B.TECH/CHE/6TH SEM/CHEN 3202/2022

MASS TRANSFER – II
(CHEN 3202)

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) The term 'approach' in a counter-current cooling tower represents
(a) the difference between outlet water temperature – inlet air dry-bulb temperature
(b) the difference between outlet water temperature – inlet air wet-bulb temperature
(c) the difference between inlet and outlet air dry-bulb temperature
(d) the difference between inlet and outlet water temperature.

(ii) The sides of an equilateral triangular coordinate (in ternary liquid system) represents a
(a) pure component (b) binary mixture
(c) ternary mixture (d) none of these.

(iii) _____ extractor uses centrifugal force for separating the two phases.
(a) Kuhni (b) Schiebel
(c) Podbielniak (d) None of these

(iv) In the context of drying, unbound moisture refers to moisture that exerts vapour pressure
(a) equal to that of pure liquid at the prevailing temperature
(b) less than that of pure liquid at the prevailing temperature
(c) more than that of pure liquid at the prevailing temperature
(d) that is none of the foregoing.

(v) A solid contains 30% moisture on dry basis. On wet basis, the moisture content is
(a) 0.15 kg moisture/kg wet solid (b) 0.23 kg moisture/kg wet solid
(c) 0.35 kg moisture/kg wet solid (d) 0.43 kg moisture/kg wet solid.

(vi) The driving force for _____ is concentration difference.
(a) reverse osmosis (b) pervaporation
(c) nanofiltration (d) dialysis

(vii) In liquid-liquid extraction, the number of phases at plait point is
(a) 1 (b) 2 (c) 3 (d) none of these.

(viii) Dew point of an air-water vapour mixture
(a) decreases with decrease in pressure
(b) increases with decrease in pressure
(c) may decrease or increase
(d) none of these.

(ix) Consider a situation where a dry gas flows over a wet solid in a batch drier. At steady state, the temperature of the solid is equal to
(a) the dry bulb temperature of the gas
(b) the wet bulb temperature of the liquid
(c) the adiabatic saturation temperature
(d) none of the foregoing.

(x) Solution-diffusion is the separation mechanism for
(a) reverse osmosis (b) ultrafiltration (c) dialysis (d) electrodialysis.

Group- B

2. (a) (i) An air-water vapour mixture has 40^0C dry-bulb temperature and 28^0C wet bulb temperature at 1 atm. pressure. Find its absolute humidity, dew point, humid volume and enthalpy.
(ii) What do you understand by 'wet-bulb depression'? [(CO1)(Evaluate/LOCQ)]

(b) A dryer requires 1.7 m^3/s of air at 60^0C and a humidity of 0.040 (kg water vapour/kg dry air). This is to be prepared from ambient air (dry-bulb temp. 28^0C and humidity of 0.010 kg water vapour/kg dry air) by direct injection of steam into the air stream followed by passage of the air over steam-heated tubes. Calculate the kilograms of steam per second required for direct injection. [(CO1)(Evaluate/HOCQ)]

(5 + 1) + 6 = 12

3. (a) Air enters the drying chamber of a tray dryer at 99^0C after having been heated from an ambient condition of 21^0C and 50 percent humidity. If the air leaves the drying chamber at 80 percent humidity as the result of an adiabatic saturation process within the dryer, what is the temperature and humidity of this exhaust air? [(CO1)(Evaluate/HOCQ)]

(b) (i) Write short note on natural draft cooling tower.
(ii) Why make up water is necessary in cooling tower operation?
[(CO1)(Remember/LOCQ)]

5 + (5 + 2) = 12

Group - C

4. (a) Write down the classification of commercial extractors.[(CO2)(Remember/LOCQ)]
(b) With example, discuss supercritical fluid extraction. [(CO2)(Analyze/IOCQ)]
(c) In a single stage leaching of soybean oil from flaked soybeans with hexane, 100 kg of soybeans containing 22 wt% oil is leached with 90 kg of solvent containing 2 wt% soybean oil. The value of N (kg insoluble solid/kg solution) for the slurry underflow is essentially constant at 1.50 kg insoluble solid/kg solution retained.

Calculate the amount and compositions of the overflow and the underflow leaving the stage. [(CO2)(Evaluate/HOCQ)]

3 + 3 + 6 = 12

5. (a) A continuous countercurrent multistage system is to be used to leach oil from meal (B) by benzene solvent. The process is to treat 2040 kg/h of inert solid meal (B) containing 800 kg oil (A) and also 50 kg benzene(C). The inlet flow of fresh solvent is 1300 kg benzene per hour. The leached solids are to contain 110 kg oil. Settling experiments similar to those in the actual extractor show that the solution retained depends upon the concentration of oil in the solution. The data are tabulated below as N kg inert solid B/kg solution and y_A kg oil/kg solution:

N	**y_A**	**N**	**y_A**
2.00	0	1.82	0.4
1.98	0.1	1.75	0.5
1.94	0.2	1.68	0.6
1.89	0.3	1.61	0.7

Calculate the amounts and concentrations of the stream leaving the process and number of stages required. [(CO2)(Evaluate/HOCQ)]

(b) In case of liquid-liquid extraction, define selectivity. [(CO2)(Remember/LOCQ)]

10 + 2 = 12

Group - D

6. (a) The following N vs. X data are obtained from a batch drying operation.

Kg moisture/ Kg dry solid	0.35	0.30	0.20	0.18	0.14	0.10	0.08	0.07	0.064
Rate of drying. 1000 (Kg moisture evaporated/ m^2 hr	0.3	0.3	0.3	0.266	0.208	0.150	0.070	0.043	0.025

(i) Draw the N vs. X curve and find the critical moisture content.

(ii) For the above solid, if the equilibrium moisture content is assumed to be zero, what amount of moisture is to be removed from 200 kg wet solid having 0.25 kg moisture/ kg wet solid to get a completely dry solid? What is the weight of the dry solid so obtained? [(CO3)(Evaluate/HOCQ)]

(b) Distinguish between cross-circulation drying and through-circulation drying. [(CO4)(Analyze/IOCQ)]

(4 + 4) + 4 = 12

7. (a) For the drying rate curve given in question 6 (a), find the time required to dry 200 kg wet solid from an initial moisture content of 30% (wet basis) to 1% (wet basis) for an effective overall surface area of 5 m^2. State any assumption made during the calculation. [(CO3)(Evaluate/HOCQ)]

(b) Starting from mass balance equation for a through-circulation drier, prove that $N/N\ max$ = 1 – exp (-N_{tG}); the notations having usual significance. [(CO4)(Remember/LOCQ)]

8 + 4 = 12

Group - E

8. (a) Discuss the working principle and applications of pervaporation. [(CO5)(Remember/LOCQ)]

   (b) A 80 μm thick polysulphone microporous membrane has an average porosity of 0.38. Pure water flux through the membrane is 26 m^3/m^2 .h at a pressure of 1.4 bar at 25^0C. The average pore size is estimated to be 1 μm. Calculate the tortuosity of the pores, the resistance to flow offered by the membrane and its water permeability. The viscosity of water at 25^0C is 09 cp. [(CO5)(Evaluate/HOCQ)]

6 + 6 = 12

9. (a) Mention one application for each of microfiltration, dialysis and nanofiltration. [(CO5)(Remember/LOCQ)]

   (b) Obtain an expression for concentration polarization modulus. [(CO5)(Analyze/IOCQ)]

   (c) A macromolecular solution (mol. wt. -6000 and concentration = 1.2 wt%) is passed through a tubular UF membrane of 1 cm ID and 1 meter long. Pure water flux from the module is 1.54×10^{-5} m^3/m^2.s. Calculate the flow velocity to be maintained in the tube in order to prevent formation of gel layer on the membrane surface. Rejection coefficient = 0.985, applied pressure difference = 1.5 bar, diffusivity of solute is 8×10^{-7} cm^2/s, viscosity of solution = 2.5 cp, concentration at which the solute forms a gel is 10.5%. Pore leakage and fouling may be ignored. [(CO5)(Evaluate/HOCQ)]

2 + 4 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	31.25	11.46	57.29

Course Outcome (CO):

1. Students will be able to analyze various humidification, dehumidification processes and will be able to design cooling towers.
2. Students will be able to analyze commercial extraction and leaching operation and determine number of equilibrium stages required for a given separation.
3. Students will be able to understand mechanism of drying, calculate drying time for batch dryers and compute rate of drying in batch and continuous modes of drying operation.
4. Students will be able to develop concepts on crystal properties, kinetics and thermodynamics associated with crystallization process, and design the crystallization equipments.
5. Students will be able to classify membrane separation processes based on driving forces, understand their applications and develop ideas on some of these processes and their applications in industries.

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