MASS TRANSFER I
(CHEN 3103)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) High value of Henry's law constant is beneficial for:
(a) Stripping (b) Rectification
(c) Absorption (d) Azeotropic distillation

(ii) The _____ theory gives the most accurate estimation of interphase mass transfer coefficients.
(a) Boundary layer (b) Surface renewal
(b) Film (d) Penetration

(iii) For a slow reaction accompanying mass transfer, the enhancement factor is approximately equal to
(a) 1 (b) 0 (c) ∞ (d) 2

(iv) A packed tower is suitable for which of the following situations?
(a) Fluids with fouling tendency (b) Heat of solution is appreciable
(c) Low pressure operation (d) Intermediate product withdrawal

(v) In case of liquid-liquid molecular diffusion, the diffusivity D_{AB} is related to absolute temperature T as
(a) $D_{AB} \propto T^{0.5}$ (b) $D_{AB} \propto T$ (c) $D_{AB} \propto T^{1.5}$ (d) $D_{AB} \propto T^{2}$

(vi) Operating velocity in a packed tower is usually _____ the flooding velocity
(a) twice of (b) equal to (c) half of (d) more than

(vii) Absorption factor is a ratio of
(a) slope of operating line to equilibrium line
(b) slope of equilibrium line to operating line
(c) slope of equilibrium distribution curve
(d) none of these.

(viii) In case of distillation, as the reflux ratio is increased, the intersection of both the operating lines
(a) moves towards the diagonal (b) moves away from the diagonal
(c) does not at all move (d) none of these

(ix) In distillation, minimum number of theoretical stages can be obtained by
(a) Kremser equation (b) Rayleigh equation
(c) Fenske equation (d) none of these

(x) Azeotropic distillation is employed to separate
(a) constant boiling mixture
(b) high boiling mixture
(c) mixture with very high relative volatility
(d) none of these.

Group- B

2. (a) Calculate the rate of diffusion of acetic acid (A) (Mol.wt. 60) across a film of non-diffusing water (B) solution 2 mm thick at 20^0C when the concentrations on opposite sides of the film are 8 and 3 wt% acid respectively. The diffusivity of acetic acid in the solution is $0.95x10^{-9}$ m^2/s. Given: Density of 8 and 3 wt% acid solutions are 1010 kg/m^3 and 1003 kg/m^3 respectively. [(CO1) (Apply /IOCQ)]

(b) How does the diffusivity of gas change with temperature & pressure?
[(CO1) (Remember/LOCQ)]
10 + 2 = 12

3. (a) Obtain an expression for the time required for the fall of liquid (A) level from z_0 to z_F in Stefan tube experiment under 1 atm. total pressure.
[(CO1) (Analyze/IOCQ)]

(b) SO_2 is absorbed from air into water in a packed tower. At a certain point in the tower, the mass transfer flux is 0.027 $kmol/m^2hr$. The liquid phase mole fractions of the gas at the interface and in the bulk liquid are 0.0035 and 0.0006 respectively. The diffusivity of SO_2 in water is 1.7×10^{-5} cm^2/s. Determine the contact time of the eddies in the water phase at the gas-liquid interface.
[(CO2) (Apply/IOCQ)]
6 + 6 = 12

Group - C

4. (a) In a scrubber, CO_2 is being absorbed. For the absorption operation, two solvents have been shortlisted as candidate solvents. Experimental results indicate that for solvent A, the Hatta number (Ha) is 3.57, while for solvent B, it is 0.156. Which solvent should be selected as the most suitable one for this particular operation? Justify. [(CO3)(Analyze/IOCQ)]

(b) A certain gas A is being absorbed using a solvent B. During this absorption, a pseudo-first order reaction between A and B is also occurring, with a rate constant k_1 = 25 s^{-1}. The partial pressure of gas A at the interface is 600 mm Hg and Henry's law constant for the system is 1200 mm Hg $gmol^{-1}cc^{-1}$. The diffusivity of A with respect to B is 3.5×10^{-5} cm^2/s. The contact time of the liquid eddies at the interface is estimated to be 0.09 s. The mass transfer flux for A has been estimated to be 0.5 $kmol/m^2h$. Determine the value of the Hatta number in this situation. [(CO3) (Evaluate /HOCQ)]

4 + 8 = 12

5. (a) In a sulphuric acid plant, SO_3 is being absorbed into 98% H_2SO_4. The flow rate of the gas is seen to vary from 60 kmol/h to 75 kmol/h. The heat of absorption is also appreciable. The newly recruited engineer has chosen to design a packed column for the operation. Is the choice correct? Justify.

[(CO4) (Evaluate /HOCQ)]

(b) Under what conditions does Murphree efficiency of a plate exceed 100%? Explain. [(CO4) (Understand/LOCQ)]

(c) In a plate absorption tower, the liquid and gas flow rates are 55 $kmol/hm^2$ and 40 $kmol/hm^2$. The equilibrium relationship between the solute-solvent is expressed as y=0.746x. The average point efficiency of a plate is 88%. Determine the Murphree efficiency of the plate. [(CO4) (Evaluate /HOCQ)]

5 + 2 + 5 = 12

Group – D

6. (a) Using Kremser equation, determine the number of theoretical stages required for absorption of 92% acetone in a gas containing 5 mol% acetone in air in a counter current stage tower. The total inlet gas flow rate to the tower is 35 kg mol/ h and the total inlet pure water flow to be used to absorb the acetone is 105 kg mol /h. The process is to operate isothermally at 300K and a total pressure of 101.3kPa. Equilibrium relation is given by :$y_a = 2.52\ x_a$.

[(CO4) (Apply/IOCQ)]

(b) What do you understand by 'minimum liquid-gas ratio' in case of gas absorption? [(CO4) (Understand/LOCQ)]

8 + 4 = 12

7. (a) Define HTU and NTU. Obtain a relation involving packed height, HTU and NTU in case of absorption of a solute gas from a mixture by a solvent in a counter current tower. [(CO4) (Analyze/IOCQ)]

(b) Mention the desirable properties of a good solvent for absorption.

[(CO4) (Remember/LOCQ)]

(c) What will be the concentration of oxygen dissolved in water at 298 K when the solution is in equilibrium with air at 1 atm. pressure. [Given, Henry's law constant = 4.38×10^4 atm./mol. fraction]. [(CO4) (Evaluate /HOCQ)]

(2 + 6) + 2 + 2 = 12

Group – E

8. (a) A column has to separate a mixture of A and B to yield a top product of x_D=0.96 and a bottom product of x_w= 0.05. Calculate the minimum number of ideal trays required to achieve this separation.
Given: Relative volatility, α_{AB}= 1.8 at the bottom condition and α_{AB} = 2.0 at top condition. [(CO5) (Evaluate/HOCQ)]

(b) What do you understand by 'optimum reflux ratio'? [(CO5) (Remember/LOCQ)]

(c) A feed (70% liquid, 30% vapour) containing 35mol% benzene and rest toluene is admitted in a distillation column. Write down the feed line equation. [(CO5) (Evaluate/HOCQ)]

7 + 3 + 2 = 12

9. (a) Write short note on 'maximum boiling azeotrope'. [(CO5) (Remember/LOCQ)]

(b) A mixture of 40 mole percent benzene (A) and rest toluene (B) is subjected to flash distillation at a separator at 1 atm. The relative volatility α_{AB} is 2.5. Find the composition of the vapour and liquid leaving the separator for following cases:
(i) fraction of feed vaporized =0.5 , (ii) fraction of feed vaporized =1. (mm graph paper required). [(CO5)(Evaluate/HOCQ)]

4 + 8 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	15.63%	45.83%	38.54%

Course Outcome (CO):

After the completion of the course students will be able to

1. Frame mathematical equations for a given steady-state or transient diffusion problem and solve them.
2. Determine mass transfer coefficients by using appropriate correlations for a given engineering problem.
3. Analyse the effect of a reaction on a specific diffusion operation.
4. Select either plate or packed column (whichever is appropriate) for a given absorption operation and design the selected type of column.
5. Design a fractional distillation column (plate-type) for a given binary distillation operation.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question

Department & Section	Submission Link
CHE	https://classroom.google.com/c/MTIyMzkyNzQzNzI1/a/NDYzOTM1NzA5NjI2/details