Transport Phenomena  
Course Code: KOU20441  
Time Allowed: 120 minutes  
Attached Sheet: Non

Answer All Questions

Q1) A gas stream contains 4 mol %  $\text{NH}_3$  and this ammonia concentration is needs to be reduced to 0.5 mol % in a packed tower operating at 298 K and 101 kPa. The tower diameter is 750 mm. The inlet pure water flowrate is 68 kmol/h and the inlet gas flowrate is 57.8 kmol/h. The individual gas film mass transfer coefficient  $k_g a = 0.074 \text{ kmol/m}^3 \cdot \text{s}$  and the individual liquid film mass transfer coefficient  $k_l a = 0.17 \text{ kmol/m}^3 \cdot \text{s}$ . Calculate the height of tower if the equilibrium relationship is given as  $P_A^* = 1.46 C_A$ .

(25 Marks)

$$\frac{1}{K_g} = \frac{1}{k_g} \quad G = (y_1 - y_2) = L(y_1 - y_2)$$

Q2) In a packed column operating at atmospheric pressure and 295 K, 10% ammonia – air mixture is scrubbed with water and the concentration is reduced to 0.1%. If the whole of the resistance to mass transfer may be regarded as lying within a thin laminar film on the gas side of the gas liquids interface, drive from the first principle an expression for the rate of absorption at any position in the column. At some intermediate point where the ammonia's concentration in the gas phase has been reduced to 5%, the partial pressure of ammonia is in equilibrium with the aqueous solution is  $660 \text{ N/m}^2$ , and the transfer flux is  $10^{-3} \text{ kgmol/m}^2 \cdot \text{s}$ . What is the thickness of the hypothetical gas film if the diffusivity of ammonia in air is  $0.24 \text{ cm}^2/\text{s}$ ?

$$\frac{N_{\text{mol}}}{h} \times \frac{1000 \text{ mol}}{1 \text{ kmol}} \times \frac{1 \text{ h}}{60 \text{ min}} \times \frac{1 \text{ m}}{60 \text{ s}} = 1 \text{ h} = 6$$

(25 Marks)

Q3) A 1 wt% solution of benzene in oil is to be stripped with steam at 1 atm and  $100^\circ \text{C}$  to reduce the benzene content to 0.05 wt %.

$$\frac{\text{kmol}}{\text{m}^3} \times \frac{\text{m}}{\text{m}^3}$$

$$C_f = \frac{P_0}{P_f} \quad C_w = \frac{P_0}{P_f}$$

(a) Calculate the steam usage per 100 kg of feed and the number of theoretical stages required for stripping tower where the steam composition is 1.8 times the minimum.

(b) If the efficiency is equal to 65% based on gas phase, calculate the actual number of trays required.

$$E = 0.65$$

Given:  $y = 1.842 x$

M.wt oil = 300 kg/kmol,

M.wt benzene = 78 kg/kmol

(25 Marks)



Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

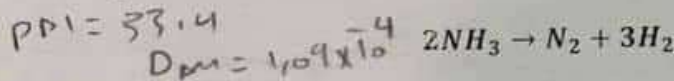
Course Title: Unit Operation I  
Course Code: UOP5521  
Time Allowed: 90 minutes

$$t = 10.6 \text{ min} \\ 600 \text{ s}$$

Q1) Hydrogen chloride is diffusing through an inert film of 1 mm thickness at 293 K and 100 kPa. Estimate the effect of increasing the pressure to 1000 kPa on the rate of diffusion if the mole fraction of the hydrogen chloride at one boundary is 20 %. Assume the concentration at the other boundary to be zero.

(25 Marks)

Q2) Ammonia is being cracked on a solid catalyst according to the reaction:



At one place in the apparatus where the pressure is 1 atm and the temperature is 200 °C the analysis of the bulk gas is 33.33% NH<sub>3</sub> (A), 16.67% N<sub>2</sub> (B), and 50% H<sub>2</sub> (C) by volume. The circumstances are such that NH<sub>3</sub> diffuses from the bulk gas stream to the catalyst and the products of the reaction diffuse back as if by molecular diffusion through a gas film in laminar flow of 1 mm thickness. The diffusion is controlled (chemical reaction very rapid) with the concentration of NH<sub>3</sub> at the catalyst surface equal to zero. Also at 1 atm and 200 °C,  $D_{AB} = 5.35 \times 10^{-5} \text{ m}^2/\text{s}$ ,  $D_{AC} = 1.66 \times 10^{-4} \text{ m}^2/\text{s}$ . Estimate the local rate of cracking ( $\text{kg NH}_3/\text{m}^2 \cdot \text{s}$ ).

Given:  $\text{Mwt}_{\text{NH}_3} = 17 \text{ kg/kgmol}$

$$NP = 8.04 \times 10^{-4} \frac{\text{kmol}}{\text{m}^2 \cdot \text{s}}$$

$$NA = 0.0136 \frac{\text{kg}}{\text{m}^2 \cdot \text{s}}$$

(35 Marks)

Q3) A chamber, of volume 1 m<sup>3</sup>, contains air at a temperature of 293 K and a pressure of 101.3 kN/m<sup>2</sup>, with a partial pressure of water vapour of 0.8 kN/m<sup>2</sup>. A bowl of liquid with a free surface of 0.01 m<sup>2</sup> and maintained at a temperature of 303 K is introduced into the chamber. How long will it take for the air to become 90% saturated at 293 K and how much water must be evaporated?

The diffusivity of water vapour in air is  $2.4 \times 10^{-5} \text{ m}^2/\text{s}$  and the mass transfer resistance is equivalent to that of a stagnant gas film of thickness 0.25 mm. Neglect the effects of bulk flow. Saturation vapour pressure of water is 4.3 kN/m<sup>2</sup> at 303 K and 2.3 kN/m<sup>2</sup> at 293 K.

$$0.036 \text{ kg}$$

(40 Marks)

Good Luck

$$t = 9.97 \text{ min}$$

$$397.84 \text{ s}$$

$$\frac{dm}{dt} = \frac{D \cdot A \cdot P}{2Rt} (X_{A1} - X_{A2})$$



# FACULTY OF ENGINEERING

Final Examination  
First Attempt - 2021-2022



Faculty: Engineering  
Department: Chemical Engineering  
Stage/ Year: 3<sup>rd</sup>  
Total Mark: 100

Course Title: Transport Phenomena  
Course Code: KOU20441  
Time Allowed: 120 minutes  
Attached Sheet: Non

## Answer All Questions

- (a) Calculate the mole flows of distillate and waste streams.
- (b) Calculate the minimum reflux ratio.
- (c) How many plates are required in the rectifying column?

Given:

x	y
0.12	0.35
0.21	0.515
0.37	0.7
0.42	0.743
0.55	0.83
0.63	0.871
0.71	0.9
0.85	0.957
0.93	0.981

Good Luck

$$W = 100 - D$$

$$RD + D$$
$$DR + 1$$