

MASS TRANSFER – II
(CHE3202)

Time Allotted : 2½ hrs

Full Marks : 60

Figures out of the right margin indicate full marks.

*Candidates are required to answer Group A and
any 4 (four) from Group B to E, taking one from each group.*

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

Group – A

1. Answer any twelve:

12 × 1 = 12

Choose the correct alternative for the following

- (i) If nearly saturated air at 45°C is contacted with water at 25°C, which of the following will occur:
 - (a) Cooling of the water
 - (b) Humidification of air
 - (c) Dehumidification of air
 - (d) Evaporation loss of water
- (ii) Pick out the correct statement
 - (a) The exit water temperature of a cooling tower can be less than the dry-bulb temperature of entering air
 - (b) The exit water temperature of a cooling tower can be less than the wet-bulb temperature of entering air
 - (c) The exit water temperature of a cooling tower can be more than the inlet temperature of entering water into the tower
 - (d) The exit water temperature of a cooling tower can be same to that of the wet-bulb temperature of entering air
- (iii) Which of the following employs an accessory known as “drift eliminator”
 - (a) Rotating Disc contactor
 - (b) Tray dryer
 - (c) Kuhni Extractor
 - (d) Forced draft Cooling tower
- (iv) In a cooling tower, ‘approach’ lies between
 - (a) 3 – 5°C
 - (b) 6 – 10°C
 - (c) 11 – 15°C
 - (d) None of these
- (v) The apex of an equilateral triangular coordinate (in ternary liquid system) represents a
 - (a) pure component
 - (b) binary mixture
 - (c) ternary mixture
 - (d) none of these

- (vi) Pick out the correct statement/s:
The larger the interfacial tension
(a) the more difficult coalescence of emulsion will occur
(b) the more readily coalescence of emulsion will occur
(c) the less difficult the dispersion of one liquid into another
(d) the more difficult the dispersion of one liquid into another
- (vii) Wet filter cakes are dried using
(a) Rotary dryer (b) Spray dryer
(c) Freeze dryer (d) Flash dryer
- (viii) An example of a batch dryer is a
(a) Rotary dryer (b) Tunnel dryer
(c) Tray dryer (d) Fluidized bed dryer
- (ix) The separation mechanism for reverse osmosis is
(a) sieving (b) solution diffusion
(c) sorption diffusion (d) ion exchange
- (x) The pore size range of an ultrafiltration membrane is
(a) 1-100 Å (b) 1-100 mm
(c) 1-100 nm (d) 1-100 μm

Fill in the blanks with the correct word

- (xi) Solvent for liquid - liquid extraction should have _____ vapour pressure.
- (xii) A cubical crystal of size 0.5 mm grows in a solution of supersaturation $s=0.07$. Given: $\rho_c=1800 \text{ kg/m}^3$, $C_s=150 \text{ kg/m}^3$, $k_L=2.5 \times 10^{-3} \text{ cm/s}$, the rate of crystal growth is _____.
- (xiii) Flash dryers are used for drying _____.
- (xiv) The driving force for dialysis is _____
- (xv) In a cooling tower, _____ are designed to capture water droplets from exhaust air stream.

Group - B

2. Water at rate of 18 kg/s is to be cooled from 40°C to 29°C by contact with air in an induced draft cooling tower. Entering air has a dry-bulb temperature of 30°C, wet-bulb temp. 24°C. An air rate of 1.42 times the minimum is to be used.
(i) Find out the actual air rate and enthalpy of outlet air stream.
(ii) the range and approach. [[CO1](Evaluate/HOCQ)]
- (11 + 1) = 12**
3. (a) Calculate the saturation humidity of a saturated mixture of nitrogen gas and benzene vapour at 50°C and 1 std. atm.
Given: The equilibrium vapour pressure of benzene at 50°C is 275 mm Hg. [[CO1](Evaluate/HOCQ)]
- (b) Discuss the working principle of a forced draft cooling tower. [[CO1](Remember/LOCQ)]

- (c) A horizontal spray chamber with recirculated water is used for adiabatic humidification and cooling of air. The active part of the chamber is 1.8 m long and has cross section 2.2 m². With air rate 3.3 m³/s at dry-bulb temperature of 64°C and absolute humidity of 0.016 kg water/kg dry air, the air is cooled and humidified to a dry-bulb temperature of 43°C. If a duplicate spray chamber operated in the same manner were to be added in series with the existing chamber, what outlet conditions could be expected for the air? *[[CO1](Evaluate/HOCQ)]*
3 + 3 + 6 = 12

Group - C

4. (a) Discuss the method of obtaining number of stages in case of a multistage counter current leaching operation with variable underflow. Give two example of leaching operation used in industry. *[[CO2](Apply/IOCQ)]*
 (b) 100 kilograms of a 50% solution of C in A (carrier) is equilibrated with 70 kg of solvent B containing 2% of C. At equilibrium, the raffinate phase has a mass of 80 kg and has 52% of A and 8% of B in it. What is the selectivity of C? *[[CO2](Evaluate/HOCQ)]*
7 + 5 = 12
5. (a) Mention the factors affecting leaching operation. *[[CO2](Remember/LOCQ)]*
 (b) Discuss the working principle of Bollman Extractor. *[[CO2](Remember/LOCQ)]*
 (c) A Nicotine-water solution contains 24 grams of Nicotine per litre. Calculate the quantity of kerosene with which 1 litre of this solution must be shaken at 308 K in order to reduce nicotine concentration to 1.8 gm/litre in the water phase. Molecular weight of Nicotine is 250 and distribution coefficient K is given as $(Y/X) = 0.60$ where, Y = Concentration of Nicotine in water, mol/litre and X = Concentration of Nicotine in Kerosene, mol/litre. *[[CO2](Analyze/HOCQ)]*
2 + 4 + 6 = 12

Group - D

6. (a) Explain the working principle of rotary dryer with a diagram. Sketch and explain the temperature profiles of solid and gas in a countercurrent rotary dryer. *[[CO3](Remember/LOCQ)]*
 (b) A sample of a porous, manufactured sheet material was dried from both sides by cross circulation of air in a drier. The sample was 0.3 m square and 6 mm thick, and the edges were sealed. The air velocity over the surface was 3 m/s, its dry bulb temperature was 52°C and its wet bulb temperature was 21°C. There were no radiation effects. The solid lost moisture at a constant rate of 7.5×10^{-5} kg/s until the critical moisture content 15% (wet basis) was reached. In the falling rate period, the rate of evaporation fell linearly with moisture content until the sample was dry. The equilibrium moisture was negligible. The dry weight of the sheet was 1.8 kg. Estimate the time for drying sheets of this material 0.6 by 1.2 m by 12 mm thick from both sides, from 25% to 2% moisture (wet basis), using air of dry bulb temperature 66°C but of the same absolute humidity at a linear velocity of 5 m/s. Assume no change in the critical moisture with the changed drying

conditions. Latent heat of vaporization of water is 2400 kJ/kg and density of air is 1.2 kg/m³. The convective heat transfer coefficient is expressed as

$$h_c = \frac{5.9G^{0.71}}{d_e^{0.29}} \text{ where } d_e \text{ is the equivalent diameter} \quad [[CO3](Apply/HOCQ)]$$

- (c) Explain what is meant by drying equilibria. Sketch and explain the moisture isotherm. [[CO3](Understand/LOCQ)]

4 + 5 + 3 = 12

7. (a) Explain the working principle of a circulating liquid crystallizer with a diagram. [[CO4](Understand/LOCQ)]

- (b) A feed solution of 2268 kg at 54.4°C containing 48.2 kg MgSO₄/100 kg water is cooled to 20°C whereby MgSO₄.7H₂O crystals are removed. Solubility of the salt is 35.5 kg MgSO₄/100 kg water. Average heat capacity of the feed solution is 2.93 kJ/kg K. Heat of solution at 20°C is -13.31×10³ kJ/kmol. Calculate the yield of crystals and make a heat balance to determine the total heat absorbed (assume no water is vaporized). Molecular weight of MgSO₄.7H₂O is 246. [[CO4](Apply/IOCQ)]

- (c) Explain the stages of crystal growth with diagram. [[CO4](Understand/LOCQ)]

5 + 4 + 3 = 12

Group - E

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

- (b) “Ultrafiltration is essentially a pressure driven process”. Justify the statement. [[CO5](Analyse/IOCQ)]

- (c) “Limiting flux in ultrafiltration depends on turbulence and the bulk concentration of solute”. Comment on the validity of the statement. Explain why flux permeate flux in ultrafiltration saturates at high transmembrane pressure drop. [[CO5](Apply/IOCQ)]

5 + 3 + 4 = 12

9. (a) Discuss an important industrial application of pervaporation with process flow diagram. Explain the principle of electrodialysis. [[CO5](Remember/LOCQ)]

- (b) An ultrafiltration membrane allows pure water flux of 0.8 m³/m².h at a transmembrane pressure drop of 6 bar. When used in ultrafiltration of protein solution (C_b=1.52%) at the same pressure drop, it gives a steady-state flux of 0.032 m³/m².h. The protein forms a gel at 15% concentration and the rejection coefficient 0.98. Calculate the mass transfer coefficient and the permeability of the gel layer.

- (c) Discuss about membrane fouling. How can it be prevented? [[CO5](Apply/IOCQ)]

(3 + 2) + 4 + 3 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	30.20	31.25	38.55