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
<u>any 5 (five)</u> from Group B to E, taking <u>at least one</u> 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 most important function of louvers in a cooling tower is
            (a) to protect against algal growth
            (b) to allow air flow while preventing water splashout
            (c) to enhance the structural strength of the wall
            (d) none of the above.

    (ii)   If the 'approach' in a cooling tower is smaller, the height of the packed section
            (a) will be less   (b) will be small
            (c) remains unaffected   (d) cannot be predicted.

    (iii)   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.

    (iv)   Drying of milk powder is carried out using
            (a) Spray dryer   (b) Freeze dryer   (c) Vacuum rotary dryer (d) Tray dryer.

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

    (vi)   During heat transfer by convection in cross-circulation drying if dry bulb and wet bulb temperatures of the air are T_G and T_w, convective heat transfer coefficient h_c and latent heat of vaporization λ_s, the drying rate is equal to
            (a) $h_c(T_G - T_w)/\lambda_s$ (b) $h_c T_G/\lambda_s$ (c) h_c/λ_s (d) $T_G - T_w$.

    (vii)   For enantitropic substances, the phase diagram shows existence of
            (a) three stable triple points   (b) two stable and one metastable triple points
            (c) three metastable triple points   (d) two stable triple points.

    (viii) Secondary nucleation rate of a crystal depends on
            (a) Supersaturation
            (b) Impeller speed
            (c) Impeller speed, supersaturation and slurry density
            (d) Impeller speed, supersaturation and crystal size.

(ix) In an MSMPR crystallizer, if L is the characteristic length, G the growth rate and τ the residence time, the crystal population distribution function is given as

(a) $n^0 \exp(-L/G\tau)$ (b) $n^0 + \exp(-L/G\tau)$

(c) $n^0 \exp(L/G\tau)$ (d) $-n^0 L/G\tau$.

(x) The range of pore size of ultrafiltration membrane is

(a) 1-100 Å (b) 1-100 nm (c) 1-100 μm (d) 1-100 mm.

Group - B

2. (a) An air-water vapour mixture has 30°C dry-bulb temperature and 20°C wet bulb temperature at 1 atm. pressure. Find its dew point, percentage humidity, humid heat and enthalpy. [(CO1)(Evaluate/HOCQ)]

(b) Compare induced draft and forced draft cooling towers.
[(CO1)(Analyze/HOCQ)]

(c) Percentage humidity cannot have a higher value than relative humidity- justify.
[(CO1)(Analyze/IOCQ)]
4 + 4 + 4 =12

3 (a) In an air-conditioning system, 2 kg/s air at 80°C K and 20% humidity is mixed with 6 kg/s at 25⁰C and 35% humidity. Determine the enthalpy, humidity and temperature of the resultant stream? [(CO1)(Evaluate/HOCQ)]

(b) Air enters the drying chamber of a tray dryer at 90⁰C after having been heated from an ambient condition of 20°C and 60 percent humidity. If the air leaves the drying chamber at 90 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)]
6 + 6 = 12

Group - C

4. (a) Write a note on the classification of commercial extractors.
[(CO2)(Remember/LOCQ)]

(b) In a single stage leaching of soybean oil from flaked soybeans with hexane, 120 kg of soybeans containing 20 wt% oil is leached with 100 kg of pure solvent. The value of N (kg insoluble solid/kg solution) for the slurry underflow is essentially constant at 1.52 kg insoluble solid/kg solution retained. Calculate the amount and compositions of the overflow and the underflow leaving the stage.
[(CO2)(Evaluate/HOCQ)]

(c) With example, discuss supercritical fluid extraction.
[(CO2)(Remember/LOCQ)]
2 + 7 + 3 =12

5. (a) Mention the factors those can affect leaching operation.
[(CO2)(Remember/LOCQ)]

(b) 150 kg of a water-dioxane solution containing 20% dioxane is being extracted with 120 kg benzene at 25°C in a single-stage extraction unit. Water and benzene are insoluble. The equilibrium distribution of dioxane between water and benzene at 25°C is as follows:

wt% of dioxane in water, solute free basis	5.1	18.9	25.2
wt% of dioxane in benzene, solute free basis	5.2	22.5	32.0

Determine
i) the composition of extract and raffinate stream
ii) the percentage of dioxane extracted.

[(CO2)(Evaluate/HOCQ)]
2 + 10 = 12

Group - D

6. (a) A batch of wet solid is to be dried from a free moisture content of 0.38 kg water/kg dry solid to a final moisture content 0.04 kg water/kg dry solid, area = 18.6 m² of top drying surface, critical moisture content is 0.195 kg water/kg dry solid. Construct the drying rate curve and calculate the time of drying. Weight of dry solid is 399 kg. Data for falling rate period is given below.

X(kg water/kg dry solid)	0.195	0.15	0.1	0.065	0.05	0.04
Drying rate (kg/m².h)	1.51	1.21	0.9	0.71	0.37	0.27

[(CO3)(Evaluate/IOCQ)]
(b) Classify the different types of crystallizers. [(CO3)(Remember/LOCQ)]
(3 + 5) + 4 = 12

7. (a) One litre suspension from an MSMPR crystallizer containing 161 g yielded the following results on sieve analysis. Determine the crystal size distribution function and nucleation rate

Given: solid density = 2163 kg/m³, shape factor = 2, residence time = 0.9 h. The average crystal size for mesh size less than 100 is 0.0745 mm.

Tylor mesh	12/14	14/16	16/20	20/24	24/28	28/32	32/35	35/48	48/65	65/100	<100
Opening (mm)	1.41/1.19	1.19/1.00	1.00/0.841	0.841/0.707	0.707/0.595	0.595/0.5	0.5/0.42	0.4/0.297	0.297/0.21	0.21/0.149	
Mass (g)	4.44	8.41	16.65	16.28	24.32	27.24	22.5	23.13	11.9	5.15	1.05

[(CO4)(Apply/HOCQ)]
(b) Discuss the basic principle of freeze drying. [(CO4)(Analyze/IOCQ)]
8 + 4 = 12

Group - E

8. (a) Derive the expression for concentration polarization modulus in ultrafiltration in terms of solvent flux. [(CO5)(Analyze/IOCQ)]

(b) An ovalbumin solution having molecular weight 5000 Da and concentration of 1 mass% is passed through a tubular ultrafiltration membrane module of 1 cm internal diameter and 100 cm long at a temperature of 25°C. Membrane water permeability is 85.85×10^{-3} m³/m³.day.psi. Rejection coefficient is 0.995, applied pressure difference 2 bar, solute diffusivity is 8×10^{-11} m²/s, viscosity of the solute 3 cP, gel point concentration of solute 10.5%. Calculate the flow velocity to be maintained in the tube to prevent gel layer formation on the membrane surface. [(CO5)(Evaluate/HOCQ)]

(c) Obtain the expression of permeate flux and separation factor from a pervaporation unit using solution diffusion model. [(CO5)(Analyze/IOCQ)]

3 + 6 + 3 = 12

9. (a) "Reverse osmosis is essentially a pressure driven process". Justify.
[(CO5)(Analyze/IOCQ)]

(b) Blood from a patient's body is pumped through a concurrent haemodialyser at a rate of 280 ml/min to reduce the urea concentration from 200 mg% to 20 mg%. The available membrane area is 1.15 m², and overall mass transfer coefficient is 1.2×10^{-6} m/s. The volume of blood in normal human body is 5 litre. If the flowrate of the dialysate fluid is maintained high, estimate the time of dialysis. Assume the dialysate fluid is solute free. [(CO5)(Evaluate/HOCQ)]

(c) Classify membranes and briefly discuss the important types of membrane. Explain the working principle of a hollow fibre membrane module.
[(CO5)(Understand/LOCQ)]

2 + 4 + (3 + 3) = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	17.8	29.1	53.1

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.